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Note on Pleistocene Glaciation Mt. Field to Strahan

By

A. N. LEWIS, LL.D.

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This paper is an attempt at a general correlation of Tasmanian glacial features along a section from east to west of the glaciated portion of the State. The area chosen for this survey has already been the subject of a number of detailed descriptions and the influence of ice on its topography has been known in part since Charles Gould's first record in 1861 and in detail since R. M. Johnston's account in 1893. The few new areas in which traces of glaciation are here recorded do little more than connect up previous accounts. This paper may be regarded as supplying examples in support of my correlation of Tasmanian Pleistocene Glacial epochs and deposits (Lewis 1934). I now confirm, with a few modifications, the ideas then advanced and am able to clear up points which I then felt to be open to some doubt.

1. SUMMARY OF PREVIOUS ACCOUNTS WITH NEW RECORDS

Mt. Field

This area, on the eastern extremity of the glaciated zone, shows the typical topography of intense mountain glaciation down to the 2500 feet contour or a little less. It has been fully described (Lewis 1922 and 1923, Griffith Taylor 1922) and I have no further observations to record.

Florentine Valley

Previously, glaciation had been recognized to the east, south and west of this area but previous investigators had not recorded glaciation in the Florentine Valley itself. The reason for this has probably been that the Florentine is covered by dense virgin forest concealing the topographical details while the bare plains of the neighbouring Gordon and Huon valleys display their glacial features to perfection. However, as the results of a visit at Christmastime 1937, I have no hesitation in saying that the upper half of the Florentine Valley was subject to glacial action as severe as was the Vale of Rasselas. This is to be seen clearly from the Adamsfield track on the northern slopes of Tim Shea, and as it crosses the Thumbs-Saw Back saddle. The headwater tributaries of the Florentine rise in a wide arc of cirques on the northern flanks of Mts. Mueller, Bowes and Wedge. The less heavily timbered upper portion of the valley south of the Adamsfield track shows a glacial topography not essentially different from that of the upper Huon and Gordon rivers. The Tiger and Gordon ranges show the typical planing action of a major glacier along both flanks, as do the lower slopes of Mt. Field West. Spurs have been shorn and the whole floor of the Florentine Valley, at least as far north as Dawson's Road, or even an east-west line through Wyld's Crag, shows all the typical features of glacial topography. Morainal deposits abound for miles on both sides of the Florentine bridge on the Adamsfield track. It appears at present that ice descended to at least the 900-foot contour and perhaps lower. There has however been considerable post-glacial river erosion below that level.

Russell Falls River Valley

Glacial action is apparent in the saddles on both sides of Tim Shea, on the slopes of the Needles and over Mt. Mueller where cirques and at least one tarn occur. There is some slight suggestion of ice action as low as Kallista (1100 feet) but stream erosion has been more active on the steeper slopes of this valley and I cannot definitely confirm glacial evidence below 1500-1600 feet in this area.

Weld Valley

There appears to be some slight remains of glaciation north west of Mt. Anne at, perhaps 1100-1500 feet. The head of the Weld-Styx valleys are heavily timbered and observations are difficult.

Adamsfield

This area is also glaciated, although the short swift tributaries of the Gordon (Adam, Boyd, &c.) have been responsible for a high degree of post glacial erosion (See also Nye 1929, A. M. Reid 1921).

Vale of Rasselas, Denison Range and King William Ranges

The Gordon Valley from its source in Lake Richmond, down to the Great Bend, and its bounding ranges are all excellent examples of Tasmanian glacial topography. The fact that the whole of this area was heavily glaciated has been known since R. M. Johnston's early investigation (See e.g. Johnston 1894, Twelvetrees 1908, Reid 1921).

The mountains are dotted with large lakes and small tarns and the Vale of Rasselas is glaciated to the Great Bend at 1550 feet. Below this spot the eastward erosion of the river which is now the westerly flowing section of the Gordon has destroyed evidence of ice action but the glacial topography is continued unbroken across the almost negligible saddle of Myrtle Creek to the Florentine Valley.

Lake St. Clair

This area has been fully described by several observers, particularly W. H. Clemes (Clemes 1925, and see references to previous works there cited). I have nothing to add to these accounts except the interesting fact, which came to light during the surveys for the Tarraleah Power Scheme, that the floor of Lake St. Clair (700 feet deep) is lower than the bed of the Derwent for 10 miles down its course, that is to the top of Butler's Gorge, where the post glacial erosion of the Derwent River cuts into the glacial physiography. Mr. Clemes's account connects with the adjoining area to the north east already described in detail my myself (Lewis 1933).

