NEW PERSPECTIVES ON THE CENOZOIC HISTORY OF THE TAMAR VALLEY AND LAUNCESTON GORGE

by Robert E Cotton

(with five figures, one plate and one appendix)

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The Tamar Rift Valley carries evidence of an often-turbulent history during the Cenozoic period. For this research the principal rock units: dolerite, sediments, basalts (vents and flows) and conglomerates, interacting over the past 70 million years were computer modelled. Reconstructions showed that the Longford Basin was integral to the evolution of today's Tamar Valley, so were extended over the north of that basin. The main outcomes were:

The Tamar Graben and Longford Basin filled with sediments to 140 m elevation in a lake (Lake Tamar–Longford) upstream of a wall-to-wall volcanic dam across the Tamar Rift Valley. This dam coincided approximately with the current Batman Highway.

Sediments of the Longford Basin sector of the lake were subsequently raised from 140 m to 190 m elevation, upstream of a second volcanic dam based on the 140-m surface near Evandale in the Tamar Valley. This sector was separated from the Tamar by a five-km-wide dolerite horst, minimum height 190 m above sea level.

The lake (Lake Longford) overflowed along fractures in the dolerite, commencing near future Hadspen at 190 m, across the Trevallyn Fault near Launceston. The resulting high energy waterfall, draining the new Lake Longford, retreated approximately 15 km back through columnar dolerite to Hadspen, forming the Cataract Gorge.

Key Words: Tamar, Cenozoic, Longford, volcanic dam, Cataract, waterfall, retreat.

INTRODUCTION

Maps of the northern coastline of Tasmania show, east of centre, a north-northwest-trending, parallel-sided estuary extending inland for some 50 km as far as the city of Launceston. The structure controlling the linearity of the estuary is well-recognised as a rift valley averaging four to five kilometres in width and extending beyond Launceston for another 20 or more kilometres (fig. 1) where it opens into the broad Longford Basin to the south and west (Matthews 1983, Direen & Leaman 2018).

At several points in and near the original trough, volcanic vents opened and erupted basaltic lavas, which the geologist FL Sutherland, mapped and later obtained age data for (Sutherland 1968, 1969; Sutherland *et al.* 2006). The Sutherland *et al.* (2006) paper establishes valuable reconciliation between those dates and spore biozones as used in Bass Strait oil and gas exploration. Sutherland, however, did not have the advantage of access to subsequent detailed (1:25,000) mapping of the basins and surrounds by geologists from Mineral Resources Tasmania.

This work owes much to Sutherland's papers and thesis. It has involved three-dimensional (3D) computer modelling to extend Sutherland's manual structure contouring of the base of the basalts to include the trough sediments and marginal conglomerates. From this base, 62 geological models were prepared to show the evolution of the Tamar and Longford basins spanning about 70 million years. This process offers new perspectives on the evolution of the Cataract Gorge, a unique natural asset on the edge of the city of Launceston.

METHODOLOGY

The research objective was to understand the evolution of the Tamar Valley landscape, including the Cataract Gorge, between about 100 Ma (million years ago) and the present day. The approach chosen was to model the contributing geological events at time intervals of three to four million years for gradual processes and about 0.5 million years for active processes. Continuity and coherence between intervals needed to be maintained, consistent with evidence from the data sources.

The study area, situated in northern Tasmania, covers over 4,000 sq km of the Tamar and North Midland regions, bounded by the central northern coast, the Eastern Tiers and Western Tiers; and the townships of Poatina and Nile to the south. The primary data sources were:

Mapping from Mineral Resources Tasmania (MRT) formed the primary geological data set covering 2,650 sq km of the central project area. These 1:25,000 maps were produced between the years 2004 and 2011.

The topographic database included parts of the Dorset, George Town, Latrobe, Launceston, Meander, Northern Midlands and West Tamar 10 m contour coverages.

Subsurface data from the MRT Drillhole database assisted computer modelling. This included mainly lithological logs but also geochemical analyses, and downhole geophysical records.

Research literature provided context and support for the interpretation of geological data. Data fundamental to sequencing were basalt ages given by Sutherland *et al.* (2006). Photographic records from MRT and Google Earth GIS images, assisted interpretation.

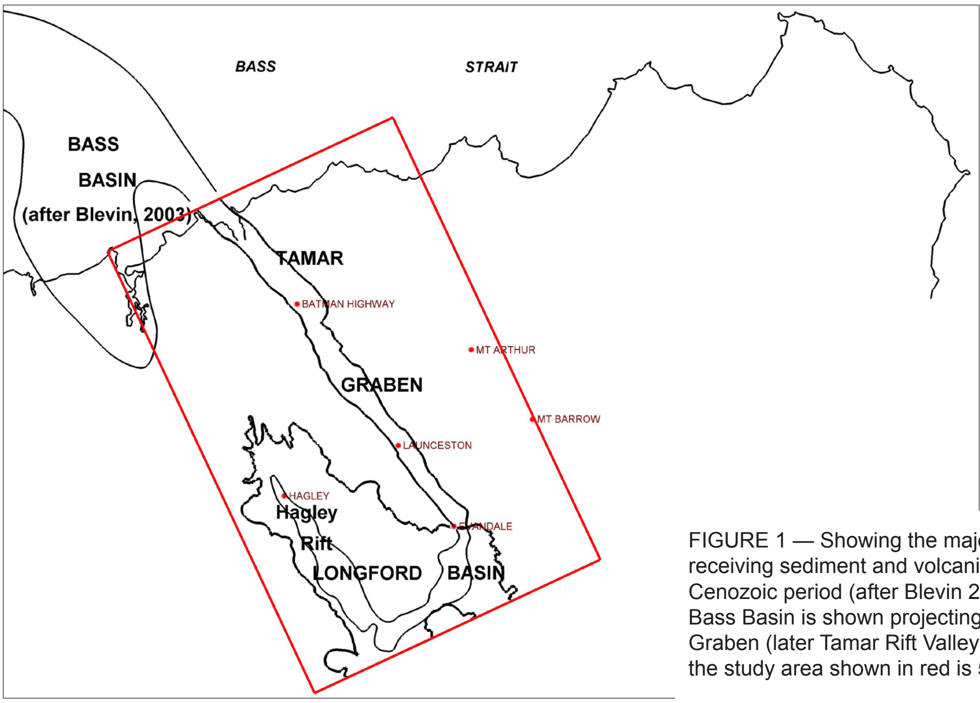

FIGURE 1 — Showing the major structures receiving sediment and volcanics during the Cenozoic period (after Blevin 2003). The Bass Basin is shown projecting into the Tamar Graben (later Tamar Rift Valley). The width of the study area shown in red is 50 km.

