Understanding the Scenery

The Geodiversity[1] of Cox's Road from Mount York to the Flag Staff in Bathurst

Chris Marshall, May 2015

The dramatic & moody Winburndale Range contrasted with the rolling hills of the Bathurst valley (photo: Wes Schulstad).

[1] Footnote: ***Geodiversity***, *The natural diversity of rocks, minerals, landforms, fossils, sediments and soils, and the processes that have shaped these features over time.*

Seeing and understanding landscape is a surprisingly personal experience. It is influenced by a diversity of views of the wider world, including cultural background, knowledge, perceptions, attitudes and values.

There is little doubt that the early European explorers, road builders, administrators and settlers saw the landscape quite differently from the world view of Aboriginal people of the early 1800s. Even today, artists, writers, poets, farmers, engineers, scientists and many others from varied backgrounds, see and experience landscape in different ways.

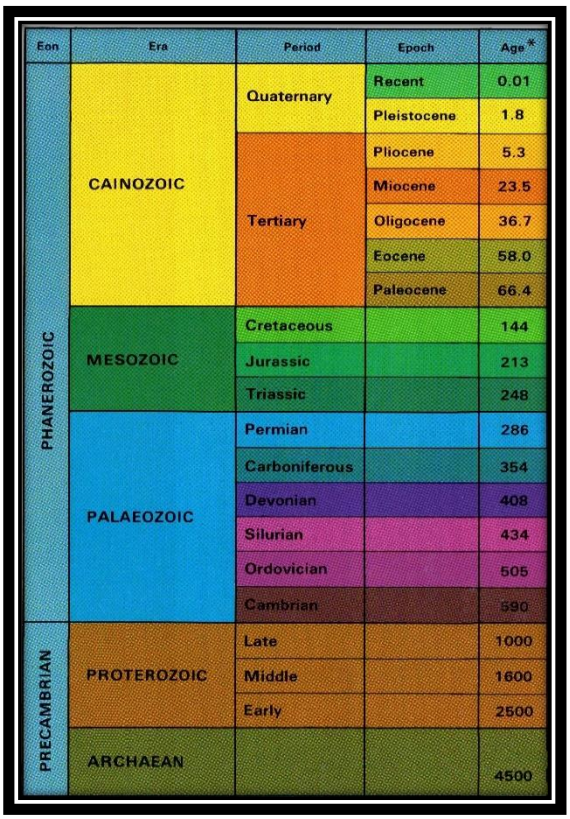
There are many powerful and valid ways of reading and valuing the landscape. There are also contested views as to how the landscape was formed, how long it took, what processes were involved and in particular, how the landscape should be used and managed. However, the consensus amongst mainstream scientists about the story of the universe and planet Earth is that it spans an awe inspiring 13.8 billion years from the Big Bang to the present. Knowledge is not finite and the speed at which we are accumulating new information and understanding via the earth sciences alone is truly amazing, particularly in the last 75 years.

The perspective of the Mount York to Bathurst landscape presented here is based on the work of hundreds of contemporary geologists, geomorphologists and other earth scientists. It is rounded out with personal insights from having lived and worked within this landscape for 30 years, as well as information gleaned from astute locals who have generously shared their knowledge and perspectives. All of these people have strived to understand the many riddles that daily confront us in the landscape. Their work is ongoing and rarely available in one source or as is often the case, not recorded. There is always the risk of misinterpreting the available scientific material or not being aware of unpublished contemporary information. Nevertheless the story presented here is one person's contemporary view of an extraordinary but very complex landscape.

Grasping the Concept of Time

Two hundred years have passed since the first Europeans trekked across the Great Divide. They were searching for well watered grazing and cropping lands to supplement the stretched rural resources of the colony on the Cumberland Plain. With this in mind, it's worth pausing to contemplate how we view and weigh the importance of time.

Early European trips to Bathurst on foot, horse or in cart or carriage took many days and in some cases weeks. We now cover the distance in a few short hours in a motor vehicle and less so by aeroplane. We can visually traverse the area on our computer via the wonders of up to date online air photos and satellite images in a matter of minutes. We celebrate what has been achieved in two hundred years of European settlement and also rightly reflect on the rich culture of the Wiradyuri[2] people who thrived here for tens of thousands of years before that.



Eon	Era	Period	Epoch	Age*
PHANEROZOIC	CAINOZOIC	Quaternary	Recent	0.01
			Pleistocene	1.8
		Tertiary	Pliocene	5.3
			Miocene	23.5
			Oligocene	36.7
			Eocene	58.0
			Paleocene	66.4
	MESOZOIC	Cretaceous		144
		Jurassic		213
		Triassic		248
	PALAEOZOIC	Permian		286
		Carboniferous		354
		Devonian		408
		Silurian		434
		Ordovician		505
		Cambrian		590
PRECAMBRIAN	PROTEROZOIC	Late		1000
		Middle		1600
		Early		2500
	ARCHAEAN			4500

Fig 1. Geological Time Scale, the ages of various Periods and Epochs in the right hand column are recorded as millions of years ago from the present. (chart: Bureau of Mineral Resources).

How old is the landscape? What about the landscape that sustained these earlier people and that now supports our contemporary economy, community and culture? In comparison with any of the above time scales our landscape is prodigiously old. The following few examples amply illustrate the concept of geological time in our region.

The oldest rocks in the regional landscape are from the Middle Ordovician Period 460 million years ago (Ma), well represented in the sandstones, siltstones and slate of the Adaminaby Group exposed south of Oberon. The intriguing Sofala and Rockley Volcanics are from later in that Period. But of course the minerals in those rocks are even older, having been recycled through numerous preceding geological processes prior to the deep ocean deposition evident in these formations. A consideration of the elements that make up the minerals take us right back to the formation of the earth 4.5 billion years ago.

We have good evidence that the first extensive area of terrestrial continental landscape in the Bathurst region only emerged from a shallowing ocean in the late Devonian Period about 355 Ma. The Great Divide was initially created about 80 Ma and reliably dated basalt flows allow us to date many of our valley systems to the order of 20 Ma or less.

Our contemporary alluvial floodplains are the products of about 20,000 years of variable deposition. The highly valuable organic component of our soils is the result of the climatic and ecological processes over the last 8,000 years.

[2] Spelling as advised by Bill Allen Jnr, Wiradyuri Elder.

These are just a selection from the many points along the long Australasian timeline that has seen the development of our unique regional landscape. Humbling stuff when compared to modern society and its short frantic, time frames.

Glimpsing Ancient Landscapes in the Rocks

History is not only recorded in our words but also in our landscape. Just as we can read about the human history of Bathurst, with the appropriate tools we can also learn to read the history of our landscape, what our forebears in the 19th C called 'natural history'.

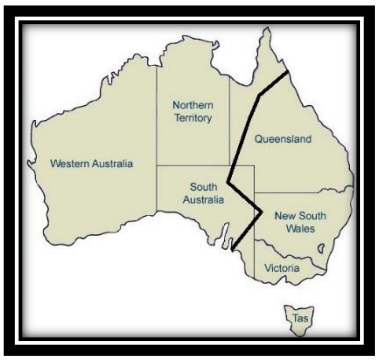


Fig 2. Approximate location of the Tasman Line at 545Ma (map: after Johnson 2004).

Summarized below is an amazing big picture sketch of 460 million years of geological history in the Bathurst region. Eight short paragraphs will set the scene for the modern landscape based on the routes traveled by Europeans from Mount York to Bathurst in the early 19th C.

The Bathurst landscape and its geological components are by any measure, ancient. It's also clear that the landscape isn't fixed in the form that we see today but has been subject to never ending change. Indeed there have been multiple diverse landscapes over the hundreds of millions of years recognizable in the region's rock formations. There will be more changes to come as the geological processes inevitably continue into the future.

It may surprise some to discover that our region didn't exist as dry land and part of a broader continent until some 355 Ma. Prior to that the coast of Gondwana, of which Australia was just a part, lay far to the west in the vicinity of today's Broken Hill along what is known as the Tasman Line (Fig. 2). Deep ocean lay where our region is today.

Fig 3. Compressed, tilted rocks of the Hill End Trough with predominantly north south alignment (photo: Chris Marshall).

The oldest exposed sequence of rocks indicate that there was once a period with a deep oceanic depositional environment. Sediments were sourced via turbidity flows from an eroding mountain range a great distance to the west beyond the Tasman Line. This is followed by evidence of discrete eruptive centres from the seamount volcanoes of the Macquarie Volcanic Arc and the associated Rockley and Sofala volcanics. Some parts of the arc were shallow enough to support fringing carbonate reefs. Crustal tension led to the formation of the deep ocean Hill End Trough. It was bounded by the shallower Molong and Capertee Highs with associated limestones. A long period of time followed with the deposition of diverse volcanic and other materials into the Hill End Trough from the two Highs. Mountain building forces led to uplift, folding, faulting, and termination of sedimentation in the Hill End Trough. The result was the creation of the dominantly north south orientation of the compressed and folded rocks seen at many localities in the region (Fig 3).

