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THE GEOLOGY AND GLACIAL HISTORY OF THE WALLS OF JERUSALEM, CENTRAL TASMANIA – A PRELIMINARY STUDY

by Keith Corbett

(with three text-figures and 11 plates)

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The Walls of Jerusalem, in Tasmania's Central Plateau, is marked by several dolerite escarpments, or "walls", enclosing sheltered grassy valleys with Pencil Pine forests. Geologically, the area is a structurally raised block between two faults, with the peaks and plateaus being 100 m or so higher than the surrounding plateau. The valleys and escarpments may be mainly due to intense faulting and shattering of the dolerite by cross-faults, and removal of this material by glaciers. The higher peaks and plateaus have all been abraded by ice, except for an extraordinary patch at Solomons Throne, which retains irregular scree piles coloured red with lichen. Virtually all the valley floors are covered by glacial till, which probably relates to the younger glacial episodes. It consists mostly of dolerite boulders and clay, and shows subdued morainal forms in most places, with a few matrix-free boulder deposits probably representing lag after meltwater washing. Bedded clay deposits formed in lakes and meltwater streams as the ice retreated are extensive within the drift deposits, reflecting the confined nature of the two glacier lobes which entered the valleys from north and south. Dolerite screes along the scarps appear to post-date most of the morainal deposits, but some older screes may also be present. The Temple eminence within the centre of the Walls consists of fragmented dolerite overlying Triassic sandstone, almost completely covered by periglacial and glacial deposits, including superb examples of solifluction flows. There are many unanswered questions concerning the glacial deposits, but the lack of any dates means it is not yet possible to establish a comprehensive glacial chronology.
Key Words: Walls of Jerusalem, Tasmania, geology, glacial history.

INTRODUCTION

The Walls of Jerusalem ("the Walls") is a distinctive alpine area near the western margin of Tasmania's Central Plateau (fig. 1) and is a popular destination for bushwalkers. A series of dolerite "walls" enclose several linked grassy valleys within which are a number of small glacial lakes and tracts of ancient Pencil Pine *Athrotaxis cupressoides* forest. The area was included in the much larger Walls of Jerusalem National Park in 1981 and is now part of the Tasmanian Wilderness World Heritage Area. The area was glaciated multiple times during the Pleistocene Ice Age and preserves a complex variety of glacial and periglacial deposits (as shown in this paper).

Aboriginal artefacts have been found in several places within the Walls, indicating that the area was used by Tasmania's indigenous people, although dates are not known. It could well have been a popular place because of its sheltered grassy valleys and abundant game.

Sheep and cattle have been grazed on the Central Plateau ("the Plateau") since the early 1800s, and cattle may have reached the Walls area in the mid-1800s, when winter fur-trapping was also being undertaken. Surveyor James Scott named a number of features in the area in the late 1840s, by which time the "Walls of Jerusalem" name was already in vogue. The term "China Walls" has also been applied to the area. Scott's early map shows a stock route for cattle from the Great Lake area via the Walls to the upper Mersey Valley (Jetson 1989, Cubit 2016). Reg Dixon brought cattle into the Walls in the 1940s, driving them across the Plateau from Mole Creek, and built the "Dixons Kingdom" log hut which bears his name. Cattle were still to be seen grazing in the Walls valleys in the 1960s (Terry 2005).

Bushwalking became popular on the Plateau in the early 1900s, and Reg Hall, a Launceston solicitor, gave many of the Walls features their interesting names in the 1930s, based on the old city of Jerusalem with its many gates and walls. Bushfires have ravaged the Plateau many times over the past century, the most recent being in 1960–61 (Marsden-Smedley 1994, Corbett 1996). This fire, thought to have been deliberately lit and maintained, burnt across much of the western Plateau and patchily into the Walls of Jerusalem area and destroyed many native Pencil Pines.

This paper is based on fieldwork carried out at the Walls on a 10-day trip in February 2011, when the area was mapped using aerial photos and 1:10 000 scale topographic maps. Over 200 field observation points were made.

PHYSIOGRAPHY AND TERMINOLOGY

The dolerite-capped Central Plateau has an average elevation of about 1300 m near its western margin, which is deeply embayed by the valleys of the Fish and Little Fisher rivers. These rivers feed into the large N–S glacial valley containing the Mersey River and Lake Rowallan at an elevation of

