NOTES ON A GEOLOGICAL RECONNAISSANCE OF MT. ANNE AND THE WELD RIVER VALLEY, SOUTH-WESTERN TASMANIA.

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

SYNOPSIS.

1. INTRODUCTORY.

(a) General.

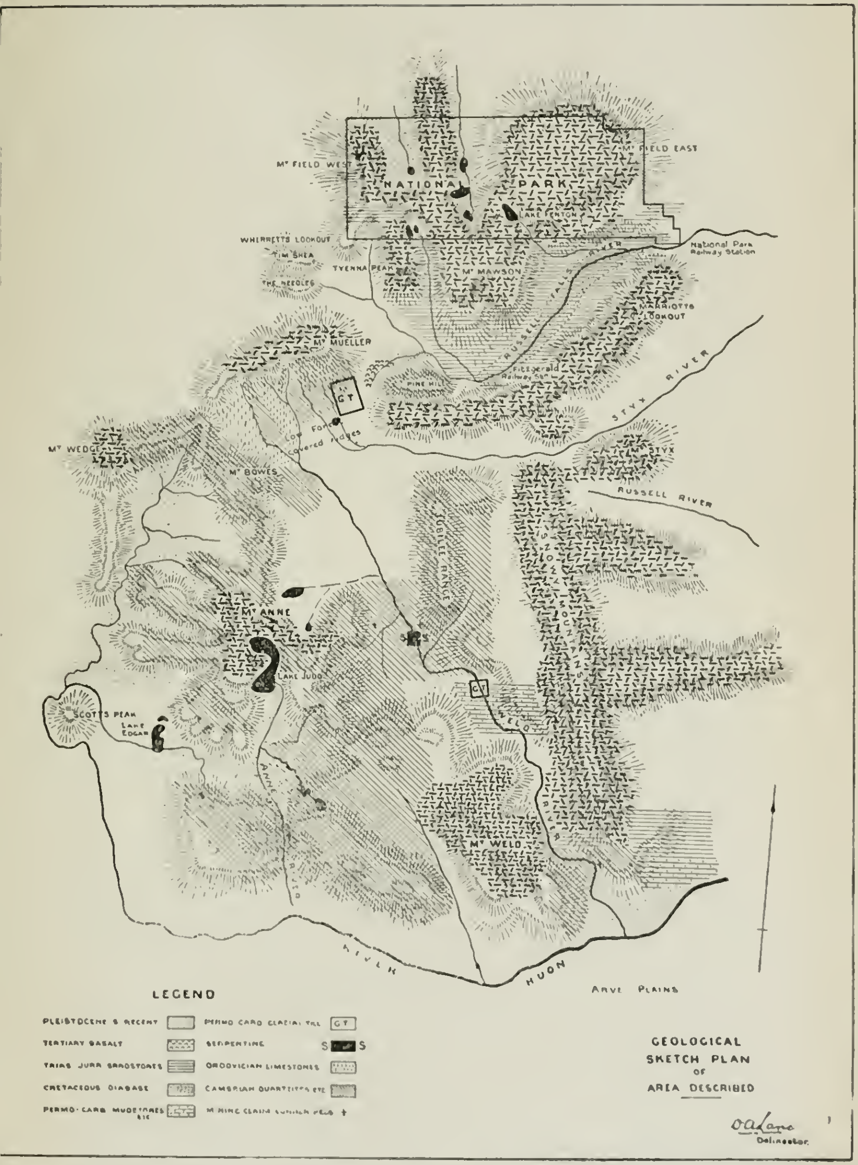
Major L. F. Giblin, D.S.O., and Mr. A. V. Giblin during the Christmas holidays of 1920, 1921, and 1922, organised and led three successive trips into the little-known country that surrounds Mt. Anne. The parties met with considerable difficulties, and most of the available time was used up in the endeavour to reach Mt. Anne, so the opportunities for an investigation of geology were few, but these fragmentary notes may be of assistance to future investigators.

(b) Geological Position and Access.

Mt. Anne lies about 45 miles due west from Hobart, near the head of the Huon River. From the top of the Tyenna Valley a line of rough hills runs westward from Mr. Mueller through Mt. Wedge to the Valley of the Serpentine. Farther west the rugged and almost unexplored Frankland and Arthur ranges bar the way to the West Coast and Port Davey. South of Tyenna, running towards the Huon Valley, is a confused mass of hills of varying height which to the east join up with Mt. Wellington. Between these two ranges is a large basin, twenty miles across in every direction, in the centre of which rises Mt. Anne, the most outstanding peak in South-West Tasmania. It is the highest point of a short ridge which extends on every side in a number of spurs. To the west is the broad, flat, swampy valley of the Huon, which passes without a perceptible divide across to the Serpentine, flowing from Lake Pedder to the Gordon. To the east runs the River Weld in a series of gorges and steep-sided valleys all filled with almost impenetrable jungle.

The area reviewed in this paper extends from the vicinity of Fitzgerald on the Russell Falls River, on the north, to the junction of the Huon and Weld rivers, on the south. These points are approximately the end of cultivation in this part of Tasmania. The area is bounded on the west by the Huon River.

Mt. Anne lies over thirty miles beyond the point to which roads have yet been pushed, and there is no natural feature giving ready access. The easiest route to the mountain is along the Tyenna-Port Davey track, which, starting where the southern road from Fitzgerald ends at Mayne's selection, winds round Mt. Mueller and Mt. Bowes to the Huon Plains, and eventually crosses the Huon River 25 miles from the end of the road. The track is a good one till it crosses Mt. Bowes and is at present passable for pack horses. On the Huon Plains, however, it is in a general state of disrepair, with bridges down and overgrown with bauera scrub and other obstacles. From the point at which the track crosses the Huon, Mt. Anne can be reached across open buttongrass plains. The second of the two western spurs presents a possible route to the summit of the Mt. Anne plateau.



ERRATA:—In Legend, for Ordovician Limestones read Silurian Limestones, and for Cambrian read Cambro-Ordovician.

SKETCH MAP OF MT. ANNE AREA.

Approximate Scale—Eight miles to the inch. Details approximate.