Field visits between 2020 and 2024 assisted interpretation of mapped geology.

PROCEDURE

Ten-metre contours for the project area were obtained by merging regional data sets into a single digital terrain model (DTM) of the project's modern surface. Individual outcrops were digitised. About half of these were grouped in sets according to rock type. With contours overlaid on the 1:25,000 geology, structure contours of rock contacts were prepared. The critical contacts were: Cenozoic sediments against dolerite, basalts against dolerite, and conglomerates against dolerite. By projecting structure contours between outcrops, pre-sedimentation contours of the walls and floor of the Tamar Graben and Longford Basin were interpolated and a pre-sedimentation DTM prepared. Much of the DTM is shown in figure 2 and figure 3 (containing sediment).

The two basins were host to a variety of fills: water, sediments, volcanic vents, basalts and conglomerates. Positive features such as the volcanic dams were modelled by increasing vent elevations and extending basalt flows consistent with the mapping. Negative features such as valley erosion within sediments required detailed shaping. 3D arrays (65 workplaces in age sequence) were populated with multiple geological entities in these categories utilising 3D geological software. Four to six screenshots of each array were made, two of which showed the entire project area from north and south. Age intervals chosen between arrays allowed conversion to video. The need for geological continuity, and for commentary on each screenshot, facilitated this paper.

For the purposes of this study, it was assumed that linear age interpolation could be made between array ages derived from (a) Sutherland's basalt ages, (b) best estimates from literature, and (c) the Time-Space Diagram for Tasmania (Seymour & Calver 1998). To avoid unnecessary complication, for the purposes of modelling all pre-Cenozoic rocks in the project area were treated as 'dolerite'.

To clarify the terms used in the paper: the Tamar Graben is a trough structure made in response to local stretching of the Earth's north Tasmanian crust. It is about five km wide and at least 50 km long made by sinking crustal rocks between two sub-parallel sets of fault lines. This process is referred to as 'rifting'.

The rock floor of the graben varies from about 40 m above present sea level near Launceston to about 200 m below sea level nearer to Bass Strait. The graben became a repository for silts and sands over time, filling the role of a sedimentary basin, and is termed the Tamar Basin. The modern landscape is strongly influenced by the ancient graben. The graben underpinning of the landscape is recognised by calling the Tamar Valley a 'rift valley'.

Pre-Cenozoic: the Tamar Graben and Longford Basin

In the east of the Gondwana Supercontinent, including future Tasmania, sheet-like expanses of mudstones and sandstones were deposited in shallow seas. In places these carry evidence of the existence of glaciers (Corbett 2019, p. 44). They were deposited almost continuously over 100 million years between 310 and 210 Ma (Seymour & Calver 1998) and still cover much of eastern Tasmania. Gondwana started to break up around 200 Ma.

The way molten dolerite masses forced their way flatly into these sediments of eastern Tasmania (with related rocks extending across Antarctica into South Africa) is well described by Corbett (2019, p. 114). The multiple