Surprise Valley

The West Coast Road has opened up a wonderful section of glacial country. In fact it was in this section that Charles Gould in 1861-2 first discovered the occurrence of pleistocene glaciation in Tasmania (? Australia, see Johnston 1894). For 65 miles, from the Clarence to Gormanston, this road traverses an unending vista of moraine strewn glacial valleys with cirques never out of view. The eastern portion of this area has been fully described (Clemes 1925 and other references there specified). From Derwent Bridge where the road crosses the lower portion of the St. Clair moraine to King William Saddle (2725 feet), the country is typical of the more open glaciated plateaux. From the road at King William Saddle is to be seen the cirque system at the head of the Surprise Valley. The road drops from 2725 feet on the saddle to 1200 feet at the junction of the Surprise and Franklin Rivers, and this marks the vertical height between the country affected by two glacial phases. The whole floor of these valleys is glaciated although this fact is partly obscured by the heavy growth of timber. The glacial evidences at the head of the Franklin River (Lakes Undine and Dixon) have been well described (Johnston 1894, Clemes 1925) but the Surprise Valley is no less intensely glaciated with a remarkable 'tind' in the middle. Under Mt. Arrowsmith and Mt. Hardy some fine examples of moraines are exposed in the road cuttings.

Collingwood Valley

The road runs along the bottom of a typical glaciated valley here. The northern slopes of the Collingwood and Raglan Ranges as seen from the road present, in a remarkably clear way, the W pattern of shorn spurs. Hanging valleys and superimposed cirques can be seen everywhere. Glacial action extends right up to the top of the Collingwood-Nelson Saddle west of King Billy.

Nelson Valley

Here the road runs, at first, high up on the side of a typical glacial valley. The characteristic shorn spurs are seen, this time, from above. The road enters the Nelson Valley also over the crest of a cirque. No more typical example of glacial erosion can be seen anywhere.

King River

This valley has been the collecting ground for a large sheet of ice descending in many tributaries glaciers from all the surrounding mountains (See Johnston 1894). Its broad floor is now covered with morainal material largely restored by post-glacial floods.

Linda Valley

This short valley provides the most spectacular example of glacial topography in the whole State and the destruction of all vegetation and humus by firewood getters, sulphur fumes and heavy rains has revealed the rocks as much as the glaciers left them. This and neighbouring areas have been well described (Moore 1894, Gregory 1903, Hills 1914, David 1924 and Lewis 1936) and I have nothing further to add.

Queenstown

A remarkable change in topography presents itself as the Linda Gap is crossed from Gormanston on the road to Queenstown. The open vista of the perfect glacial valley crowned by the huge Gormanston moraine gives place to a confused jumble of waterworn gorges. These are the head waters of the Queen River, which have cut easterly into the western slopes of the West Coast Range and here have removed all trace of glacial topography. The same has occurred in the Comstock Gap to the north. (Nye and Blake 1938, p. 15). Evidence of ice action is again apparent in a tributary valley north of the saddle at Renedeena on the Mount Lyell Railway between Lynchford and Renedeena. In the valley of the King River, south of the saddle, the traces of glaciation have likewise been largely removed (See David 1924).

Strahan

It is clear that final confirmation of the various theories relating to superimposed glaciations must be sought at the edge of the glaciated area. Unfortunately this evidence has been destroyed in most localities by post-glacial erosion. However, at Strahan a most instructive, if confusing, section is to be seen. The Strahan terraces are well known and their glacial origin is recognized (see David 1924 p. 116 and plate XI). The recently constructed Strahan-Queenstown road has opened up a section which provides remarkable confirmation of Sir Edgeworth's explanation of these terraces and which deserves a brief description.

The road winds out of the Queen River basin (largely post-glacial river topography) on to Howard's Plains and thence a distance of approximately 20 miles across the 'Henty Peneplain' reaching a height of 1100 feet above sea level at a spot just north of Renedeena. Thence it descends to 550 feet at a distance of 3 miles from Strahan. This area is occupied by white brachipod sandstones of the Queen River Series (Silurian) with included grey slates and white to green tuffs and porphyry. These rocks end at a large cutting on the western slope of the peneplain 3 miles from the boundary of the Strahan township and 550 feet above sea level.