The change was followed by the gradual development of shallow marine sedimentation commencing in the west and moving relentlessly towards the east. Later there is an abrupt change to coarse riverine sediments indicating the presence for the first time of extensive areas of dry land. Further widespread deformation followed. The large area of deformed sediments from these ancient times is known as the Lachlan Fold

Belt. It was an important product of the gradual accretion of material eastward from the Tasman Line leading to the extension of continental crust. This process created much of the south eastern part of modern Australia as we know it today.

The intrusion of granite forming the Bathurst Batholith in the Middle Carboniferous Period (312-330 Ma) followed this deformation. Initiation of the intrusion is likely to have been associated with the forces that triggered the extensive deformation. A long period dominated by erosion followed. The development of the Sydney Basin to the east during the Permian and Triassic Periods (298-205 Ma) and to the north, of the Great Australian Basin during the Jurassic and early Cretaceous Periods (205-100 Ma), provided destinations for the eroded materials.

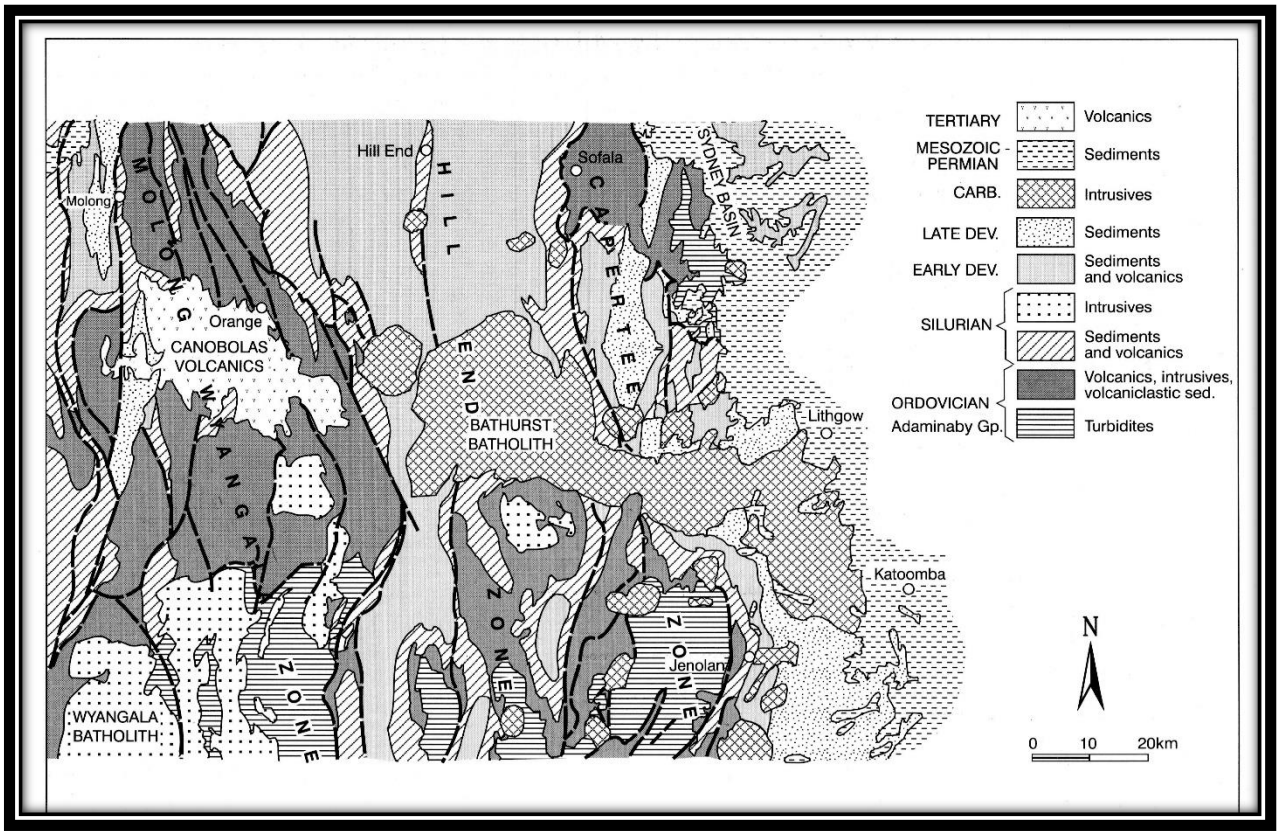


Fig 4. Generalised geology of the Bathurst region (map: adapted from Branagan & Packham 2000).

By the Mid Cretaceous Period (100 Ma) Australia had been worn down to a very level peneplain and much was then submerged in continent wide seas. The buckling of this vast Cretaceous plain in the process of forming the Great Divide, was the critical event in a major new round of landscape change. At this point the clock started ticking, setting loose the powerful forces of landscape scale erosion and deposition that have created the modern landscape as we know it. In fact those forces continue even now. They are working to reduce the landscape once again to a level plain while ongoing subtle uplift rebalances the loss of weight to erosion, gradually maintaining the relative relief of the landscape.

Later volcanism involving lava fields with multiple outlets as well as a major shield volcano that developed in time into a central volcano also imprinted its character on the region. More recently, the influence of the last of seventeen glacial extremes and its moderating aftermath has been felt. It shaped the landscape with profound impacts on vegetation, hydrology, erosion, deposition and soil formation.

Continents Adrift in Time

The driving force for this sequence of significant geological events has been the global process of plate tectonics. Fragments of cold, rigid, brittle crust, including the uppermost part of the mantle, floating on the weak, hot, plastic section of mantle below, have drifted around the globe. All is driven by the forces of convection currents. The result has been the colliding and joining of plates only for them to be rifted apart and rejoined in different configurations on a number of occasions during the long life of Earth. It is this jostling of plates, driven by deep heat transfers in the mantle that is responsible for many of the geological processes that have created our landscape.

Significant to our region has been the relatively recent breakup of the continent of Gondwana extending from approximately 160 Ma till about 50 Ma. At this point Australia finally severed its last ties with Antarctica. Of particular importance has been the stretching and eventual rifting that created the Tasman Sea with the drifting away and partial sinking of the New Zealand sub-continent. Intimately associated with this was the initial raising of the Great Divide some 80 Ma. This created new and changing climatic conditions associated directly with the near coastal uplift as well as with Australia drifting north east into new climatic zones at a rate of about seven centimetres per year.

What did the Early Europeans see as they first travelled through the Landscape?

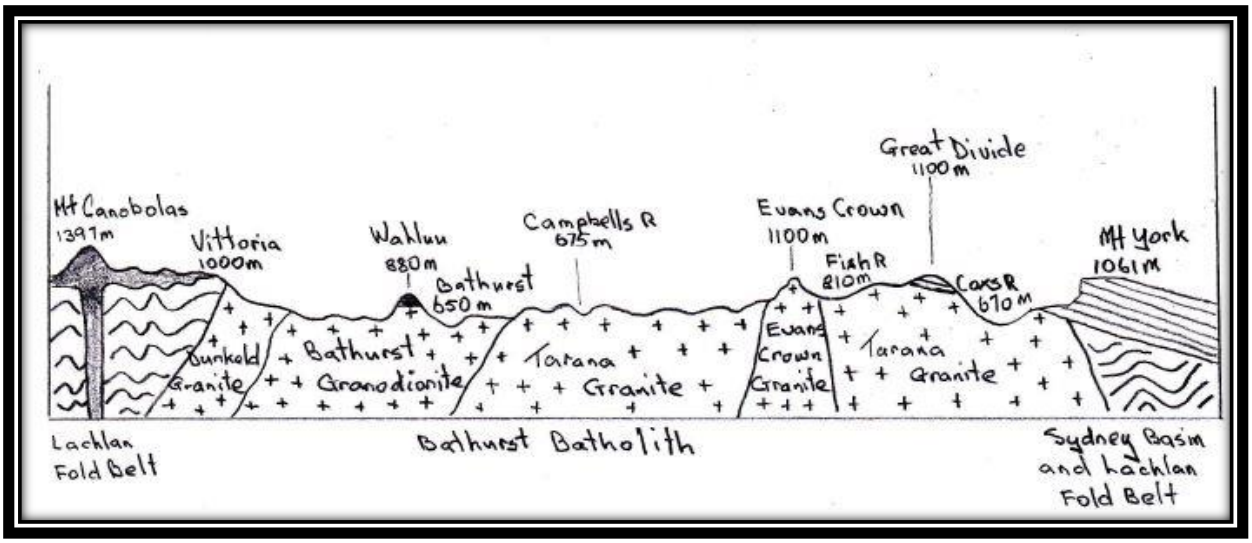


Fig 5. Generalised geological cross section of the route of early travellers, Mt York to Bathurst. (diagram: Chris Marshall)

There can be little doubt that the early Europeans were blind to the nature and reason for many of the geological and landscape features and forces that we now take for granted. They would have been clearly constrained by the science of their time, their personal exposure to that science as well as by the limited physical view from their defined route of travel. We can be confident they were alert to elements of the landscape that indicated ease of route as well as of future potential resources for personal and colony exploitation. Evidenced by entries in their diaries, they could for example differentiate between sandstone and granite. They quickly grasped the understanding that certain vegetation communities were associated

with soils where farming could be undertaken. Beyond this we must remain uncertain as to their broader interest and grasp of the aesthetic, ecological and geomorphic aspects of what they saw.