In the south of the area a passable road extends up the north bank of the Huon as far as the divide between the Denison and the Weld Rivers, from which point it is continued by a pack track to the Weld River at a point about three miles above the junction of the latter with the Huon, where a prospector named Fletcher has a lease and a hut. About 30 years ago a track was cut up the Weld Valley for about 10 miles, but this is now obliterated by horizontal scrub, and, although originally a well-made track, is useless in its present state. On the Tyenna-Port Davey track just east of the 14-mile hut is a notice "To Huonville 54M." This is a dangerous signboard, as there is no vestige of a track for the first ten miles, and the country is under heavy timber and dense scrub.

The old Craycroft track, a possible means of access to the Huon Plains, is reported to be quite obscured. The Valley of the Huon to the vicinity of its junction with the Anne River, and thence across the open plateau lying to the south of Mt. Anne, is a possible line of approach, but in the absence of any other cut tracks the route from Tyenna along the Port Davey track at present presents the fewest difficulties.

(c) Routes followed when the Investigations here recorded were made.

In December, 1920, Major L. F. Giblin and Mr. A. V. Giblin, with Messrs. V. C. Smith, J. Walch, and F. Steele, proceeded along the Tyenna-Port Davey track. Pack horses were got up to where the track debouches on the Huon Plains. The party made their main camp at the Huon crossing, but were here hampered by wet and misty weather. However, they accomplished the ascent of the Mt. Anne plateau, going by the southern of the two western spurs.

In December, 1921, the Messrs. Giblin, with a party consisting of Messrs. H. Hutchison, W. F. D. Butler, V. C. Smith, J. Walch, H. Kelly, H. Cooper, A. Hackett, V. E. Chambers, and the writer, endeavoured to reach Mt. Anne via the Weld Valley from the Huon. The party forced its way up the Weld Valley through horizontal scrub for three and a half days, reaching a point about 18 miles from its junction with the Huon, and then for another day up a large tributary flowing from the west, until a bare hill was reached. It was then seen that it would still take some days to reach the mountain, and the party was compelled to turn back. Great difficulty was experienced throughout the trip in cutting through the heavy scrub, carrying heavy loads. This route would be quite impossible in a wet season.

In December, 1922, the same party, with the exception of Messrs. Butler, Cooper, and Hackett, and with the addition of Dr. L. McAulay, made a further attempt, this time by the Tyenna-Port Davey track. The weather was almost continuously bad, and only one fine day was experienced. The pack horses could not be taken more than a mile beyond Mt. Bowes, and the party had the greatest difficulty in crossing the many flooded feeders of the Huon. The main camp was made under the second westerly spur of Mt. Anne. Several attempts were made to get round or across the third (south-westerly) spur in order to reach Lake Judd, but heavy scrub intervened, and it appears that the easiest access to the lake would be by a long circuit by Lake Edgar and the northern end of the River Anne gorge. On the one fine day Mt. Anne was ascended by the second westerly spur and the plateau examined. Messrs. Hutchison and Chambers attempted to ascend the pinnacle, but were stopped by a virtual face about 30 feet below the summit, which had blocked an attempt by the 1920 party.

(d) Previous Literature and Acknowledgments.

No detailed account of the district can be found. In 1874 the late Mr. R. M. Johnston, when exploring the Arthur ranges, does not appear to have crossed to the east of the Huon. In 1880 Mr. Henry Judd, of the Huon, after several attempts in earlier years, succeeded in penetrating the scrubs of the Weld Valley and reaching the plateau of Mt. Anne. He discovered and named Lake Judd, and has left a brief but vivid account of the remarkable features of the lake and the great north-eastern gorge in a little-known pamphlet dealing for the most part with quite other matters (Judd, 1898). In 1908 the late Mr. W. H. Twelvetrees and the late Mr. A. S. Atkins were engaged in a geological exploration of the country between Tyenna and the Gordon, but their investigation only extended to the north of the area described in these notes. Mr. Atkins ascended Mt. Anne, and there is a brief reference to it in Mr. Twelvetrees' report (Twelvetrees, 1908). In 1920 Mr. A. McIntosh Reid covered the area described by Mr. Twelvetrees, during the investigations for his Bulletin "Osmiridium in Tasmania," and added more information, with a very complete geological map (Reid, 1920). Mr. Renison Bell and other prospectors visited the district during the 90's, but no written reports can be found.

The present writer had the plans of Mr. Twelvetrees and Mr. Reid with him on the 1922 trip, and made full use of them as far as they extended.

The writer also wishes to acknowledge his indebtedness to all the members of the parties for the assistance rendered throughout the trips, to Sir T. W. Edgeworth David for his kind encouragement and suggestions, and to Colonel D. A. Lane for assistance rendered in drafting the plans accompanying this paper.

2. PHYSIOGRAPHICAL GEOLOGY.

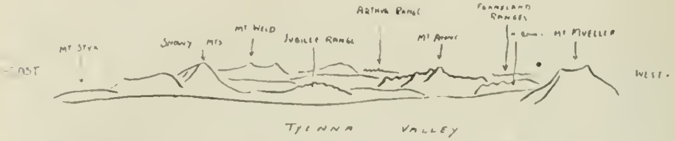
(a) Present Topography of Area.

The north of the district in question is marked by the line of elevated country extending from Mt. Mueller (about 4,000 feet) on the east about ten miles westward to Mt. Wedge (about 3,500 feet) and produced for three miles southward by the bold outlier, Mt. Bowes (2,500 feet). These hills form the watershed between tributaries of the Gordon. Derwent, and Huon Rivers. The valley of the Weld, which runs through the centre of our area, the divide between the Weld and the Huon, and the north-eastern portion of the valley of the Huon make up the area here described.

The Weld rises in many small streams in the centre of the range above mentioned between Mt. Bowes and Mt. Mueller. It is separated from the Styx for the first few miles of their courses by a watershed consisting of a confused series of small ridges densely covered with forest, among which it is difficult to tell which river many of the streams ultimately reach. The Styx, after flowing a few miles in a south-easterly direction, bends to the east, and passes out of the area with Marriott's Look-Out and the hills south of Tyenna on its north bank, and the Jubilee Range, Snowy Mountains, and Mt. Styx in succession on its south side. To the west the watershed of the Weld is separated from that of the Huon first by Mt. Bowes and then by a scarcely perceptible ridge joining that mountain to Mt. Anne, and farther south by the Mt. Anne range.

The Weld flows in a south-easterly direction for about twenty-five miles, the first five of which are through a broad valley with numerous insignificant ridges. Opposite Mt. Anne its course becomes a tremendous gorge with precipitous, scrub-covered sides rising to the eastern spurs of Mt. Anne on the west, and to the Jubilee Range on the east.

