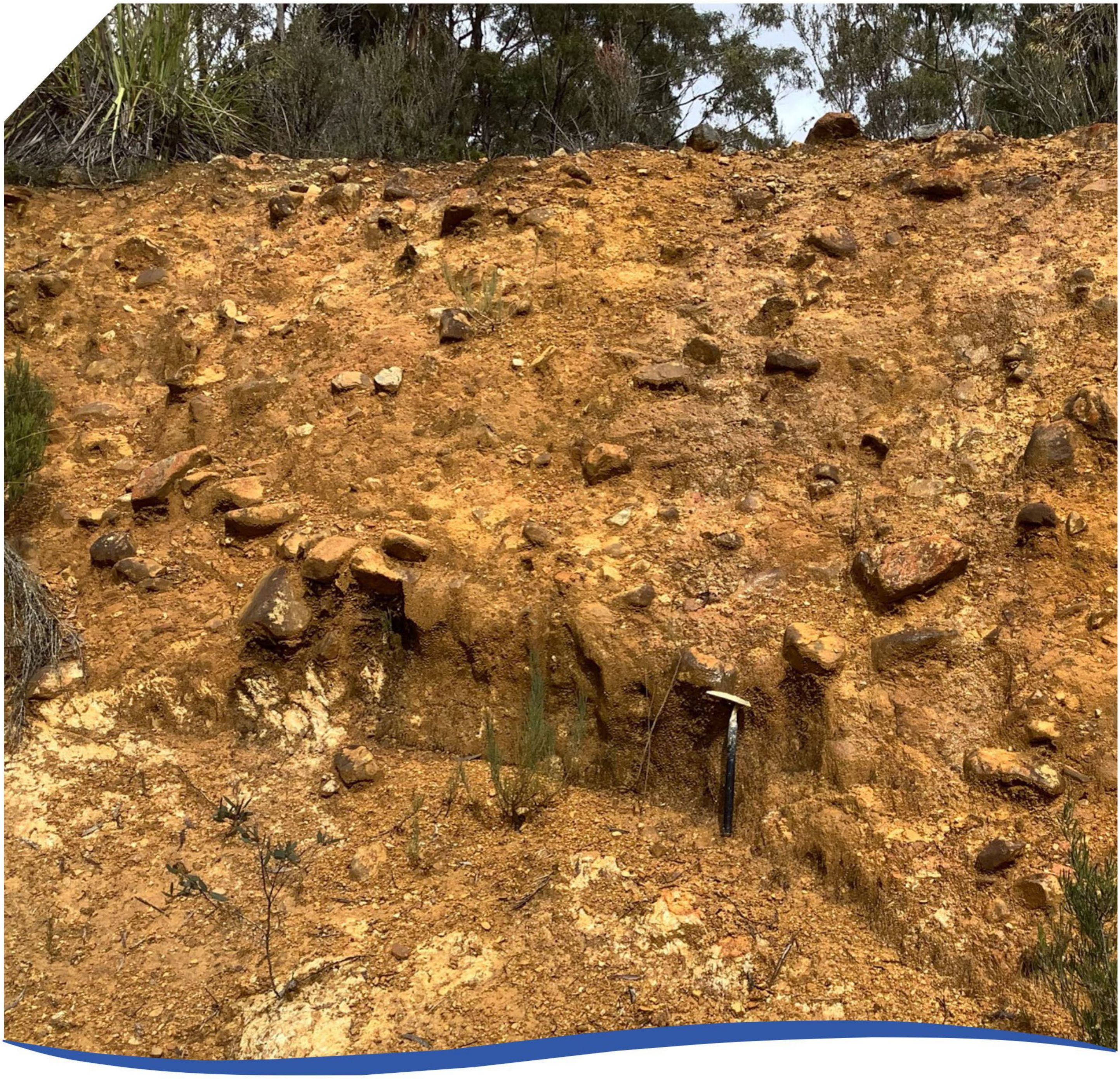
Subglacial and Englacial Hydrology and Geology Field Guide - Maydena, Tasmania

10-12 October 2023



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Subglacial and Englacial Hydrology and Geology Field Guide - Maydena, Tasmania

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This excursion guide was prepared by MRT staff as part of a three-day workshop held in October 2023. Each outing had a different theme: glacial geomorphology (Mount Field massif); glacial geology (Tyenna River and Florentine River valleys); and infill of karst systems likely spanning multiple glacial-interglacial cycles (Junee Cave).

Cover: Undated late-Cenozoic pebble-cobble till eroded into weathered preglacial, valley-bottom materials, upper Florentine Valley at Pontoon Hill along Gordan River Road.

CONTENTS

INTRODUCTION

This workshop considers glacial and glacio-hydrologic processes as well as their resultant geologic and geomorphic records. Much of the research being presented and discussed deals with modern glaciers, particularly in Antarctica. However, the location of this meeting – amongst deposits and landforms recording several of Tasmania's many Phanerozoic glaciations – provides opportunities to illustrate cryosphere impacts during several of Earth's past cool periods.

Geologic and geomorphic features of the Maydena area span subglacial, ice-marginal, and periglacial settings. The records include those of continental late-Palaeozoic glaciation (ca. 300 Ma) of Gondwana, then much nearer the South Pole, as well as more restricted late-Cenozoic alpine and valley glaciation (15 ka to possibly ca. 2.6 Ma) at Tasmania's present latitude. The contrasting styles of glaciation during these two ice ages involved differing processes and thus produced distinct morpho-stratigraphic records.

We will embark on several brief outings over the three-day workshop. Their timing and order will depend mainly on weather conditions. Each outing has a different theme: glacial geomorphology (Mount Field massif); glacial geology (Tyenna River and Florentine River valleys); and infill of karst systems likely spanning multiple glacial-interglacial cycles (Junee Cave). The sites are located within Mount Field National Park as well as along the floors of the adjacent Tyenna River valley and nearby upper Florentine River valley. Together, these areas record diverse influences of glaciers and meltwater. However, they illustrate only some of the many surface features and sediment deposits formed in glacial landscapes.

BACKGROUND NATURAL HISTORY

Although we will focus on the features imparted by glacial and related processes, it is worth noting that Tasmania has an incredibly diverse geosphere and biosphere, especially for its relatively small land area. Its geologic units span nearly every geologic Period over the last billion years and represent most of Earth's rock and sediment types (e.g. Figure 1; Corbett et al., 2014). Together they record nearly every Earth-surface – and subsurface – process imaginable.

Glaciation and accompanying climatic changes have directly influenced Tasmania's ecology and human population. Various Tasmanian ecosystems, including soils, are now recognised as the best or last surviving examples of particular biomes. Many of them were shaped by repeated alternation between climatic extremes at the Australian continent's most temperate edge. The First Tasmanians arrived by 35 ka and possibly closer to 45 ka, during the last glaciation but well before its peak at ca. 20-18 ka. Thus, people have lived in Tasmania's glacially tempered environments for as long as – if not longer than – they have in its post-glacial landscapes.

Mount Field National Park is part of the Tasmanian Wilderness World Heritage Area (TWWHA), which is one of Australia's largest conservation areas. Inscription into UNESCOS's World Heritage listing requires a site to meet at least one of ten selection criteria spanning cultural and natural heritage. The TWWHA meets seven of these criteria. In that measure, it exceeds all other UNESCO World Heritages Sites expect for Mount Tai, China, which also meets seven criteria. In many cases, the TWWHA meets UNESCO's natural and cultural criteria by direct or indirect result of its glacial history. Appropriately, UNESCOS's description of the TWWHA begins with recognition of it as "…a region that has been subjected to severe glaciation…" (UNESCO World Heritage Convention, 2023).

AVAILABLE DATASETS

Refinements in remote sensing and geochronology have heavily influenced understanding of Tasmania's glacial records – usually with advances, but sometimes with setbacks. Until ca. 1950, knowledge of Tasmania's glacial history came largely from astute observers spending long field outings in hard-to-access areas. They included both professional and amateur geoscientists[1]. The ages of glacial features were then only broadly constrained, based on the relative degree of weathering, lithostratigraphic and morphologic relationships, and biostratigraphy.