From that spot a well preserved glacial moraine is exposed in the numerous road cuttings. This is mostly dark yellow to greyish clay full of grits, pebbles and boulders, numerous ones of which show distinct ice scratches. As far as can be observed in this section the maximum height of this moraine is 600 feet above sea level and it descends on the terraced slopes east of Strahan to 300 feet above sea level. This by no means necessarily records the thickness of the moraine but on the section in question the till is replaced at 300 feet by the Strahan terraces. Its absolute thickness in a vertical section may be much greater but no exposure could be found to indicate this.

The Strahan terraces are at three distinct levels. The top of the highest (more easterly) averages 300 feet. The top of the second, upon which the central portion of Strahan is built and which extends westward to the ocean beach, averages 60-75 feet above sea level. The lower terrace is to be seen as a narrow margin round Macquarie Harbour and rises from 5 to 25 feet above sea level. The moraine mentioned above abuts on the 300 foot terrace and appears to merge into it. The terraces all appear to consist of blown sand, river grit and partly rounded but ill sorted pebbles averaging 2 inches in diameter with a few larger ones. Layers of peat sometimes two feet or more in thickness are included. No consistent arrangement of strata can be observed. The pebble bands vary from a few inches to twenty or more feet in thickness and are distributed without apparent arrangement amongst the sandy accumulations. The arrangement of the whole series bears no relationship to existing topography. Much of the sand is clearly river or fresh water grit. No sign of sea life can be found and aboriginal artifacts are conspicuously absent. The western edge is covered by very recent sand dunes. No distinguishing feature, or in fact any difference other than height, can be identified between the various terraces. Their depth is unknown. They show no traces of varves (see also David 1924 p. 116

for a section of the 60 foot terrace at Strahan railway station which may be taken as typical of the whole series subject to frequent local variations).

In my opinion, the Strahan terraces are all of the same age and are, taken as a whole, contemporaneous with the moraine immediately to the east. At Malanna, the moraine described by Sir Edgeworth David appears to overlie blown sand and pebble deposits undistinguishable from the material of the Strahan terraces. Although no section at Strahan illustrates this so clearly, it appears to me that the same relationship exists at 550 feet 3 miles east of the township. I can find no justification for assuming that the moraine was the product of the earliest glaciation and that the terraces were deposited at lower levels during subsequent glaciations. This is probably the effect produced in river valleys in non-glaciated regions where the terraces lie parallel to the drainage (see Lewis 1935) but such is not the case where the terraces lie at right angles to the direction of the drainage and cover a wide area.

The explanation which appears best to fit all the evidence is that the Strahan terraces were formed from the outwash from melting glaciers or an ice sheet of the Malanna glacial phase. These deposits were laid down originally on a very low and level shore platform or in a wide shallow bay which stretched from Kelly's Basin to Trial Harbour some two to five eastward of the present shore line and perhaps behind a line of sand dunes which may have quite blocked access to the open ocean. In any case the actual floor is not anywhere visible. Some remains of marine life may exist at the level of this floor. A large area was covered with such outwash gravels and blown sea sand was constantly encroaching. Vegetation established itself from time to time but was continually being overwhelmed by newer deposits. There is evidence of very many fluctuations during the deposition with alternations of retreating and readvancing ice, growth and dispersal of sand dunes, accumulation and destruction of peat bogs and forests. There is also evidence that each example of outwash pebble banks, sand dunes and vegetable accumulations were nowhere individually widely distributed and often showed great differences in vertical height with marked erosion effects during the whole period of deposition.

The outwash apron as a whole was widely distributed at first, perhaps further westward than the present coast line. Finally the ice advanced over much of this outwash gravel and actually deposited terminal moraines rising several hundred feet higher. Subsequently to this maximum phase, water flowing from the retreating ice margin assisted to redistribute morainal material in a sharply descending slope to the lower terrace. The present topography is the result of influences ubsequent to the maximum glacial phase—that is to erosion of the moraines and outwash gravels, not entirely to deposition factors.