The valley opens out a little between Mt. Anne and Mt. Weld, and then narrows as the river runs between Mt. Weld and the Snowy Mountains in a steep-sided valley over 3,000 feet deep. For the three miles before its junction with the Huon it runs through a broad alluvial plain. The river consists of long deep pools separated by series of rapids. The river is difficult to cross throughout the lower half of its course, and appears liable to floods. It is one of the finest rivers in Tasmania, with a very considerable flow of water, and the scenery along the quiet reaches rivals that on the Gordon. A fine view of the valley of the Weld, which compares favourably with the gorges of the Forth and Mersey in the North, may be obtained from the slopes of Mt. Bowes.



The eastern side of the valley of the Weld is formed by the Jubilee Range and the Snowy Mountains, both running roughly north and south from the Styx Valley to the Huon, the Jubilee being about 10 miles long and lying west of the northern and less elevated extension of the Snowy Mountains. The Jubilee Range is a line of sharp, partly isolated, quartzite peaks, displaying the rugged outline and bare, precipitous flanks usual in these earlier Palæozoic ranges. It averages about 3,000 feet high, and when opened up will prove one of the most picturesque pieces of mountain scenery near Hobart. The Snowy Mountains are more elevated, but round in contour, as is the case with most of our diabase mountains. Their summit is roughly east of the summit of Mt. Weld, and their western slopes are broken by cliffs and huge talus slopes.

The Huon rises in the forest-covered southern slopes of Mt. Wedge and flows in a generally southerly direction to the south in a series of considerable bends and loops through a flat, swampy, buttongrass plain in places ten miles broad and clearly of glacial origin. The plain is continued to the north-west to Lake Pedder and the Serpentine Valley, and in places the flatness of the country makes it quite impossible to fix the location of the Huon-Gordon divide. The Huon, 20 miles south of Mt. Wedge, turns sharply to the east and ultimately joins the Weld, which thus becomes one —and probably the most considerable—of its tributaries.

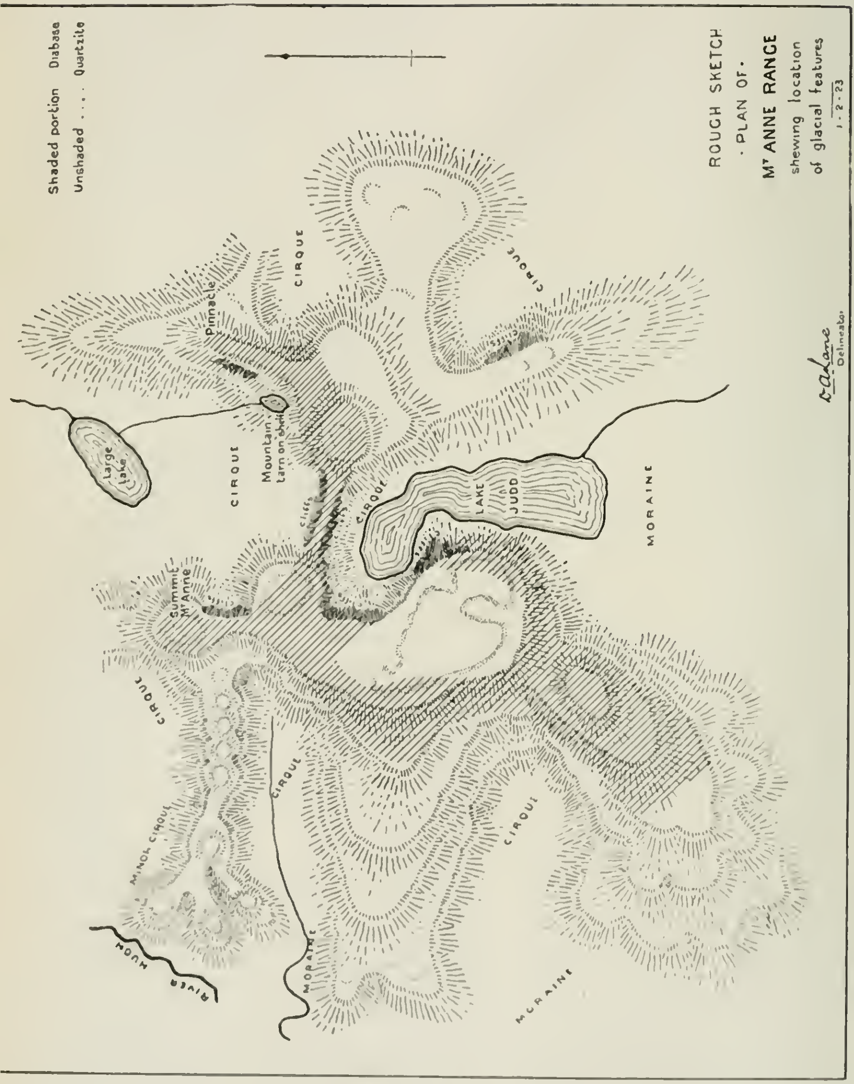
Fig. 1.

MT. ANNE RANGE FROM THE WEST.

Fig. 2.

THE MT. ANNE RANGE FROM MT. WELD.

(A. N. Lewis, photo.)



SKETCH PLAN OF MT. ANNE.

The country between the Huon and the Weld is rugged in the extreme. To the north is Mt. Anne, a narrow ridge running roughly north and south, perhaps four miles long, with the summit at the extreme northern end standing several hundred feet above the ridge of the mountain and over 4,500 feet above sea level. From the summit the mountain drops steeply to the north, north-west, and north-east, so that viewed from Mt. Field or any mountains to the north it appears as a fine pointed cone rising straight from the plains and far higher than any other of the mountains of the south-west.

Lower spurs radiate on every side. To the north, the least significant connects the mountain with Mt. Bowes. On the west two ridges run out to the Huon. The more northerly is a rugged chain of peaks, about 3,000 feet high, steep on all sides and precipitous on the north-west. The sky-line of this ridge is very picturesque. The second ridge runs parallel to it about a mile and a half farther south. The contour of this ridge is smooth and rounded, but the sides are nevertheless steep. A couple of miles farther south and running south-west from the corner of Mt. Anne is a third spur, shorter than the other two, but broken into a number of ridges covered with undergrowth, which extend in a series of low, broken, but steep hills for some miles towards Lake Edgar.