The advent of appropriate geochronologic tools has subsequently allowed substantial dating of Tasmania's glacial or glacially related deposits and landforms to varying degrees of precision. The most impactful techniques have been radiocarbon, palaeomagnetic, terrestrial cosmogenic nuclide (TCN), and optically stimulated luminescence (OSL) dating. However, the number and specific timing of glaciations recorded by many of Tasmania's glacial deposits and landforms remain poorly constrained, as will be demonstrated by sites visited during this workshop.

The initiation of aerial photography surveys in the mid-1940s provided the first comprehensive "bird's-eye view" of Tasmania's glaciated landscapes. Subsequent air photos were acquired as often as every few years in developed areas but only every decade or two in more remote areas where most evidence of Tasmania's past cryosphere is found. The first two decades of Tasmania's aerial photography supported creation of the *Glacial Map of Tasmania* (Derbyshire, 1965), which also drew heavily on earlier geologic investigations and mapping.

[1]Arndell Lewis contributed much to early understanding that Tasmania experienced multiple Pleistocene glaciations. He was, foremost, a lawyer based in Hobart. However, he also worked as a Lecturer and occasional Acting Professor in geology at the University of Tasmania from 1926 to 1931.

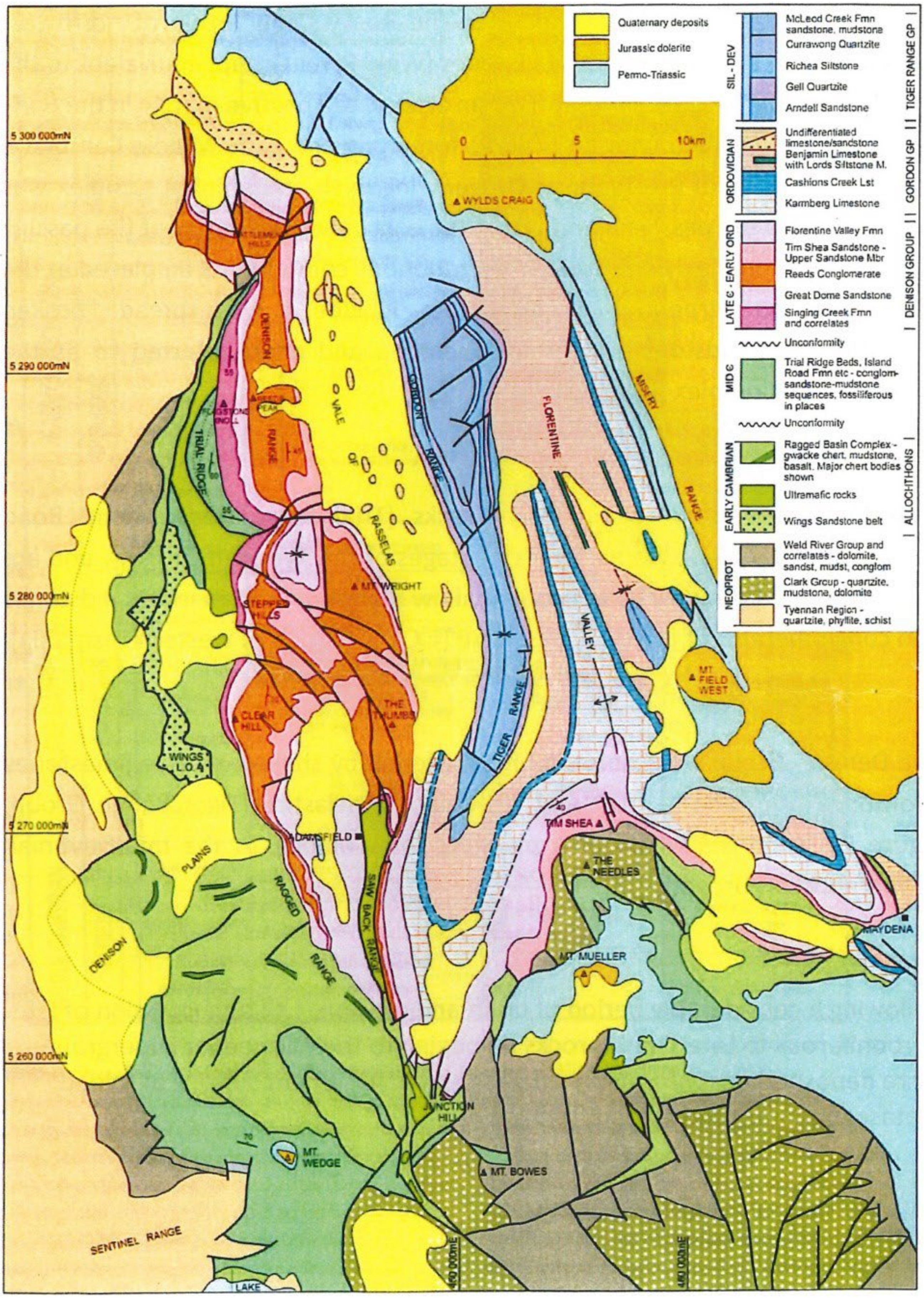

Figure 1. Regional geology of the Mount Field massif and surrounding region (modified from MRT sources).

Most of Tasmania's modern geologic mapping combines information from air photos, high-resolution satellite imagery, field visits of varying spatial density, and insights from aerial radiometric and magnetic surveys. The scale of mapping available ranges from 1:25,000 to 1:250,000, with many wilderness areas such as the Mount Field massif only being covered at the smallest scale. Unlike regions that were extensively glacially modified during the Late Pleistocene (e.g. Canada, Scandinavia), Tasmania lacks systematic surficial geology mapping.

LiDAR surveys by airplane began in Tasmania in 2008, with new collections occurring every year since. These datasets provide high-accuracy (generally sampled to 1-m grid resolution or higher) digital elevation models (DEMs). Critically, these can be processed to represent bare-earth surfaces from which vegetation has been artificially removed. These datasets are providing new insights and improved understanding of Tasmanian landscapes by helping to identify landforms and infer the composition of underlying geologic units. Landforms visible in LiDAR clearly illustrate that some glacial features of southwest Tasmania are missing from the 1965 *Glacial Map of Tasmania*, but also suggest that a few features then interpreted as glacial in origin are possibly non-glacial. By the end of 2024, Tasmania's government-coordinated, open-access LiDAR coverage will surpass 75% of the state's land area, although several regions with important glacial records will still have been missed.

FIELD SITES

Leg 1. Alpine glacial features, Mount Field massif (4-5 hours)

This circuit (Figure 2) will take roughly four hours to complete, depending on walking speeds, weather, and how far along the trail we choose to wander. We will complete a loop trail from the Lake Dobson car park with stops at and overlooking geomorphic features produced by alpine glaciers during the last glaciation, including at its peak (Marine Isotope State [MIS] 2) and seemingly during the preceding warmer period (MIS 3) midway through the glaciation. Glacial landforms and deposits scattered across the state record at least four earlier glaciations (Colhoun and Barrows, 2011). We will see faint evidence of at least one of these on the Mount Field massif.

The Mount Field massif is representative of the physiography and underlying geology across much of Tasmania's high country. It is capped by durable Jurassic dolerite that was injected as a laterally extensive sill into a thick stack of nearly flat-lying marine and continental sedimentary rocks comprising the mostly Permian through Triassic Parmeener Supergroup. Widespread sills of dolerite across the state, as well as the correlative Ferrar Dolerite in Antarctica, were intruded several hundred meters below surface and are thought to record magmatic activity coincident with the breakup of Gondwana. Younger parts of the Parmeener Supergroup were long ago eroded away exposing the comparatively resistant dolerite as broad, undulating plateaus. Sub-dolerite Parmeener units range from diamictites through sandstones to mudstones. They are more easily eroded and form more typical valley landscapes with localised benches on more competent beds. These sedimentary rocks are commonly mantled by colluvial aprons, particularly where nearby dolerite cliffs contribute abundant debris through rockfall or, locally, rock flows.