It is admitted that the absence of sea shell presents a grave objection to any explanation of the formation of these terraces by marine erosion. Sir Edgeworth David also raises the objection that there is no evidence of any terrestrial uplift during the period in question (David 1924 p. 116). However, there is evidence elsewhere of successive rises in the land all over Tasmania (Lewis 1935) and the absence of sea shells may be explained from several causes such as subsequent erosion, or erosion by a virtually fresh water 'inland sea' such as Macquarie Harbour. However, Sir Edgeworth David actually only affirmed that the Strahan terraces were not raised beaches, a conclusion which is now accepted, and my chief point is that the glacial origin recognised by Sir Edgeworth David and proved by the discovery of the moraine immediately to the eastward must be referred to one glacial phase not to three, as may be tempting.

I postulate that the 60 foot terrace and the shore platform at Strahan are referrable to the same positive earth movement as produced the similar features in south eastern Tasmania (Lewis 1935). These are marine erosion features without contemporaneous deposits. The 150 foot terrace noticeable in unglaciated areas is obscured by the higher moraine and outwash gravels.

I also note that the erosion features of the subsequent phases of the Pleistocene glaciation in what I have taken as the type area are to be seen in panorama from the Strahan-Queenstown road near its highest point. The cirque gorge of the Yolande, with the Lake Margaret pipe line, is plainly visible on a clear day. The contour of Lake Margaret is also marked by the pipe line. It is also noticeable that the slope from the top of the Gormanston moraine in the Lyell-Owen Gap to the moraine just east of Strahan represents the natural slope of the western fall of the range prior to the removal of a great portion of the intervening country by the headward erosion of the Queen River.

2. General Correlation

In my previous paper on correlation of glacial epochs, I summarized the arguments advanced in support of a threefold glaciation during Pleistocene times and gave the names Malanna, Yolande and Margaret to the three Tasmanian ice invasions. These ideas worked out well in some localities but I was not very satisfied as to others. Chief amongst the doubtful areas was the Mt. Field plateau where the Margaret ice tarn stage is distinct, and, at 1200-1600 feet lower down the mountain side the remains of the Yolande stage is equally distinct. This Yolande stage is divided into two separate phases showing superimposed cirques, lakes and moraines (See Lewis 1922). However, these two phases are only separated by a vertical interval of 200-400 feet and the time interval did not appear as apparent as in some other localities (e.g. the type area, Henty Valley). On the other hand, if the lower glaciation on Mt. Field did not represent the Malanna stage, this phase was missing here and the temptation to force a correlation was strong.

Similar doubts as to the glaciation of Mt. La Perouse were resolved by observations recorded in 1935 (Lewis and Murray 1936). We there indicated the possibility of a double phase during the Yolande glaciation. The recent discovery of glaciation in the Florentine Valley now provides the confirmation I sought in 1935. This involves the retraction of the statement in my 1933 paper to the effect that the Yolande stage could not be subdivided, which I now amend to read that the second or later phase of this stage cannot be subdivided.

The sequence as now made clear by a consideration of the cross section of glaciated country from Mt. Field East to the Thumbs is as follows:—The Florentine Valley was at one time filled with ice which descended to at least the 900 foot contour and probably somewhat lower. This ice at its maximum must have filled the valley to a height above the saddles east and west of Tim Shea, that is a thickness of 1200 feet at least. At this time Mt. Field plateau was probably entirely covered by an ice cap which did not leave observable traces on the mountain sides—the glacier forming in the Florentine Valley. It is a distinct possibility also, that the final elevation of the plateau occurred subsequently. In any case stream erosion has been very active on the steep slopes and would be sufficient to remove traces of the ice cap on the eastern and southern sides of the plateau. Two distinct glacial phases occurred during the Yolande stage. In the first, the more intense, ice did not descend the plateau valleys quite to the 2400 foot contour, and in the second, below 3000 feet, giving an average difference in the altitude of the nivation layer in the two phases as about 500 feet. In the quite distinct Margaret stage the nivation layer did not descend lower than 4000 feet (See Griffith Taylor 1922).

We thus can identify in Tasmania four separate ice invasions. Of these, the two middle ones occurred in quick succession, relative to the dates of the preceding Malanna stage and the succeeding Margaret stage. I consider that these two middle glaciations should be regarded as both phases of the one stage. We probably see the effects of a rapid onset reaching its maximum intensity relatively early, then a partial waning followed by a second onset less intense and less sustained than the earlier phase. I therefore prefer to retain the name Yolande for the whole glacial invasion, separating it into a first and a second phase where the evidence is sufficient.