Behind this ridge lies Lake Judd, perhaps two miles in length and half a mile wide, resting in a kidney-shaped cirque which has been carved out of the very heart of the mountain. East of the head of Lake Judd stands another peak only a few hundred feet lower than the Mt. Anne plateau, to which it is connected by a jagged comb ridge circling round the north end of Lake Judd. From this peak several spurs radiate. A short one to the south-east forms the other side of the Lake Judd cirque, and is again cut into on the south-east by another cirque. A second spur appears to connect this peak with a flat-topped and isolated plateau which forms the south-eastern buttress of the Mt. Anne range, and is bounded on the south by the last mentioned cirque and on the north-east by another cirque. Farther north a third spur radiates to the east, stretching out several miles to the Weld Valley. On the end of the higher portion of this is a peculiar pillar of rock, standing several hundred feet above the level of the top of the main ridge in a tower only a few dozen feet in diameter, and forming the most conspicuous landmark of the range. It is one of the most remarkable mountain features in Tasmania, and the Messrs. Giblin appropriately named it "Lot's Wife." To the north of this spur is a very considerable precipitous walled cirque, in which lies a large bush encircled lake, not far from the Weld River.

South of Mt. Anne runs a long, rugged, but comparatively low quartzite plateau deeply dissected by gorges and occupying most of the country between Mt. Anne, Mt. Weld, and the Huon. It is separated from Mt. Anne by a deep, narrow, but flat-bottomed valley drained on the west by a stream flowing into Lake Edgar in the Huon Plains, in the centre by the Anne River, into which Lake Judd drains, and on the east by a considerable tributary of the Weld which has been named "Judd's Reward Claim Creek" from an old claim situated on its bank.

On the wall-like face of this plateau opposite Mt. Anne can be seen one large and three smaller mountain tarns, for the largest of which the name Smith's Tarn has been suggested, after Mr. V. C. Smith, who, of our parties, first saw it. The Anne River cuts through the plateau in a deep gorge. The plateau extends eastward to Mt. Weld, which eminence rises a thousand feet or more above it and forms its eastern buttress on the edge of the Weld Valley. Mt. Weld is over 4,000 feet in height and stretches for about eight miles, a narrow flat-topped ridge, ending precipitously at its northern end, and appearing an isolated peak when viewed from the north. It descends on the east very steeply to the Weld and on the west also steeply for a thousand feet or so to the level of the quartzite plateau. On the south its ridges reach to the Huon Valley.

(b) Development of Present Topography.

The present cycle of erosion in Tasmania dates from the time of the diabase intrusions, and it is difficult on the evidence at present available to be certain of conditions during the earlier ages. There is undoubtedly evidence of an old peneplain, lying between the Weld and Huon Rivers, formed in the Cambro-Ordovician strata prior to the diabase intrusions, and probably during late Devonian or early Permo-Carboniferous times. This peneplain is now much dissected by fluviatile and glacial action, but looking south from Mt. Anne the remarkable flat top of the quartzite plateau between Mt. Anne and the Huon catches the eye at once. The fact that the top of this stands at the same general level as the top of the quartzite under Mt. Anne, under Mt. Weld, under

Mt. Wedge, on the sides of Mt. Mueller and the exposed summit of Mt. Bowes, indeed of all the rocks of this series in the locality, points to the conclusion that these must all have once formed the top of a plain. Farther south and west the peaks of the Arthur and Frankland Ranges consisting of the old Pre-Cambrian schists have a remarkable accordance in altitude, suggestive of an ancient peneplain, but whether of the same or an earlier cycle of erosion is a problem for the future. There is no evidence at present upon which to fix the date of the peneplanation of the Cambro-Ordovician rocks of the area, but it was certainly earlier than the Permo-Carboniferous glaciation.

The diabase intrusions raised the sediments that had been deposited from the western lands in the coastal seas of Jurassic times and earlier and instituted our present cycle of erosion, but the extent to which the land to the west was affected by these intrusions or earlier and later earth movements and whether the older rocks of the West Coast were ever covered by the Trias-Jura sediments is not yet known. The diabase, however, certainly did force its way through the older quartzites in places, as at Mt. Anne.

The direction of the present drainage was probably determined by the landscape immediately after the diabase intrusions, during the Upper (?) Cretaceous. The rivers are therefore here, as throughout Tasmania, subsequent streams. The fact that the diabase with incumbent sediments rose to a height of 4,000-6,000 feet above present sea level, while the top of the older rock to the west now does not exceed 3,000 feet, yet the rivers run from west to east cutting, from the comparatively low lands of the west, in huge, steep sided valleys and gorges through the mountain systems that now stand highest, indicates that in Cretaceous times the mountains to the west stood, or were covered with other rock, since removed, which stood, twice as high as they now are to be seen—e.g., the Huon could reach the sea from its point of origin by several channels that do not rise over 1,000 feet, but it appears to cut through a ridge between Mt. Weld and Mt. Picton, 3,000 feet higher. It thus provides a good example of a subsequent stream being kept in its course by its original channel, formed in very different strata (in this case probably Trias-Jura sandstones) from those lying below, which now stand out as mountains of circumerosion.

The Huon, Weld, and Serpentine Rivers are on the verge of maturity although their tributaries are, as usual in Tasmania, typical of juvenile drainage. The main streams have cut through the diabase sill and extended their valleys considerably in the softer rocks below. They have thus captured the drainage of very considerable areas of country, and in widening their valleys have isolated remnants of the old plateau which stand out as erosion residuals, Mt. Anne being one of the best examples of this type of mountain in Tasmania. [Sir Edgeworth David has asked whether the topography has been all caused by differential erosion and suggests faulting as responsible for the escarpments east of Mt. Anne. The writer had this possibility in view, but could find no evidence of large scale faulting, and respectfully submits that erosion is responsible for the present topography. But the possibility of a fault scarp running up the west side of the Weld, past Mt. Stephen (Tim Shea), west of the Vale of Rasselas, and even to the west of the Cradle Plateau, should be borne in mind in future investigations.] In eroding their valleys the rivers have removed later sediments from and exposed the early Palæozoic topography, which, as Mr. Ward has remarked, is now exerting an influence on present topography (Ward, 1909). An interesting example of this is to be seen at the mouth of the Weld, where several miles of Cambro-Ordovician quartzites with an already developed topography are being exposed from beneath the sandstones. The topography of the western portion of the area has been moulded by glaciers during the Pleistocene Ice Age, the work of which will be dealt with later. The rivers are at present engaged in removing the morainal dams of the lakes and other remains of the glaciers.