Fig 6. Hartley Vale landscape (photo: Chris Marshall).

The travellers would have been unaware of the evidence of the gentle lifting of the vast flat Cretaceous plain to form the Great Divide. They may well have been startled to know that the detailed outline of the hills and valleys that lay before them had only taken that form in the preceding 20 million years or even less. The presence of extensive basalt flows across the region at this time indicates a continuity of landscape without the deep valleys and stark ridges that we are now familiar with. The basalt covered terrain has been subsequently mostly eroded, leaving a scattering of distinctive basalt caps on many of the Blue Mountains high points as well as in the Bathurst region. The dated basalts have proved a key to understanding the ages of at least parts of our familiar landscape.

Descending from the Triassic sandstone cliffs into the broad Permian valley of Hartley Vale. Through the long traverse of the Blue Mountains the early visitors had been travelling across Triassic aged sediments of river and estuarine origin. The relative strength of these rocks is largely responsible for the plateaus edged by dramatic cliffs and narrow gorges that developed as the sandstones eroded. The uplift associated with the forming of the Great Divide created the long, relatively gentle plateau that appeared as an extended ramp for the travellers to follow. They encountered a number of notable steep steps on their journey through this country caused by the buckling of the ramp as it was uplifted.

Fig 7. Glacial drop stone in Permian sediments, Merrangaroo (photo: Col Bembrick).

Descending abruptly from Mount York the travellers would have noted a reduction in slope as they entered the area of the older Permian sediments on the lower slopes. They finally broke out onto the broad valley of the upper River Lett (Fig 6). The observant few may have noticed coal beside the new road as they descended from Mt York. With less strength than the overlying Triassic sandstones, the Permian sediments tend to erode faster, undercutting and destabalising the cliffs above. The result is the formation of long foot slopes and broad plains below as showcased in the cliffed amphitheatre of Hartley Vale (Fig 6). The low sloped, swampy and woodland character of this upland plain was the first relief the travellers received from the constraining rocky plateaus, steep cliffs and narrow gulches of the sandstone country they had been travelling through till then.

The early travellers were denied the benefit of the large cuttings of the modern Great Western Highway near here. Contemporary travellers can now view dramatic evidence exposed in the highway cuttings of the Permian ice age glaciation that occurred in ancient Gondwana. A sharp eye will note the mixed conglomerates including occasional extra-large boulders that indicate that at least some of this material was

deposited as drop stones from rafting ice bodies (Fig 7). Above these sediments but below the overlying Triassic rocks is evidence of the cold climate swamps that developed as the glaciers waned. These formed the coal and shale oil deposits that have been exploited in this area since European settlement.

Entering the Bathurst Batholith. Having traversed this contrasting landscape and approaching the site of future Hartley, the early Europeans crossed into an almost unbroken region of variable granite that stretches all the way to Bathurst.

Fig 8. The granite gorge at Hyde Park Reserve (photo: Chris Marshall).

Their first encounter with this terrain occurred as they began to traverse the middle section of Cox's River catchment. Here the river is continuing to carve a deeply dissected valley into the erosion prone granite. Just to their north, at the Hyde Park Public Reserve near Hartley, is a spectacular gorge carved by the River Lett (Fig 8). It is just downstream of the point where the older Carboniferous granite meets the overlying Permian sediments. The granite must extend underneath these younger rocks well east and north of this contact.

The slope of the granite valleys on this section of the route proved challenging. More so than the gentler slopes that revealed themselves later as the travellers moved further west through the section of the Bathurst Batholith beyond the Great Divide.

The granites of the Bathurst Batholith represent multiple landscape scale intrusions during the middle to late Carboniferous Period. The intrusions become older from east to west. Each intrusion having discretely different mineral constituents recently revealed by the use of high resolution airborne magnetic image technology.

The Tarana granites that dominate the eastern end of the batholith are characterized by a distinctive pink colouring and the coarse texture of the minerals. These qualities have been exploited for high quality construction material including aggregate in concrete panels forming the forecourt and exterior walls of the podium of the Sydney Opera House.

Based on the size and character of the mineral crystals in the granite across the Bathurst Batholith, it has been estimated that they formed at least 5 kilometres below the ancient land surface. The overlying rocks may well have been altered and cracked by this massive intrusion leading to accelerated erosion, eventually exposing the underlying granite. Once exposed it became deeply weathered and eroded, creating the distinctive middle reaches of Cox's River valley. To the west of the Great Divide is a landscape scale granite erosion basin segmented into the Tarana and Bathurst valleys. In contemplating these great depths and associated processes it's important to grasp that as the erosion occurred and the weight of material was reduced, the intruding body of granite continued to rise, maintaining the relative elevation of the land surface.

The character of the granite landscape while variable in slope, relief, soil type and rock exposure, is often distinguished by attractive rounded hills. It has long, relatively low sloped swales and valleys. These later features invariably comprise deep fills of Pleistocene (1.8 Ma) aged sands and gravels. They are topped by Holocene aged (8,000 year old) swampy meadows with dark coloured clay loam soils. All of which must have made for pleasant, relatively easy travel and excited speculation as to future grazing and farming

opportunities. Apart from the sandy topsoil on the hills, there was little to indicate the fragility of this landscape that is so widely evident in the present day deeply gullied flow lines across much of the granite country.

Reaching the Great Divide. Climbing steadily through granite country west from Cox's River at Glenroy Crossing, the travellers were no doubt aware of reaching yet another prominent high ridge. However, they would have been unaware that they were in fact reaching the crest of the Great Divide at about 1100 metres. A similar altitude to the top of the Triassic sandstone that they had traversed near Mount York.

Fig 9. Permian Sydney Basin sediments deposited directly on Carboniferous granite at Cheetham on the Great Divide (photo: Chris Marshall).

At this point the travellers encounter one of a number of narrow outliers of the Permian sediments of the Sydney Basin, last seen on their route in the Hartley Vale. They are intriguingly preserved and isolated on the ridge crests of the modern landscape. The outliers provide clear evidence of the ancient western spread over the granite of the Permian marine sediments in this enormous depositional basin (Fig 9). Looking back into the deep intervening valley of the Cox's river, it's a strong reminder of the power of erosion to strip away vast overlays of rocks.

Remnants of an ancient plain. Although their route was now one of easier undulations, the early travellers may have noted they were passing numerous points of relatively high elevation. With grazing in mind they are likely to have noted small instances of attractive plains in the uplands. They were not to know that these features are likely to be remnants of the ancient Cretaceous plain that was elevated in the process of the creation of the Great Divide. The remnants, together with the Jenolan Caves mentioned later, are very likely the oldest landscape units in the region.

The terrain retains a gently undulating profile with higher residual hills. On all sides the forces of erosion have carved out steepening side slopes and valleys. Gerry's Meadows to the south and Cheetham's Flats and Honeysuckle Flat to the north are well named and good examples of these special features. The travellers may well have also noted the generally level skyline to their south west indicating the edge of the extensive Oberon plateau that shares a similar provenance. However, they surely would not have seen the plunging Fish River gorge. Here the river exits that plateau, carving through the ancient Lachlan Fold Belt rocks, chasing the lowered base level created by the scoured Bathurst granite valley downstream.

The prevailing evidence suggests that the alignment of many of our modern rivers is still tied to the pattern established when the ancestral form of those same rivers flowed across the ancient Cretaceous plain. These were Gondwanan rivers. They flowed in large catchments rising far to the south and east on an ancient Tasman Divide that has since disappeared with the creation by rifting of the Tasman Sea. It has been suggested that the rising of the Great Divide has since beheaded many of these rivers. The gradual uplift involved has allowed the river remnants to continue to follow their ancient alignments. In many cases the modern rivers cut against the rigid grain of the geology.

