A PRELIMINARY SKETCH OF THE GLACIAL REMAINS PRESERVED IN THE NATIONAL PARK OF TASMANIA.

By A. N. Lewis, *M.C.*

Plates VI.-XIV.

(Read 11th July, 1921.)

INTRODUCTORY REMARKS.

This paper is offered as a preliminary and very general sketch of the district described, upon which more detailed examinations of separate sections may be based. The author cannot at present offer a complete geology of the National Park of Tasmania. Its size, ruggedness, and general inaccessibility, aided by the usually inclement weather of the mountains, make the task difficult, and demand a far greater expenditure of time than has been available up to the present. Much of the Park is still unexplored, and parts were first visited that some of the information contained in this paper might be gleaned. But an outline description is urgently needed, firstly as a frame into which more detailed investigations may be fitted, secondly, for the information of visitors, who, in annually increasing numbers, spend holidays on the Park's highlands, and also as an assistance to the parties who are now inspecting this region in connection with water supply questions.

The author also offers the information as a small contribution to the Geology of Tasmania, information which, in the absence of local text books, it is hoped will be of assistance both to students and teachers. Tasmania is our home. It provides us with wonderful examples of every geological phenomenon. These are of living interest to us. Let us rather study them, and know our own home, than seek our geology from books published about distant countries describing objects that are mere names to us.

As far as can be ascertained, the glacial remains on the Mt. Field ranges have never been described. They do not appear to have been observed, or at least their existence recorded, before the proclamation of the area as a National Park. There is, therefore, no previous literature on the subject to which to refer.

AN OUTLINE SKETCH OF THE GEOLOGY OF THE NATIONAL PARK OF TASMANIA.

The National Park of Tasmania is located about 50 miles from Hobart, among the Mt. Field ranges, on the northern slope of the Russell Falls River, a tributary of the Derwent. It comprises some 38,500 acres of wild mountain tops and dense forests, and contains the most varied scenery within a day's trip of Hobart. The Park was originally set aside in an endeavour to preserve some native fauna and a little of the romantic virgin bush from the depredations of a misguided civilisation, but with the opening up of the area it has been discovered that there are contained within its boundaries geological features of considerable interest.

Topographically the Park is a portion of the very much dissected Central Plateau of Tasmania, itself cut off from the remainder of the plateau, and isolated by the valleys of the Derwent and the Russell Falls Rivers. The smaller plateau so formed is itself a dissected tableland. This tableland consists of diabase that intruded into the older strata of most of Tasmania during the Cretaceous period, and the general topography conforms to the outline of this diabase. Probably the area was raised to its present height in one uplift by this diabase, contemporaneously with the elevation of the Mt. Wellington Range to the south and the Central Plateau to the north. Any overlying rocks carried up by the intrusion have since been removed by erosion.

In the past the Mt. Field Range has been considered a portion of the Mt. Wellington Range. This appears to me to be stretching the term mountain range too far. The diabase is undoubtedly of the same age, but the Mt. Field Range is separated from the Mt. Wellington Range by the Tyenna Valley. This valley is not entirely waterworn. The West Coast rocks extend into it at an altitude of less than 1,000 feet, and Ordovician limestones circle round from the Florentine Valley to the Junce. Above these, large beds of Permo-Carboniferous and Trias-Jura sediments bound the western face of Mt. Field West, and the entire northern slope of the Tyenna Valley. and there is no surface connection between the diabase of Tyenna Peak and that of

Mt. Mueller. We are, therefore, bound to conclude that the diabase intrusion raised the country from Mueller to Styx to an elevation of 4,000 feet, and similarly raised the Mt. Field plateau, but left the valley of Tyenna-Westerway at an altitude of less than 1,000 feet above sea level.

From the Tyenna Valley, through which flows the Russell Falls (or Tyenna or Crooke) River, the edge of this diabase mass rises rapidly, attaining an altitude of 4,000 feet in a mile or so. The backbone of the range extends roughly east and west from Mt. Mawson, through Mt. Monash, and Seager's Look-Out, to Mt. Field East, to which the land rises steeply from the Tyenna Valley on the south. From Mt. Field East and Mt. Mawson two large parallel ranges stretch away slightly west of north, reaching to the southern edge of the Derwent Valley, about 10 miles farther north, and maintaining an elevation of over 3,000 feet. Between these runs the deep valley of the Broad River.

To the west of this system stands the third parallel chain of the Tyenna Peak—Mt. Field West Range, a western outlier from the main diabase mass, to which it is connected by K. Col. The wonderful escarpment on the west of this range, dropping nearly sheer to the Florentine Valley, 3,000 feet below, represents the western edge of the diabase upthrust in this part of Tasmania.

These three great mountain ridges show the form of the diabase intrusion. Sedimentary rock skirts the lower slopes of the mountains from Mt. Field East to Mt. Mawson. It then runs a mile or more up the valley of the Humboldt Creek, and back round the end of Tyenna Peak, and right across the western face of Mt. Field West. Undoubtedly, the intrusive diabase took the form we now see it in, and erosion has worn out the softer sedimentary rocks between the lines of intrusion, forming the valleys now existing. If any further proof were required that such was the case, and not that water has worn the valleys out of a plateau of solid diabase, we can find it in the Lake Hayes Valley, where the face of the valley is lined with sandstone.

Of course, erosion has affected the diabase mountain tops to a certain extent, but the great valley regions of the Park are caused by the absence of diabase there. The columnar cliffs so common near the tops of all the mountain ranges in this area probably represent the edges of laterally intruded sills of diabase.

Time has not allowed a detailed examination of the sedimentary rocks of the Park. Near the entrance, and extending for some distance up the Tyenna Valley, are beds of Permo-Carboniferous lime—and mud—stones. These are overlaid by over a thousand feet of sandstone in huge, compact beds, in which strata can be scarcely distinguished. From general observations, all these sandstones appear to be of the Trias-Jura age, similar to the Knocklofty series so well known in Southern Tasmania. These beds have been distinguished by Mr. Loftus Hills at the foot of Mt. Field West in the Florentine, but their age requires confirmation elsewhere.

The drainage is typical of the stage known as juvenile, and most of the streams are mere mountain torrents. During the Pleistocene times, the cycle of river erosion was interrupted by glaciers in the higher altitudes. These have widened many of the valleys and dammed them in places. forming lakes and causing the streams to meander over an almost level bed. The Upper Broad River has the appearance of being in the mature stage, but it is really cutting through a valley not of its own making, and from which it has not yet had time to remove the remains of the glacier. In a day's walk along this valley, the student can see every form of river erosion.