Similarly, glacial records of the Mount Field massif broadly reflect patterns of Pleistocene glaciation in other parts of Tasmania, particularly on the northwest margin of Central Plateau and in the mountain ranges west and southwest of Mount Field. Due to their elevation, higher surfaces and peaks were nuclei for repeated development of alpine glaciers during Pleistocene cool periods. During cooler or wetter conditions, cirque glaciers grew and coalesced to form valley glaciers reaching farther from and lower below ice sources. Where snow accumulation was insufficient for glaciers to develop, permafrost influenced solifluction and related processes in periglacial landscapes.

Due to their high elevation, deposits produced by these glacial and periglacial processes largely – if not exclusively – comprise dolerite. Exposures of these materials is mostly at surface, limiting their stratigraphic characterisation. However, their geomorphic expression provides excellent insights into the timing and extent of cryosphere influences.

1.1 Lake Dobson end moraines

Cirque glaciers that formed on the edge of Rodway Range to the west (trail left) built two conspicuous end moraines north of Lake Dobson. The trail first crosses the inner/younger moraine in line with the south end of Eagle Tarn. Roughly 300 m farther along the trial we skirt the crest of the outer/older moraine. This cirque now contains two tarns: Eagle Tarn and Lake Dobson. A third, even younger moraine dams the north end of Lake Dobson below us. Note the differences in moraine appearance and elevation, and what their morphology and position tell us about them (cf. Figure 3).

Barrows et al. (2002) report a TCN exposure age of 18.6 ± 1.9 ka for the inner moraine northeast of Lake Dobson, which we crossed first. This coincides with the local Last Glacial Maximum (LGM) at ca. 20-18 ka. The outer, undated moraine is older, but probably not by all that much. The recessional moraine forming the northern shore of Lake Dobson records glacier retreat following the LGM. Further constraint on this cirque's deglacial history could be provided by collecting and radiocarbon dating lake-bottom cores or by TCN exposure ages from the lake-edge recessional moraine.

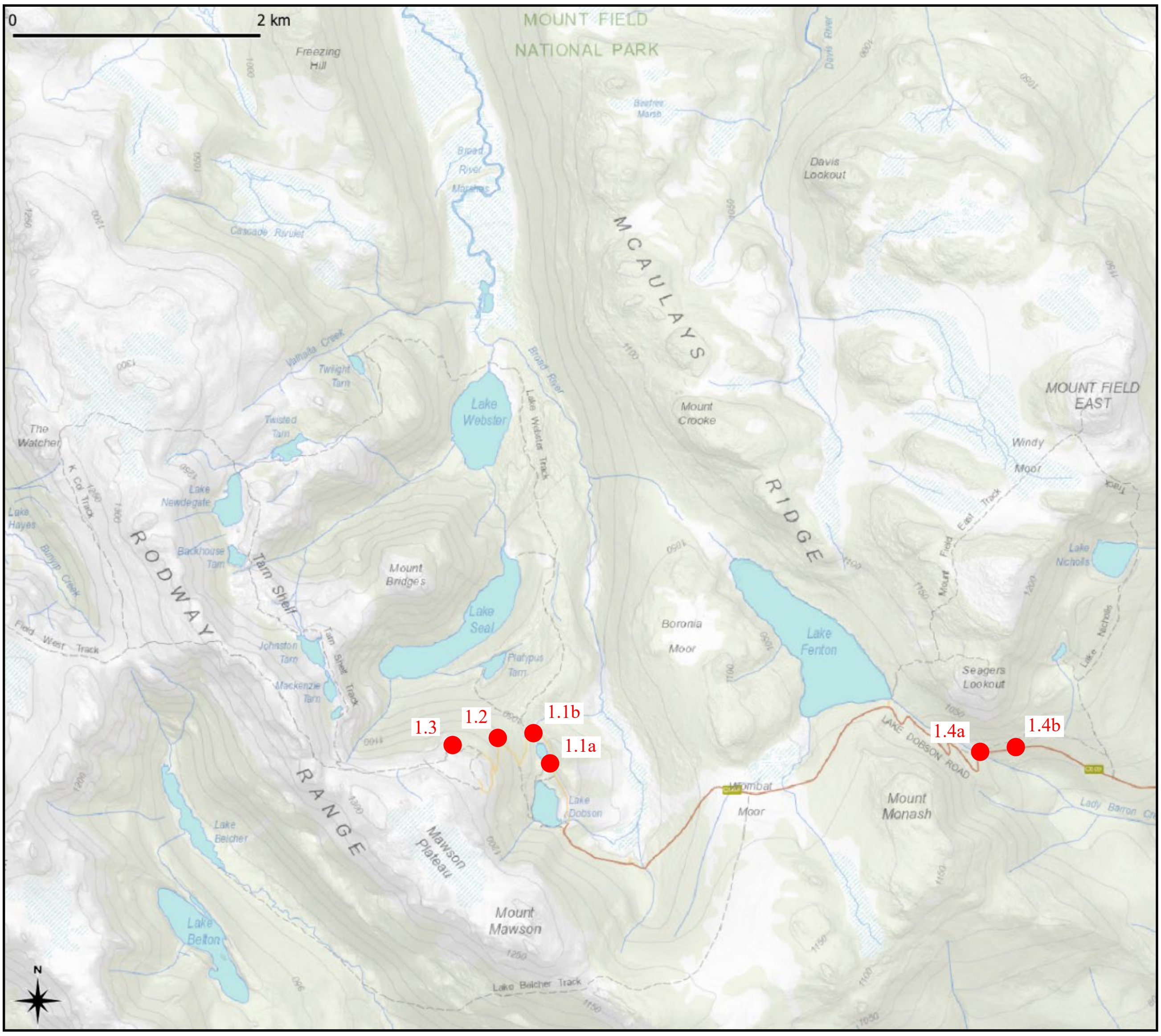

Figure 2. Map of relevant sites within the Mount Field massif.