Hidden marvels, Jenolan Caves and other features of warm-ocean carbonate reefs. Much of the varied detail of the landscape and geology was hidden from the early travellers by the confines of their chosen

route and the complexity of the terrain around them. South of where they crossed the Great Divide and out of sight to the travellers, is one of the region's iconic geodiversity features. Here, hidden deep in a steep valley are the Jenolan Caves and their associated complex of karst features. This and other less well known outcrops of karst topography in the area have developed in remnants of ancient Silurian Period (434-410 Ma) carbonate reefs. The coral reefs had formed on the shallow shores of the large sea mount volcanoes emerging from the deep ocean. These distinctive materials later became incorporated into the rock structures that now make up the landscape in this location.

The complex contains karst features dated as some of the oldest in the world with evidence of progressive and ongoing formation.

The dramatic ramparts of Evans Crown. While to most who view the Bathurst Batholith it appears rather homogenous, there are subtle differences in its various intrusive bodies. Perhaps one of the most spectacular expressions of exposed granite is seen in the outstanding Evans Crown ridge. It was of such prominence that explorer George Evans gave it his own name. This particular granite is one of the youngest (312Ma) of the multiple intrusions making up the Bathurst Batholith.

It would appear that the Evans Crown Granite is substantially more resistant to erosion having intruded into the older Tarana Granite. It now stands spectacularly as a rugged, well-defined ridge of tors above the expanse of more rounded Tarana landscape (Fig 10).

The tors have an origin in the pent up pressures developed during the original deep intrusion events. As the weight of the overlying rock layers is removed by erosion the pressures within the granite are released. Fractures and lines of weakness are created that lead to patterns of focused decomposition and erosion. This eventually creates the exposed blocky structures we call tors that give Evans Crown its special character.

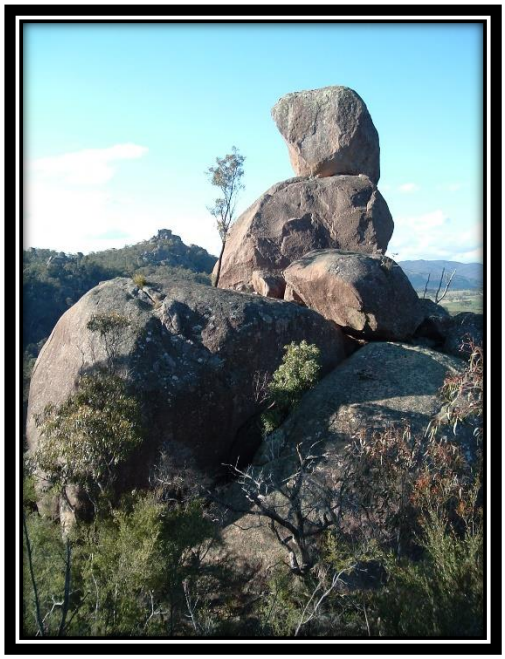


Fig 10. Distinctive granite tors on the ridge of Evans Crown (photo: Chris Marshall).

It is not the only incidence of tors in the Bathurst Batholith. However, Evans Crown is undoubtedly the most extensive, prominent and easily accessible concentration of these special landscape features. Its values are well protected in the Evans Crown Nature Reserve. Other higher elevation locations of resistant granite in the batholith, not all with tors, include Mount Stromlo, Windy Corner, Gresham, The Rocks, Devils Marbles and Mount Rankin.

Lachlan Foldbelt sediments. From the vantage of their elevated position near Evan's Crown, travellers would have observed the steep sharp ridged terrain that seemed to wall them in from the north. They would have noted it as formidable country. Today we know that the peaks of Mounts Lambie, Tarana and Tennyson are prominent high points beyond which lie the dissected plateau country of Eusdale, Yetholme and Meadow Flat. These fragments of plateau are further examples of the remnants of the raised Cretaceous plain mentioned earlier. The clear, cool, tumbling waters of Solitary, Diamond Swamp, Eusdale and Frying Pan Creeks may have turned the travelers' thoughts to the possibilities of such a well-watered plateau if they had ventured that far from the route of Cox's Road.

The prominent escarpment that they skirted as they travelled west is their first real view of the Lachlan Fold Belt geology that dominates so much of the Bathurst region north and south of the Bathurst Batholith. There is much complexity in the diversity of mostly deep ocean deposited materials that make up this belt of distinctive rocks. What the travellers saw from this locality was a soaring forested escarpment. It is composed mainly of Gibbons Creek Sandstone as part of the Lambie Group of Late Devonian aged rocks (Fig 11).

The ancient volcanics of Lowes Mount. Rising almost immediately in their path and blocking their view as they travelled to the west is the long ridge of Lowes Mount. It protrudes into the valley from the south as an extension from the Oberon plateau and guides their eyes to the broadening valley to the north west. This prominent feature is also part of the Lachlan Fold Belt and showcases some of the older rocks to be seen along the entire Cox's Road route. It is from the Late Ordovician Period some 440 million years ago. It comprise diverse materials derived from marine volcanoes deposited in a deep ocean environment.

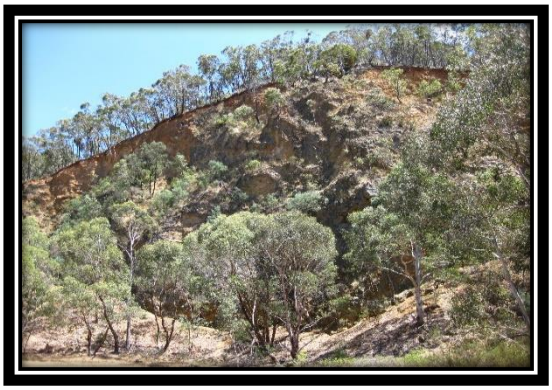


Fig 11. Deep exposure of Gibbons Creek sandstone in Tarana quarry (photo: Chris Marshall).

High points on the horizon. By now these early travellers had noted that they were following a river flowing generally westward and then more northerly. It is separate from the systems they were familiar with further east. While generally descending on this part of their route, the high points they could see in the distance above the basin rim, must surely have caught their attention. They had an eye for potential navigation points to assist future trips.

We now recognize a number of more prominent high points above and beyond that rim. The Brothers at Caloola, Mount Macquarie behind Carcoar, Smith's Hill near Newbridge and of course the remnants of the Mount Canobolas central and shield building volcano.

The 41 Ma basalts on Middle Brother give us a point to ponder. The scale of landscape erosion that has occurred since the fiery flow that enveloped the valleys of that ancient landscape is indeed prodigious. Solidified basalt now caps this particular geographic high point. This and other high points such as Mount Macquarie and Smith's Hill Trig, sit as prominent residuals on a stepped plain that is bound in some instances by quite dramatic erosion scarps.

The trigger for the start of this spectacular landscape sculpturing was initially the uplift of the Great Divide. It activated accelerated erosion in the ancient Wambuul/Macquarie River that flowed from a catchment boundary far to the south of its current headwaters. The second trigger was the process of continental crustal sagging that created the Murray Basin to the south west about 65Ma. The upper parts of the ancient Wambuul/Macquarie River catchment were dragged down to create a slope to the west initiating the formation of the Kalare/Lachlan River. It was separated from the now shortened and beheaded Wambuul /Macquarie River by what has become known as the Canobolas Divide.

The most spectacular erosional feature of this activity is surely the Abercrombie Gorge. It is in places rimmed by basalt flows from the 15 to 22 Ma Abercrombie lava fields once again enabling us to estimate the age of the gorge features eroded below this level.

Mount Canobolas, a once fiery and explosive beacon. Lurking just beyond the travellers' view to the west was the regions highest and most prominent residual feature in the form of Mount Canobolas. At

1,397 metres altitude this is a substantial remnant of a shield volcano that subsequently developed into a spectacular central volcano with a cluster of trachyte cones and domes as well as an extensive lava plain. It has capped the previously uplifted Cretaceous plain in this area. By dating the basalts at around 12 Ma we once again are able to infer the age of the landscape features in that area. It's worth noting the distinctive radial drainage pattern that now extends out from this iconic high point, further altering the Canobolas Divide that had been created in earlier times.

Windy Corner. This high point on today's Lagoon to O'Connell Road is the divide between the Fish and Campbell's rivers. Its prominence afforded the early travellers an opportunity to visually review their progress and to scan ahead in anticipation. From here can be sensed the junction of the two rivers to form the Wambuul/Macquarie River and the broadening of the Bathurst granite basin to the north. It's a landscape of open, rolling hills with extensive outlooks and a soft beauty when compared to the more dramatic steep ridges that define the visual rim of the great erosion basin.

Just east of here the travellers had already made special note of the broad floodplain of the Fish River. In the next days they would marvel at further beautiful expanses of floodplain on the Campbell's and Wambuul/Macquarie rivers.

From Windy Corner can be seen Rockley Mount that was to become a future locality of mineral wealth involving the mining of copper, silver and zinc. Fitzgerald Mount marks the alignment of the modern highway out of the Wambuul /Macquarie River valley into that of the Kalare/Lachlan River to the west and south. Wahluu /Mount Panorama and the Bald Hill behind Perthville are supremely prominent on the route they were to follow down the broadening granite basin to their terminal camp at the site of Bathurst.