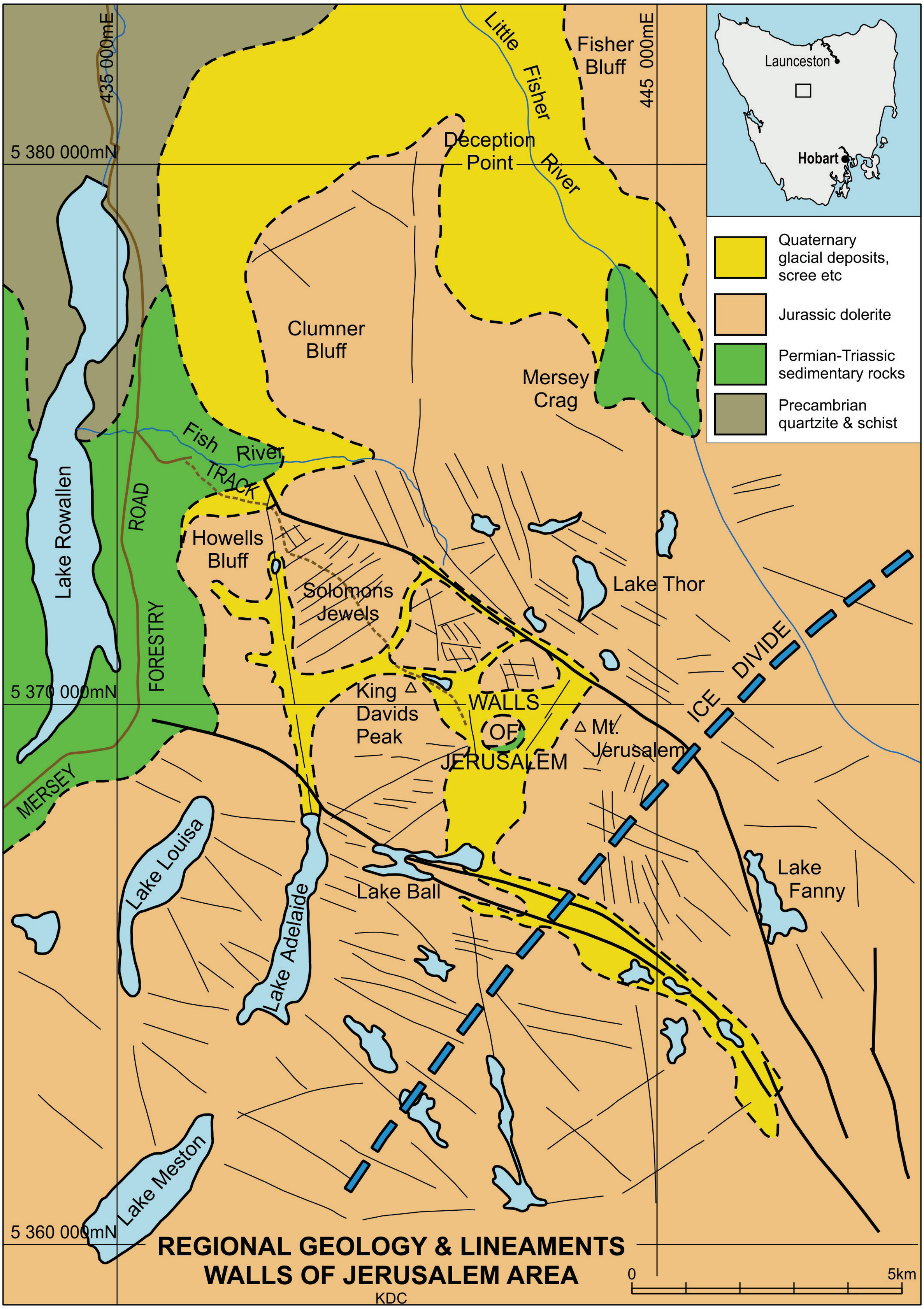

FIG. 1 – Regional geology of the western Central Plateau–Walls of Jerusalem area, showing major lineaments in the dolerite. Modified after Jennings *et al.* 1961.

about 500 m. Access to the Walls is via the Mersey forestry road and a side road near the Fish River which leads to the beginning of the walking track. This track climbs the escarpment, more or less following the old stock route, to Lake Loane, then crosses the plateau past a series of small lakes known as Solomons Jewels, to enter the Walls at Herods Gate, on the NW corner (figs 1, 2). An alternative walking route crosses the Plateau from the east, via Lake Fanny and a cairned route to Mt Jerusalem.

The Walls area comprises a N–S trending roughly Y-shaped depression, 1–3 km wide and 4 km long, bounded to the east, west and north by dolerite escarpments, averaging about 100 m high, with some gaps or "gates". The East Wall has Mt Jerusalem (1459 m) as its highest point at the northern end, and its southern extension has three prominent dolerite buttresses separated by saddles. The western escarpment is V-shaped in plan and comprises Mt Moriah (1362 m) in the south, followed by the Wailing Wall leading to Solomons Throne (1469 m) at the point of the V, followed by the NW-trending West Wall, with King Davids Peak (1499 m) forming the high point at the northern end. The northern margin of the Y is formed by two rounded flat-topped dolerite hills, Mt Ophel (1335 m) and Zion Hill (1395 m), separated by a narrow, glaciated valley referred to as Ephraims Gate. To the north of these hills is the NW-trending valley of Zion Vale, which joins the eastern arm of the Y at the foot of Mt Jerusalem.

At the centre of the Y is the rounded dolerite hill known as The Temple (1446 m), which has saddles to the west and east at about 1300–1350 m, referred to as Damascus Gate (west) and Jaffa Gate (east).

The two northern arms drain generally northwestwards into the Fish River and thence into the Mersey, while the southern arm drains into Lake Ball and thence southeastwards into the Pine River and eventually into the Derwent River. The main lakes within the Walls are Lake Salome, just inside Herods Gate, the Pool of Siloam just to the NE of this, within Ephraims Gate, the small Pool of Bethesda under the NW flank of The Temple, and the much larger Lake Ball at the southern entrance. Several smaller lakes and ponds dot the valleys. The area surrounding the Walls to the north, east and south has hundreds of small lakes, and is known as "the land of a thousand lakes". To the SW of the Walls are several N–S-oriented narrow valleys containing large lakes such as Adelaide, Meston and Louisa.

The vegetation in the valleys varies from wetlands with *Sphagnum* sp. and *Richea scoparia* to open grassland and sedgeland to scrub- or heath-covered areas, to native pine forest and Snowgum *Eucalyptus coccifera* woodland. Copses and clumps of Pencil Pine are common, as are the larger forest areas, which include the largest known Pencil Pine forest in the state, on the south side of The Temple. The pine forests are unusual in having a grassy understorey in large part, their formation possibly influenced by Aboriginal burning.

REGIONAL GEOLOGICAL SETTING AND GLACIAL HISTORY

The Central Plateau consists essentially of Jurassic dolerite, in the form of a large sub-horizontal sill of the order of 200–400 m thick. Many faults and joints are present in the dolerite (fig. 1), along which weathering and erosion has produced small escarpments and linear valleys and grooves all accentuated by glacial erosion. The major escarpments at the edges of the Plateau have significant cliff sections in many areas, displaying classical organ-pipe columnar jointing. Howells Bluff, Clumner Bluff, Mersey Crag and Fisher Bluff are typical examples in this general area. The other feature which is typical of dolerite areas is the presence of extensive fields of coarse bouldery slope deposits below the cliffs.

The basic geology of the area was established during the only previous geological survey, this being the mapping of the Du Cane sheet (1:63 360) by the Government Geological Survey in 1961 (Jennings *et al.* 1961, Macleod *et al.* 1961). Many of the linear features in the dolerite were mapped during this work, as were the Triassic rocks at The Temple. A sequence of Triassic sandstone and Permian mudstones underlies the dolerite and extends down to valley level on the western escarpment, with the underlying basement of Precambrian quartzite and schist exposed at the northern end of Lake Rowallan. Much of this sedimentary sequence is covered by slope deposits. A few small exposures of the Triassic sediments are found on the Plateau itself, beneath the dolerite at some of the higher escarpments, such as within the Walls of Jerusalem.

Faults and lineaments can clearly be seen in the dolerite on aerial photographs. The most prominent fault in the Walls area trends WNW along the line of the Great Pine Tier escarpment, passing through Lake Ball on the south side of the Walls and out into the Mersey Valley (fig. 1). This fault has a north-side-up displacement of the order of 170 m (Macleod *et al.* 1961). A sub-parallel NW-trending fault lies just north of the Walls, following the Zion Vale lineament and extending SE of Mt Jerusalem, where it converges on the Pine Tier structure. The escarpments along this fault indicate south-side-up displacement of the order of 100 m. Thus, the Walls of Jerusalem area lies within a wedge-shaped 5-km-wide upfaulted block or horst, which is of the order of 100 m higher than much of the surrounding plateau. Many other lineaments are apparent in the dolerite, ranging from WNW to ENE in orientation.