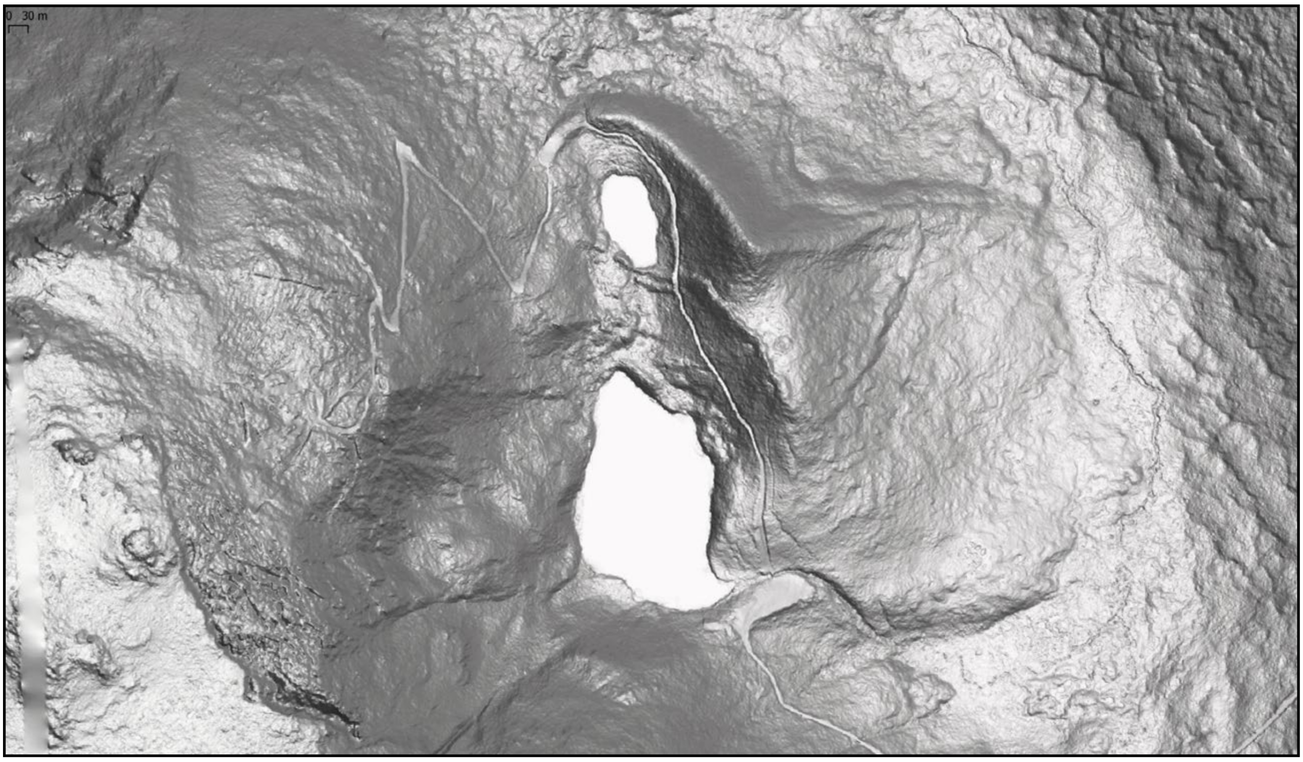

Figure 3. LiDAR hill-shaded DEM of the Lake Dobson area.

1.2 View over Tarn Shelf

From this vantage point we can (hopefully) see several more moraines emplaced by cirque glaciers between Rodway Range, which we are ascending, and McAulays Ridge across the valley (Figure 4). The position, elevation, and cross-cutting relationships of some moraines indicate their relative ages.

Sixteen TCN exposure ages are published for boulders within end moraines in Mount Field National Park, but we will save two of these for discussion at the next site. Barrows et al. (2002) report 12 ages, ranging from 16.1 ± 1.5 to 43.1 ± 3.0 ka. Mackintosh et al. (2006) report two ages for boulders on the Lake Newdegate end moraine (18.4 and 19.1 ± 1.3 ka). Twelve of those 14 ages cluster at ca. 18 ka: the inner moraine we crossed at Lake Dobson (n = 1) and the inner moraine at Lake Seal (between Rodway Ridge on the west and McAulays Ridge on the east) (n = 1); the moraine at Lake Newdegate (east of Rodway Ridge) (n = 2); and the outer of two end moraines at Lake Belton (west of Rodway Ridge) (n = 8). The two ages from the end moraine of Lake Nicholls (northeast of Seagers Lookout – above the road we drove up) are older: 33.1 ± 2.4 and 43.1 ± 3.0 ka.

The 16 cirque TCN ages on moraines indicate at least two, and possibly three, Late Pleistocene ice advances. The younger cluster (12 ages ca. 18 ka) is near the end of the LGM. The 33.1-ka age could indicate that ice again reached the position it attained about 10 ka earlier or could reflect age underestimation due to erosion or exhumation (common issues with TCN exposure dating). The older cluster (three ages just prior to 40 ka, including the two to be discussed at site 1.3) falls during MIS 3 when global climate was warmer than the LGM. The outer moraines at Lake Seal and Eagle Tarn may well date to the ca. 40-ka advance.

1.3 View down Broad River

We have already noted at least three generations of moraines visible in the foreground: ~40 ka, ~18 ka, and ~16 ka. However, these are only a few of the progressively older moraines forming transverse ridges down the Broad River drainage system. As many as 15 more moraines extend down Broad Valley beyond the Lake Seal moraine (Figure 5). Some of the distal ones were recognised over a century ago. Lewis (1921) describes a pair of moraines (approximately the 11th and 12th beyond Lake Seal) and several large, blocky boulders – Griffith Erratic and Taylor Erratic – just past the northern of those two moraines. Mackintosh et al. (2006) report TCN exposure ages for two of the blocks of 41.0 ± 2.0 and 44.1 ± 2.2 ka, suggesting they were emplaced at the same approximate time as the dated blocks on the end moraine 200 m higher, just beyond Lake Nicholls reported by Barrows et al. (2002). Notably wet hydroclimates in much of Australia from ca. 49 to 40 ka (Kemp et al., 2019) could explain the greater extent of glaciers during MIS 3, despite global temperatures intermediate between those of MIS 2 and the last interglacial (MIS 5).

The 12 moraines between the Lake Seal moraine and the Griffith and Taylor erratics are thus between ca. 44 and 18 ka. Some moraines record valley glacier snouts that were short-lived, given their narrow, low form. The one directly south of the dated erratics is much wider and higher, suggesting that the valley glacier's terminus was there for longer; that ridge (or pair of closely spaced ridges) is either a recessional moraine related to the erratics or a substituent terminal moraine.

The number of moraines suggested beyond the erratics differs between sources. Mackintosh et al. (2006) suggest three whereas Lewis (1921) describes only one. LiDAR-derived profiles (Figure 5B) suggest two. Regardless of the number, their form is markedly different than those farther up the valley. They are relatively low, wide, and indistinct, likely reflecting their gradual muting during long periods of erosion. The youngest possible glaciation recorded by the moraine(s) beyond the Griffith and Taylor erratics is MIS 4, which spanned 71-59 ka and culminated at ca. 65 ka in Australia (De Deckker et al., 2019). However, the very muted form of the distal moraine(s) may reflect much earlier glaciation. Similarly muted, distal moraines of uncertain age are visible in LiDAR in other glaciated valleys in central and northwest Tasmania.

1.4 Dolerite blockstream, Lake Dobson Road

The landform before you is one of the many blockfields – areas of coarse, blocky colluvium – occurring at high elevations across the state, predominantly in dolerite. This instance (Figure 6) is a flow-type feature best classified as a blockstream because of its descent downslope and the formation of flow-parallel furrows. Tasmania's blockfields and blockstreams are presumably of periglacial origin: frost wedging enhances talus formation below dolerite cliff lines (forming blockfields) and interstitial ice subsequently promotes downslope flow (forming blockstreams) that would likely not be possible during ice-free conditions. Their rates of formation and movement, whether they develop over multiple glaciations or just one, and their activity during interglacials including the Holocene all remain unclear.

From the roadside pull-out at Lady Barron Creek we can see common aspects of these enigmatic features. The source of debris is visible along the cliffs above near Seagers Lookout (Figure 6A). Angular boulders form an open framework of clasts without matrix; their high permeability allows Lady Barron Creek to flow through this deposit. The lowered surface along the creek's axis suggests lowering by either erosion of the blockstream material or of the underlying slope deposit it rests upon.