Fig 12. The dramatic Winburndale Range demonstrating its deeply dissected plateau character (photo: NSW Land & Property Information).

The Winburndale Range, a moody presence. The spectacularly rugged Winburndale Range dominates the northern view from the high point at Windy Corner and indeed fills the eastern horizon from the modern city of Bathurst (Fig 12). The impressively steep, sharp ridges of hard sandstone are part of a sequence of deep marine rocks, overlain in part with distinctive coarse terrestrial sediments. These red and purple conglomerates are starkly evident in the wonderful cliff lines of the Winburndale Nature Reserve (Fig 13). The appearance of these sediments marks the first transition in the Bathurst region late in the Devonian Period from a deep ocean environment to continental landscapes. Evidence for an intermediate shallow

water phase is clear in the common occurrence of beautiful Brachiopod shell fossils to be found in the sediment beds. They occur below the conglomerates and are scattered in the broken rocks on the slopes below (Fig 14). . Keen fossickers can spot these fossils in rounded river transported rocks in the streams and creeks that flow from these ranges.

Fig 13. Conglomerate cliffs in Winburndale NR (photo: Chris Marshall).

This local transition to dry land occurred later than further west where the world class fish fossil beds at Canowindra testify to riverine and lake environments being pushed progressively to the east.

It would have been beyond the comprehension of the early travellers to grasp the significance of even older sediments in this range of hills and high plateaus. These rocks reflect extended periods of intense volcanic activity from mountains emerging from the ocean in the great Macquarie Volcanic Arc during the Silurian and early Devonian periods. To further complicate the picture is the notion of geological compression, deformation and continental crust building that is also prominently displayed in these local rocks.

The older rocks have been subject to compression from the east in the Tabberabberan mountain building phase giving them a dominantly north south alignment (Fig 3). These and the younger sandstones and conglomerates were then uplifted during the Kanimblan orogeny. The result is an obvious syncline that can be observed in the cliff lines of the Winburndale Range (Fig 13). The final tectonic event involved the gentle uplifting of all these features to create the Great Divide in the Middle Cretaceous Period.

With no known specific Wiradyuri name and only a couple of prominent high points named on the official topographic maps, this area remains informally the Winburndale Range for those who know and love it. Much of it is protected and actively managed for its outstanding natural and cultural values as the Winburndale and Eusdale Nature Reserves.

Fig 14. Brachiopod fossils from the Winburndale Range (photo: Chris Marshall).

It can be a brooding, moody range in mist or snowy weather. In contrast its skyline of ridges and cliffs is often sharply etched against the blue sky on clear winter days.

Mysterious and rugged to visit, it reveals many interesting features for those willing to explore. Big Flat within the Winburndale Nature Reserve is an excellent example of a remnant of the Cretaceous plain uplifted with the formation of the Great Divide. It is now almost isolated by the rapidly eroding sharp ridges that drop away from it on three sides. The alignment of the Winburndale Rivulet and Clear Creek across the grain of the north south trending geological structures give good indication of stream alignments on the ancient plain. The alignment has been retained in tightly gorged forms in the uplift. The sandstone and conglomerate cliffs give special visual outlooks to the Bathurst plains and beyond.

Perhaps most importantly the range gives insight into the unique point in time when extensive land first emerged from the shallowing ocean at Bathurst.

Fig 15. Remnants of the ancient complexly meandering channel of Raglan Creek on the floodplain at Bathurst (photo: NSW Land & Property Information).

Floodplains and wetlands. Descending to Campbell's River the travellers were no doubt unaware of the evidence of the vastly different landscape that prevailed during the various glacial periods of the last two million years.

Approximately 20,000 years ago, at the climatic extreme of that worldwide glacial, the Bathurst region was more seasonally dry, cold and windy than it is today. In responding to these conditions the vegetation across the catchment would have been sparse with less transpiration leading to increased surface runoff and groundwater discharge. The result was accelerated rates of catchment erosion and spasmodically energetic, shallow braided rivers. There was a dominance of coarse bed loads in the rivers. The evidence for this lies in the extensive beds of sands and gravels that underlie the clays and loams on the modern flood plains.

Fig 16. Pleistocene river bed materials above the modern floodplain of the Winburndale Rivulet (photo: Chris Marshall).

Similar beds of gravel are found on surrounding higher slopes. They hint at similar situations with a high energy river system carrying a large coarse bed load during other multiple glacial extremes going back beyond 2 Ma (Fig 16).

With the moderating of the climate after the last glacial extreme about 15 thousand years ago, vegetation cover on the catchment increased. The streams transitioned to a sediment load dominated by finer clay and loam materials which built the upper layers of the modern floodplains. There is clear evidence that the river that built these organic clay loams was of a shallow and complexly meandering nature. Modern air photos reveal channel remnants and soil patterns related to this system (Fig 15). It remains a mystery as to when and why that meandering shallow system converted to the more entrenched rather straighter river channel that confronted the early travellers

and remains evident today. The modern river is a likely misfit for the floodplain that is an artifact of older and different catchment conditions.

Fig 17. Apsley Lagoon on the floodplain of Campbell's River (photo: Chris Marshall).

The modern climate patterns emerged about 8 thousand years ago. With this came the steadying of the earlier widespread catchment erosion and commencement of soil forming processes that began creating the valuable organic component of the modern floodplain and hill soils of the region. These processes operated across the catchment with clear evidence of deep valley fill sands and gravels topped by organic dark soils in the numerous swampy meadows. It's notable that the early travellers recorded sighting of these features in the many creeks and flow line swales along their route.

Much of the extensive riverine floodplain encountered by the early travellers would have comprised ephemerally or permanently wet meadows, billabongs and back plain lagoons. They were no doubt frustrated by the waterlogged nature of the floodplains with their extensive beds of reeds that constrained their travel. Perhaps this is the reason for them picking their place to cross the Campbell's River at one of its narrower points. They chose a route to Bathurst on the ridgeline above the widening floodplain of the Wambuul/Macquarie River and the constraining Vale Creek converging from the south west.

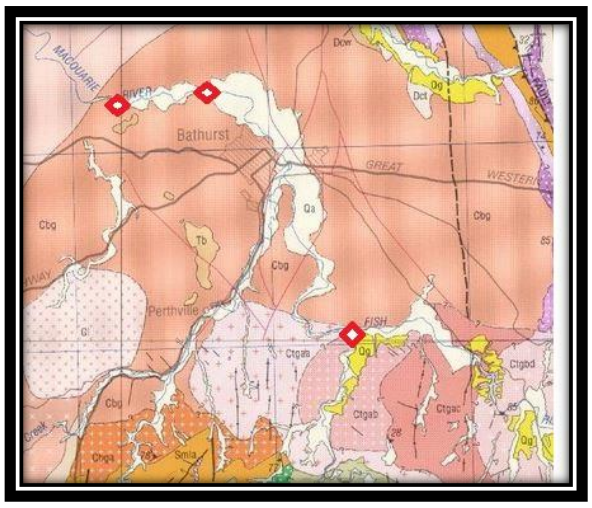


Fig 18. Floodplain Qa with examples of key nick points marked with red diamonds (base map: Geological Survey of NSW).

Modern remnants of these extensive wetlands are now largely confined to a small percentage of their original extent. Vast areas have been subject to drainage, grazing, cultivation for crops and development as parklands and playing fields.

One remnant of note is the distinctive back plain pond that is the Apsley Lagoon on the Campbell's River floodplain (Fig 17) near where the travellers first descended from Windy Corner. Another outstanding example is the series of wet meadows, meander remnants, manmade channels and brick pit excavations that make up the Raglan Creek Wetland Complex on the Bathurst Plains (Fig 15). Both remnants support impressive populations of water birds and remain valuable as wetlands.

Why is there a floodplain at Bathurst? A major element of the landscape that drew the early Europeans and no doubt the Aboriginal people before them, to the locality of Bathurst, was the presence of the broad areas of organic rich, dark soiled floodplain. They may well have pondered the geomorphic forces at play that created these regionally significant features.

The highly erodible nature of the Bathurst granite compared to the surrounding Lachlan Fold Belt rocks has already been mentioned. This significant imbalance led to the scouring of a massive landscape scale erosion basin. It created an expanse of gently rounded hill country that now forms the familiar Bathurst valley. The basin is largely edged by steep, sharp ridged and harder rocked escarpments. Streams drop over and carve through them into the granite valley from the surrounding more resistant higher plateaus.