The western part of the Central Plateau has been glaciated multiple times through the Pleistocene Ice Age (from 2.6 million years ago), and evidence of glaciation is widespread in the form of abraded dolerite landscapes, scraped out lineaments, numerous glacial lakes, and areas of moraine. Jennings and Ahmed (1957) recognised that there was an ice divide just to the east of Mt Jerusalem (fig. 1), between west-flowing and east-flowing ice, and this work was expanded by Derbyshire *et al.* (1965). A regional study by Kiernan (1990) showed that during the glacial maximum period, in the early Pleistocene or possibly late Pliocene, a large ice sheet extended for 100 km from the

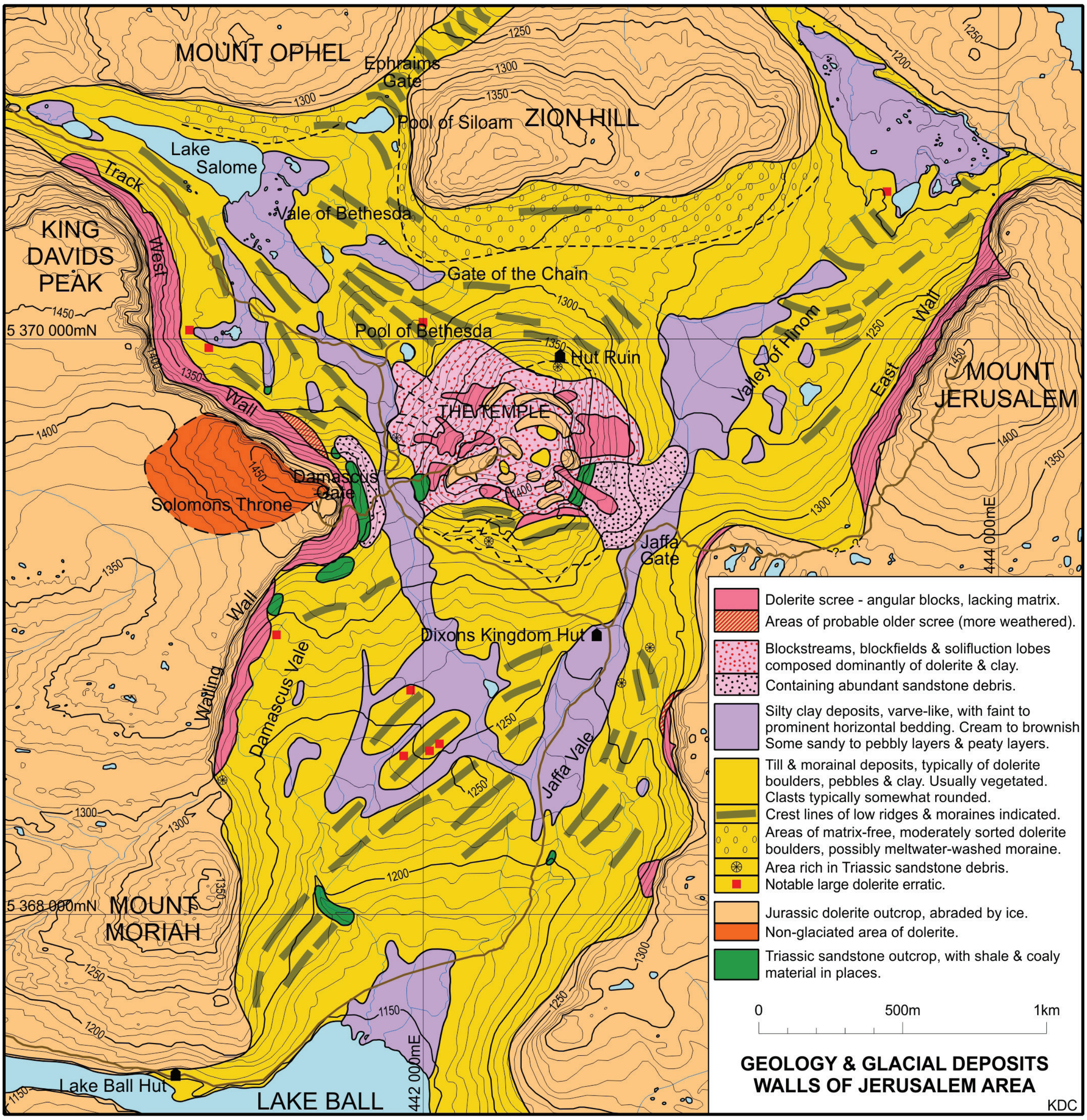

FIG. 2 – Geology and glacial deposits of the Walls of Jerusalem area, as mapped by the author.

Central Plateau west to the West Coast Range, with large valley glaciers down the major river valleys such as the Mersey, Forth, Pieman, King and Derwent. The maximum ice thickness is estimated to have been at least 700 m in the upper Murchison River area, some 20–30 km west of the Central Plateau. This ice would have overridden all but the highest peaks. Ice from the Central Plateau and adjacent areas flowed down the Mersey Valley to well beyond Sheffield. However, the east-flowing ice on the Central Plateau at this time was apparently much thinner and less active and appears to have just reached the western margin of Great Lake.

During the most recent glacial period, known as the Last Glacial Maximum (19–26 ka), ice in Tasmania reached its greatest extent between ~19–22 ka, but was less extensive than during earlier glacial periods. At this time, the ice sheet covered just the western part of the Plateau, and a glacier flowed down the Mersey Valley for a few kilometres north of Lake Rowallan. This stage was named the Rowallan Glaciation by Hannan and Colhoun (1987), from studies in the Mersey Valley. The east-flowing ice from this stage extended for only a few kilometres and did not reach Great Lake. The previous, or penultimate glaciation, approximately 130 000 years old, was somewhat more extensive, and was named the Arm Glaciation (Hannan & Colhoun 1987). Hannan and Colhoun (1991) briefly examined the evidence for glacial activity within the Walls of Jerusalem as part of a more regional reconnaissance study of the larger Walls of Jerusalem National Park area, as discussed later. Further observations on the glaciation of the Plateau were recorded by Sib Corbett (Corbett 1996).