3. STRATIGRAPHICAL GEOLOGY.

(a) Pre-Cambrian.

The highly foliated quartz-mica schists, ordinarily referred to the Proterozoic [the Algonkian of Ward and Twelvetrees], with which the Arthur and Frankland Ranges are made up do not appear to cross to the east of the Huon unless Scott's Peak [which was not examined] consists of these rocks, but this is unlikely. Mr. R. M. Johnston in his Geology of Tasmania placed the rocks of the western ranges in this system, and Mr. Twelvetrees describes the junction with the quartzites visible north of Mt. Wedge (Twelvetrees, 1908), but in the area being described the junction appears to be obscured beneath the glacial deposits of the Huon Valley. The Geological Map of Tasmania issued by the

Geological Survey in 1914 shows the eastern boundary of the Pre-Cambrians here from 3 to 5 miles too far east.

(b) Early Palæozoic.

Rocks of this age predominate in the area. They consist of massive and extremely hard quartzites with occasional beds of slate and conglomerates. The age of these beds, which occur considerably in south-west Tasmania, is not definitely fixed. They are to be seen overlying the Proterozoic (Twelvetrees, 1908) and at Tim Shea, the Needles, and the Thumbs they underlie beds of West Coast Conglomerate, now known to be the base of the Silurian (G. A. Waller 1904, Loftus Hills 1921) which cap these peaks. Beds of limestone occur south-west of Mt. Mueller, and these can be seen to be overlying the quartzites. Mr. W. S. Dun considers these limestones (Gordon River series) from palæontological evidence to be undoubtedly members of the Silurian system, and these beds of quartzite, allotted by R. M. Johnston, Twelvetrees, McIntosh Reid, and others, to the Cambrian, appear certainly to be Pre-Silurian. For the present Cambro-Ordovician appears the most correct classification.

On the east side of the Huon every eminence protruding from the glacial plain consists of quartzites of this age, always inclined at a high angle and in massive layers separated at intervals by thin layers of more flaky rock. Time did not permit of the working out of the details of the stratigraphy of these beds, but almost every outcrop showed a different angle of dip. The colour is generally white, but often tinged with pink. The cliffs to the north-west of the more northerly of the two western spurs of Mt. Anne show a beautiful salmon-tinted shade visible from some distance. On the western side of Mt. Anne the quartzite is dipping at an angle of about 50 degrees in a direction about 45 degrees W. of N. The quartzite is traversed in all directions by veins of white quartz, often over an inch in thickness.

The quartzite extends under the diabase cap of Mt. Anne, which is about 1,500 feet in thickness. Perched on the top of the diabase is another small layer of quartzite. This will be commented on later when dealing with the diabase. The quartzite can be seen emerging from under the diabase on every side of the mountain, and is continued southward at least as far as the valley of the Huon, comprising the plateau mentioned as lying south and south-east of Mt. Anne and extending eastward until obscured by the diabase of Mt. Weld.

South-east of the latter mountain it emerges again in a small outcrop round the mouth of the Weld River, where it forms a low line of hills some three miles long on the west side of the river, and on the east of the Weld a number of isolated cone-shaped, buttongrass covered hills known as "Glover's Paddocks." The quartzite is here dipping at an angle and in a direction similar to the beds on the west of Mt. Anne. Five miles up the Weld from its junction with the Huon the older quartzites disappear under Permo-Carboniferous and Trias-Jura sediments, which also cover the older rocks to the east and form the divide between the Weld and Denison Rivers. To the west it is obscured by the diabase of Mt. Weld.

At a spot some twelve or fifteen miles up the Weld the older rocks again appear in the bed of the valley, stretching right across from Mt. Anne to the Jubilees and northward to the head of the river. The Jubilee Range appears to consist of the same massive white quartzites, which, however, do not extend farther east than the foot of the Snowy Mountains. To the north, similar beds compose Mt. Bowes and the southern foothills of Mt. Mueller. On Mt. Bowes the quartzite is dipping at an angle of about 60 degrees a few degrees south of west.

On the west of Mt. Bowes are large beds of a hard reddish slate resembling burnt fireclay, which appear to be included in the quartzite beds. In the course of the Weld roughly 12 miles from its mouth are considerable beds of grey slate resembling in general appearance the Dundas slates of the West Coast (Cambro-Ordovician), but no indication of its exact horizon was found. Opposite the end of the Jubilee Range there is a small outcrop of serpentine or serpentinised rock to be seen in the bank of the river. It is overlying unconformably some beds of white sandstone which show no signs of contact. On the old track just above this outcrop is a corner peg blaze apparently of an intended claim, but no application was ever lodged. A bed of grey slate of small extent lies across the Port Davey track to the north-east of Mt. Bowes near the old Junction Huts.

The older rocks extend eastward in the Russell Falls River Valley as far as Pine Hill, three miles west of Fitzgerald Station. (On the beforementioned Geological Map they are shown as extending some eight miles too far east in the Tyenna Valley). They are overlain to the north and east by Permo-Carboniferous mudstones, to the west by basal conglomerates of that system, and to the south they are separated from the similar rocks of the Jubilee Ranges by ridges of diabase. They appear to underlie the diabase throughout the whole area and to be exposed when the valleys have been eroded sufficiently deeply. The writer is inclined to think that the area shown on Mr. Reid's map as occupied by Permo-Carboniferous sediments is too extensive, and that most of this country, except on the south-eastern slopes of Mt. Mueller, consists of older quartzites. The quartzites outcropping on the road to Mayne's Farm at the base of Pine Hill is streaked with veins of quartz containing quantities of iron pyrites.

As indicated on Mr. Reid's map and on the sketch accompanying this paper, two beds of limestone occur in the valleys of the two northern branches of the Weld. This is a hard white rock of the Gordon River Limestone series (Twelvetrees, 1908). The writer can only confirm Mr. Twelvetrees' remarks on the occurrence, which should be referred to for a more detailed account of the country traversed by the South Gordon track.

(c) Permo-Carboniferous and Trias-Jura.