This generalization appears to fit all the field evidence, both of glacial topography and river terraces in non-glaciated areas, which latter do not show definite differentiation between the two phases of the Yolande stage. It is the only explanation which will explain the topographical details of all the glaciated country when considered as a whole from east to west and it can only be seen when such a section is studied as a whole.

3. Malanna Stage

The remnants of the Malanna glaciation are relatively rare. Mostly, they have been removed by post Malannan river erosion. Through the area under discussion the country consists, in a general way, of plains standing at about 1000 feet above sea level with mountains rising out of them to 3000-5000 feet above sea level. Sometimes the mountains are so closely parallel that the plains become mere valleys. The Malanna stage can be seen on these plains where its features have not been removed by subsequent river erosion or obscured by Yolande glaciers which, where the mountains are high plateaux and the valleys between are narrow, more or less covered the traces of the earlier stage.

The glaciation of the valleys of the Florentine, the Vale of Rasselas, the Huon and Serpentine are attributed to this stage. The same is also the case with Lakes Sorell and Echo and the eastern areas of the central plateau. Any possible glaciation in the Russell Falls and Weld Valleys are likewise referable to this earlier stage. The Surprise Valley is an excellent example of a Malanna cirque and glacial valley. The underlying features of the King River valley and probably of the Franklin and Collingwood Rivers were moulded by Malanna ice flows. The terraces and moraines at Strahan, and the moraines at Malanna are of similar age.

Through the Lake St. Clair valley and thence to the King River there is much morainal material of the Yolande stage strewn over the older glacial valleys along the section traversed by the West Coast road. The Linda moraine is probably a highly eroded fragment of a Malanna moraine. I have already described this feature of outstanding interest (Lewis 1936). It is obviously very ancient and took an immense period to accumulate. I consider that it was deposited in a lake or flat plain. It is clear that this deposition must have taken place when the physiography of the West Coast Range was very different from that presented at the present time. I quite agree with the remarks of Nye and Blake as to the moraines in the neighbouring Sedgwick Gap (Lyell-Comstock) and the relationship of the erosion of the Queen River (Nye and Blake 1938 p. 15). Similar features are apparent in the Linda Gap. Gregory's explanation of glacial features must now be regarded as superseded except as to descriptive detail. Nowhere is the distinction between the Malanna Stage and the succeeding Yolande Stage more pronounced or clearer than in the section from King William Saddle to the Franklin River i.e. the panorama southward from Mt. Arrowsmith. Here the Yolande glaciation of the St. Clair area, extending to the saddle can be seen at 2400-2800 feet and, below, the old forest covered cirques at the head of the Surprise Valley 1000-1200 feet lower. In the same area the traces of the lesser Margaret stage can be seen in the small cirques high on Mt. King William.

The effect of post Malannan uplift is apparent everywhere. The Gordon and the King Rivers and their tributaries have cut deeply into the glaciated valleys (See David 1924). The waterworn topography round Queenstown is a typical example. This waterworn topography extends eastward up the Gordon Valley to the Great Bend and is very marked round Adamsfield. It is carried up the valleys of all the tributaries of the Gordon for some distance. On the other watershed, the Derwent has cut even more deeply into the glaciated area south of Lake St. Clair, having removed all traces of glaciation below the northern end of Butler's Gorge, where the Tarraleah fluming commences. The Nive, Dee and other south flowing tributaries have cut back to the line of the West Coast road or further and the Florentine has cut into its glacial valley to a point west of Mt. Misery. The Russell Falls and Weld Rivers have almost removed all trace of Malanna stage glaciation from their valleys below about the 1500 foot contour.

It is difficult to fix one elevation as the contour to which more recent river erosion has cut. This varies with each stream. In some cases the present river valley has cut into one side of the older Malanna glacial valley, or cut a sharp trog in the old wider valley, leaving traces of glaciation still surviving. In some valleys the tributaries have removed all trace of Malanna glaciation in other places only one or several tributary valleys have been thus affected, leaving a nearly dry glacial valley at a higher level. For this reason, many apparent contradictions exist. However, it appears clear that during the Malanna stage, ice descended to sea level on the coast and to 900-700 feet at least at the meridian of Mt. Picton-Mt. Field-Lake Echo. During this early stage therefore all the western third of Tasmania, with the southern coast, the central plateau and the north eastern plateau must have been under an ice cap, although it was a Tasmania essentially different in topographical details from what we now know.