GEOLOGY OF THE WALLS AREA

The Walls area stands out within the general plateau landscape, firstly for having several higher points, by 100 m or so, and secondly by having a larger than normal area of till or moraine. The actual extent of the glacial drift has not been appreciated until the present study, which has revealed that virtually all the valley floors at the Walls, including the areas of the saddles beside The Temple, are covered by either till or lacustrine/fluvial clays derived from the till (fig. 2). The study also shows several outcrops of Triassic sandstone beneath the glacial drift, suggesting that much of the valley floor area consists of Triassic rocks rather than dolerite. This suggests that the valleys of the Walls, rather than being a series of down-faulted areas, may represent highly faulted and broken areas from which the dolerite has been excavated by ice. The faults responsible are no longer visible because of the drift cover but are presumably second-order structures on roughly NNW and NNE orientations. Many lineaments of this orientation are apparent in the surrounding dolerite. The upstanding Temple edifice appears to be a remnant of the original plateau, highly affected by faults and joints and consequently highly fragmented.

There is some suggestion that the dolerite sill which forms all the higher ground at the Walls may be thinner than normal for the general plateau area. The outcrop of sandstone under Solomons Throne, and that on the eastern flank of The Temple, reach to about 1370 m altitude, with the top of the dolerite at 1469 m and 1446 m, respectively. This gives a maximum dolerite thickness of 100 m at the Throne and 76 m at The Temple. There has been some erosion of the top of the dolerite at Solomons Throne, and probably more at The Temple, but nevertheless it could well be the case that the Walls was an area of thinner and weaker dolerite, which may have influenced the initial formation of the upfaulted horst structure.

Triassic rocks

Several small outcrops of Triassic rocks have been mapped within the Walls, some of them not previously noted. The most prominent outcrop is the obvious one on the eastern face of The Temple (pl. 1), where a large collapsed mass has exposed a strip of horizontally-bedded grey sandstone and shale, with some carbonaceous material and plant fossils in places, approximately 30 m thick. Large masses of this shale and sandstone are contained in the adjacent collapsed mass. The outcrops at The Temple have been ascribed to the "feldspathic sandstone" which forms the upper part of the Triassic sequence elsewhere (Macleod *et al.* 1961).

Similar sandstone and shale are exposed on and beside the walking track on the western flank of The Temple, and as a low cliff and several outcrops partly covered by till on the lower slopes of Solomons Throne and along Wailing Wall. Another major sandstone outcrop is present on the floor of the southern valley in the creek draining the eastern side of Mt Moriah, and a smaller one in another creek south of Dixons Kingdom hut (fig. 2). There is a very small outcrop at the head of a small creek below the West Wall.

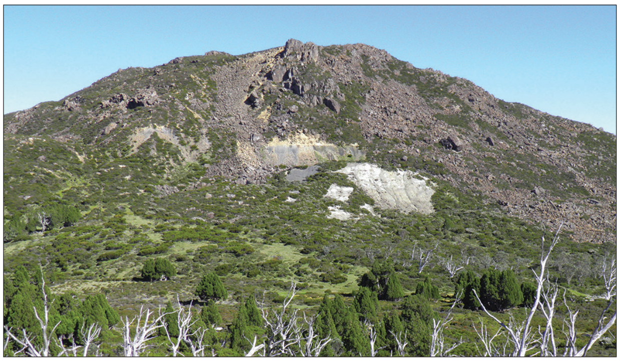

PLATE 1 – View of eastern side of The Temple showing outcrop of Triassic sandstone and shale at head of a large, slumped mass of mixed Triassic rocks and dolerite. Note remnant dolerite outcrops and extensive blockfields and scree.

PLATE 2 – Contrast between glaciated area, in foreground, and unglaciated area at Solomons Throne. Note colour difference and abundance of scree in unglaciated area. Photo: Alan Pegg

In addition to the outcrops, there are several areas in the till deposits where there is an abundance of Triassic sandstone and shale fragments within seemingly shallow drift, strongly suggesting that there is outcrop of these rocks nearby. Some of these are noted in figure 2.

The distribution of the outcrops and sandstone-rich drift patches strongly suggest that nearly all the floor of the Walls valleys consisted of Triassic rocks before being covered by glacial deposits – an area of perhaps 5 km^2. This is far greater than any other occurrence of sedimentary rocks on the Plateau proper and serves to emphasise the uniqueness of the Walls area.

UNGLACIATED AREA OF PLATEAU DOLERITE

Although only limited fieldwork was carried out on the higher plateau parts of the Walls area for this study, it was apparent that nearly all of the high areas (e.g., the tops of Mt Jerusalem, King Davids Peak, Mt Moriah, Zion Hill, Mt Ophel, The Temple) had been ice-covered and were ice-abraded. The dolerite bedrock in these areas is smoothed, outcrops are rounded and typically grey in colour, and some small swales and depressions contain deposits with rounded clasts and clay which appear to be till (e.g., pl. 2).

The one extraordinary exception is an area of approximately 600 x 300 m at Solomons Throne, on the West Wall, at an altitude of 1460 m (fig. 2). There is a striking contrast between the glaciated and unglaciated areas here (pl. 2), with the glaciated area being smoothed, relatively free of loose material, and grey in colour, whereas the non-glaciated area is largely covered by angular blocky scree which is notably reddish in colour due to an abundance of red-brown lichen on all exposed surfaces. The reason for the extraordinary colour difference is uncertain but may in part be due to the red lichen being inhibited from developing on the ice-smoothed surfaces. It will be interesting to see if this criterion is applicable elsewhere.

It is difficult to see why the top of Solomons Throne, which is 30 m lower than King Davids Peak and only 10 m higher than Mt Jerusalem, was not glaciated at the same time. Perhaps the saddle on its eastern lee side meant there was less accumulation of snow and ice than in the deeper valley under King Davids Peak, or perhaps the presence of The Temple edifice to its east caused ice flowing from this direction to be thinned and somewhat deflected.

PLEISTOCENE GLACIAL AND ASSOCIATED DEPOSITS IN THE WALLS VALLEYS

Apart from the small "windows" of Triassic rocks, the floors of the Walls valleys, and much of The Temple area also, are covered by superficial deposits. These consist mostly of till or moraine made up of dolerite boulders and clay in most places, with some areas of clay-free "washed" boulders, particularly around Zion Hill. Perhaps somewhat unexpectedly in such an obviously glaciated area, narrow strips of dolerite scree are present along the cliff lines of the Western and Wailing Walls, and below Mt Jerusalem and several of the small buttresses along the southern part of the East Wall. The Temple area is most striking, being almost completely covered by periglacial deposits, particularly blockstreams and blockfields, with only a few scattered tors and small ridges of dolerite bedrock remaining (fig. 2).

Another unusual feature of the drift deposits is the extensive area of bedded clay and sandy clay extending down the valleys from the saddles on either side of The Temple and best developed across the flatter areas (fig. 2). These clays appear to be lacustrine and possibly fluvial deposits.