Sediments of this age appear along the eastern side of the area, the line of the valley of the Weld being approximately the present junction line between the newer and older rocks in this part of Tasmania. The base of the Permo-Carboniferous system consists of glacial conglomerates. Two small but excellent examples of this formation, which is so well developed at Wynyard, are to be seen in the area.

One of these occurrences extends from about a mile west of Fourteen Mile Creek on the Tyenna-Port Davey track, to the top of the Russell Falls River-Styx divide on the south-eastern spur of Mt. Mueller. The beds are exposed for three miles or so along the track. They consist of the typically grey, clayey matrix, showing little signs of stratification, and only just resistant enough to require the use of a hammer, studded with pebbles and boulders of all sizes, but chiefly smaller than a cricket ball, consisting of grey quartzite, quartz, slate, and mica-schist. There is a strange absence of red granite. Mr. Twelvetrees mentioned the existence of Permo-Carboniferous conglomerate here, but apparently did not recognise its glacial origin. The Pre-Cambrian mica-schist boulders reported by him from Fourteen Mile Creek were probably derived from this tillite. Mr.

Reid states that he knew it was tillite. The present writer found ample confirmation in the numerous ice-scratched pebbles which were found in greater profusion than at Wynyard, although, as at the latter place, large patches of the tillite occur in which no scratched pebbles can be found. The glacial beds seem to occur between the 1,400 and 1,800 foot contour lines, and appear to be overlain by beds of a coarse sandstone at a height of 1,800 feet above sea level, but neither its highest point nor its boundaries can be ascertained from the track. It rests, on both sides, on Cambrian quartzites.

The second occurrence of glacial tillite of this age was noticed in the course of the Weld about 15 miles from its mouth, at an altitude of about 500 feet. The river has cut through the morainal deposit, which is exposed on its bank. It is similar to the Wynyard formation and that just described, on Mt. Mueller. The proportion of red granite pebbles and boulders is high, and several erratics are of considerable size.

It may be worth noting, in passing, the fact that four occurrences of the rare Permo-Carboniferous glacial till, namely these at South Cape Bay, Wynyard, and the two described, lie in an almost straight line, which if produced passes near Bacchus Marsh in Victoria, where similar beds occur. This may be only a coincidence but it is a point to be borne in mind when investigating these beds.

These beds are succeeded by 300 feet of a coarse but regular conglomerate of Permo-Carboniferous age, resembling in general appearance the recent river drifts of the Derwent and elsewhere, and consisting of a hard yellowish matrix cementing together quartzite pebbles about the size of a cricket ball. Its age is definitely fixed by some strata that occur in its upper layers on the ridge to the east of the river and which contain fenestella. The conglomerate appears to be the river drift or delta deposit of some ancient river which perhaps flowed through the marked gap which now separates the Arthur and the Frankland Ranges and is continued east in the deep valley south of Mt. Anne and north of Mt. Weld.

Lower down the Weld, Permo-Carboniferous mudstones flank the valley. In the bed of the river they are the lower marine series and contain many of the typical fossils of those rocks. They flank the southern end of the Snowy Mountains and probably the eastern side of Mt. Weld. An outcrop of horizontal strata under the diabase organ pipes of the northern end of Mt. Weld could be distinguished from

Mt. Anne. This looked like rocks of this or the succeeding system, but their actual nature could not be confirmed. Here as elsewhere the Permo-Carboniferous mudstones are succeeded by the Knocklofty sandstones of the Trias-Jura.

The Russell Falls River is cutting through the upper marine series of the Permo-Carboniferous, which is traversed at intervals by bars of diabase and overlaid at about the 800 foot contour round the valley by Trias-Jura sandstones through which the river has cut and which are now nearly all denuded away, leaving the diabase of the hillsides bare. Elsewhere in the area, if the older rocks were ever covered by these sediments erosion has now removed all trace of them.

(d) The Diabase Intrusions.

The reader is referred to Mr. P. B. Nye's remarks on the occurrence of the Cretaceous diabase in his "Underground Water Papers, Nos. 1 and 2," undoubtedly the best account of the subject yet published. The area described in this paper would repay detailed study on this point.

In Tasmania the diabase appears to occur either in laccolith-like mountains of greater or less extent such as are common in the centre, east, and south, and of which the Central Plateau, Mt. Field East, and Mt. Wellington provide examples, and which may be distinguished by the immense beds of Permo-Carboniferous and Trias-Jura sediments hoisted up on their flanks, or, more rarely, as mountains isolated by erosion from a once extensive sill of diabase which spread over the top of early Palæozoic rocks, for example, Barn Bluff, the Eldon Range, and most of the more western diabase mountains (see The Geological Survey's publication "Coal Resources of Tasmania," 1922).

The Snowy Mountains, Mt. Styx, Marriott's Look-Out, and the diabase hills south of the Tyenna Valley are of the laccolithic type and probably are connected with the Mt. Wellington range intrusion. Probably diabase has covered beds of the older quartzites along the edge of the known occurrence of these, and this is undoubtedly the case on the lower Weld and west of Tyenna, but it is difficult at present to say where the main upthrust of the diabase occurred and where the sills joined the laccolithic intrusions.

Mr. Twelvetrees has classed the diabase of Mts. Mueller, Anne, and Wedge as portions of sills (Twelvetrees, 1908). This certainly appears to be the case in regard to Mt. Anne and Mt. Wedge, but Mt. Mueller and Mt. Weld seem rather to belong to the laccolithic type with extensions westward in the form of sills. On the south-eastern shoulder of Mt. Mueller basal conglomerates of the Permo-Carboniferous appear at a height of at least 1,800 feet, while at Fitzgerald, six miles away, the top of the system can be seen at an elevation of 900 feet. This points either to a diabase uplift on the eastern slope of Mt. Mueller of at least 2,000 feet, or to a fault with a throw of that height running along the face of Mt. Mueller. In view of what has occurred throughout Tasmania it seems more probable that the diabase of Mt. Mueller has raised the tillite, with the quartzite that underlies it, to their present height. The diabase of Mt. Mueller appears to reach a low level on the north-eastern slope, but it does not appear to be connected with the diabase from the Mt. Field ranges, which extends westward in a broad sill now seen capping Field West, Tyenna Peak, the Knobs, and Wherrett's Look-Out. To the south-east the diabase of the hills south of Tyenna approaches, if it does not join, that of Mt. Mueller. To the west, the Mueller diabase appears to have extended over the quartzites in a sill in the direction of Mt. Wedge.