The glaciers which caused this, and the way they have moulded the topography of the plateau, it is now the main purpose of this paper to describe.

THE COURSE OF THE PLEISTOCENE GLACIERS.

At the same time as the western half of Tasmania was more or less under ice, and from the same cause, snowfields accumulated on the Mt. Field Plateau, and glaciers flowed a little way down the valleys. It is well known that the Pleistocene Ice Age was not of uniform coldness. During periods of milder climate the glaciers shrank towards the mountain tops, and in intervals of intense cold they pushed out down the valleys. Unfortunately, a glacier tends to erase all traces of earlier action by its latest flow, but still we can see to what point the glacier reached, and trace the stages of its final retreat.

During the period of maximum glaciation, a permanent snow cap covered the entire top of the Mt. Field Plateau, and probably extended down the sides to an altitude of 3,000 feet. The great snowfields that accumulated on the more level portions of the highlands fed glaciers that pushed down the valleys.

The chief of these ice rivers flowed down the Broad River; one branch fed by the snowfields extending from Mt. Monash to Mt. Mawson pushed straight down the valley. It was soon joined by a second flow of equal size from Lake Seal Valley, fed by accumulations of snow on the ridges above that lake, and later by a third branch flowing down from Lake Newdegate to Lake Webster. Together, these pushed four or five miles farther down the valley of the Broad River, and during its prime the glacier must have been seven miles in length, and over half a mile wide, and 300 feet deep. It extended to a point 2,400 feet above sea-level, where it melted, and the water was carried off down the Broad River to the Derwent. In the track of this glacier we find the most extensive evidences of ice action to be found in the Park.

On each side of this considerable glacier existed a group of smaller ice-streams. To the east, growing from snowfields on Mt. Field East, Kangaroo Moor, and on the eastern side of Wombat Moor, a glacier flowed down the valley now occupied by Lake Fenton, breaking up at about 3,000 feet above sea-level, not far below the present shore of Lake Fenton, at about the six mile peg on the track from the entrance to the Park.

Farther to the east, under the slope of Mt. Field East, two other glaciers developed. The larger, flowing south-east, was responsible for Lake Nicholls and Lake Rayner, and the other flowed south-west over the present site of Beattie's Tarn. Neither of these reached much lower than 3,000 feet, and both were small, as they were situated on the eastern, and, therefore, the dry and warm, side of the ranges.

The western group comprised two glaciers of considerable extent flowing in opposite directions, one southward through the Belcher-Belton Valley, and the other north through the Hayes Valley. These were fed by the snow from the lofty crags that surrounded them. The Belcher-Belton glacier was a composite one, and flowed for about two miles down the valley of the Humboldt Creek to an altitude of about 2,900 feet. The other was only about a mile in length, and reached to about the 3,000 feet level.

It must be borne in mind that the erosion of the various creeks working up their valleys may have destroyed traces of ice action lower down than the altitudes mentioned, but this cannot have happened to any great extent, as the erosion has had little effect on other glacial remains in other parts equally exposed, so short has been the time since the disappearance of these glaciers.

Up to the present, there have been found in this part of Tasmania no indications calculated to throw any light on the age of this glacial period, but the remains are of most recent age, and evidences elsewhere in Tasmania place the occurrence in the Pleistocene period. The glaciers in the National Park were contemporaneous with those elsewhere, and strong evidence to the contrary would have to be deduced to alter the settled opinion that these glaciers belong to the Pleistocene.

Unfortunately, the entire area affected by this agency is of diabase. This makes it impossible to observe different kinds of rock in the moraines or to guess where the materials came from. Also the diabase weathers too rapidly to retain any trace of striæ. This is also the case with very much harder rocks. "It must be borne in mind that weather- "ing agencies have been at work so long and disintegrational "forces so active, that all positive traces on the rock sur- "faces would have been destroyed in the case of such rock "as granite." (Waterhouse, 1916.) "The Conglomerate" (West Coast Series Conglomerates of the Cambrian system, one of the hardest of rocks) "does not possess the requisite "texture for the preservation of the striations which almost "invariably have been effaced by exposure to the weather." (Reid, 1918.) Perhaps glaciated pebbles that have been protected from weathering processes by clay or sand may yet be found in the National Park with signs of striations.

Time and weather have prevented a complete exploration of the National Park, and other regions of glaciation may yet be found, especially north of Mt. Field East, and between the valleys of the Broad River and Bunyip Creek, and even over the shoulder between Mt. Field West and the Florentine Peaks. There is still ample scope for the enthusiast. The author can only hope that this paper may be of some assistance.

DESCRIPTIVE ACCOUNT OF THE GLACIAL REMAINS.

I. THE BROAD RIVER VALLEY (See Plates VI. and VIII.)

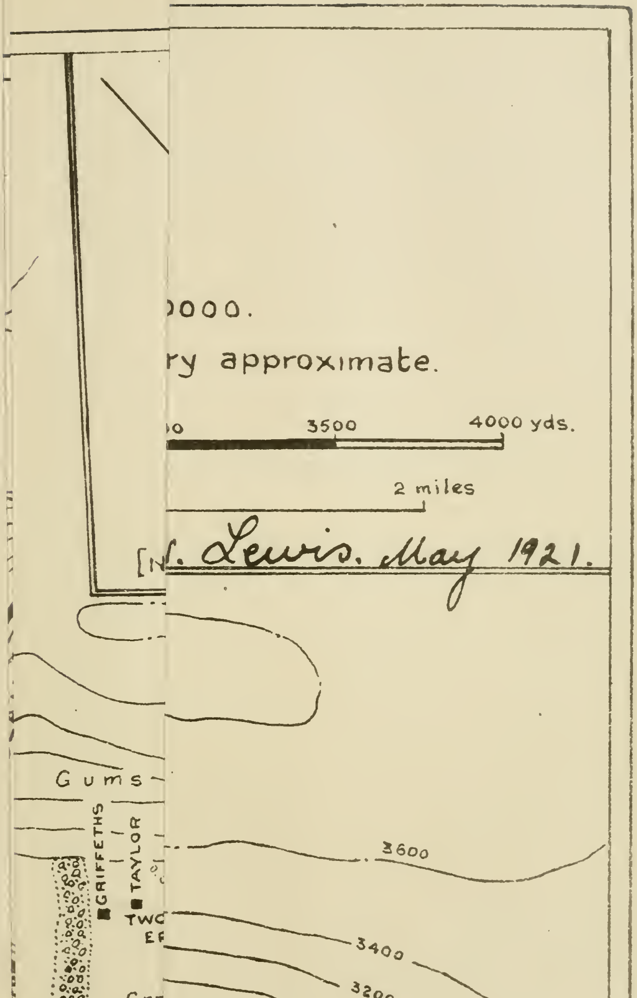
(a) Below Lake Webster.