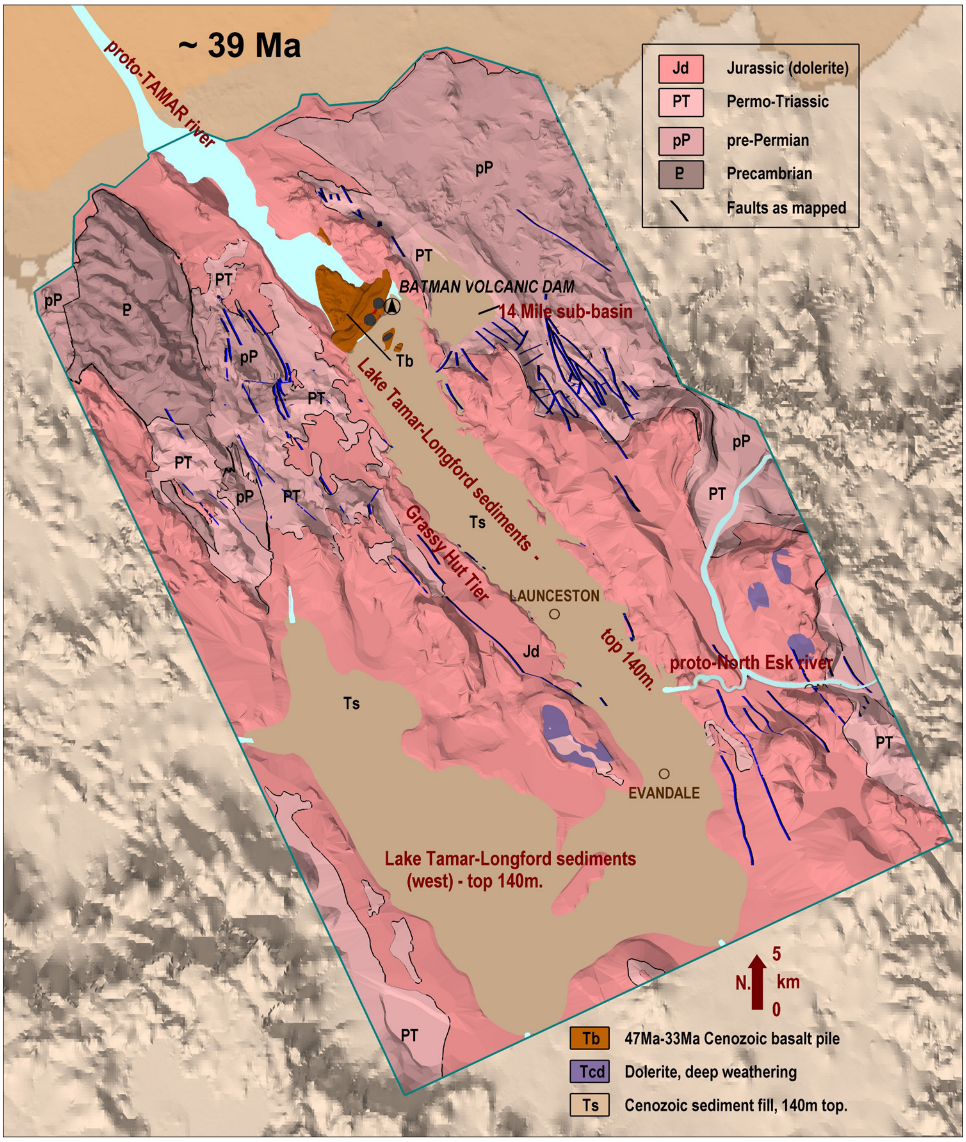

FIGURE 2 — Cenozoic sediments deposited in Lake Tamar–Longford extend upstream from the barrier created by the Batman volcanic dam, named for the Batman Bridge area.

intrusions happened in pulses between 180 and 167 Ma when Tasmania was at approximately 65° south latitude.

The deep Bass Basin in Bass Strait was initiated in the latest Jurassic–early Cretaceous period (150–130 Ma) due to crustal extension related to pre-breakup rifting between Australia and Antarctica (Cummings *et al.* 2004). Between about 125 and 100 Ma, Australia and Antarctica together became the last remnant of Gondwana following the departure of India (White *et al.* 2013). Rifting, but not spreading, between Australia and Antarctica began off southwest Western Australia about 165 Ma and extended slowly east until about 80 Ma (White *et al.* 2013). If the rifting line had continued east through Bass Strait, Tasmania would have remained linked with Antarctica while Southern Ocean spreading took mainland Australia north.

Eighty Ma saw a breakup between the two continents, coinciding with spreading in the Tasman Sea. The new spreading away from Antarctica continued very slowly until 45 Ma. Major transform faulting off the Tasmanian west coast released Australia and Tasmania to move rapidly north (25° latitude in 45 million years).

After the breakup, Bass Basin rifting continued to propagate southward resulting in the opening of the Tamar Graben in the latest Cretaceous, at approximately 75 Ma (fig. 1). The Longford Basin had begun to form in the mid-Jurassic, possibly contemporaneous with the massive dolerite intrusion event. It is divided into western and eastern sectors by a buried north–south dolerite ridge. A deep rift (to 800 m below sea level) developed south of future Hagley within the Longford Basin.

The rifting underpinning the Tamar Valley is still apparent today in vertical steps of 50–100 m or more from below sea level in the Tamar Estuary across to the crests of Mount Arthur, Mount Barrow and Ben Lomond above 1,200 m elevation. The west wall of the valley is also stepped by faults to crests 300 m above sea level in the up-faulted (horst) block separating the Tamar Basin from the Longford Basin, the Grassy Hut Tier (figs 2, 3).