Mt. Weld is certainly a diabase uplift. There are considerable occurrences of diabase in the valley of the Weld between 5 and 10 miles from its mouth at a height under 300 feet above sea level, whence it appears to lead right to the summit over 4,000 feet above. Alongside Fletcher's Hut on the banks of the Weld the diabase can be seen penetrating the quartzites in a large dyke of very close-grained rock. To the west the diabase appears to extend for some distance in a sill over the top of the quartzites.

Mt. Wedge is crowned with a cone of diabase, apparently a portion of an old sill resting on the older quartzites, but the writer has no data at present on which to determine from which direction the sill originally came.

Mt. Anne is also capped with diabase, probably portion of an old sill. It lies on top of the highly inclined quartzites, and appears now to be 1,200-1,500 feet in thickness. The most interesting feature of its occurrence here is the existence on the top of the Mt. Anne plateau of a small area of quartzite, perhaps a square mile in extent and 100 feet thick. This is an almost unique feature in the Tasmanian occurrence of diabase. This mass of quartzite, which appears to be a remnant of the rocks through which the sill penetrated and which probably originally overlaid it, has either been lifted 1,500 feet from its bed by the intruding sill or has been sheared from the top of some mass of quartzite and been carried along by the diabase. As the quartzite varies considerably from one locality to another it should be possible to discover whence this mass came, and the light such an investigation would throw on the mechanics of the diabase intrusions would well repay the trouble.

The diabase adjacent to the quartzite is of a glassy, homogeneous texture for about 100 feet, in which space it changes to the ordinary coarse-grained crystalline rock common on the mountain tops. This is interesting as showing conclusively that coarse crystals in the diabase are not an indication that the rock in question cooled at a great distance below the then surface. This close-grained diabase is sufficiently different in nature to be clearly distinguishable from the ordinary diabase at a distance of several hundred yards.

In the centre of the quartzite patch a small cirque has cut into it to a depth of about 75 feet, and in the centre of this depression can be seen a dyke of glassy diabase about 12 feet wide penetrating the quartzite. The junction line between the quartzite and the diabase is finely marked, but the former rock shows no signs of having been affected by the diabase.

The diabase cap of Mt. Anne has been greatly denuded by glacial action and has nearly disappeared. On the sides of the cirques that eat right into the heart of the mountain the junction between the diabase and the country rock it overlies can be clearly distinguished. There is probably no place in Tasmania in which the diabase intrusions can be studied with greater prospects of good results.

(e) Post-Diabase Sediments.

Since Cretaceous times this portion of Tasmania appears to have been enjoying sub-aerial conditions, and no signs of Tertiary sedimentary rocks were seen. A little Pliocene (?) basalt occurs at Mayne's selection, six miles west of Fitzgerald, as shown on Mr. Twelvetrees' and Mr. Reid's maps. Pleistocene glacial deposits litter a great part of the countryside. These will be described in the next section. Post-Tertiary alluvial deposits exist in the Russell Falls River Valley (Twelvetrees, 1908) and on the lower Weld, at the mouth of which there is a curious delta of alluvial material stretching some three miles up the river and three miles along the bank of the Huon, consisting of small, round, water-worn pebbles, chiefly of quartzite, and is more or less swampy ground. This appears to be a flood plain of the Weld, deposited as the swift current was slackened as it debouched into the Huon Valley. As the Huon deepened its bed or the sea level altered, the Weld has cut through and partially drained this plain. An apparently similar, though more extensive feature occurs on the other side of the Huon, and is known as the Arve Plains.

4. GLACIAL GEOLOGY.

(a) Descriptive Account.

The western half of the area dealt with in this paper and all the mountain tops in it show evidence of intense glaciation during the Pleistocene. In the Upper Huon Valley between Mt. Wedge, Lake Pedder, Mt. Anne, and the Arthur Range, the whole topography has been moulded by ice action. The flatness of the plains, stretching, as they do, for ten miles and more in an almost level swamp, and the sinuous courses and sluggish currents of the streams indicate that these plains are not due to the erosion of the streams that now occupy them. A recent elevation above the sea could have produced such a landscape, but there is no evidence of any sufficient uplift or of marine deposits here, and it is not the still undrained top of a plateau, as it is surrounded by lofty peaks. The rivers starting their course as mountain torrents flow for several dozens of miles through plains in a very mature stage of erosion and then finish their course in a more or less juvenile stage. Clearly an "accident" has occurred to the drainage of the Huon and Serpentine Plains, which do not present the characteristic features of river erosion, and the cause of that accident has been the intervention of the ice sheets and glaciers of the Pleistocene glacial epoch.

The general aspect of the whole region, the sides of the hills rising in a clean curve nearly vertically out of the plain, the U-shaped gaps between adjacent hills when they occur close together, the absence of water-worn valleys in the extraordinary level plain, all support this view. Some low hills break the surface of the plain at considerable intervals. These are almost always narrow, steep-sided ridges, apparently scraped bare by ice. The lower slopes of the main mountains and spurs are in general smooth and decidedly concave in section—ordinary water-worn hills being convex, streams gathering strength to erode as they descend—while the more elevated crests are extremely rugged above the 3,000-foot contour with picturesque pinnacles and crags. The outstanding spur of the Frankland Range that rises to the south-east of Lake Pedder is decidedly Tind-like when viewed from Mt. Anne.

Fig. 3.

LOOKING SOUTH FROM THE SOUTH END OF MT. ANNE PLATEAU.

Fig. 4.

THE HUON PLAINS LOOKING WEST FROM THE S.W. OF MT. ANNE.

(A. N. Lewis, photo.)

All this can be seen at a glance when the landscape is viewed in panorama from an elevation and points to an invasion of the whole district as indicated, by a great ice sheet, probably 1,500-2,000 feet in thickness [the elevation of the rugged and apparently unglaciated crags above the floor of the glacial valleys], growing from the tremendous snow precipitation of the West Coast and moving down the Huon, Serpentine, and Anne River Valleys, and perhaps reaching the sea at Port Davey. An ice cap must cover the whole of the land surface of the area (Hobbs, 1910). It is doubtful at present whether the ice that filled the Upper Huon at this stage covered the top of the surrounding mountains with a continuous white sheet. The rarity of moraines definitely attributable to this epoch of glaciation is an indication that here at any rate very little rock surface was showing above the ice. But even if the more prominent ranges protruded it was a very considerable glacier bearing close resemblance to an ice cap, and the ice moved radially over the flat country between the ranges impelled rather by weight of successive accumulations of snow than by the slope of the ground. This ice cap carved the main features of the topography of these western plains before the advent of the glaciers, which have left us the more obvious traces, and which by the action of their cirques eating into the sides of the mountains have carved the present topography of the elevated mountain ranges.