The whole seven miles of the Upper Broad River Valley is a typical glacial trough, most markedly U-shaped, straight, and devoid of spurs. The floor, averaging half a mile in width, is quite flat, and the sides, gently sloping at first, rise abruptly 500 feet in a slope that is often precipitous. At the top of these sides depressions and spurs have begun to appear, but these have been shorn off lower down.

Glacial remains can be traced over four miles below Lake Webster. In this distance, the floor of the valley is nearly level, dropping only 150 feet. It is covered with button-grass growing on a stiff clay, and crossed at intervals by definitely marked and easily visible moraines. The Broad River winds through these button-grass plains, and cuts through the moraines first on one side, then on the other, and where it does so it drops quickly in a succession of stony rapids, passing out again on to the flats hardly to drop at all until the next moraine is reached. The river has cut down in places to a depth of six feet below the surface of this plain, and there you can see what underlies the vegetation.

Evidently, the glacier deposited in its retreat the various moraines which have successively blocked the valley from side to side. Behind these dams, large, shallow lakes were once banked up. The glacier dropped the larger boulders, as it melted, in the spot where we now see them as moraines, while the water escaping from the melting ice carried the finer materials out into these lakes as silt, and formed great beds of clay and sand on their floors. Across the surface of the lakes floated blocks of the glacier as icebergs, and dropped stones and pebbles into the clay. A large volume of water was liberated as the glacier melted, and these lakes overflowed at the lowest side of the moraine. In time this overflow cut away the loosely knit material of the dam, and eventually drained the water from the lakes, leaving the peculiarly level beds of clay we now

Plate VI.



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see covered with button-grass. Lake Webster and the watery marsh half a mile lower down the valley are all that are now left of a line of at least five lakes. Each lake must have been at least 30 feet lower than its higher neighbour. Perhaps they did not exist contemporaneously.

By following the course of the Broad River, it can be seen that the present floor of the valley consists of a fine grained, almost greasy, clay, usually of a yellow ochre colour, but also varying from light yellow to brown. It is never red, and iron deposits do not appear to exist in it. Boulders measuring a few feet in diameter are common throughout this clay, more particularly on the edges. In some places it can be clearly seen that stones have been dropped into the sediment from ice by the bending of the layers of the clay immediately below them, and here and there stones can be seen that are standing up on edge in the clay. In some places there are thin but extensive layers of gravel, suggesting a change of conditions, such as a flood; in other places there are layers of water-worn flaked cobbles, suggesting a wind-swept beach. In a few spots there exist considerable beds of sand and fine conglomerate, which here and there has already solidified into a rock of some hardness. These, however, are only occasional in the lower reaches of the glacial valley, the clays predominating.

Nearer Lake Webster, sand, gravel, and more typical glacial till increases in proportion until the clays vanish at about the confluence of the Broad River and the outlet of Lake Webster.

The entire deposit shows the characteristic confusion of a glacial deposit, except perhaps, where the stream has recently accumulated piles of alluvial drift. These are few, and confined to the river bed, and no notice is to be taken of them when studying the glacial deposits.

From these beds of clay rise at intervals masses of morainal debris, in some cases stretching in thin belts right across the valley, and in others standing in groups promiscuously dotted about in the button-grass flats. These rise to any height up to twenty feet above the floor of the valley. They consist of a brown earth and gravel freely mixed with oblong slabs of diabase, and containing many boulders of all sizes, up to 10 feet in diameter. Rain has washed the lighter material off the top of these piles of boulder clay, and the larger rocks stand out predominantly, but their entire section can be studied where the river has cut through any one of these banks.

These were formed where the glacier halted for an interval during its retreat, from the debris tumbled out of the melting ice. We see them to-day just as the rocks and finer materials fell in a heap off the end of the glacier. Owing to their elevation above the surrounding flats, they are well-drained, and trees, chiefly dwarfed swamp gums, cover them, giving a rough guide to their whereabouts.

Probably there existed a small moraine below the place where the glacial remains now appear to end, at the spot at which the Broad River turns from north-west to north, and drops into a narrow V-shaped water-worn gorge, as lacustrine clays continue below the last remaining moraine. Once past these glacial flats, the river drops rapidly, and so has greater cutting power. Perhaps in the future further traces of glacial moraines will be found on the side of this water-worn valley, but this is doubtful.

The lowest of the remaining moraines can be clearly distinguished by the belt of trees growing on it. It is not very clearly defined, rising some five feet above the button-grass plain above it, and about twenty feet above the lower flat below. It averages fifty yards in width.

The next two moraines up the valley in the direction of Lake Webster are most distinct. The northern one of the pair has two large erratics standing about 50 yards from its north-west corner. These blocks (see Pl. XIV., Fig. 3) are roughly square, and measure 10 feet by 15 feet, and are resting on the clay beds of the button-grass swamp. From this point upwards nearly to Lake Webster lateral moraines on both sides of the valley can be traced, although they only stand a few feet from the surrounding country, but are marked by many large boulders. Both these moraines rise some 15 feet from the button-grass on the upper side, and about 30 feet on the lower. They both stretch from one side of the valley to the other in a wonderfully straight line. The lower one averages 200 yards in width, while the upper of the pair, which is the best example of a moraine in the Park, is only about 20 yards in width.

From a spot about 2,000 yards below Lake Webster, and a little distance below the considerable marsh that lies some way below that lake, this country of definite moraines, separated by beds of lake-formed clay, gives place

Lake Webster and the Broad River Valley, National Park, Tasmania.

to a confused bed of glacial till, rising more quickly, and covering the whole floor of the valley. Evidently, here the glacier receded with an even movement, distributing its terminal moraine equally over an area of country extending up to Lake Webster.

(b) Lake Webster to Lake Seal, Including the Tarns.

(See Plates VI. and VII.)

From a point somewhere about the junction of the Broad River with the outlet from Lake Webster, up the valley to about level with the end of Lake Seal, it is difficult to trace any definite movements of the ice-river. The whole valley is strewn with accumulations of morainal material of unknown depth. The surface of the ground is rendered very uneven by lines of this moraine in every direction, and at all angles, and by the many boulders scattered over the surface of the till.

Lake Webster lies in a depression in this moraine. It is a shallow lake seldom exceeding 10 feet in depth, and overflowing over the lower slope of the morainal mass. The Broad River flows down the eastern side of the valley, and is slightly lower than the lake, from which it is separated by a considerable ridge of glacial till running parallel to the course of the river and the side of the lake.