While the granite valley was being rapidly scoured across its area, its overall downward erosion was being delayed at a number of key geomorphic nick points by harder rock structures. These nick points include localities where the river exits and reenters the harder Lachlan Fold Belt rocks. They also occur at points at which there are more erosion resistant granitic materials (Fig 18). The result is a river system with steep narrow valleys at the entry and exit points from the granite. There is a broad valley and much flatter grade through the granite reaches. There also appears to be a steepening of grade and a narrowing of the valley at each internal granite based nick point. Upstream of each of these, significant areas of alluvial deposits have developed in the sections of flatter, broader valleys (Fig 19).

Fig 19. Landscape nick point near the junction of Evans Plains Creek and WambuulMacquarie River with extensive area of flood plain upstream (photo: Chris Marshall).

The early travellers had already passed nearby to one important nick point in the vicinity of White Rock on their inbound trip. Here is the boundary between the Bathurst and Tarana granites. The travellers had specifically noted the extent and quality of the broad floodplains on the Fish and Campbell's River but it's unlikely they were aware of the significance of the nick point in creating those plains.

Fig 20. The rain shadowed Bathurst valley landscape (photo: Wes Schulstad).

When they explored downstream to Pine Ridge from their eventual terminal camp at Bathurst, the travellers would have passed another two of the most important nick points in the valley. One at the site of the future Ranken's Bridge near Eglinton. The other near the Evans Plains Creek junction with the Wambuul/Macquarie River where the boundary between the Bathurst and Dunkeld granites crosses the river (Fig 19). These are clearly visible from local roads which also provide a wide views of the broad expanses of floodplain banked up behind the nick points.

By the time the early travellers reached the high point above the river at Pine Ridge they would have noted, perhaps in trepidation, the narrowing and steepening of the valley into a distinct gorge. From here the river once again begins its descent through the rugged terrain of the Lachlan Fold Belt rocks with very limited instances of floodplain development.

A <u>rain shadowed</u> erosion basin. By now the travellers had become familiar with the rounded granite hills. Theirs had been an extended traverse of this attractive landscape, slowly descending from the high country

in the east into an ever widening valley to the north west. The Lachlan Fold Belt rock structures continued to dominate much of the skyline with their distinctive steep ridges.

Closer to their terminus at Bathurst they may have begun to speculate on the consequences of this widening valley (Fig 20). Perhaps they sensed from the changing vegetation structure that they were travelling ever deeper into a natural rain shadow with all its implications for future land use in the valley. Modern travellers still marvel at the frequency with which steady rain can fade at the edge of the high rim as they begin to descend to Bathurst. The valley is noted for its less frequent and more erratic rainfall. It seems all access to Bathurst involves a descent from higher wetter country. Much of the dependable flow in the valley's streams is sourced beyond the steep rims on the better watered remnants of the raised Cretaceous plateau.

Fig 21. Abercrombie House constructed substantially from local granodiorite (photo: Chris Marshall).

This part of the basin is underpinned in part by Granodiorite, one of the older granite intrusions in the sequence making up the Bathurst Batholith. It is grey in overall colour in contrast to the pink of the Tarana granites observed earlier and also seen nearby in the even older Dunkeld Granite. The Bathurst granodiorite is very deeply weathered with little natural surface exposure.

Granodiorite was successfully quarried on site for building material for the historic Abercrombie House (Fig 21) in the late nineteenth century. Civic uses of this beautiful stone can be seen at the George Street gates in Machattie Park as well as the bases of the Boar War and Evans Memorials in Machattie Park.

The soils on this part of the Batholith are variable but it is notable that the better drained ridge crests are often dominated by quite distinctive red chromosols that have come to be the official soil emblem for the NSW Branch of Soil Science Australia. They are described as "the workhorse soils of agriculture in NSW" because of their extent and the diversity of rural uses to which they have been put.

An ancient river filled with basalt. Having established their comfortable river side terminal camp at the future site of Bathurst, did the early travellers sense the geological significance of Wahluu/Mount Panorama? It dominates the skyline nearby to the south west as does Mount Pleasant to the north west.

Fig 22. 19 million year old river bed material on Wahluu/Mt Panorama. Note the scale of erosion needed to create the modern Bathurst valley in the background (photo: Chris Marshall).

They couldn't possibly have grasped that the presence and form of these high points was linked to the forces associated with continental break up. Particularly the raising of the Great Divide and the creation of a number of volcanic provinces in the region.

Of great importance for Bathurst is the 19 million year old Abercrombie Volcanic Province to the south. It comprised lava fields that delivered molten basalt in vast flows down the ancient Wambuul/Macquarie River bed, filling its channel and capping its sediments.

Today remnants can be found of both the ancient river bed in the form of sand and rounded river pebbles (Fig 22), and the basalt capping (Fig 23), outcropping on Wahluu /Mount Panorama and other nearby hills. At the contact between the basalt and the river materials at some localities is a layer of the river bed material fused into a distinctive matrix of silcrete and ferricrete. Large fragments of these incredibly hard rocks can be found scattered down slope of their original outcrop.

Below the river bed material at some sites, are profiles of pale kaolinite clay. This material provides evidence of deeply decomposed granite formed in a very humid and perhaps warm climate. Some of the kaolinite may have been concentrated in localised lake deposits associated with the ancestral Wambuul/Macquarie River. This river most probably flowed on a broad flat plain supporting subsidiary lakes in which this very fine material was deposited.

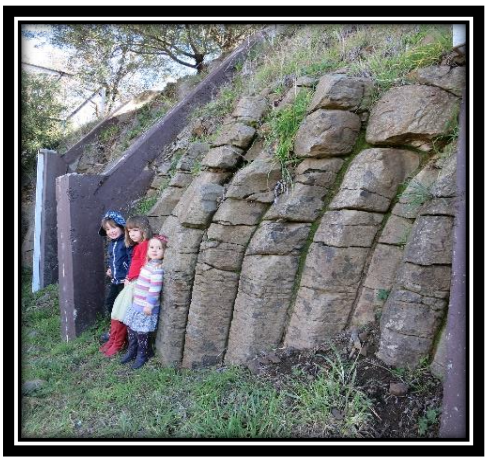


Fig 23. Basalt columns form part of the intriguing volcanic capping to Wahluu/Mt Panorama in the Wahluu Gamara Reserve (photo: Chris Marshall).

The modern valley of the Wambuul /Macquarie River. The dating of the volcanics is the key to grasping the scale of change that has created our contemporary landscape. It's sobering to stand beside the exposed river bed materials in the road cuttings on Wahluu/Mount Panorama (Fig 22) that were overwhelmed by the molten basalt flow (Fig 23). The challenge is to understand that 19 Ma ago this was the river bed in the bottom of the valley cut by the ancient Wambuul/Macquarie River. The depth of relatively resistant basalt emplaced in the river valley was sufficient to see the river diverted to the side. Here it could continue its erosive work in the more erodible granite materials. The result is remnants of the ancient river bed and associated basalt capping now standing as the high point in the modern landscape.

Today, looking east across the broad rolling valley, the modern version of that river is located some 200 metres lower. It and its tributary streams has carved the vast volume of material from the valley that stretches from that point to the Winburndale Range. Its work has proceeded at a rate in the order of 10 metres per million years.

This is a story of prodigious geological work on a grand scale.

Fig 24. Ancient river stones from a Bathurst garden (photo: Chris Marshall).

Remnants of ancient river beds. In descending the slopes of Wahluu/Mount Panorama one passes over soils carrying the mixed erosion products of that prominent landmark. Granite derived sands of quartz and feldspar, black basalt rock fragments and intriguingly, small rounded quartz pebbles in a variety of subtle colours. They are spread across the hills and are continually making their way down slope under the ongoing forces of landscape erosion. At the base of the mountain can be found deep deposits of these mixed materials in the gullied foot slopes and valley fills (Fig 26).

At various localities and altitudes around the city of Bathurst can be found concentrated deposits of very similar quartz gravels together with river sands cemented by iron and silica. Some may well be the remnants of river beds long left stranded as the Wambuul/Macquarie River pursued its relentless down cutting of the valley. Other more dispersed examples may be remnants of materials from higher river positions being spread downslope in the manner observed on the higher slopes of the mountain. Gardeners in the city are often puzzled and frustrated by these seemingly strange rounded stones mixed throughout the soils of their gardens (Fig 24).

Fig 25. Pleistocene aged deflation basins east of the village of Raglan (photo: NSW Land & Property Information).

There are other observable traces of the ancient Wambuul/Macquarie and Fish Rivers. Road cuttings at Gorman's Hill, Eglinton, Kelso and near O'Connell reveal quite remarkable deposits of river rubbles and gravels 10 to 20 metres or higher above the modern river, indicating ages in the order of 1 to 2 Ma. Similar materials are evident in the valley of Campbell's River that the travellers may have noticed in passing on their way to Bathurst. Dramatic deposits also exist above the outer edges of the modern floodplain of the Winburndale Rivulet (Fig 16) that the travelers visited in a day trip from their terminal camp at Bathurst. The size and spread of these deposits hint at large, high energy rivers and actively eroding catchments compared to today.