The stratigraphic relationships between the various deposits appear to be complex and have not been fully resolved. No age dates are available, and what few conclusions are possible are based on field relationships, i.e., what can be seen to overlie what, and to a lesser extent, on the relative degrees of weathering. Much of the complexity became apparent when the field data were analysed back in Hobart, with no opportunity for further field checking. Most of the deposits appear to be relatively "young", in the sense that no deeply weathered deposits, i.e., with dolerite clasts having thick weathering rinds (>15 cm), have been observed, but some differences in age are apparent.

The following account describes the deposits according to where they occur within the Walls, rather than their age, from The Temple area to the valley drift deposits, the clay deposits and the screes.

The Temple area

The Temple is a particularly complex area and could be described as a showcase of periglacial deposits. Although it projects 150 m or more above the general valley level, it has just a few remnant ridges and tors of solid dolerite remaining, surrounded by a "sea" of fragmental deposits. "The Ruined Temple" might be a better descriptor.

The most abundant material consists of a chaotic mixture of dolerite boulders with variable amounts of clay matrix, referred to as blockfields and blockstreams. Areas of similar material which lack clay have been mapped as scree. Much of this material appears to have "flowed" down the slopes as large solifluction flows, and there are superb examples of these on the NW flank near the Pool of Bethesda (pl. 3). The most prominent flow has a bulbous lower end near its contact on the underlying clay deposits and appears to have "ruckled" the clay into low ridges near the contact. This flow mass has patches rich in Triassic material, indicating that it has flowed over the Triassic outcrop zone. There is abundant clay in the lower part of this mass, but in its upper reaches are irregular zones of loose dolerite boulders, lacking matrix, the larger areas being mapped as scree. Similar areas of open matrix-free scree are present on the blockstream deposits around much of The Temple.

In profile, this NW face of The Temple shows a series of large steps within the blockstream material, suggesting a series of mass collapses, with boulder-covered slip faces at their head. This topography is similar, although at a smaller scale, to the great periglacial "topples" of dolerite which occur around the flanks of Ben Lomond (Caine 1983, Corbett, 2019). Similar stepped topography indicative of mass collapses is apparent on the south flank also.

A large composite blockstream, or solifluction flow, containing abundant Triassic debris as well as dolerite, is prominent on the eastern flank of The Temple, just below the outcrop of Triassic sediments (fig 2, pl. 1).

The slip face at its head contains the Triassic bedrock exposure, and a second slip face, marked by white-weathering Triassic material, is present within the upper part of the flow mass. The trench at the head of this mass has been partly infilled with coarse dolerite boulders, as is the case with several other blockstream masses. The "downstream" end of the complex flow mass has a well-exposed contact on the lacustrine clays above Dixons Kingdom hut (pl. 4) and shows several sub-lobes which have rolled over the underlying clays.

The southern flank of The Temple has a slightly different arrangement which has been more difficult to interpret. A large composite "hump" of coarse bouldery material, which appears to be till, is piled against the flank of The Temple here (pl. 5). At its upper limit, however, the mass of till appears to rest against blockstream-like material, which has a headwall trench filled with scree-like boulders, and a slip face scarp behind. In this area the till has been deposited, as an end moraine, against a slope consisting of

PLATE 3 – Large solifluction flow on NW flank of The Temple near the Pool of Bethesda. Note bulbous nose, upper scree-like deposits, and remnant tors of dolerite bedrock. Zion Hill to left, Mt Jerusalem on skyline to right.

PLATE 4 – Downstream end of large mass flow on east flank of The Temple, showing lobes which have rolled over the underlying lacustrine clays. Near walking track at Jaffa Vale.

PLATE 5 – The large "hump" of moraine on the SE flank of The Temple, viewed from the east. Note scalloped edge of Pencil Pine Athrotaxis cupressoides forest.

mass collapse material. Several nested ridges are apparent on the northern part of the hump, interpreted as end moraines related to the glacier lobe which must have filled the southern valley, presumably at multiple times.

A distinct sloping topographic surface, marked by the change from scrubby heath above to grassy Pencil Pine vegetation below, runs along the lower flanks of these moraine humps, separating them from the more "normal" moraine cover below (fig. 2, pl. 5). This scalloped surface appears to have been moulded by the most recent ice, perhaps as the ice retreated. The reason for the change in vegetation on this surface is not clear since both substrates appear to be moraine of dolerite boulders and clay.

There are also several patches of what is interpreted to be compacted moraine, identified by having some rounded clasts, pebbles and clay matrix, across the rounded summit area of The Temple. These patches are interspersed with dolerite outcrops and coarse angular blockfield material, but the age relationship between the moraine and blockfield was not determined. The dolerite outcrops are ice-abraded, in being smoothed and rounded, except where subsequently broken up, and grey in colour.

On the northern flank of The Temple, in the vicinity of the Temple Hut ruin, there is again a cryptic association of moraine and blockstream-like material. The deposits here are interpreted as being essentially lateral moraines related to the northern glacier lobe, with some later addition of dolerite boulder material from upslope.

The western slope of The Temple, in the vicinity of Damascus Gate, appears to be largely free of mass wastage deposits, perhaps because of the lower gradient in this area. Across the saddle, however, there is a band of solifluction flow material around and beneath the sandstone outcrop under Solomons Throne.

My observations at The Temple suggest the following conclusions:

- The Temple has been subject to intense periglacial, and direct glacial activity, for a very long period, and now consists largely of fragmental deposits, with only remnant patches of solid dolerite. It probably represents the last remnant of the great deal of shattered bedrock which has been removed to make the valleys.
- The Temple has been overridden by ice at least once, to produce the ice-abraded outcrops and the remnants of moraine around the summit as mapped.
- More recent glacial episodes have mainly reached the upper flanks of The Temple, depositing large hump-like end moraines particularly on the south side.
- Mass collapse/solifluction/blockstream masses have flowed off The Temple in several directions, some carrying significant amounts of Triassic material as well as dolerite.
- Several of these masses have overridden the lacustrine clays and moraine deposits around the flanks of The Temple.

The valley moraines and associated deposits

Till or ground moraine extends throughout all the valleys at the Walls, and onto the flanks of The Temple. Most of the till is in the form of low ridges with a subdued "smoothed off" appearance, but there are also areas of matrix-free bouldery material, particularly around Zion Hill, and of little-modified end moraine ridges in the narrow valley at

Ephraims Gate (fig. 2). Viewed from Mt Jerusalem (pl. 6), the moraine surface in the Valley of Hinom has a "scabby" appearance, with the low ridges and rises of moraine marked by speckled heathy vegetation, separated by more uniform grassy or sedgy vegetation in the wetter swales.