Three ice streams met in the vicinity of Lake Webster to form the great Broad River glacier. From the amount of work done, it appears that the glacier that flowed down the Lake Seal Valley was the most considerable. Rising in the great cirque that stands at the head of Lake Seal, and fed by ice flows from the higher ridges behind, some of which excavated the tarns, it conformed to the curve of the valley where now Lake Seal lies, and flowing round the eastern foot of Mt. Bridges until it emerged into the Broad River Valley, where it was joined by a second ice river flowing straight down the valley from the snow-field on the ridge between Mt. Monash and Mt. Mawson. Together, these glaciers passed on for a short distance, till they were met by a smaller flow descending from Lake Newdegate, and the ridges beyond, and joining the main flow at the site where we now see Lake Webster. The jumbled nature of the morainal deposits in this area probably reflects the confusion which this junction of three great glaciers caused in their component ice flows.

On the east of Lake Webster there are ridges running parallel with the sides of the valley, which may be medial moraines formed on the larger glacier from the laterals of the tributaries. But the traces are too confused to allow certainty on this subject, and signs of the erosive effect of the volumes of water that escaped from the glacier and flowed over this newly-formed bed of till can be seen everywhere.

The great gorge running west from Lake Webster, half a mile into the hills, shows most typically the sculpturing work of the glacier. It is decidedly U-shaped, with sides rising 1,000 feet nearly sheer, and it finally ends in a perfect cirque over which the outlet from some of the tarns and Lake Newdegate falls in cascades hundreds of feet in height.

Passing from Lake Webster to Lake Seal, you rise 200 feet in under half a mile. The surface of this rise consists entirely of glacial till, which runs out in a ridge or series of ridges already mentioned lying between Lake Webster and Lake Seal. This rise is probably a great moraine blocking the Lake Seal Valley completely, making the floor of Lake Seal on approximately the same level as Lake Webster. This could only be verified by soundings, and if it is not the case, Lake Seal could only be a wonderful example of hanging and overdeepened valley, but this latter view is unlikely.

Following up the outlet of Lake Seal, just after leaving the shore of Lake Webster, you cross a large transverse ridge of morainal material, through which the stream from Lake Seal has cut, and behind which run tributary streams. Past several more ridges the ground rises abruptly to the shore of Lake Seal. This slope consists of glacial till containing boulders of all sizes, set in red or brown earth and gravel, the typical decomposition product of diabase. Huge boulders rest on the surface of this lying tilted at the angle of the slope, evidently toppled off the edge of the glacier, melting just above, at the present shore of the lake. The outlet of Lake Seal falls over this moraine in a series of pretty cascades, and has cut a small valley in the glacial till, but nowhere in its course can solid rock be seen. The glacier was not confined to the gully of this outlet, but spread at least 400 yards wide right across the valley of the lake, and thus swung round into the Broad River Valley.

Lake Webster, National Park, Tasmania.

Lake Seal lies in a long, deep valley, decidedly U-shaped, which is blocked by the moraine at the eastern end of the lake. The top of this stands 200 feet above Lake Webster, but has been much worn down near its junction with the solid rock of Mt. Bridges. Farther east it is at least another hundred feet higher. This as it stands represents the largest specimen of a moraine in the Park. The moraine bounds the eastern edge of the lake, and curves round the southern shore, abutting on to a ridge running down past Platypus Tarn from a shoulder of Mt. Mawson. The shore of the lake on this moraine is bordered by a beach of water-worn cobbles, testifying to the force of the waves churned up by the winter hurricanes.

On the Broad River, opposite the end of this lake, can be seen half a mile of diabase outcrops rising 100 feet abruptly from the river, but on the Lake Seal side these rocks are covered with glacial till of the moraine just discussed, and are invisible. It was here that the glacier turned north. The depth of ice must have been tremendous, perhaps 1,000 feet. One of the most useful pieces of investigation in the Park would be to ascertain the height on each side of Mt. Bridges to which the glacier extended, and to ascertain the depth of Lake Seal by a series of soundings.

The line of glacial till extends over the whole slope from the Broad River to Lake Seal, reaching its highest point some six hundred yards south-east of the lake, whence it drops sharply to the southward into the gully of an unnamed tributary of the Broad.

A spur bounds Lake Seal on the southern side, gradually rising until it becomes part of the configuration of Mt. Mawson. This doubtless has a core of solid diabase, although it is deeply overlaid with glacial till. Along this ridge south of the lake, and parallel to the shore, run lines and ridges of this morainal material, perhaps representing lines of lateral moraines, but more probably ridges caused by lateral pressure of the ice. Some of the hollows between them contain ponds. Some of these hollows may have been formed by the imprisoning of large masses of ice in the moraine, the melting of which has caused the surface of the ground to sink. Among these ridges lie whole lines of huge boulders, many exceeding 20 feet in every measurement, and often piled on top of each other. Nowhere in the Park are there finer examples of erratics. In one place the author saw two stones measuring 6 feet by 2 feet sticking on their ends out of the ground at different angles, and balanced across them lay a flat boulder, with a diameter of about 6 feet and a thickness of 1 foot. These deposits descend to the shore of Lake Seal, 200 feet below, and it is impossible to tell the depth of the deposit on this side, but on the edge of the Broad River Valley they soon disappear. They extend westward beyond Platypus Tarn, which lies in a hollow in this till.

From the centre of this ridge the morainal deposits curve round the top of the steep gully immediately to the south, and run past Eagle Tarn to the eastern shore of Lake Dobson. They appear to keep the same level at which we saw them on the ridge, not stretching far down the gully, and they do not extend far up the slopes of Mt. Mawson.

At the western end of Lake Seal there can be seen a most perfect specimen of the glacial phenomenon known as a cirque. The glacier has eaten the foot of the hill away until the lake now ends in a wall 1,000 feet high, consisting of a series of rugged cliffs. The glacier has cut farther in to the north-west corner, and here formed a smaller cirque within the greater feature, making, indeed, a nail-shaped valley, a common feature in glaciated country.

The ice fed by the snow on the ridge above the tarns flowed in a sheet down the slope until it hit the ridge on which the tarns are now to be seen, which appears to run right round the eastern face of Mt. Mawson, a common feature on diabase mountains. Here its pace was checked, but it pushed on, until divided by the shoulder of Mt. Bridges, one half dropped over into the Lake Seal cirque, and the other into the cirque at the head of the valley leading to Lake Webster.