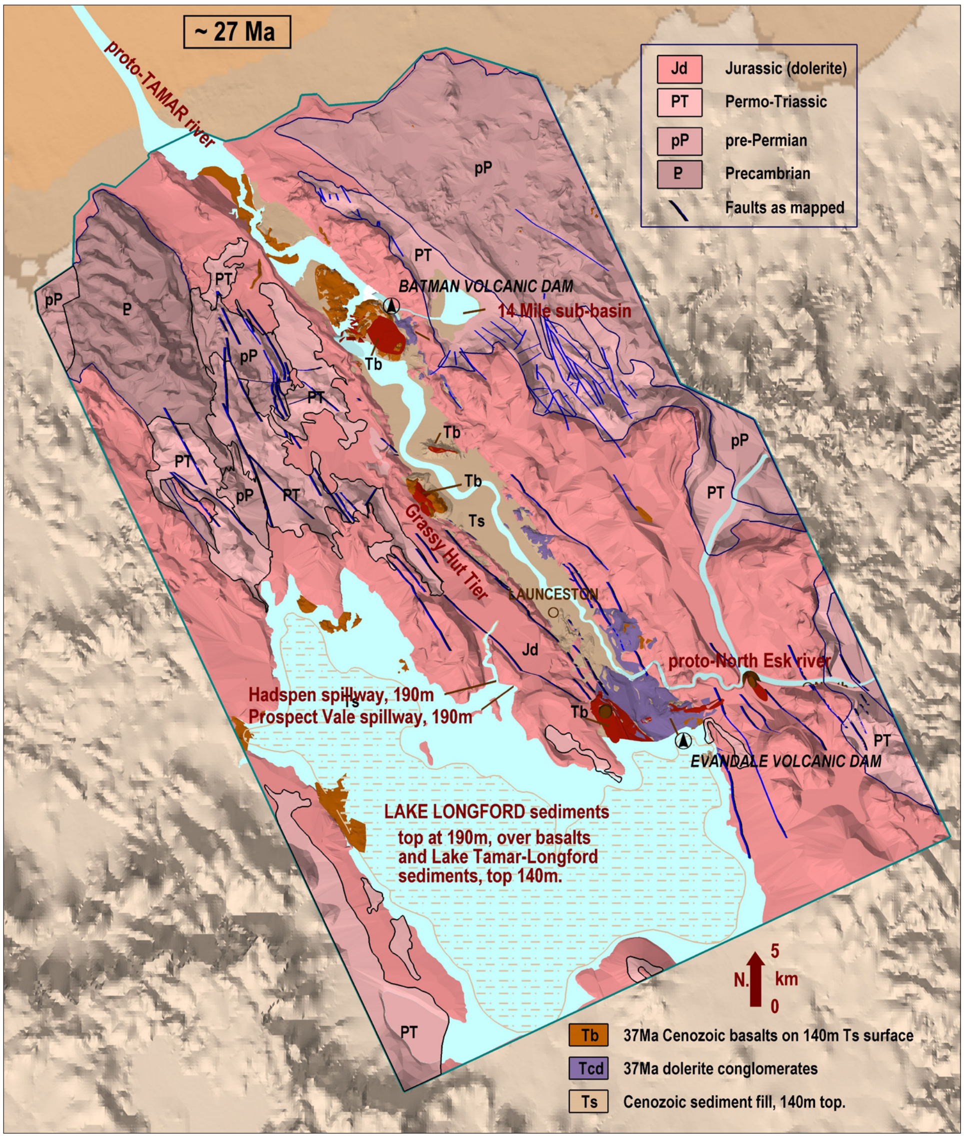

FIGURE 3 — Water and sediments of the new Lake Longford (blue) have accumulated upstream of the Evandale volcanic dam and risen to an elevation of 190 m and start to overflow the dolerite horst (Grassy Hut Tier) separating it from the Tamar Rift Valley. The sediments upstream of the earlier Batman volcanic dam are reduced in width by erosion (compare fig. 2).

Cenozoic sediments

Sedimentation began within the Tamar Graben about 70 Ma and continued until at least the dated Georgetown basalts at 25 Ma (Sutherland *et al.* 2006). Sedimentation continued after this time but was significantly broader than the Tamar Graben as defined. This was about the time when sedimentation transitional to marine in the Bass Basin became open marine (Cummings *et al.* 2004, p. 139). The first seawater entered Bass Strait west to east over saddles in the King Island rise. It appears it did not enter the Tamar Graben as all sediments there are freshwater. Either the graben was above sea level, or barriers to marine incursion existed.

Sedimentation in the Longford Basin, including filling the deep Hagley Rift (fig. 1), was effectively continuous from 65 to 20 Ma (Corbett 2021). Sediments in both basins are mainly lacustrine sands, silts and clays. However, higher energy sediments are frequent. These include coarse sands, gravels and conglomerates, often with pebbles or cobbles from distant sources. These features suggest that the basins were fed by fast-running streams carrying their sediment loads well offshore.

The proto-Kanamaluka/River Tamar probably had a similar catchment area to the present North Esk, South Esk and Macquarie rivers. Fault scarps, affecting mainly dolerites, were in retreat and the debris was being carried into the Tamar and Longford basins, thence into Bass Strait where the Bass Basin was in active subsidence.

Cenozoic volcanics – the first volcanic dam and Lake Tamar–Longford (140 m)

The oldest dated volcanic vents intruding the Tamar Basin were in the vicinity of the Batman Highway, 30 km north-northwest of Launceston. When these started erupting basaltic lavas, the Tamar Graben (in dolerite) was complete and the periodic earthquakes generated by the faulting and rifting of dolerite had given way to seismicity associated with volcanism.

After a period of volcanic activity, the first lavas flowed out over the earliest (65–50 Ma) Cenozoic sediments deposited in the Tamar Graben. In this area, a sample of the Rowella Basalt, 80 m below sea level in a drill hole, was dated at 47 Ma (Sutherland *et al.* 2006). A sample from a higher level of the pile gave an age of 33 Ma suggesting at least 14 million years of volcanism. Over time the lavas built up, layer on layer, gradually spreading wider. A volcanic pile started to accumulate as more vents opened south of the future Batman Highway. Continued flows down the flanks of the pile started to meet the dolerite walls of the valley. These built up until basalt extended wall to wall. Water flowing to Bass Strait in the new valley had the effect of cooling the molten lavas on the upstream (Launceston) side, effectively making a wall which dammed the stream and increased its depth as the barrier built higher. Its position roughly coincided with the present Batman Highway. Although in places the basalts reached higher, the water retention height of the dam was finally 140 m above current sea level. The new dam was probably completed prior to the marine transgression marked by the Demons Bluff sequence in Bass Strait at 43–44 Ma.

However, with the advent of the Batman volcanic dam, water and sediments steadily accumulated upstream of the dam. This new lake initially stretched from the dam wall at the Batman Highway to about 10–15 km southeast of future Evandale. This lake has been described as Lake Tamar (Carey 1947, p. 37; Manchester 2010, p. 13). The parallel deep Hagley Rift to the west also filled with Cenozoic sands and clays. When the rift filled, its sediments extended over the floor of the Longford Basin commencing about 65 Ma. The latter is referred to as Lake Cressy by Carey (Carey 1947) and more recently as the Longford Basin or Lake Longford by Matthews (Matthews 1983, p. 151).

Initially the two lakes were separated by a fault-bounded horst or dolerite ridge which connected the Grassy Hut Tier and Devon Hills dolerite, two km west of Evandale, to the Hummocky Hills dolerite near Epping (Corbett *et al.* 2014, p. 444 & fig. 9.29). Cenozoic sediments accumulated on either side of the ridge (Matthews 1983, fig. 2). The low point of the dolerite ridge was a saddle 80–90 m above sea level, now buried.

As the two lakes grew deeper, this saddle eventually allowed water and sediment to equalise between Lake Tamar and Lake Longford (about 41.5 Ma), effectively becoming a single Lake Tamar–Longford. Sediment accumulated across the entire combined area until the 140 m retention level of the Batman volcanic dam was reached. This combined lake area thus extended through future Launceston, past Evandale, then southwest beyond Cressy and Longford (fig. 2).

Another extension to Lake Tamar occurred when the lake reached 80 m above sea level, and water and sediment crossed a spillway east of East Arm into a small triangular sub-basin now drained by Fourteen Mile Creek. The total lake sediment surface is shaded light brown in figure 2.