In the southern valley, there are several broad NE-trending moraine ridges with a similar speckled appearance, typically with scattered Snowgums *E. coccifera*, although much of the till-covered area is blanketed by Pencil Pine forest or mixed forest.

The moraine ridges are generally only 5–10 m high but up to 20 m or more in places. On the ground, the immediate impression is of a "smoothed off" surface, with small to large dolerite boulders projecting slightly above a vegetated surface (pl. 7). Most of the visible clasts are slightly to moderately rounded. Washout exposures show abundant smaller clasts to pebble size, again mostly rounded, in a brownish clayey matrix. The clasts do not appear to have significant weathering rinds.

Large to very large (>5 m) dolerite erratics are scattered over the moraine in all the valleys, and some have been mapped (fig. 2). The largest one measured was 30 x 20 x 10 m, just NE of the Pool of Bethesda. Some have partially broken up since being deposited. In one or two cases, it was difficult to confirm whether the dolerite mass projecting through the till was a large erratic or bedrock.

"Washed" moraine

What appear to be "washed" moraine deposits are present along the northern edge of the valley (Gate of the Chain) flanking Zion Hill (fig 2, pl. 8), extending into the side valley at Pool of Siloam, and was noted in several other smaller areas. The most notable example is a linear zone along the contour, several hundred m long and roughly 15 m wide, completely lacking vegetation (pl. 8). It consists of sub-rounded dolerite boulders, mostly less than 0.5 m, hence apparently sorted with no apparent matrix. The reason for the lack of matrix, and the apparent sorting, is uncertain, but perhaps best explained as being due to washing by meltwater running off the ice along this edge (K. Kiernan, pers. comm.).

Two series of arcuate end moraines are present within the narrow valley containing the Pool of Siloam (Ephraims Gate, fig. 2). One set is concave to the south, indicating deposition by ice retreating from the Lake Salome area, and the second series, in the northern part of the valley, is concave to the north, related to retreat of ice from Zion Vale.

The valley moraine has an interesting contact with the scree slope in one area under the West Wall. A distinct low ridge of unvegetated bouldery material is present along the contact here, consisting partly of moraine boulders, i.e., rounded, and partly of angular scree boulders. A mixture of very coarse scree, with boulders to 4 m+, and finer scree, possibly of two different ages, extends up the slope. This contact is interpreted as the edge of the ice, possibly the most recent in the valley, interacting with an existing scree field to produce a lateral moraine containing a proportion of scree boulders. Washing by meltwater running off the

PLATE 6 – View from Mt Jerusalem over Vale of Hinom to The Temple, showing low moraine ridges on valley floor separated by grassy/sedgy swales. Lake Salome in distance between King Davids Peak and Zion Hill. This photo taken in 1986 shows patches of fire damage from the 1961 fire.

PLATE 7 – Typical moraine surface near the Pool of Bethesda. Dolerite boulders project above smoothed vegetated surface. Washout shows brownish clay and rounded pebbles.

PLATE 8 – Matrix-free boulder deposit along south flank of Zion Hill, looking east to Mt Jerusalem. Considered to be due to washing by meltwater coming off the ice.

ice edge may be the cause of the lack of matrix. This type of lateral moraine may only be of local extent along the western walls, and elsewhere it appears that younger scree has come down over the margin of the moraine.

THE LACUSTRINE – FLUVIAL CLAY DEPOSITS

Most of the flatter areas and creek lines in the valleys are underlain by deposits of creamy yellow to brownish clay, typically with faint to prominent horizontal bedding (pl. 9). The clay is firm but not fully consolidated and is being eroded in some of the creek beds. Large areas of these clays are present beneath swampy ground around the head of Lake Salome and the NE corner of Lake Ball, across the large wetland area at Zion Gate under Mt Jerusalem, and along the creek lines draining north and south from the saddles at Jaffa and Damascus gates. Surprisingly perhaps, the clay is also present on the saddles at Damascus and Jaffa gates. The clay typically carries grassy to open vegetation, with Pencil Pines in a few places. The thickness of the clay is usually difficult to discern but varies from about a metre to more than 5 m. The clay can be seen to overlie bouldery moraine in some places and wraps around several large dolerite boulders just south of Damascus Gate. It is clearly overlain by the margin of the large composite mass flow unit below the eastern flank of The Temple (pl. 4), and by the prominent solifluction lobe near the Pool of Bethesda (pl. 3).

The few good exposures of the clays show horizontal colour banding on a scale of mm to several cm, with colours varying from cream to brown to grey/black. The darker layers appear to be peaty, although this was not examined in detail. Some sandy to pebbly layers are commonly present. Alternation of graded sandy layers, 3–5 cm thick, with silty/clayey layers 1–2 cm thick, is evident in some places, such as on the north side of Damascus Gate. These layers are suggestive of flow into a water body and might, in part, represent seasonal varves.

Most of the larger areas of clay are associated with existing lakes, or with silted up lakes, as at Zion Gate, under Mt Jerusalem. A large area of wetland/sedgeland here, some 300 m wide by 800 m long, extends well down Zion Vale, where the clays have covered or partially covered several low-end moraines. The area features numerous small ponds and is slowly being reclaimed by sedges and Pineapple Grass *Astelia alpina*. The clays also occupy an open valley within the large Pencil Pine forest south of The Temple (pl. 10), where a small "remnant" lake is still present, fed by an active stream from the Damascus Gate area. This stream has banks of clay at least 5 m deep just upstream of the lake, suggestive of flow into a water body at a higher level than the present small lake, which appears to be the remnant of a much larger water body now almost silted up.

The clay deposits do not seem to be directly related to the present stream activity and represent fine material washed out of the moraines and deposited along stream courses and in former lakes. These would have included ice-dammed lakes, formed as the ice melted and retreated from the Walls valleys, probably multiple times. The clays on the saddles at Damascus Gate and Jaffa Gate are interpreted as lake deposits formed when ice on either side of these saddles dammed temporary lakes. This may have been at the maximum ice level during the Last Glacial Maximum, but the presence of some ground moraine across the saddles also (at least at Jaffa Gate, and probably beneath the clay at Damascus Gate) indicates that ice has overtopped these saddles, probably at several stages. The presence of mass-flow solifluction deposits overlying the clays at Jaffa Gate and near the Pool of Bethesda indicates the clays are not simply post-glacial deposits.

PLATE 9 – Bedded clay in creek bed below Dixons Kingdom Hut.