Where it hit the ledge of rock in its descent it ground great basins out of the solid rock, and it polished and rounded the outer portion of the ledge. In these rock basins water has accumulated which we now know as the six tarns, and between them and the edge of the two cirques —only a matter of fifty yards in the case of Robert Tarn— the diabase has been rounded and smoothed into waves of *roches moutonnees*, very distinct towards the southern end of the line of tarns. Many huge erratics stand on these and lie scattered over the country side, and towards Lake Newdegate there are considerable deposits of morainal material.

The size of these cirques has probably been increased by later action of frost, but undoubtedly the ice is responsible for the outline of this rugged stretch of country. Lateral expansion of the Lake Seal glacier, and the upward movement of its load as it swung round Mt. Bridges, also had something to do with the forming of its wonderful valley.

(c) The Head of the Broad River Valley.

Returning to the third branch of the main glacier, the one flowing straight down the trough of the Broad River. To the east of Lake Webster the river now flows on the east of the lines of ridges of glacial till already described, and for which the Lake Seal glacier was probably responsible. Shortly after passing the level of the end of Lake Webster, the glacial deposits in the actual valley of the Broad disappear, and within the general U-shaped valley the river runs for over half a mile down a typical water-worn gully over a series of pretty cascades. On both sides of this gully native diabase outcrops, and no signs of glaciation exist in the bed of the creek or further east, although a mile to the west, and 400 feet up the side of Mt. Mawson, we see the ridge of glacial till already mentioned, and glacial deposits abound above this gully as below. Evidently here, with a more abrupt slope in the floor of the glacial valley, the river has had more cutting power, and has cut a small valley of its own out of the floor of the larger valley, a floor probably largely composed of loose materials, and cut by the considerable flow of water escaping from the melting glacier, thus giving us an example of a valley within a valley. It does not appear reasonable to suppose that the glacier never pushed down over this section of the valley, and that the glacier lower down came entirely from the Lake Seal Valley, but rather that all traces just here have been removed by subsequent water action.

Once this short stretch is passed, the Broad River Valley assumes again an appearance somewhat similar to that below Lake Webster. But here the bottom of the valley is not so flat nor so wide as in the lower reaches, and is clearly the work of a smaller ice-river. The whole floor is covered with till consisting of earth, a quantity of clay, and a high proportion of boulders, especially towards the sides. These erratics increase in size and frequency until the Broad bends west to its source in Lake Dobson.

Just beyond this bend is a large bed of ice-borne erratics lying so thickly as to resemble a "ploughed field" of a mountain top rather than the bottom of a wide valley. The head of the glacier rested on the ridge connecting Mt. Monash to Mt. Mawson, where it has developed a broad but shallow and "young" cirque. This valley head is shaped somewhat like a nail head, too.

Lake Dobson lies in the western side of the head of the Broad River Valley. It is a shallow sheet, lying behind a slight moraine, which its outlet has cut through in a deep channel. To the east of the lake rises a high ridge completely covered by, if not entirely composed of, glacial till, which circles west past Eagle Tarn, and then east, joining the ridge south of Lake Seal, already described. The lateral creases are continued across this ridge, especially in the vicinity of Eagle Tarn, the outlet of which, cutting through several ridges, drains through a pretty gully to Lake Dobson. This whole ridge, with that nearer Lake Seal, appears to be a great pressure ridge formed in the V between the Broad River Valley glacier and the Lake Seal Valley glacier, and was doubtless largely formed by lateral pressure from both great flows.

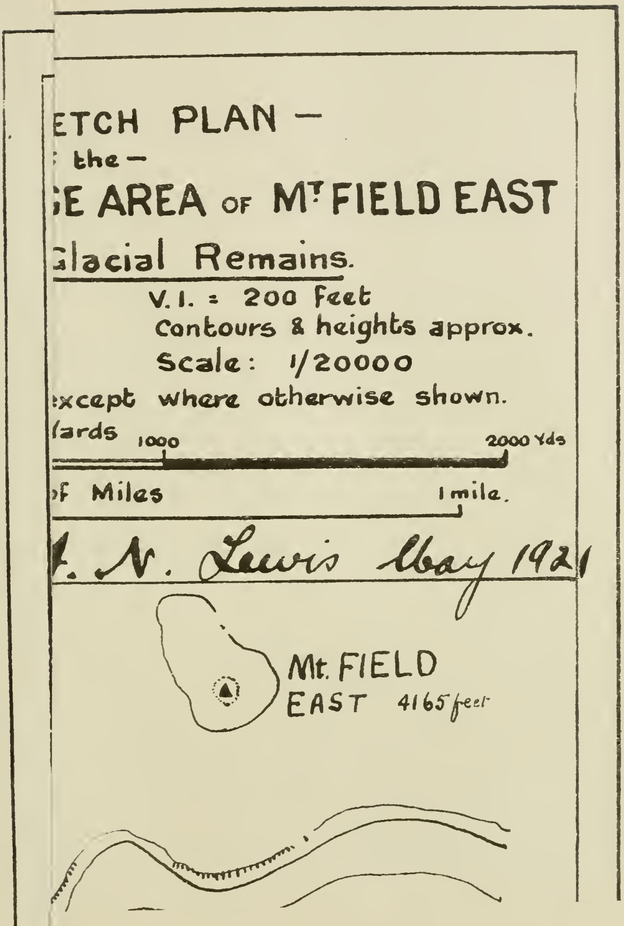
The moraine that dams up Lake Dobson, and the deposits that run from there a few hundred yards into the Broad River Valley, appear to be the work of the last phase of the glaciers, and to have been caused by a small flow from the slopes of Mt. Mawson.

This whole valley of the Broad River can be traversed in an easy day's walk from Lake Fenton, and it would be difficult to imagine a locality of equal size that can provide such a series of points of interest to a student of nature or of pleasure to the picnicker.

II. THE EASTERN GLACIAL GROUP.—(See Plates IX. and X.).

(a) The Lake Fenton Valley.