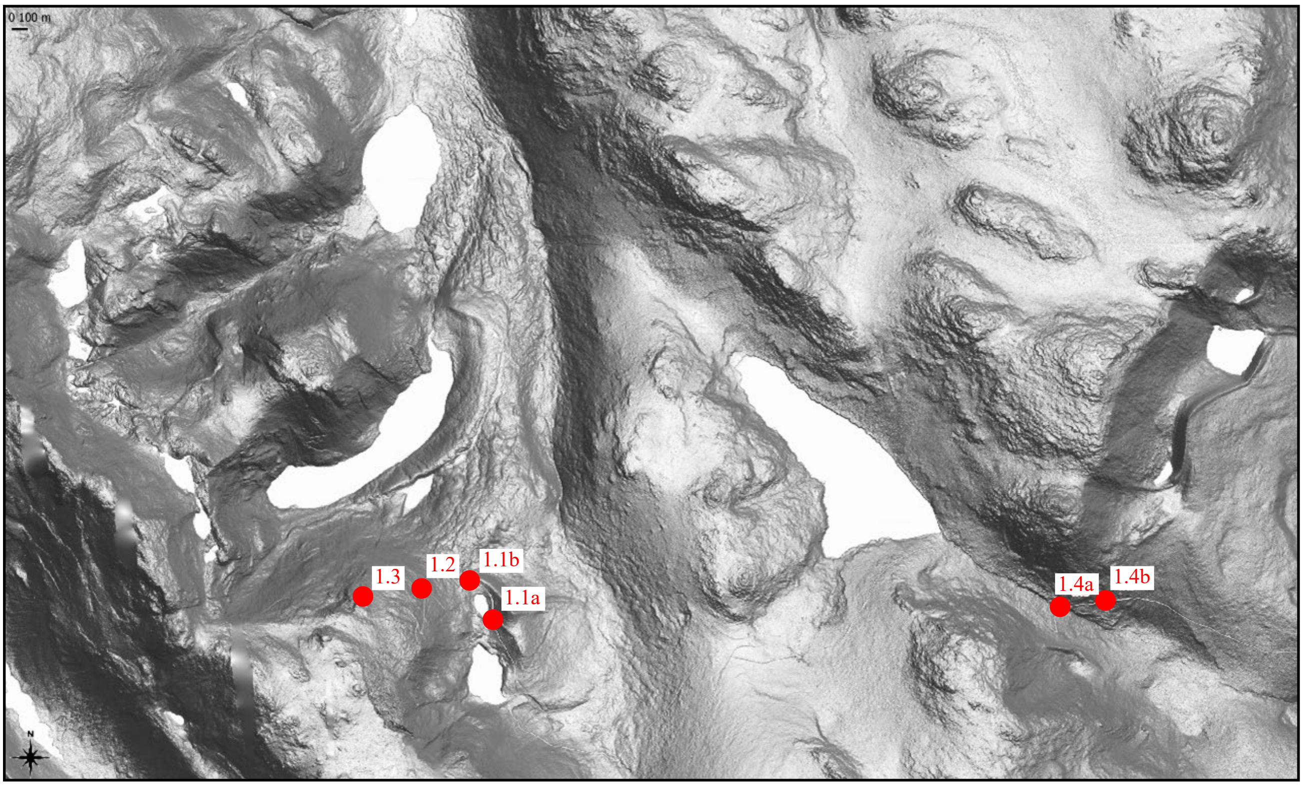

Figure 4. LiDAR hill-shaded DEM of the upper reaches of Broad Valley.

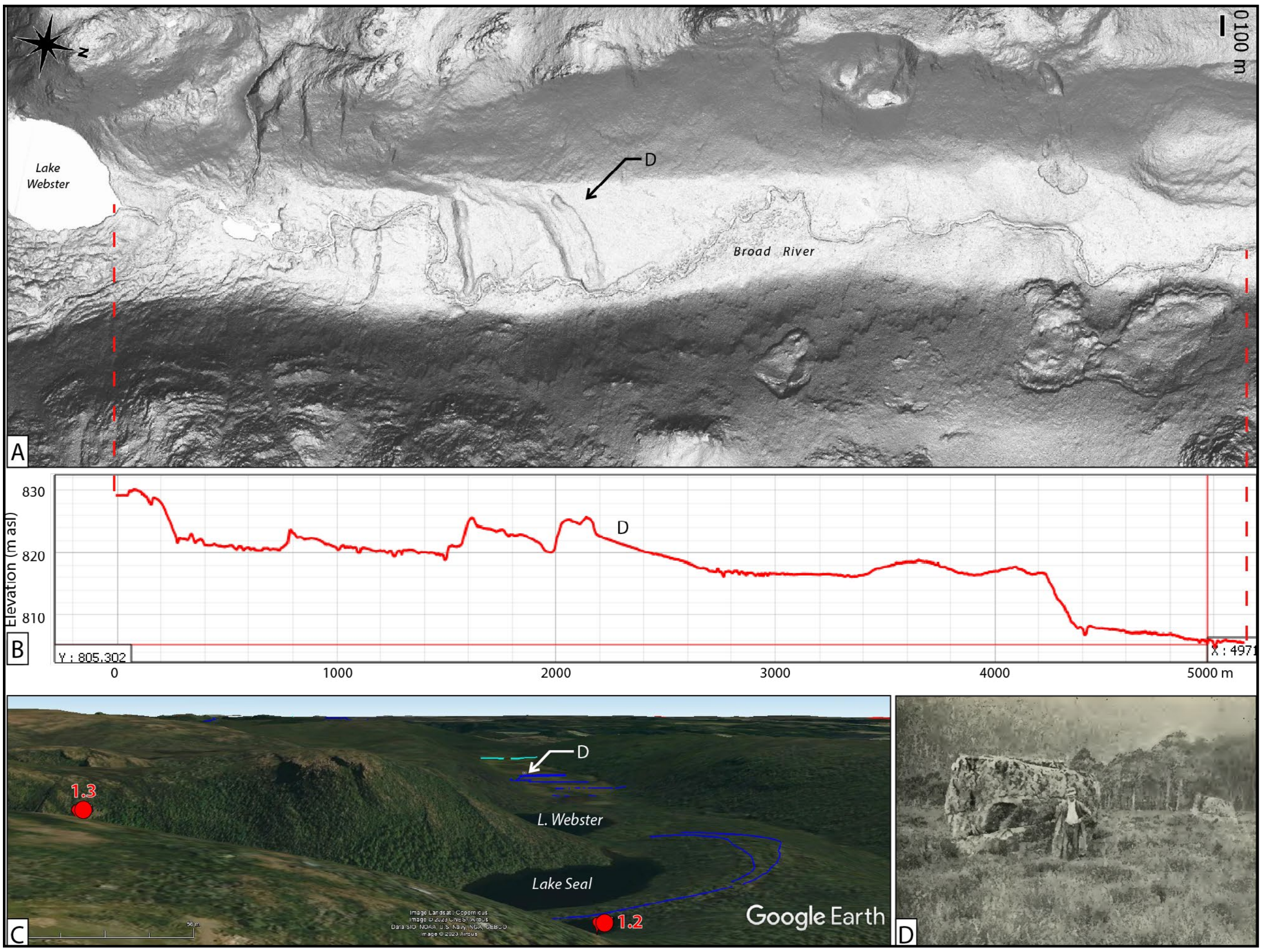

Figure 5. Evidence of earlier glacier advance farther down Broad Valley including moraines visible in LiDAR hill-shaded DEM (A) and elevation profiles (B) extending well past Lake Seal (C), as well as erratic boulders (D: image from Lewis, 1921).

Low cuts we will drive past slightly farther east along Lake Dobson Road expose fine-grained matrix between the dolerite blocks (Figure 6C). It is unclear whether these fines are contemporaneous with the block or have been subsequently washed in by slope wash and Lady Barron Creek.