Meanwhile, dolerites of the highlands east and west of the Tamar Basin (ex-graben) were slowly weathering deeper (fig. 2). Multiple fractures resulting from the long faulting and rifting episodes assisted penetration by water. The weathering produced a mantle of structurally weak dolerite clays (Mazengarb 2005, p. 13) containing residual dolerite boulders (Slee *et al.* 2017, p. 3). At this stage, frequent earthquakes were related to volcanism rather than faulting. These factors led to the initiation of gradual mass movement of dolerite conglomerates down slopes towards the proto-Kanamaluka/River Tamar (Carey 1947, Saroli *et al.* 2021).

Reduction of the Batman volcanic dam

The Batman volcanic dam was in place long enough for the Tamar-Longford basin to fill with sediments but also several metres' depth of water. Leakage under pressure from the lake along columnar jointing and fractures, assisted deep weathering of the blocking basalts, reducing the integrity of the dam. The active seismicity was also a factor. Possibly related to a particularly strong earth tremor, the dam gave way catastrophically, focussed on the weak contact with dolerite north and south of the present Batman Bridge. The lake-fed torrent and debris scoured a new valley opposite the breach, filled now by the Devils Elbow backwater. When the torrent ran out of momentum up-slope it returned to the present easterly course of Kanamaluka/Tamar River (fig. 3).

More significantly, large volumes of unconsolidated Cenozoic sediments were undercut and sluiced downstream. This initiated the re-birth of the proto-Kanamaluka/River Tamar and the start of the riverine valley-in-valley erosion responsible for revealing the present Tamar landforms. Strong evidence for this event comes from interesting work by Calver (2011). As a result of undercutting of sediments, substantial blocks of basalt broke off and were dislocated down slope. Calver's measurements show that some blocks rotated in the process, one rotation of 50° ± 30° testifying to the violence of the event. Such dislocations are clustered in the vicinity of Whirlpool Reach near Batman Bridge. Whirlpool Reach itself (30 m deep) is likely to be the result of related scouring.

By the time Lake Tamar–Longford drained completely, a new river system started to etch into the 140-metre Cenozoic surface (about 37.2–37.1 Ma). The entry points for these rivers into the Longford Basin were probably much as they are today (fig. 2). They converged into a single stream (proto-Kanamaluka/River Tamar) which ran east above the buried saddle, entered the Tamar Graben near future Evandale, then flowed north to landlocked future Bass Strait. Its bed was around the 110 m level within banks still at 140 m. It then continued north, cutting into the 140-m sediment surface of the Tamar Basin (Carey 1947, p. 42; Nicolls 1960, p. 6).

At a stage when the proto-Kanamaluka/River Tamar was flowing at about 90–80 m above present sea level, it was flowing east of future Windermere and the 140-m sediment surface was continuous from Windermere to Grindelwald. The Grindelwald vents erupted about 37

Ma (Sutherland *et al.* 2006) and basalt spread east over the surface almost to the river. At about 80 m elevation the proto-Kanamaluka/River Tamar encountered resistant bedrock and a course change to the west resulted, separating Grindelwald and Windermere and leaving the latter as a mesa of sediments capped at 140 m by the Grindelwald basalt (Macdonald 1998).

The collapse of the Batman volcanic dam allowed a strong erosion face to develop upstream in the weakly consolidated Cenozoic lake sediments. A V-shaped valley in sediments started migrating south from the breached volcanic dam. Although the erosion was strong, it was not complete. Where protected by basalt and/or dolerite conglomerate, the 140-m lake top was preserved in mesa-like landforms at Murphys Hill, Grindelwald, Windermere, Airport and from the water tunnel north of Evandale (plate 1) around the 140-m bench around to Whites Hill.

At future Launceston the erosion face divided, leaving behind the modern High Street ridge landform. Its current high point is only 20–30 m below the original Lake Tamar–Longford surface.

Cenozoic volcanics – the second volcanic dam and Lake Longford (190 m)

By the time the proto-Tamar had lowered its bed to an elevation of about 110 m relative to the 140-m surface at Evandale, another volcanic vent opened, this time just north of the future airport. This is now a rather unimpressive hill, Cocked Hat Hill, but its top is still above 200 m elevation. The hill itself was an active vent and the basalt has been dated at 37 Ma (Sutherland *et al.* 2006). The Cocked Hat Hill basalts flowed out covering a mass-movement dolerite conglomerate deposited on the Airport bench of the 140-m surface. The flows continued down-slope towards the banks of the new channel being cut by the proto-Kanamaluka/River Tamar at 110 m elevation (fig. 3).

Similar events were taking place 12 km northeast of Evandale. The Stromboli vent opened and basalt filled a linear valley which faulting had made in the dolerite surface. The base of the basalt here was at about 300 m elevation, about 150 m above the local top of the Tamar Basin sediments. The seismicity associated with the Cocked Hat Hill and Stromboli vents assisted the mobilisation of dolerite conglomerate lobes towards the proto-Kanamaluka/River Tamar (fig. 3). In the White Hills area on the east side there was interlayering and intermixing of basalt with dolerite conglomerates (Corbett *et al.* 2014, p. 443) above Rose Rivulet (Sutherland *et al.* 2006, p. 51). A stratigraphic diamond core hole put down by the Tasmania Department of Mines, WH-DH4, intersected dolerite conglomerate with frequent basalt inclusions between 198 m and 161 m elevation. This was underlain by a basalt flow between 161 m and 156 m elevation. Below this were two metres of conglomerate then fine silts and clays to the end of the hole.

PLATE 1 — A remarkable photo taken by MRT geologists near Evandale showing the flat top of Lake Tamar–Longford sediments in the lower part of the tunnel, covered by a darker basalt flow. The contact is at 140 m elevation. The source of the basalt was a volcanic vent (now Cocked Hat Hill) just north of Launceston Airport.