To-day the country east of the Broad River Valley is drier, and the climate milder than the country farther west, and we may presume that during the ice age this condition prevailed in proportion So we see few glaciers on the eastern slopes of the mountains. Also the snowfields had far less area on which to accumulate, and the absence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Glacial Remains.
V. I. = 200 Feet
Contours & heights approx.
Scale: 1/20000
except where otherwise shown.
Yards 1000 2000 Yds
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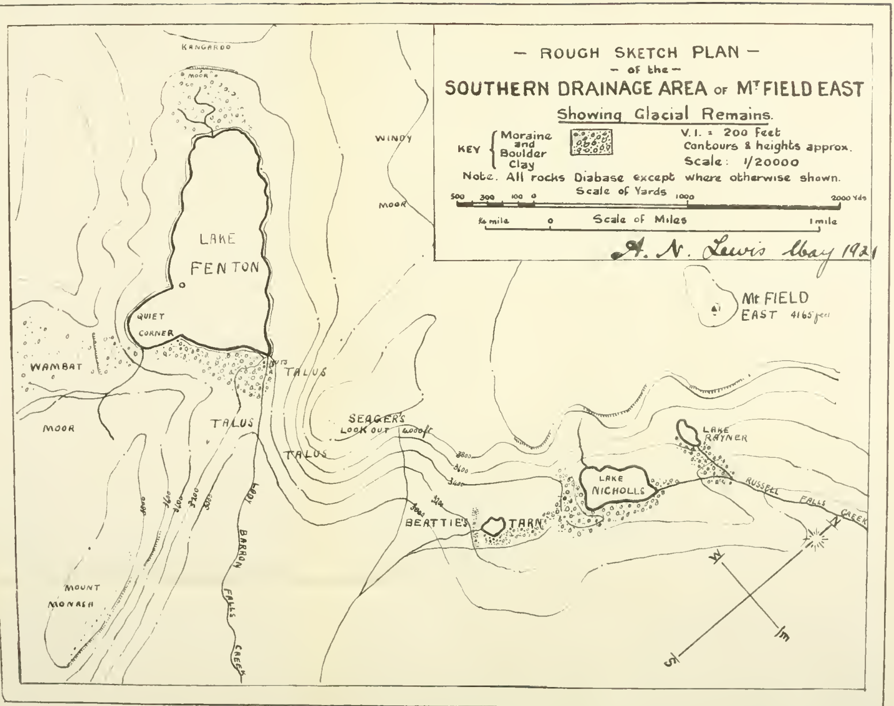
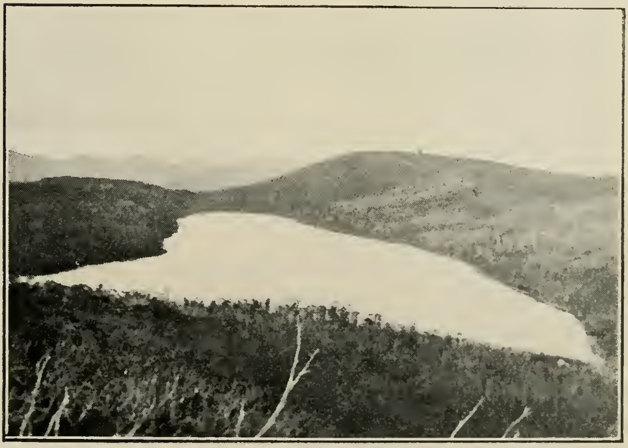
A. N. Lewis May 1921
Mt. FIELD
EAST 4165 feet



- ROUGH SKETCH PLAN -
- of the -
SOUTHERN DRAINAGE AREA OF MT FIELD EAST
Showing Glacial Remains.
KEY
Moraine and Boulder Clay
V.I. = 200 feet
Contours & heights approx.
Scale: 1/20000
Note. All rocks Diabase except where otherwise shown.
Scale of Yards
500 300 100 0 1000 2000 Yds
Scale of Miles
¼ mile 0 1 mile
A. N. Lewis May 1921
KANGAROO
MOOR
WINDY
MOOR
LAKE FENTON
QUIET CORNER
WAMBAT
MOOR
TALUS
TALUS
TALUS
SEAGER'S LOOK OUT
4000 ft
3800
3600
3400
3200
3000
MT FIELD EAST 4165 feet
LAKE RAYNER
LAKE NICHOLLS
BEATTIE'S TARN
RUSSELL FALLS CREEK
LADY BARRON FALLS CREEK
MOUNT MONASH
N
S
W

(Fig. 1). Lake Fenton (looking East).



(Fig. 2). Lake Fenton (looking N.W.),
National Park, Tasmania.

of long, gently sloping, valleys militated against extensive glaciation on the south and east of Mt. Field East. But in places short glaciers formed and pushed down to about the 3,000 feet level.

One of these glaciers flowed down the valley now filled by Lake Fenton. (See Plate X., Fig. 1.) This was a small flow, arising from the limited snowfield on Kangaroo Moor and the low hills immediately surrounding the lake, and flowing down an old valley, of which the Lady Barron Falls Creek Valley is now the lower portion. The snowfield was too limited to supply a long ice-flow, and the glacier was probably never more than a mile in length, and probably no wider than we now see Lake Fenton. The ice pushed about a quarter of a mile below the present shore of the lake. The bank over which the Lake Fenton pack-track rises just after the sixth mile peg represents the end of the moraine deposited by this glacier.

The valley of the Lady Barron Falls Creek is bounded by the precipitous sides of Seager's Look-Out to the east and Mt. Monash to the west, forming a very sharp V, the sides of which are strewn with a talus of enormous blocks of diabase torn from their seats largely by the action of frost, and tumbled down the slopes in a perfect wilderness of huge rocks. Over the top of this valley the glacier has deposited its moraine until now, looking from Kangaroo Moor through this gap, a distinct U-shaped valley is seen.

The ice appears to have retreated very slowly, but very regularly, covering the bottom of the valley with glacial till extending a quarter of a mile. The surface of this moraine is very level, a noticeable fact on the walk to Lake Fenton, and here and there boulders of all sizes protrude from the reddish soil and gravels. The moraine completely blocks the valley, and dams back Lake Fenton, stretching from a few yards across the overflow from the lake right along the southern shore of the lake, and a little distance on to a spur running down from Mt. Monash.

The outlet from the lake at one time flowed over the eastern end of the moraine, but in the course of time it has washed the earth and lighter materials away from the boulders, and now, except in flood time, runs out of sight below an accumulation of loose rocks of all sizes.

The eastern shore of Lake Fenton is strewn with a mass of huge boulders, which have the appearance of a talus. Perhaps they are the frost-disintegrated remains of a small cliff carved out by the glacier, but more probably are a continuation of the talus slopes on the side of Seager's Look-Out, to be seen below the lake, the bottom portion of which has been covered by glacial and lacustrine deposits, now forming the floor of Lake Fenton. On the western side of the lake there is a narrow shore, which shows slight traces of glaciation, before the ground rises sharply to the hill behind.