4. Yolande Stage

The obvious glaciated features of the uplands belong to this stage. In favourable localities glaciers pushed down valleys to about the 2000 foot contour and developed very fine cirques and comb ridges at their heads. These extend upwards to about the 4000 foot contour, above which ice cap conditions left little mark on the topography. This is the stage responsible for the glaciations of the Mt. Field plateau, Mts. Anne and Mueller, the King William Range, the Eldon Range, and many of the valleys of the West Coast Range including Mts.

Jukes and Tindal. The two phases are frequently in evidence. See particularly Plates XI and XIII in my account of Mt. Field (Lewis 1922). Similar features have been described at Lake St. Clair and Du Cane Ranges (Clemes 1924) and Mt. Jukes (Hills 1914), also at Cradle Mountain (Benson 1917 esp. p. 34) and La Perouse (Lewis 1925). Yolande glaciation is also responsible for many details of the features at the head of the Florentine, Gordon and Surprise Valleys and is the glaciation of the western edge of the central plateau and at the headwaters of the King and Pieman Rivers and their tributaries.

The double phase of the Yolande glacial stage follows over the higher mountains of western Tasmania with sufficient regularity to establish the main features of the stage. The difference in level varies considerably but 400 feet is the average difference and its absence in any particular glaciated locality is to be explained from outside causes, usually the obliteration of the first phase by the second or a sufficiently identical development to cause confusion.

To-day therefore, we have advanced beyond the stage when the existence of glacial features are recorded as an item of interest since we can say positively that all the country west of the 147th Meridian and which is over 1000 feet has been subjected to ice action. Where this is not apparent the explanation is post glacial stream erosion. Moreover, the details of the traces of ice invasions as outlined above are consistent throughout this area varying only with such local features as slope and size of neve catchment.

5. Margaret Stage

This glaciation was the most recent but as the nivation layer at this time did not descend below 4000 feet on the eastern boundary of the area described to 2000 feet on the West Coast Range, only the higher and more westerly mountains were affected. In some areas this glaciation is very distinct (See Griffith Taylor 1922 and Lewis 1922 Plate VIII, Clemes 1925 p. 71, and Plates XI fig. 1 and XIV fig. 1). Pine Lake (Lewis 1933) is referable to this glaciation as are most of the small lakes and other glacial features in the higher levels of the Lake St. Clair-Cradle Mt. National Reserve, and over the western edge of the Central Plateau. Many of the higher lakes on Mt. King William, Denison and Eldon Ranges belong to this stage but without a detailed examination I am not prepared to draw a definite line in these localities between the Margaret and Yolande stages. The glaciation of this stage at the type locality has been well described (Moore 1894, Montgomery 1894).

There is little to add to these descriptions. Cirques with occasional lakes and frequent moraines referable to the Margaret stage lie dotted over our more elevated highlands. The features produced by this glaciation are seen usually on a definite shelf or ledge cut into the cirque heads of valleys still showing the characteristic features of the Yolande stage. Very often the evidence of the Margaret glaciation is no more than a line of ledges, hollows and miniature cirques round the mountain side at a constant height. In more favoured localities only has this glaciation developed features in any way approaching those of the Yolande stage and then, often, the two stages overlie or merge in a very confusing way. The areas where this glaciation can be established as a distinct stage are those such as Mt. Field, Du Cane Range, La Perouse, and Mt. Anne where the Margaret cirques have distinctly cut into the Yolande cirques. It is often impossible to disentangle the moraines referable to these two stages. However, the evidence of the cirques, ledges and tarns is sufficient to establish the stage as an event quite distinct from both phases of the Yolande glaciation. The best description of the features of this stage were given by T. B. Moore (1894) and Griffith Taylor (1922). Most, if not all of the existing ice scratched pavements are to be referred to this glaciation, a fact which led to much early confusion and I stress again that cirque erosion and not morainal deposits form the only sure guide to differentiate the various stages.

[NOTE.—Since writing the above I have found a reference by T. B. Moore (1896) to glaciation on the Lyell-Strahan road. This was probably an early observation of the moraine now more fully exposed in the road cutting made in 1937 (see *ante* p. 165). Due credit should be given to Moore for his observation under difficult conditions in 1895.]

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