At a depth of 13 m in this hole, basalt was noted welded to dolerite/basalt conglomerate. This testifies to the synchronicity of the volcanic and conglomerate events. The basalt and conglomerate masses, generally separate but close in time (37 Ma), converged on the 140-m surface towards the banks of the proto-Kanamaluka/River Tamar (fig. 3). The arrival of further basalt from east and west, and conglomerate from east and west, eventually blocked the stream. It filled the channel of the proto-Kanamaluka/River Tamar from its bed at 110 m to above the 140 m level for two or three kms. Further fill continued to raise the dam edifice to 190 m retention level and above. The vents of the east and west basalts were above this level and dolerite conglomerates were available well above these levels in both areas. This became the second volcanic dam to block the Tamar Valley but with its starting base 140 m higher.

The effect of the Evandale barrier was for water and sediment to start filling the upstream proto-Kanamaluka/River Tamar valley. This new lake expanded over the 140-m western surface of Lake Tamar–Longford and eventually accumulated a further 50 m of sediments.

Some unpublished accounts have the South Esk River immediately diverted by this blockage to the entrance to the Gorge at Hadspen. These accounts assume that the present Gorge entrance level (135–140 m) has not changed over 37 million years. This concept would require another agency to excavate a gorge through the dolerite horst ahead of the arrival of the diverted South Esk River. These difficulties are removed by the high barrier created by the Evandale volcanic dam adding 50 m elevation to the 140-m surface. This barrier in turn gave a 190 m elevation to the top of Lake Longford and the Longford Basin sedimentary fill (Matthews 1983, fig. 2: Longford Basin Geology). This extensive lake provided abundant water to cut the Cataract Gorge.

With the Evandale Dam in place and Lake Longford filling, the Tamar Valley was deprived of the waters of the proto-Kanamaluka/River Tamar leaving only the flow of the proto-North Esk River. Accordingly, erosion in the valley was much reduced. At this stage relationships are as indicated in figure 3.

Gorge initiation at 190 m

Four kilometres east of the Cataract Gorge is evidence of a second waterway which had the potential to cut a gorge through the high dolerite into the Tamar Valley. On the west side of Prospect Vale is a pre-Cenozoic saddle in the dolerite horst separating the Longford Basin from the Tamar Valley (fig. 4). Prospect Vale itself is on a domed sediment outwash fan delivered over the saddle when the Cenozoic Lake Longford was at its maximum elevation.

The mapped level of Lake Longford Cenozoic sediments at the saddle is currently 180 m (post-erosion) with the dolerite saddle a little higher. The fan outwash delivered over the saddle is 'partly consolidated clay, silt and clayey sand with some iron oxide-cemented layers and concretions, some leaf fossils' (Prospect 1:25,000 geological map legend).

At Prospect Vale, implications are that water and sediment were delivered from Lake Longford over the dolerite saddle

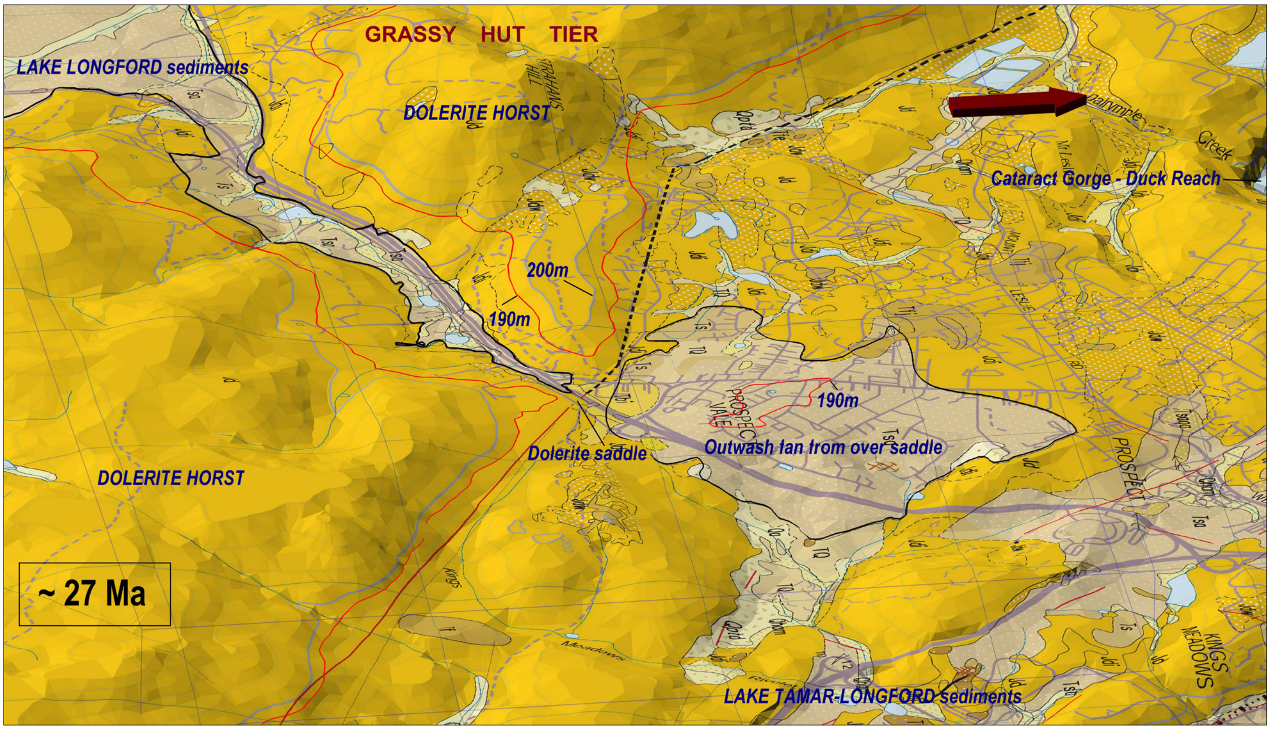

FIGURE 4 — Looking west. The Bass Highway traverses a dolerite saddle between the Tamar and the Longford drainages, which here are only 150 m apart. Discharge events from Lake Longford towards the Tamar (left to right in the figure) created a domed outwash fan, now Prospect Vale, on a near-flat dolerite surface at 180 m elevation. This spillway failed when the Cataract spillway dominated. North arrow is 0.5-km-long. Prospect 1:25,000 Geological map