Kangaroo Moor, especially along the northern shore of the lake, shows traces of glacial till, and Wombat Moor is covered with erratics, many of tremendous size. Probably a feeder flowed from the snowfields north of Mt. Monash into the Lake Fenton glacier, and about 200 yards from Quiet Corner along the Lake Dobson track there is a ridge of boulders crossing the moor that seems to be a small moraine. Evidently just prior to the vanishing of the glaciers, a small ice flow found its way down from Mt. Monash, scattering debris over Wombat Moor, but melting before it reached Lake Fenton.

(b) The Lake Nicholls Area. (See Plates IX. and XI.).

The southern slope of Mt. Field East drops precipitously some 700 feet from the edge of the plateau. At an altitude of 3,200 feet lies a considerable ledge on the mountain side, on which lie Lake Nicholls and Beattie's Tarn. Circling round the south and south-west of Lake Nicholls, and separating that lake from Beattie's Tarn, is a very considerable ridge of morainal material. This rises sharply from the eastern end of Lake Nicholls to a height of 200 feet above the level of the lake, and forms a round hill between this lake and Beattie's Tarn, from which hill the ridge dips in a wide U northward until it rests on the diabase buttress of Mt. Field East. This U can be distinguished with equal clearness from either Beattie's Tarn or Lake Nicholls. It is extremely steep on both sides, and has the appearance of a pressure ridge, consisting of boulder clay, containing some huge rocks, and probably largely caused by the glacier passing materials up from below and piling them over this bank.

There were probably several small glaciers flowing down the several creases in the otherwise abrupt escarpment of Mt. Field East, the largest of which, flowing down the gully at the head of Lake Nicholls, on reaching the

Lakes Rayner and Nicholls, National Park, Tasmania.

stretch of more level ground, gouged out a considerable portion of the bed of Lake Nicholls, which is of great depth, and shows us a good example of an over-deepened valley. This glacier flowed south-east for a few hundred yards down the branch of the Russell Falls Creek, and deposited a considerable quantity of boulder clay below the outlet from the lake. It is impossible to estimate the depth of this moraine, and difficult to determine how far the glacier descended the valley, but probably it did not flow many hundred yards beyond where we now see the shore of Lake Nicholls.

Another glacier flowing down a gully a little farther to the east was instrumental in forming Lake Rayner. This may have joined the larger Lake Nicholls glacier at a point below both lakes, but this is not certain. It had a smaller snowfield than the other, and probably melted somewhere below the present site of Lake Rayner. The hill below this lake is strewn with glacial debris. During one of its halts during the period of final retreat, it deposited the moraine that now encircles the lower side of Lake Rayner.

(c) Beattie's Tarn Area.

The remaining glacier of this group had its origin immediately west of that of the Lake Nicholls glacier, but flowed west of the intervening ridge down towards the Lady Barron Falls Creek, instead of the Russell Falls Creek. This glacier has left several very prominent, if small, moraines, one of which banks back Beattie's Tarn. On the track to this lakelet one of these moraines is crossed. It stands out ten feet above the surrounding country fifty yards from the shore of the tarn, and consists of small boulders almost free from earth. To the left of the track, as you approach the tarn, another very distinct moraine, similarly constructed, stands out unmistakably. This marks the limit of this glacier, which melted at about the same altitude as the Lake Fenton glacier, a mile farther west.

These traces of past ice action are clearly discernible to even an untrained observer. They lie not six miles from the railway station, on an excellent track, and can be reached on horseback. An energetic person can here study the work of a glacier in the course of a day's trip from Hobart.

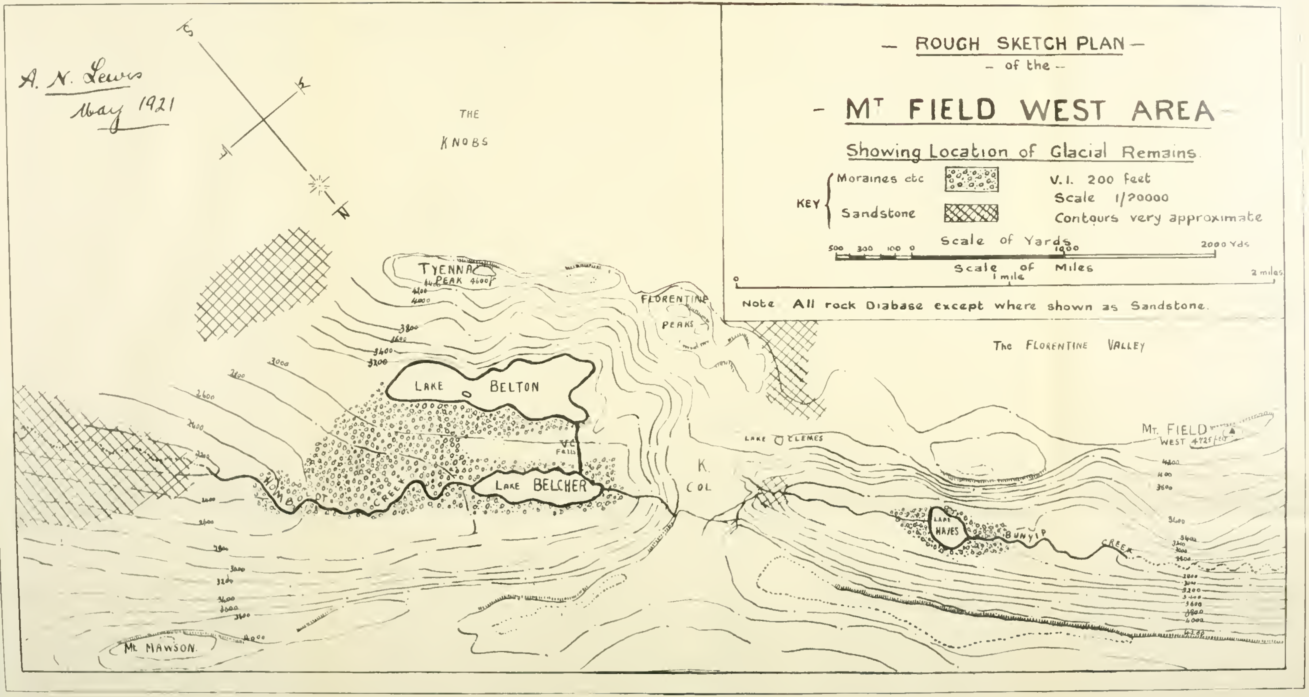
III. THE WESTERN GLACIAL GROUP. (See Plate XII.).