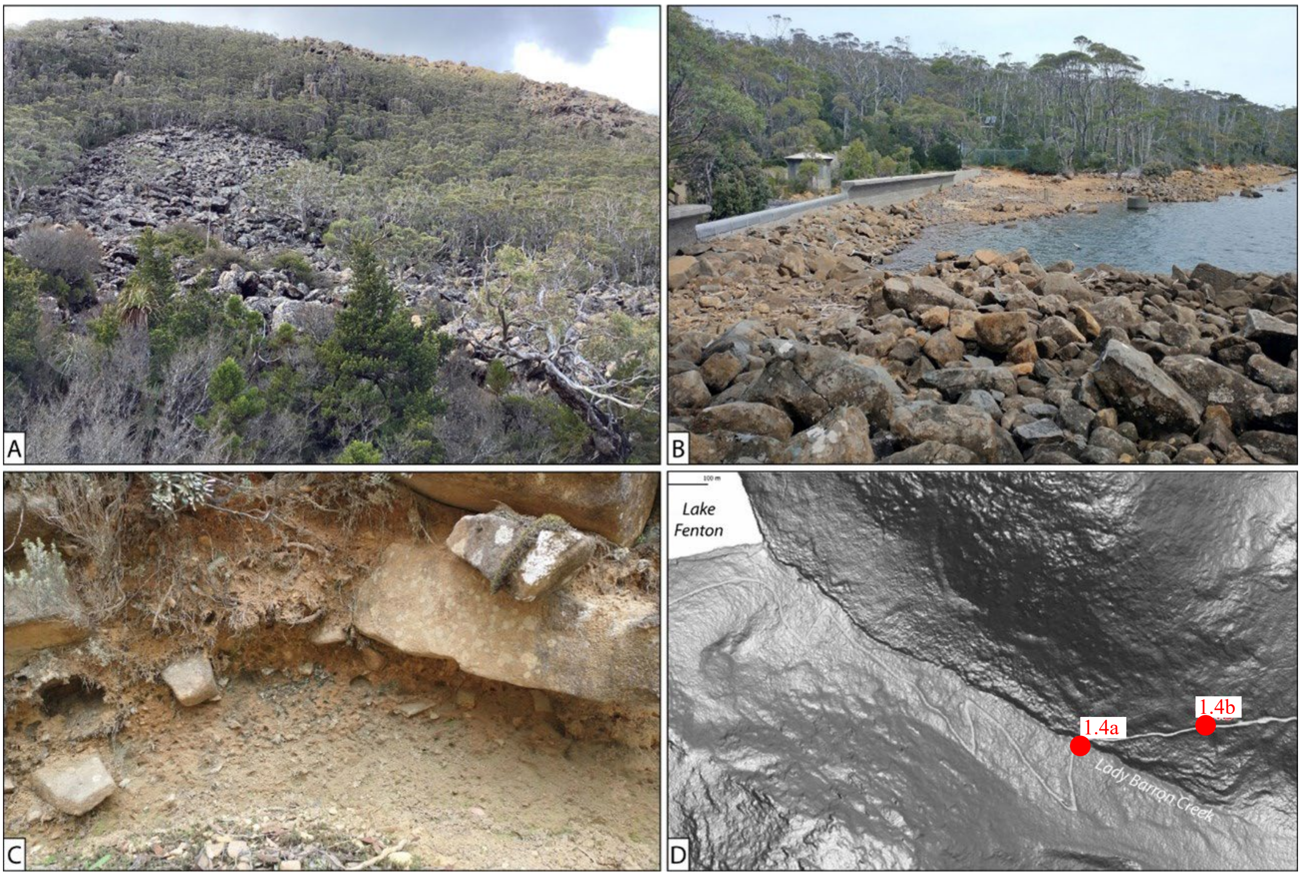

Figure 6. Features of the blockstream damming Lake Fenton including material source (A), dam formed at the outlet of Lake Fenton (B), internal composition exposed in Lake Dobson Road cut (C), and LiDAR hill-shaded DEM overview of the landform (D).

Leg 2. Lowland glacial features, Tyenna and Florentine River valleys (~2 hours)

This circuit (Figure 7) involves just under an hour of driving time. Assuming 15-20 minutes at each of three sites, it will take ~2 hours to complete. The route passes through wide valleys formed in rocks that are older than those of the Mount Field massif. In the Styx River valley south of the Mount Field massif, valley slopes comprise the lowest units of the Parmeener Supergroup, which record Permo-Carboniferous glacial conditions. To the west, upper reaches of this valley expose still older bedrock units, predominantly clastic and carbonate sedimentary and metasedimentary rocks of Neoproterozoic and Cambrian age.

The valley floor is covered by Quaternary alluvium and locally by undated Pleistocene glacial units that are generally only a few meters thick. Lower valley slopes are mantled by Pleistocene talus deposits. The composition of these valley-bottom deposits reflects the local bedrock geology. Their dolerite content reduces from limited to absent toward the west. These sites were included in fieldtrips by the Geological Society of Australia (Sansom and Calver, 2018) and the Tasmanian Geoconservation Database Reference Group (TGDRG, 2018), which are the source of some of the information provided here.

2.1 Pontoon Hill, western exposure

From Giants' Table Cottages drive 20 minutes west from Maydena along Gordon River Road toward Strathgordon. Most of this distance ascends the upper reaches of the Tyenna River valley. Just before reaching this site, we cross Humboldt Divide – between the peaks of Tim Shea on the north and The Needles on the south – and enter the headwaters of Florentine River. Both the Tyenna and Florentine rivers flow into River Derwent, and ultimately the sea near Hobart.

This site probably contains Tasmania's youngest visible folds (Figure 8). Organic-rich horizons strongly contrast with the non-organic layers, helping to illustrate the folds and associated faults. The organic horizon together with intact logs slightly farther along Gordon River Road suggest non-glacial deposition. The deformed sediments record ice advancing over valley-bottom sediments that were still wet, at least locally. Cobbles and occasional boulders higher on the slope surface are lag deposits of an overlying till deposited by ice that overran this area.

2.2 Pontoon Hill, northern exposures

From the western slope of Pontoon Hill, we backtrack ~800 m toward Maydena to where cuts on both sides of Gordon River Road expose several metres of stratigraphy (Figure 9A,B). These opposing roadcuts provide an opportunity to better visualise the relationship between the till and overrun units in three dimensions. They clearly expose a diamicton unit (a pebble-cobble till) that has eroded into an underling putty-like unit with a preserved, steeply inclined fabric. This lower unit shows subtle signs of brittle and plastic deformation. The contact between the units is erosional. Together, units on Pontoon Hill record ice advance over a valley bottom, including non-glacial (or possibly advance-stage, pro-glacial) lake-floor sediments.

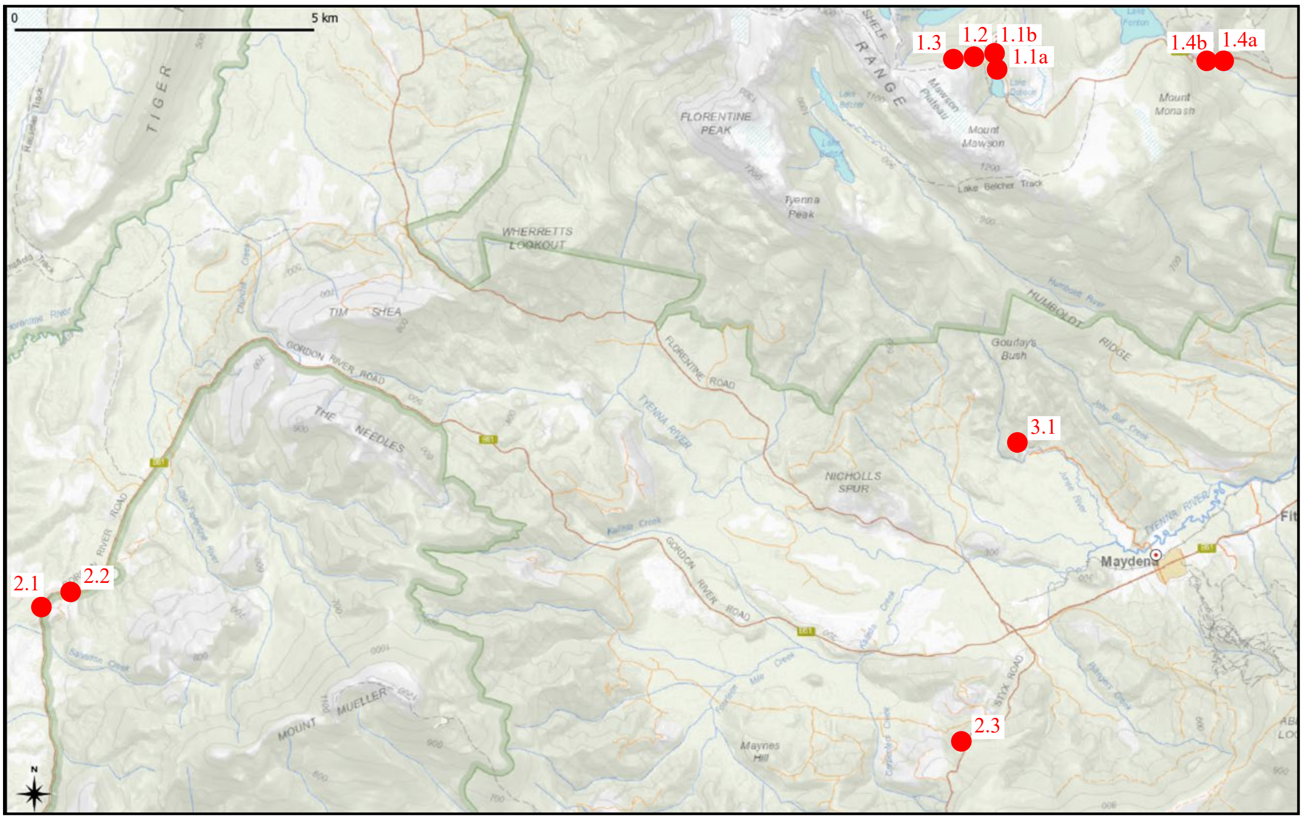

Figure 7. Map of upper reaches of the Tyenna and Florentine River valleys showing relationship between stops on all three legs of the trip.