when the saddle was 15 m higher (190 m elevation) and spread out as a fan on a perched 180-m dolerite surface on the Tamar side of the saddle (fig. 4). On the Prospect 1:25,000 scale geological map and in the contours, there is no evidence of the Lake Longford water flow etching the top of the saddle. Overflow of the lake has happened here but it appears to have been a quiet event, perhaps at the very top of the lake rise. Meanwhile lake overflow (proto-Cataract River) was making its way slowly along about 15 km of dolerite fractures towards the west edge of the Tamar Graben. It became a more successful spillway than the Prospect Vale saddle where fault-related conduits were not present. The spillway became a river capable of excavating the Cataract Gorge, and the leakage of lake water and sediment over the saddle to Prospect Vale ceased.

The implication is that the Prospect Vale discharges could not have happened if all water and sediments upstream of the Evandale volcanic dam were not at or close to 190 m elevation. This evidence of limited lake spill right at the top of its rise confirms 190 m ± as the elevation of the entire Lake Longford, from Hadspen west to the Western Tiers and from Evandale south to Epping Forest and surrounds. This is shown graphically in Matthews (1983, fig. 3) by the blue shaded contact between Cenozoic sediments and dolerite basement around the basin.

To test this, elevations of points on Matthews' (1983) map of the contact between Cenozoic sediments and pre-Cenozoic basement were identified from overlaid current topographic contours. These fall in the 190–210 m range around much of the Longford Basin perimeter. However, in the southeast of the basin, just east of Campbell Town, sediments locally ramp down from above 230 m, through 210 m to 190 m and represent a major sediment input to the basin. Three locations in the western margin also show sediment sources at 230 m or more. These are limited in width, marking former watercourses into the basin from the Western Tiers.

Overall, there is considerable geomorphic evidence for the Northern Midlands plains being the residual of a once-continuous 190 m ± 10 m Cenozoic sediment surface upstream of the Evandale volcanic dam (figs 3, 5). A corollary is that the modern courses of all the Northern Midlands rivers, except for the North Esk River, commenced at an elevation of 190 m and have eroded down to their present elevations of 140–150 m. In places this riverine erosion has exhumed the tops of basalt flows resting on the buried 140-m surface.

Excavation of Cataract Gorge

The new Lake Longford filled with water and sediment upstream of the Evandale barrier. Sediments attributable to the Evandale barrier are shown in yellow on the cross-section of figure 5. Near its top at 190 m elevation, a small arm of the lake bypassed future Hadspen and entered the fracture system of the Grassy Hut Tier (dolerite horst) initially as a narrow backwater (fig. 3). Its course was northerly until it intercepted a fracture trending northwest–southeast at a slightly lower elevation. Enlargement of this spillway confirmed capture of the new Lake Longford by a Tamar-flowing watercourse. This watercourse led the lake waters to the dolerite fault scarp (Trevallyn Fault) 100 m or more above the site of the future Kings Bridge resulting in a high-energy waterfall.

Increasing energy of the 100-m-high waterfall resulted in a 15-m-deep plunge pool under what is now the Kings and West Tamar bridges. As the lake spillway enlarged, continuously increasing volumes of water undercut the tall dolerite columns. Slowly the waterfall retreated upstream, carving out the steep-sided gorge familiar today.

The First Basin is different in character to the simple picture of a migrating waterfall. From the bridges to the First Basin the course is simple and linear. Broken dolerite columns remain in the bed of the Cataract which were undercut by the ancient waterfall. At the First Basin the dolerite shows frequent vertical fractures in addition to the normal columnar partings. This relates to an intersecting fault system (Manchester 2010, p. 14). There the erosive power of the waterfall was spread and its progress delayed until the easier erosion was complete over a broad area.

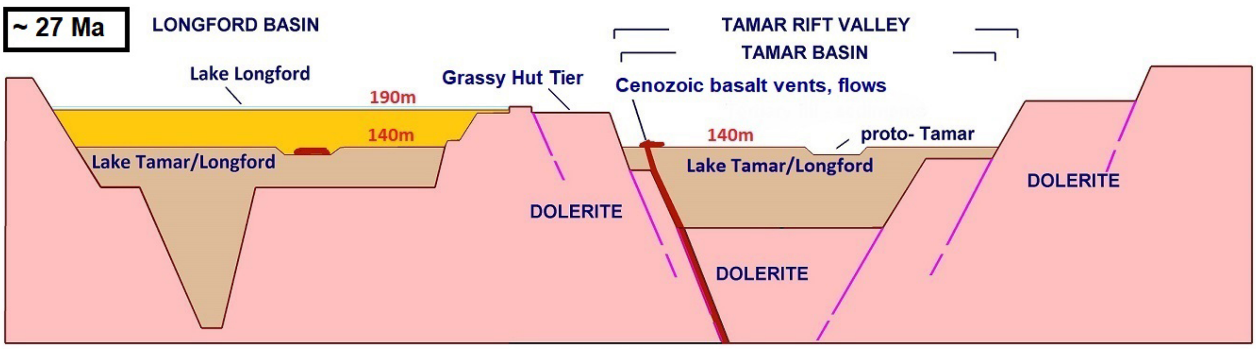

FIGURE 5 — Diagrammatic cross-section looking north shows Cenozoic sediments of Lake Tamar–Longford as in figures 2 and 3 (light brown) upstream of the Batman volcanic dam, with superimposed Lake Longford sediments (yellow) deposited upstream of the Evandale volcanic dam. This is the situation at the start of the Cataract Gorge spillway.

Eventually the new basin was surrounded by normal resistant dolerite and the water was forced to resume erosion confined to a single faulted exit structure.