PLATE 10 – View west across small "hidden lake" on valley floor south of The Temple. A remnant of the original lake formed as the ice retreated. Creek feeding the lake enters via a spring mound centre left. Wailing Wall and Solomons Throne on skyline.

The screes

Dolerite scree deposits occur beneath the cliffs along the Wailing Wall, under Solomons Throne, along the West Wall to King Davids Peak, under Mt Jerusalem, and in several places along the southern extension of the East Wall. The deposits range from almost completely unvegetated in some places (e.g., pl. 11), to mostly vegetated in others. There are also several occurrences of similar unvegetated angular material on The Temple, associated with the extensive blockfield deposits, and in patches above the West Wall and Solomons Throne. Surprisingly perhaps, there are no apparent screes under the cliffs of Mt Moriah. The scree deposits have not been examined in detail, but there is evidence to suggest that they may be complex and multi-aged.

Along the Wailing Wall, there is a puzzling alternation of lobes or patches of unvegetated "fresh" scree with zones of shrubby vegetation and grassy strips. Some of the vegetated material appears to be scree – possibly older than the unvegetated material – but some is moraine (with clay matrix), and some is planed-off sandstone outcrop. Vegetated moraine extends almost to the foot of the cliffs in one area.

Under Solomons Throne (pl. 10), modern scree blankets the slope above a subdued cliff of sandstone and shale which has a patchy veneer of (old?) moraine across it, with the modern scree coming over the top of both the moraine and the sandstone. A large, closed depression partly infilled with coarse scree lies just behind this sandstone cliff about 70 m south of the track up the Throne, possibly indicating an incipient large slide. Further to the NW, a low terrace of apparently older vegetated scree has been mapped below the modern scree. This terrace is overlapped by the modern scree just to the north.

The screes north of this, under West Wall and King Davids Peak (pl. 11), are the largest in the area, and appear to be still active. They were not examined in detail. There is a strong connection between fans of scree and "funnels" in the cliff line. The sub-vertical upper main cliffs form about two-thirds of the overall face, with the scree and some lower outcrops of dolerite forming the lower part at a slope angle of 20–30°. The base of the screes is a sharp, almost linear contact with ground moraine in this area, but whether this indicates they have been "clipped" by ice is uncertain. The deposits along the Wailing Wall and West Wall include older-looking vegetated scree as well as younger unvegetated deposits.

PLATE 11 – Northern part of West Wall showing prominent screes. Photo: D. Boyer

Two ages of scree were also identified under one of the southern buttresses south of the East Wall (fig. 2). The narrow strip of older material seen here is vegetated, more weathered looking, and coarser than the nearby younger scree.

COMMENTS ON THE GLACIAL HISTORY

Hannan and Colhoun (1991) made a relatively brief study of the glacial features at the Walls as part of a more regional study of the wider National Park area and gave some initial interpretations of the glacial history. They recognised the young moraines near the Pool of Siloam and considered that these were deposited by a small lobe of Last Glacial Maximum Rowallan ice which entered from Zion Vale to the north. They thought that other such small lobes had entered at Zion Gate under Mt Jerusalem, and at Wild Dog Creek, in the next valley west of the Walls. It was considered that this ice had *not* flowed across the Gate of the Chain into the Lake Salome area because of the presence of "significant block stream development to the east of the col between the Temple and Zion Hill" (Hannan & Colhoun 1991, p. 4). It is not clear what this refers to, but it is probably the bouldery material here interpreted as washed moraine on the slopes of Zion Hill. They thought that the more prominent moraine ridges near the Pool of Bethesda were probably remnants from the Arm Glaciation and suggested that the deep clay "soils" seen at Lake Salome (the lacustrine clays of this investigation) represented "soil formation not found in areas known to have been glaciated by Rowallan age ice".

The present study shows that ice has occupied all of this area, including the Gate of the Chain col, and deposited significant amounts of till, but is not able to distinguish between the most recent ice event (Rowallan) and previous events. The small arcuate moraines near the Pool of Siloam may be recent, but most of the other moraine ridges appear to have been overridden and smoothed off by ice. There are no obvious retreat/end moraines in the Vale of Bethesda between Lake Salome and the Pool of Bethesda, suggesting that the recent ice in this area may have decayed without depositing moraines. There are curved end moraines in the Valley of Hinom, under Mt Jerusalem, but these also have an overridden smoothed-off appearance. This may imply that the most recent ice did not carry sufficient debris to produce end moraines.

Hannan and Colhoun suggested that Rowallan ice had entered the southern valley via Lake Ball, and that the NE-trending moraines in this area might reflect lineaments in the underlying ice-eroded landscape inherited from the Arm Glaciation. Again, the moraine forms in this valley have an overridden smoothed-off appearance, suggesting they may not have been deposited by the most recent ice event.

The presence of screes within the Walls was given considerable weight by Hannan and Colhoun. They believed that the "thick coarse screes" at the base of the West Wall and East Wall "were developed over a long time and are therefore unlikely to have been formed since the decay of the Rowallan ice" (Hannan & Colhoun 1991, p. 4). The present study indicates that some of the screes are certainly recent, but that more than one age of screes is present. Some younger scree overlaps the moraine deposits, some has been impacted by ice to form a mixed deposit, and some is older and more weathered, and appears to pre-date at least some of the moraine.

Hannan and Colhoun concluded that the Arm Glaciation had probably covered most of the Walls area, with the possible exception of the higher parts of the West Wall, while the less extensive younger Rowallan Glaciation had left an uncovered "window" encompassing Mt Jerusalem, The Temple, Lake Salome valley, West Wall, East Wall, Mt Ophel, Zion Hill and the Solomons Jewels area. The present study shows that ice of Rowallan age occupied most of the Walls valleys and a large part of The Temple, but determination of the ice limits during different glacial stages must await further studies and dating in particular.

General nature of ice movement at the Walls

The mapped extent of glacial deposits, and the plot of the moraine ridges, allows the general nature of ice movement during the most recent glacial stages to be reconstructed (fig. 3). The older, more extensive stages would have involved continuous ice cover across all valleys and overriding of The Temple and higher areas, except for the small unglaciated area at Solomons Throne, but the last glaciation seems to have involved the valleys only. The plot of the ridges for the southern valley (fig. 2) clearly suggests that ice entered this valley from the southern (Lake Ball) end, and reached the flanks of The Temple, before the ice front retreated over the same ground. At some stage, this ice has reached almost to the top of The Temple and deposited the large "humps" of moraine on its southern flank. The most recent ice may have moulded these moraine humps at a lower level, along the scalloped surface, perhaps during retreat.