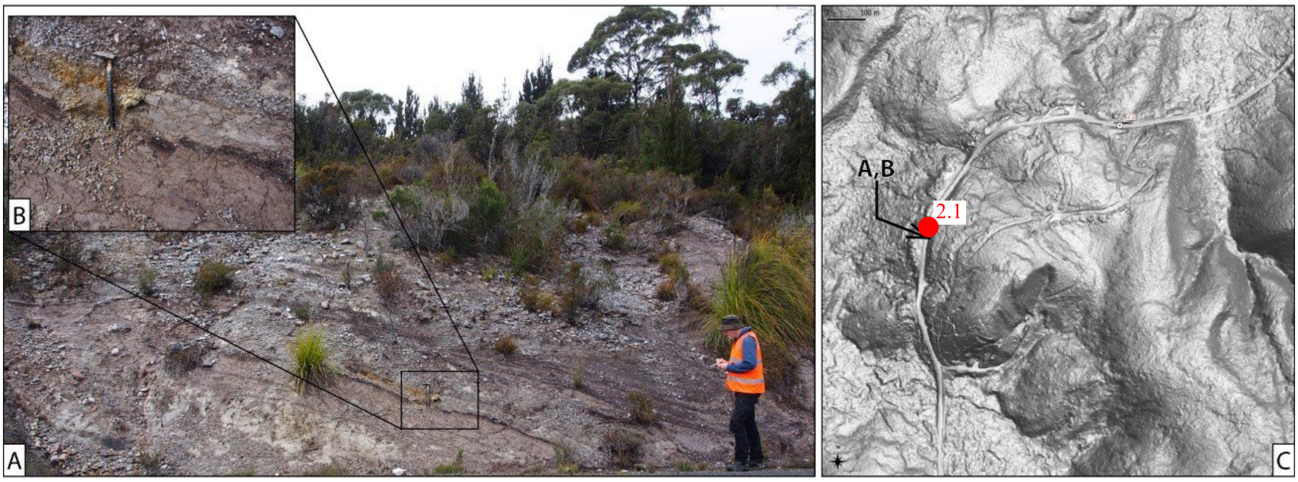

Figure 8. Features indicating ice overrunning lacustrine sediments. Asymmetrical folded stratigraphic sequence (A) with interbedded organics offset by closely spaced faults (B). The glaciation at this site is less clear from the geomorphology visible in LiDAR hill-shaded DEM (C).

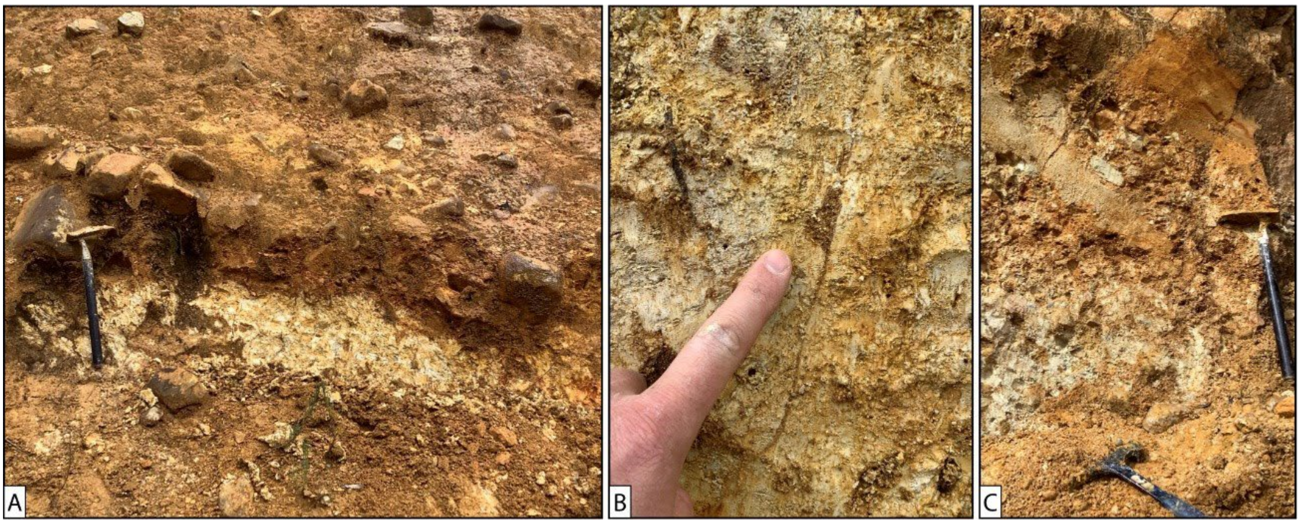

Figure 9. Relationship between till and underlying, overrun materials: A) descending erosion at basal contact of till; B) small fault with clastic dyke; and C) rip-up clast in basal part of till (recent slumping has tilted beds from their original sub-horizontal form).

If time – and interest – allows, walking ~100 m farther east along Gordon River Road brings us to a locally slumped roadcut on the south (right-hand) side of the highway exposing more of the till. Here the sub-till unit is less deformed. However, the till's irregular basal contact and inclusion of sub-till rip-up clasts (Figure 9C) indicate its erosive nature, suggesting subglacial deposition.

2.3 Permo-Carboniferous Tillite

We will continue east toward Maydena. At Styx Road we follow the gravel track a short distance north before looping south and passing under Gordon River Road. After the junction with Maynes Road, Styx Road ascends Tyenna Valley's lower, southern slope, through the lowest units of the generally flat-lying to gently dipping Parmeener Supergroup (Figure 10).

The diamictic unit exposed here is similar to the till at the last stop. However, this unit is lithified (a "tillite") and contains notably different clast sizes and lithologies to the region's late-Cenozoic glacial units (Figure 11). It is a local equivalent of the Wynyard Tillite and records glaciers entering a marine basin adjacent to the supercontinent Gondwana, at ca. 300 Ma. The lithified nature of this glacial deposit allows clearer definition of its composition and features (without the need for cleaning sediment cuts). Preferential erosion of less resistant zones emphasises multiple units or subunits of tillite, although whether they record sperate depositional periods is unknown.