Dolerite, being a resistant rock, the rate of progress was slow, perhaps the width of three to four dolerite columns (4–5 m) per 1,000 years on average, the height of the waterfall gradually reducing upstream. At this rate the excavation of Cataract Gorge would have required about three to four million years. The flow of water feeding the Cataract waterfall eventually started to lower the level of water in Lake Longford until the lake drained completely and exposed the lake's 190-m Cenozoic sedimentary surface.

The proto-South Esk, Macquarie and Meander rivers and tributaries etched new courses in the exposed surface. The river courses were modified by the variable resistance of lower surfaces, as the rivers deepened. The new focus of all drainages (except the North Esk River) was the Gorge entry near future Hadspen. Thus, the Evandale volcanic dam did more than divert the South Esk River, it diverted all the rivers of the catchment, via Lake Longford. These courses were essentially those we see today.

Approximately 30 cubic km of Cenozoic sands, silts and clays (which filled to near the level of the current Grindelwald Resort) have been eroded out of the Tamar Rift Valley following the catastrophic collapse of the Batman Dam and laid down in a new repository, the Bass Basin. The remaining valley-in-valley topography has been further modified by the incursion of the sea, creating the modern estuary.

By 20 Ma the stepped dolerite fault blocks of the region were in place and stable. The earthquakes and fires of the volcanic vents which dammed the proto-Kanamaluka/River Tamar in two places were long extinguished. Only the resistant basalts and their sedimentary legacy, which have survived the millennia, remained. The baking Earth temperatures of the Eocene Optimum appear not to have left their mark on the Tamar Valley. Spores and leaf impressions in the remaining Cenozoic clays testify to millions of years of fertility. If we move forward to the LGM (Last Glacial Maximum) only 20,000 years ago, Bass Strait was again dry apart from the freshwater Lake Bass in its centre, still receiving water from the Kanamaluka/River Tamar.

CONCLUSIONS

Pre-Cenozoic events summarised in this paper, are fully described in the literature. These include Jurassic dolerite intrusion, Antarctic breakup and related rifting of the pre-Cenozoic basement, creating the Bass Basin, the Tamar Graben and the Longford Basin, including the deeper rift south of Hagley. Early sedimentation in the pre-Cenozoic Tamar Basin was then accompanied by periodic eruption of basaltic lavas from vents; first in the Batman Highway area, then in the Grindelwald, Cocked Hat Hill and Stromboli areas. The Batman basalts formed a wall-to-wall volcanic dam from below sea level to a retention height of 140 m.

Cenozoic silting upstream of this dam created an essentially flat surface back through future Evandale and across to the Western Tiers at 140 m elevation. With the demolition of the Batman Dam by water erosion, a V-shaped valley head migrated south by riverine erosion of the loosely compacted Cenozoic sediments. Near Evandale, two new volcanic vents spread flows on the 140-m surface. These basalt flows, assisted by the arrival of moving masses of dolerite conglomerates triggered by volcanic seismicity, created a second massive volcanic dam at future Evandale. This new dam rose to a retention elevation of 190 m across the valley, leaving the proto-North Esk River as the only water to supply the lower reaches of the proto-Kanamaluka/River Tamar.

A new lake formed upstream of the Evandale Dam. The proto-South Esk River, the Macquarie and the Meander river systems filled the Longford Basin to 190 m, the height of the Evandale Dam. At this level the now mature Lake Longford found an escape route, utilising fractures, across the dolerite horst separating it from the Tamar. An ensuing 100-m waterfall at the future Kings Bridge retreated along the fractures excavating the Cataract Gorge. The present-day river system developed on the Lake Longford 190-m sedimentary surface. In places these have exposed basalts resting on the 140-m surface below.

The modern Tamar Estuary occupies a valley within a valley, that is, a riverine erosion valley in sediments, contained within a structural rift valley basement of dolerite. A second volcanic dam within the valley has generated much of the modern landscape of the Northern Midlands.

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APPENDIX
Table of events

Faulting. Rifting.	Volcanic Dam1 Batman area -60 to 140m	Volcanism Grindelwald	Volcanic Dam2 Cocked Hat Hill 140 to 190m	Volcanic Dam2 Stromboli 140 to 190m	Volcanic Dam2 Dolerite cgts. 140 to 190m	Sedimentation - mainly lacustrine some fluvial	Erosion Tamar
					dolerite intrusion		180Ma 167Ma
Tension 95Ma Faulting 80Ma Rifting Graben complete 65Ma 47Ma	seismicity seismicity seismicity seismicity Batman Rowella basalts				erosion of Permo-Triassic cover rocks dolerite weathering starts dolerite weathering	basins separated by dolerite horst. L. TAMAR	L. LONGFORD	47Ma
140m top	Volcanic Dam 1 start 47Ma Volcanic Dam 1 complete at 140m retention level. Batman Rowella basalts continue VOLCANIC DAM 1	LAKE TAMAR-LONGFORD FILL COMPLETE			local deeply weathered dolerite local re-worked conglomerate. seismicity	Lake levels equalise across 80m saddle in dolerite horst continue as LAKE TAMAR-LONGFORD sedimention complete, surface of fill at 140m.	
37Ma	COLLAPSE, VD 1 Batman Rowella	seismicity volcanism start	seismicity volcanism start	seismicity volcanism start	seismicity mass-movement dolerite conglomerate,	sedimentation downstream of collapsed volcanic dam 1	strong valley erosion
33Ma	lavas continue Batman Rowella	basalts flow out on 140m surface. Grindelwald Grindelwald	Cocked Hat Hill basalt - dolerite conglomerate synchronicity VOLCANIC DAM 2	Stromboli	locally re-worked	LAKE LONGFORD only, start fill	valley head
	basalts	basalts	above Lake Tamar-Longford, 140 to 190m - LAKE LONGFORD FILL COMPLETE			Lake flows over horst. A 100m waterfall results, on Trevallyn fault scarp. Waterfall retreating through columnar dolerite creates: CATARACT GORGE	passes airport near Evandale
25Ma	Georgetown basalts	25Ma					