As the ice retreated from saddle level, there may have been several "still-stands" (or "slow-downs") when temporary ice-dammed lakes were formed, as the level dropped down the gentle slope of the valley. Larger lakes formed on the drainage from Damascus Gate and below Dixons Kingdom hut on the drainage from Jaffa Gate. Lake Ball was the final part of this retreat process. Clays washed from the upper slopes of moraine partly filled these lakes, and this process has continued slowly. The abundance of lacustrine clays is probably a function of the confined nature of the ice, which had to retreat over the same ground, forming lakes and promoting deposition of the eroding clay as it did so.

The northern valley presents a different picture, with ice entering from the NE corner (Zion Gate), and possibly over the low divide south of Mt Jerusalem, and exiting via the narrow outlet at Herods Gate (and probably over the nearby low part of Mt Ophel). This ice appears to have pushed part way up the north flank of The Temple and around into the second valley in the vicinity of the Pool of Bethesda, before exiting. The NW-oriented moraines in the Pool of Bethesda area are more suggestive of lateral moraines, with no clear examples of end moraines in the Damascus Gate area. Some of this ice entered and retreated from the narrow valley of Ephraims Gate, above the Pool

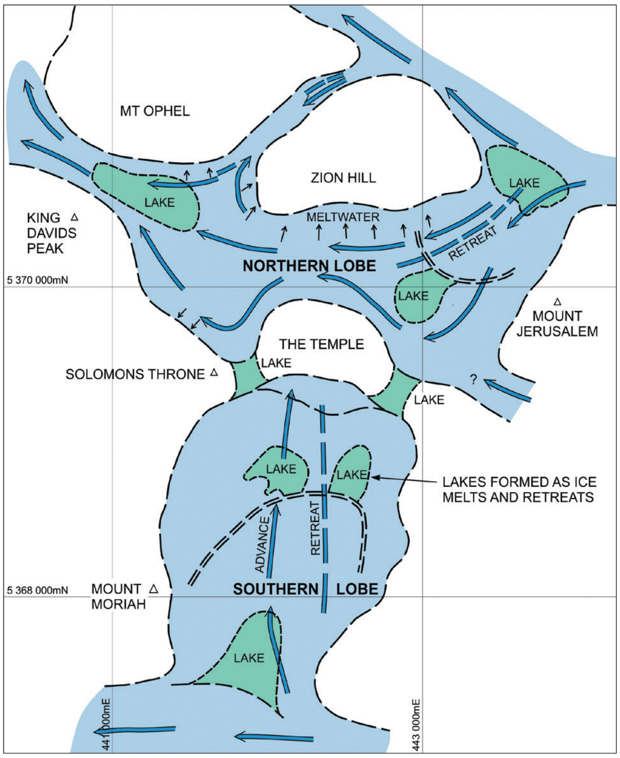

FIG. 3 – Preliminary reconstruction of ice movement and behaviour during the younger glaciations at the Walls of Jerusalem. Separate lobes of ice enter the Walls from north and south. Lakes are formed as the ice retreats.

of Siloam, as indicated by the set of end moraines. Ice also entered the northern part of this valley from the Zion Vale area, as indicated by a series of northwards-concave end moraines. The ice between The Temple and Zion Hill probably sloped to the north, such that meltwater runoff along the northern margin caused washing of the morainal material to produce the matrix-free boulder deposits seen along this edge.

Several temporary lakes were formed as this northern ice retreated, including one in the Valley of Hinom, and larger ones at Lake Salome and Zion Gate. These received much clay material washed in following ice retreat and have been slowly silting up and diminishing in size since. Small lakes also formed at the saddles between the northern and southern ice lobes, at Damascus and Jaffa gates, as evidenced by the presence of lacustrine clays.

DISCUSSION AND CONCLUSIONS

The Walls of Jerusalem are located on a raised horst of dolerite of the order of 100 m higher than the surrounding plateau, bounded by NW-trending regional faults. How the valleys of the Walls were formed is less clear, as the presence of Triassic sandstone in a number of places suggest that nearly all of the dolerite has been removed down to the level of the sandstone. Intense fracturing and jointing of a relatively thin part of the dolerite sill might account for this, as indicated by the highly fractured and fragmented nature of the remaining section at The Temple.

Ice has obviously overridden and abraded all the high points and escarpments in the area except for an extraordinary patch of about 18 ha at Solomons Throne, where irregular piles of blocky scree coloured red with lichen have not been glaciated. This high-level abrasion most probably relates to an earlier period of major ice cap development.

Ground moraine, probably mostly related to the most recent glaciations, covers virtually all the valley floors. It is mostly in the form of smoothed-off low ridges of clay-rich bouldery till, but also includes significant areas of matrix-free boulder deposits thought to be where meltwater running off the ice has washed the till. This requires further investigation.

Extensive areas of clays seem to mark the locations of lakes formed as the ice retreated from the valleys, and of streams feeding these lakes. Some of these lakes persist, including Lake Salome, Lake Ball, and a small lake south of The Temple, but others have silted up, and this process continues. The Temple is largely covered by periglacial deposits, with only small remnants of bedrock, and could be regarded as a showcase of such deposits for the Tasmanian dolerite country. Blockstream/solifluction flows of dolerite and clay with bulbous ends are very well displayed, and a large composite flow, which is rich in sandstone debris, has a well-exposed lobate toe. These flows appear to mostly overlie, and post-date, the lacustrine clays and ground moraine.

Dolerite screes occur along most of the escarpments and are particularly well developed along the West Wall and under Mt Jerusalem. Much of the scree appears to post-date the moraine deposits, but there are examples where the moraine partly incorporates scree, and where an older, more weathered scree may pre-date some moraine. There is much scope for detailed examination of the screes and indeed of all the glacial and periglacial deposits.

The lack of dates on any of the deposits, and the complex overlapping nature of the deposits and landforms, makes it impossible to accurately reconstruct the glacial history at this stage. It is most likely that deposits and landforms from both the Rowallan Glaciation of the LGM MIS2 and older deposits of the Arm Glaciation of MIS6 are present within the Walls. Hannan and Colhoun (1991) report a radiocarbon date of 8270 + 270 years BP from 2 m depth in a Sphagnum bog in "Zion Vale below Mt Jerusalem" (Whinam *et al*. 1989, p. 14). This suggests that these clays have continued accumulating since ice melted from the area well over 13 000 years ago.

The Walls of Jerusalem is an extraordinary place in many respects, and this study, possibly the first moderately detailed one to be undertaken there, has found considerable complexity and interest in the geology and geomorphology. Further study is required and recommended, including of its vegetation, fire history and Aboriginal occupation as well.

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