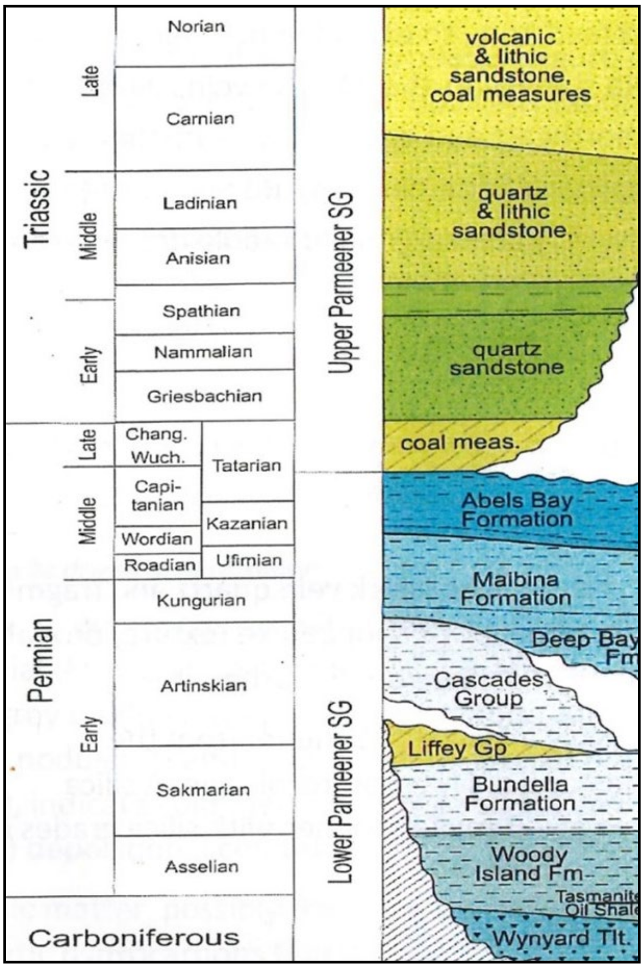

Figure 10. Stratigraphic overview of the Parmeener Supergroup (from Corbett al., 2014).

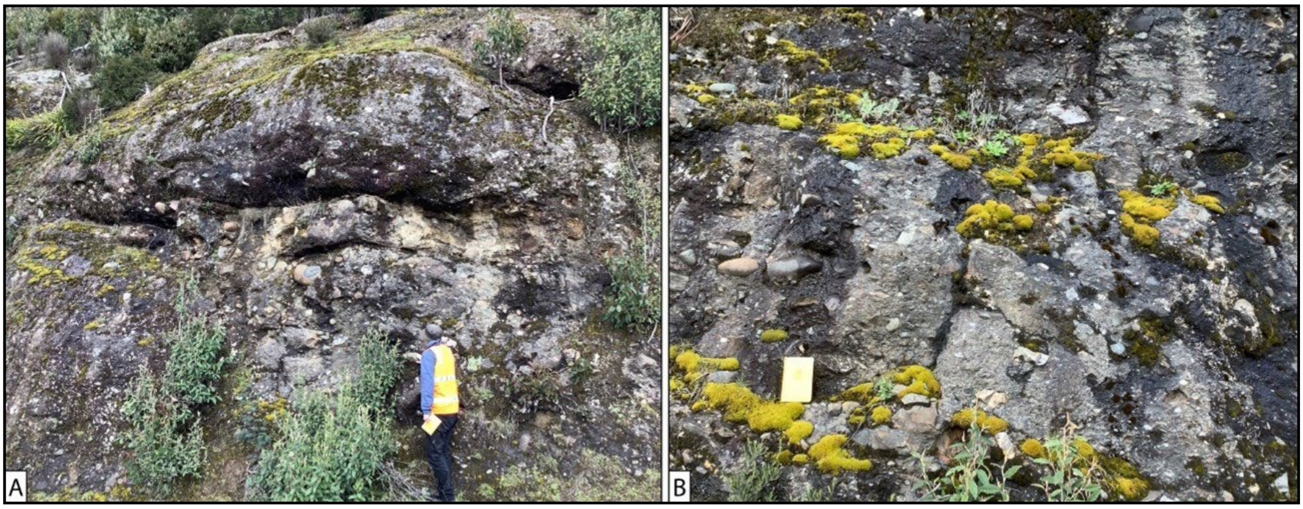

Figure 11. Features of the glaciomarine tillite at the base of the Parmeener Supergroup.

Roughly 150 m farther south along Styx Road, a quarry has been excavated into rocks of the overlying unit of the lower Parmeener Supergroup (Figure 12). It exposes very finely laminated mudstone with well developed joint sets. This is a local equivalent of the Woody Island Formation, which elsewhere contains oil shale in its lowest part. The quarry is notable because its rocks contain glendonites. These rose-shaped calcite pseudomorphs form by replacement of the hydrated carbonate ikaite, which naturally occurs between -2 and +7°C (Rogov et al., 2023). They thus indicate near-freezing benthic conditions. Globally, Permo-Carboniferous glendonites correlate with the late-Palaeozoic Ice Age, although other Phanerozoic occurrences record cold environments including upwelling along continental margins, high-latitude tidal flats and barrier bars, alkali lakes, or select cold terrestrial environments associated with caves or ice (Rogov et al., 2023; Schultz et al., 2023).

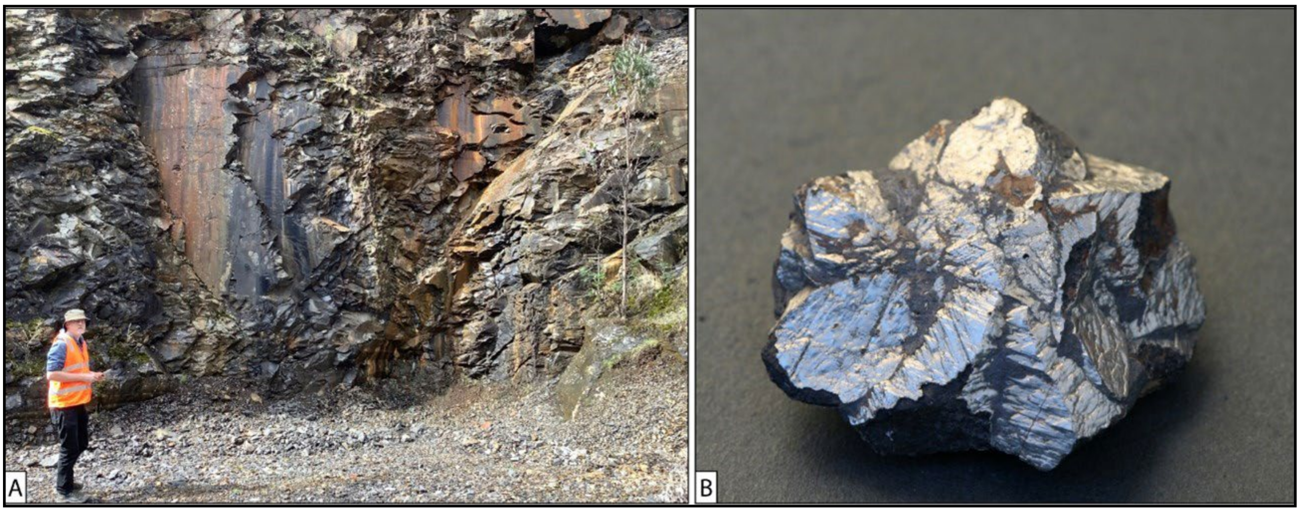

Figure 12. Siltstones overlying the basal Parmeener tillite. Within the largely homogeneous unit (A) are excellent examples of the mineral glendonite (B: image from R. Bottrill).

Leg 3. Junee – Florentine Karst system (~2 hours return)

3.1 Junee Cave

Sedimentation in these caves, developed in the Ordovician Gordon Group limestones, is peripherally related to Tasmania's Middle and Late Pleistocene glaciation in that it spanned several glacial cycles. The sediments are alluvial and predominantly composed of dolerite, suggesting transport from slopes along the southern and eastern margin of the Mount Field massif (Figure 7). The work on sediments in this cave are succinctly summarised by Eberhard's (1997) abstract:

"Uranium-thorium dating of speleothems from two caves [Niggly Cave and Sesame Cave] in the Junee-Florentine karst, Tasmania, provides some age constraints for associated clastic sediments including coarse dolerite-rich fluvial gravels, which underlie the three oldest dated speleothems. The results suggest minimum ages of 15 ± 5 ka, ~325 ka and >350 ka (two dates) for the gravels, implying that they are considerably older than the early Last Glacial age suggested previously for some fluvial gravels in other Junee-Florentine caves" (Eberhard, 1997, page 67).

ACKNOWLEDGEMENTS

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