The remaining area of glaciation lies west of the mountain mass running like a wall north from Mt. Mawson to the Derwent, and between that range and the Tyenna Peak-Mt. Field West system. It includes the Belcher-Belton Valley to the south, and the Hayes Valley farther north. Geographically, these lie end to end, separated only by the narrow ridge of K. Col. Before the glacial epoch these two valleys were probably in existence, but sloped in a broad, shallow hollow from K. Col, and the surrounding mountain peaks. Snowfields accumulated around K. Col, and probably precipitation in this part was heavier than farther east. Huge glaciers flowed north and south from K. Col, and their bases cut deep into the foot of that saddle, excavating the pair of enormous cirques we now see, and making K. Col a wonderful example of a Razor-back ridge, with sides that stand a thousand feet perpendicularly from the lakes below. Both sides of the ridge are very much alike, and present an excellent example of glacial symmetry, a very uncommon feature.

(a) The Belcher-Belton Valley. (See Plates XIII. and XIV.).

The glacier that filled this valley grew from the enormous snow-covered areas from Mt. Mawson past K. Col, and the Florentine Peaks to Tyenna Peak. It has cut into the mountain, forming an enormous cirque, over two miles long and a mile across, and 1,100 feet deep at the lowest point. It is really a composite cirque, consisting of at least three smaller curves. Down each of these flowed a tributary glacier, one from K. Col (see Plate XIV., Fig 4), a second from the saddle north of the rugged Florentine Peaks, and the third from the plateau between those crags and Tyenna Peak.

This glacier must have pushed over two miles down the valley to an altitude of about 2,700 feet, stopping near the spot where now the button-grass ceases. The floor of the valley is remarkably U-shaped, with a pair of ledges half-way up the sides, on the western of which reposes Lake Belton. The floor of this U is strewn for the whole two miles with a deposit of boulder clay, in which lies Lake Belcher. It is impossible to guess the depth of these deposits, which are remarkably evenly distributed, although piled here and there into the small ridges running at all angles typical of terminal moraine country. In one place, Florentine Peak (also Lakes Belton and Belcher), National Park, Tasmania.


A. N. Lewis
May 1921
— ROUGH SKETCH PLAN —
— of the —
— MT FIELD WEST AREA —
Showing Location of Glacial Remains.
KEY
Moraines etc
Sandstone
V.I. 200 feet
Scale 1/20000
Contours very approximate
Scale of Yards
500 300 100 0
1000
2000 Yds
Scale of Miles
0
1 mile
2 miles
Note. All rock Diabase except where shown as Sandstone.
THE KNOBS
TYENNA PEAK 4600 ft
FLORENTINE PEAKS
The FLORENTINE VALLEY
LAKE BELTON
LAKE BELCHER
VC Falls
HUMBOLDT CREEK
K. COL
LAKE CLEMES
MT. FIELD WEST 4725 feet
LAKE HAYES
BUNYIP CREEK
MT. MAWSON.

Florentine Peak (also Lakes Belton and Belcher), National Park, Tasmania.

(Fig. 3). Erratics in the Broad River Valley.

(Fig. 4). Lake Belcher and K. Col.

(Fig. 5). Lake Belton and Florentine Peak, National Park, Tasmania.

near the spot where the old Dobson-Belcher track crossed the Humboldt Creek, the water has cut about six feet into the glacial till, and falls in a cascade a few feet high over a layer of this boulder clay that has solidified sufficiently to cause the waterfall, and is almost conglomerate. The matrix is of sand, requiring a hammer to break it, and lying embedded in it are pebbles and cobbles of all sizes. They are absolutely unsorted, and have been worn by the glacier. One was found in the shape of a pyramid, but striæ, if they were ever developed on the diabase, have since rusted away. Perhaps this spot would be a likely place to search for ice-marked pebbles.

Lake Belton presents rather a problem. It appears to have been the work of two glaciers. The inner, or north-west, end is certainly a rock basin, scooped out by the glacier descending the gully that stands at its head, while the lower end is certainly impounded by a moraine that looks to be the work of the southern glacier. This moraine also extends the whole length of the eastern shore, and appears to have been formed either from a line of small glaciers or on the end of an extremely wide ice flow dropping down from Tyenna Peak and the Florentine Peaks. Perhaps this represents the melting point of several glaciers during their later stage, while a main glacier passed down the bottom of the valley, deepening that, and leaving Lake Belton as a hanging valley 300 feet above.

The moraine on the eastern shore of Lake Belton stands 20 or 30 feet above the slope of the hill, and is 100 yards in width, containing many charming pools and tarns. Below Lake Belton the slope of the hill is strewn with morainal material, as if the melting glacier tipped its load down the hillside. The configuration suggests that at a period of maximum glaciation a large glacier filled the valley to a point level with Lake Belton and its corresponding ridge on the eastern slope, scooping out a U-shaped floor in this large valley. Then, as the ice flows shrank, a small glacier cut out a second U within the larger one, at the bottom of the valley, while tributaries melting on the side of the hill were responsible for Lake Belton, making this latter lake an example, if a poor one, of a hanging valley.

(b) The Lake Hayes Valley.

North of K. Col, a shorter glacier, growing from more limited snowfields, was responsible for the tremendous gulch east of Mt. Field West. It stretched down the valley about a mile to a point just beyond Lake Hayes. It deposited a considerable pile of morainal material that now stretches in a bank a quarter of a mile north of Lake Hayes, and through which the Bunyip Creek has cut to a depth of 50 feet. The glacier must have been melting in this vicinity throughout its existence, withdrawing very slowly and evenly. It deposited this considerable bed of glacial till behind which Lake Hayes now lies, and, gradually shrinking, covered the floor of the valley above the lake with debris.

The moraine is of interest from one point. Unfortunately, throughout the National Park the uniform diabase gives little variety in the textures of these moraines, but here, right in the centre of the cirque at the head of Lake Hayes Valley, is still to be found a tiny pocket of sandstone. This is only about 200 feet in depth, and below it, as above and all round the rock, is diabase. But there are several large blocks of this sandstone visible in the moraine beyond Lake Hayes, over a mile from where its parent bed is now to be seen. Some of these can be seen behind a large clump of King William Pines on the north-west side of the lake. This valley is not as extensive as most of the other areas, but shows the wonderful sculpturing action of an ice-river.

In conclusion, our National Park can afford a student of nature a comprehensive series of examples of the eroding and constructing work of glaciers, enabling him to study at his own back-door these mighty forces, and provides an insight into the geological history of our island, all obtainable with the expenditure of an insignificant expenditure of energy and time. It is doubtful if any other 40,000 acres of the surface of the globe can supply the variety of interests that the public of Tasmania is striving to save from destruction in its National Park.

LIST OF WORKS REFERRED TO IN TEXT.

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