The legacy of a <u>periglacial</u> climate. Evidence suggests that we are currently in an interglacial period. This has been preceded by a series of glacial and interglacial events over at least two million years or more. The extreme of the last worldwide glacial is estimated to have occurred approximately 20 thousand years ago. A waning from the extraordinary cold occurred from about 15 thousand years to conditions somewhat similar to today at about 8 thousand years. While there were no actual glaciers in the Bathurst region, there is evidence of periglacial conditions with a seasonally dryer, colder, windier climate. Temperatures were on average about six degrees colder than today. There was a lack of groundcover and reduced transpiration induced by the cold constrained vegetation. Despite the dryer climate its likely there was more groundwater and rainfall runoff and rivers had spasmodically higher energy because of those hydrological changes.

Fig 26. Deep coarse valley fill material exposed in the gullied Hawthorndon Creek in Boundary Road Reserve (photo: Chris. Marshall).

Evidence of this trying environment can be seen in the small regionally significant <u>deflation basins</u> scoured by strong winds out of the upland plain just east of Raglan at this time (Fig 25). While often dry, they

occasionally have enough water in them to support nesting swans and other water birds. They are unusual and special spots in our landscape.

Other emerging evidence exists of windblown soil materials on the crests of high points in the Sunny Corner area as well as instances of coarse slope wash deposits in many granite soil profiles in parts of the Bathurst valley. There is also evidence in the form of the deep coarse valley fill deposits now exposed in many of the gullied swampy meadows of the region (Fig 26) and the fact that the floodplains are underlain with coarse gravels and sands.

Cox's Road Terminates at the Site that has become the Modern City of Bathurst

Governor Macquarie, with the guidance of Evans and Cox, was drawn to the pleasant camp site at the junction of the Wambuul/Macquarie River and Vale Creek. The character of the site is still largely defined by the long, low slopes that rise from here towards Wahluu/Mount Panorama as a catchment divide between the lower ends of the Vale and Jordon creeks.

The slopes here are distinctly different to the steeper rounded slopes of the surrounding granite hills. These locally unique features are in fact reshaped and eroded remnants of ancient flood plain terraces of the Wambuul/Macquarie River. They have been left stranded as the river continued its downward cutting of the landscape through the ages. Using the estimated erosion rates previously mentioned, the terraces may be in the order of 1 to 2 Ma.

The gentle slopes close to reliable water but above apparent flood levels, offered obvious advantages for Macquarie's camp, as it did for the early settlement that followed.

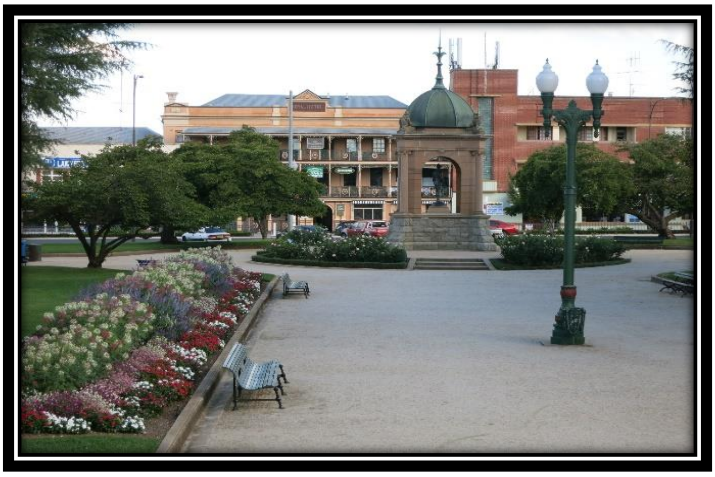


Fig 27. Low sloped ancient flood terraces proved attractive for civic, commercial and residential development at Bathurst (photo Chris Marshall).

It's surely no coincidence that the historic surveyed alignment of Macquarie's Flag Staff and the centre line of the iconic Bathurst Town Square closely follows the catchment divide between the Vale and Jordon creeks. The divide, defined by the survey, creates the spine for the city's historic grid patterned layout. From its beginning the town has been intimately linked to the landscape. Major civic buildings, cathedrals and parks are located on the flattest area of the ancient terraces straddling this divide (Fig 27).

The soils of the older part of the city carry evidence of the flood plain terraces, the underlying and surrounding decomposing granite as well as the clays developed from the ancient basalts on Wahluu /Mount Panorama. While very attractive for agriculture, the tendency for these clay dominated soils to shrink and swell has proved problematic and destructive for many of the heritage buildings in old Bathurst. Cracking of foundations and walls as well as rising damp is common.

In acknowledging this important connection to landscape we should also reflect on the fact that the Wiradyuri people had recognized, valued and creatively utalised this landscape for tens of thousands of years. They were here long before the arrival of the first European settlers. Indeed they were most likely

here 20,000 years ago during the last glacial extreme. They would have witnessed the wide, braided, and shallow, bed load dominated stream form of the Wambuul/Macquarie River at that bleak time. They must have celebrated the gradual waning of the extreme weather over multiples of generations. Such long residence surly imparted much knowledge, deep wisdom and strong landscape connection.

Much remains to be told of this intriguing landscape story. A modern, vibrant community has been established within this beautiful landscape. It is testimony to the landscape wisdom of the Wiradyuri people who have long lived in this valley as well as the gumption of the early explorers, surveyors, road builders and administrators who found their way to this special place in 1815.

While foresight, endeavour and creativity are key elements to the success of our modern community, we need also to reflect on and celebrate the special values within the landscape that allowed that community to establish and flourish.

In concluding this brief outline of the landscape, it is tempting to include an account of how the landscape has been shaped by our community. Also indeed, how the landscape in turn shaped it. Such an account would undoubtedly describe the effects of long term Aboriginal presence, the winning of great mineral wealth and the development and exploitation of soil, water and other landscape resources. It would also explore the wonder we feel and the beauty we see in the landscape, our spiritual connections to it as so often expressed through artistic endeavours, nature appreciation and the simple joy of being in the landscape.

No doubt it would also document our ongoing inquisitiveness, our striving to understand the landscape and our quest to live in harmony in it. This is a story for another occasion.

APPENDIX 1

This paper has been prepared as part of the Cox's Road Dreaming project as a contribution to the bicentenary celebrations for Bathurst. It focusses on the landscape features and the associated geodiversity that can be seen from the route of the historic Cox's Road between Mount York and Bathurst. It is a brief paper and in no way does justice to the enormous detail that is available on this intriguing subject for the entire region and beyond. Those people expecting more than I have given are guided to the bibliography provided where they may find more satisfaction. There are others who may be visiting this field for the first time and may be daunted by the terminology, the scale and the complexity of it all. I trust that I have provided enough explanation and definition to allow them to enjoy visiting Cox's Road and to inspire them to seek more information so as to further understand, value and enjoy this special landscape and its geodiversity.

I would like to thank Greening Bathurst (GB) and David Goldney for the opportunity to record my interpretation of this wonderful landscape. It's been a challenging project. Thank you also to David Goldney, Barb Mactaggart, Jim Lavis, Ernst Holland and others who have shared with me their insights into many aspects of the Bathurst landscape over the years. To Col Bembrick, thank you for your positive editing and refereeing as well as your diagrams and photos. Thank you also to Wes Shulstad for your beautiful moody landscape photos.

Chris Marshall May 2015

APPENDIX 2

Glossary of terms

Abercrombie Volcanic Province a region of ancient volcanic activity named after the Central Tablelands locality of Abercrombie south of Bathurst.

Accretion an increase of crustal material by gradual additions of geological materials over time.

Adaminiby group Ordovician aged sediment beds in the eastern part of the Lachlan Fold belt named after the original type area in the Snowy Mountains area.

Airborne magnetic technology measurements of magnetic variation in rock structures using equipment mounted in air craft.

Alluvial floodplain an area of largely flat landform created by the deposition of sediment over a long period of time by a river.

Amphitheatre a semis circle of higher steeper country overlooking a flatter area of low hills or plains.

Basalt a dark-colored fine-grained extrusive igneous rock.

Basalt cap a part of the landscape covered by basalt rock, often a high point remaining as a residual after surrounding lands have been eroded away.

Basement geology the thick foundation of ancient metamorphic and igneous rocks that forms the crust of continents generally with overlying sedimentary rocks.

Bathurst Batholith is a large emplacement of igneous intrusive rock formed from cooled magma deep in the Earth's crust. In this case a number of variable intrusions make up the batholith stretching from west of Bathurst city, east to the Blue Mountains.

Beheaded rivers a situation where ancient rivers have been disrupted by earth movements forcing their headwaters to be diverted in new directions leaving a shortened river to follow the old course**.**

Braided rivers a stream consisting of multiple small, shallow channels that divide and recombine numerous times forming a pattern resembling the strands of a braid.

Canobolas Divide the water catchment boundary between the Wambuul (Macquarie) and the Kalare (Lachlan) rivers.

Carboniferous Period a geological period of time that extends from the end of the Devonian Period, about 358.9 ± 0.4 million years ago, to the beginning of the Permian, about 298.9 ± 0.15 Ma.

Central volcano a volcano with a central vent. The volcano's cone-shaped structure, or edifice, is built by the more or less symmetrical accumulation of lava and/or pyroclastic material around this central vent system.

Chromasol a soil characterized by a strong texture contrast between the A and B horizons. The B horizon is only mildly acid, non-sodic in its upper 0.2m and is brightly coloured.

Consolidated beds layers of geological materials that have been compressed.

Cretaceous Period a geological period and system 145 ± 4 to 66 Ma.

Crust building a process involving an increase of the earth's crustal material by gradual additions of geological materials over time.

Deflation Basin a depression created on the surface of the land by the removal of soil by wind.

Deformation when rocks change form in response to imposed stress they exhibit strain, which is the differential change in size, shape, or volume.

Depositional basin a low area in the Earth's crust in which sediments accumulate.

Elements are chemically the simplest substances and hence cannot be broken down using chemical methods.

Estuarine beds layers of sediments laid down in a body of water formed where freshwater from rivers and streams flows into the ocean, mixing with the seawater

Faulting a planar fracture in a volume of rock, across which there has been significant displacement along the fractures as a result of earth movement.

Ferricrete a hard, erosion-resistant layer of material at the land surface that consists of near surface sediments cemented by iron oxide.

Folding occurs when one or a stack of originally flat and planar surfaces, such as sedimentary strata, are bent or curved as a result of permanent deformation.

Geological compression a set of stresses directed toward the center of a rock mass.

Geological history the story of the origin, and structure of the earth through time.

Geological processes natural processes whereby geological features are modified.

Geologist an expert in the field of geology, the study of what the Earth is made of and how it was formed.

Geomorphologist an expert in the field of geomorphology, the study of the evolution and configuration of landforms.

Gibbons Creek Sandstone the dominantly marine quartz-rich siltstone and sandstone geological unit within up the Lambie Group of sedimentary rocks in the Bathurst region.

Glacial extreme the peak of extreme conditions in a period of long-term reduction in the temperature of the Earth's surface and atmosphere.

Glaciation the process or state of being covered by glaciers or ice sheets.

Gondwana the name given to the more southerly of two super continents, the other being Laurasia, which were part of the Pangea supercontinent that existed from approximately 510 to 180 Ma.

Granodiorite a coarse-grained plutonic rock containing quartz and plagioclase, between granite and diorite in composition.

Great Australian Basin a continental scale depositional structure that received sediments during the Jurassic and Cretaceous Periods, becoming the contemporary Great Artesian Basin.

Great Divide a catchment boundary separating eastern and western flowing rivers in south east Australia.

Hill End Trough a regional scale geological depositional structure formed in the late Silurian Period that dominates the geological character of the Bathurst region north and south of the Bathurst batholith.

Holocene The more recent of the two epochs of the Quaternary Period, beginning at the end of the last major Ice Age, about 10,000 years ago. It is characterized by the development of human civilizations. Also called Recent.

Intrusion rock formed from magma that cools and solidifies within the crust of the planet.

Jurassic Period a geological period and system that extends from 201.3± 0.6 Ma to 145± 4 Ma; from the end of the Triassic to the beginning of the Cretaceous.

Kalare Wiradyuri word for Lachlan River.

Kanimblan orogeny a mountain building event in eastern Australia during the Carboniferous Period named after the locality of Kanimbla.

Kaolinite clay a soft white clay formed from the chemical weathering of minerals like feldspar.

Karst topography landscape underlain by limestone which has been eroded by dissolution, producing caves, ridges, towers, fissures, sinkholes and other characteristic landforms.

Lachlan Fold Belt is a geological area of the east part of Australia. It is a zone of folded and faulted rocks of similar age. It dominates New South Wales and Victoria, also extending into Tasmania, the Australian Capital Territory and Queensland.

Lambie Group a distinctive and extensive series of sedimentary rocks preserved in synclines in the Bathurst region**.**

Lava fields localities of volcanic activity where the bulk of the lava comes from numerous vents or fissures.

Lava plains a large expanse of nearly flat-lying lava flows. Such features are generally composed of highly fluid basalt lava, and can extend for tens or even hundreds of kilometers across the underlying terrain.

Macquarie Volcanic Arc a line of ancient seamount volcanoes.

Molong and Capertee Highs areas of geographic high ground either side of the Hill End Trough.

Ordovician Period a geological period and system and covers the time between 485.4 ± 1.9 and 443.4 ± 1.5 Ma.

Orogeny an event where a continental plate is crumpled and is pushed upwards to form mountain ranges, and involve a great range of geological processes collectively called orogenesis.

Peniplain a low relief plain representing the final stage of fluvial erosion during times of extended tectonic stability.

Periglacial intensely cold conditions without a covering of ice with freeze-thaw activity producing distinctive features and landforms.

Permian a geologic period and system which extends from 298.9 ± 0.2 to 252.2 ± 0.5 Ma.

Plateau an area of elevated, generally level land standing above the surrounding area.

Plate tectonics a scientific theory describing the large scale motion of plates made up of pieces of the rigid outermost shell of the Earth comprising the crust and upper mantle.

Pyroclastic material composed chiefly of rock fragments of explosive origin associated with volcanic eruptions. Volcanic ash, obsidian, and pumice are examples.

Rain shadow a dry area on the lee side of a mountainous area. The mountains block the passage of rain-producing weather systems and cast a "shadow" of dryness behind them

Residual hills localities of high country left after the surrounding landscape has been eroded away.

Rifted a geological process involving a linear zone where the Earth's rigid crust and upper parts of the mantle are being pulled apart.

Sandstone a sedimentary rock composed mainly of sand-sized minerals or rock grains. Most sandstone is composed of quartz and/or feldspar because these are the most common minerals in the Earth's crust.

Seamount volcano a volcanic mountain rising from the ocean seafloor that does not reach to the water's surface, and thus is not an island.

Shield volcano a type of volcano usually built almost entirely of fluid lava flows. They are named for their large size and low profile, resembling a warriors shield lying on the ground. This is caused by the highly fluid lava they erupt. This results in the steady accumulation of broad sheets of lava, building up the shield volcano's distinctive form.

Silcrete sand and gravel cemented by dissolved silica. It is a hard and erosion resistant material

Siltstone A fine-grained sedimentary rock of consolidated silt.

Silurian Period a geological period and system spanning from the end of the Ordovician, about 443.4 ± 1.5 Ma, to the beginning of the Devonian, about 419.2 ± 3.2Ma.

Slate a fine-grained, foliated metamorphic rock that is created by the alteration of shale or mudstone by low-grade regional metamorphism.

Sofala and Rockley Volcanics areas of late Ordovician aged rocks derived from volcanic and volcanoclastic materials. Named after the localities of Sofala and Rockley where examples can be found.

Stretching elongation of sections of the Earth’s crust and upper mantle as part of process of plate movements.

Swale a low tract of land, especially one that is moist or swampy.

Sydney Basin an ancient depositional site of Permian and Triassic rocks.

Tabberabberan orogeny a mountain building event in eastern Australia during the middle Devonian Period named after a locality in Victoria.

Tarana Granite a major unit of the Bathurst Batholith named after the locality of Tarana and made up of eleven different units of generally coarse grained pink granite.

Tasman Divide an ancient mountain range in the super continent of Gondwana located east of the contemporary coastline of south east Australia.

Tasman Line a line depicting the ancient coastline of the super continent Gondwana prior to the geological processes that led to the accretion of the continental crustal material that now makes up contemporary south east Australia**.**

Tasman Sea the area of ocean between Australia and New Zealand.

Tor exposed rock mass of jointed and broken blocks.

Trachyte an igneous volcanic rock

Triassic Period a geological period and system that extends from about 250 to 200 Ma.

Turbidity flow a current of rapidly moving, sediment-laden water moving down a slope through water. The current moves because it has a higher density than the fluid through which it flows—the driving force of a turbidity current derives from its sediment, which renders the turbid water denser than the clear water above. The deposit of a turbidity current is called a turbidite.

Uplift vertical elevation of the Earth's surface in response to natural causes.

Volcanic cone a conical hill produced by eruption of ash, cinders, or lava

Volcanic dome a roughly circular mound-shaped protrusion resulting from the slow extrusion of viscous lava from a volcano.

Volcanoclastic a rock made up of fragments chiefly composed of volcanic materials.

Wahluu Wiradyuri word for Mount Panorama.

Wambuul Wiradyuri word for Macquarie River.

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