These later glaciers have left remains that are easily recognisable all round Mt. Anne, which has been subjected to the biscuit-cutting process described by W. D. Johnson (Hobbs, 1910), and approximates to the topography he calls a "karling" (using Nussbaum's term) illustrated on Plate 8 of Hobbs' 1922 edition. The mountain has been cut to the heart by three tremendous cirques, in two of which lie considerable lakes dammed back behind walls of morainal material which covers the plain at the entrance to the cirques Other cirques have cut into the outliers on the south-east and west.

Between the two western quartzite outliers is a tremendous cirque, cutting into the mountain to the diabase cap and standing at the head of a decidedly U-shaped valley some three miles long. The cirque that terminates the valley had not started to enlarge at its head before the conclusion of the glacial period and the walls do not present as fine a circle of cliff as is common in Tasmania. The glacier that flowed from here has strewn the floor of the valley with moraine in which diabase boulders alternate with quartzite ones. The moraine has not at any place completely dammed the valley, and there is no lake here. At the time this glacier was in the field several other ice flows must have moved a few miles out on to the plain from the numerous small recesses along the south-western face of the mountain. These have not left any well-defined cirques and could never have been extensive, but the plain near the foot of the mountain is littered with morainal material, amongst which diabase boulders are common, and these must have been carried some miles.

Apparently the crest of the more northern of the two western spurs stood out from the ice at this period, and the glaciers that flowed along each side have sapped back into the quartzite and produced a fine comb ridge. For the whole length of this spur its top culminates in a knife-like edge which the sapping effect of the ice has cut through at regular intervals, with the result that the top is crowned with a series of pinnacles rising precipitously 100 feet or more from the general line of the summit of the ridge. Its northern face shows some fine ice sculpturing, and is cut by several cirques. The Port Davey track skirts the foot of an escarpment 1,000 feet in height that appears to be a cirque wall. The end of the spur is divided into several minor features by cirques that have cut deeply into it and have, by enlarging their heads, thrown into relief the rock sentinels at the entrance to the cirques described by Professor Hobbs (Hobbs, 1921) which now stand out as quite prominent peaks. The second spur appears to have been under the ice for a long period and possesses a round contour without cliffs or irregularities, which anyone ascending the mountain finds to be a great advantage.

Farther to the south lies the Lake Judd Cirque, which, commencing at the south-west corner of the mountain, has eaten right into the centre of the pre-glacial plateau and nearly meets the western cirque just described. It is a fine example of this glacial feature, that to such an extent makes our mountain scenery. The floor of the cirque is almost entirely occupied by Lake Judd, a handsome sheet of water, perhaps two miles in length and a half a mile wide, crescentic in shape and set in the very heart of the mountain, with cliffs probably 2,000 feet high rising on three sides almost vertically from its waters. To the north-east and the south-east the cirque has enlarged its basin until it has met other cirques and eroded the entire pre-glacial surface

Fig. 5.

LOOKING EAST FROM NEAR THE SUMMIT OF MT. ANNE.

Fig. 6.

THE WESTERN END OF LAKE JUDD FROM THE MT. ANNE PLATEAU.

(A. N. Lewis, photo.).

of the plateau. The cirque wall now terminates in a unique example of a comb ridge, so precipitous and jagged that it would defy experienced climbers to traverse it. Impounding the lake is the most pronounced moraine in the locality. For a mile or more the country between the shore of the lake and Lake Edgar in the Huon Valley to the south-west and the Anne River to the south-east is covered with the confused succession of ridges and hollows typical of terminal morainal country so admirably described by Mr. A. McI. Reid (Reid, 1919). Lake Judd closely resembles Lake Seal in the National Park and Lake Dove on Cradle Mountain, but is a grander piece of scenery than either of these.

To the east of Mt. Anne is the most extensive cirque in the district. It appears to be deeper and is certainly broader than the other two mentioned. Its western wall must descend in a series of sheer precipices for 3,000 feet to the level of the Weld Valley, where lies a forest-encircled lake perhaps half a mile long, presumably of glacial origin. This cirque has eaten through the plateau until it has just met the western cirque and has carved out the other side of the comb ridge at the head of the Lake Judd Cirque. The size of this cirque gives another example of the general rule that the maximum snow action occurs on the lee of the ridge—in Tasmania, the eastern side. This cirque is a composite one with two main lobes and many smaller sub-divisions. In its south-west corner it meets another cirque that has grown from the south-east of the mountain. Between these two cirques is a second comb ridge, somewhat shorter but as rugged as the one before described. This forms the summit of a long diabase spur at the end of which stands the peculiar feature that has been named "Lot's Wife," mentioned earlier. This pinnacle, standing many hundred feet as perpendicularly and straight-sided as a tower, is a striking example of a glacial horn. It has grown at the entrance to two cirques, which, enlarging their heads behind it have removed the entire top of the pre-glacial spur to a depth of some 500 feet and left this pillar of rock standing at the end of the dividing ridge, the uneroded remnant of the pre-glacial spur with its summit representing all that is left of the original surface.

On the south-east side of the mountain there are two considerable cirques, the one mentioned above which has met the eastern cirque, and the other a mile farther west which has left a narrow ridge separating it from the Lake

Judd Cirque and a plateau of quartzite between it and the former of this pair. Between these two cirques, the Lake Judd Cirque and the one on the eastern side of the mountain, is a peak which provides a good example of a young glacial horn. The cirques have met or all but met all round it and have started to cut down the comb ridges, leaving this mass of mountain standing well above the surrounding cols, which are in process of being lowered, although the process was not a quarter of the way towards completion when the glaciers vanished.

These glaciers ended where we now see their terminal moraines, but the water flowing from them carried much material with it. To the east this was washed down the comparatively rapid Weld to the sea, but to the west the many streams emerging from the glaciers' ends spread their deposit over the flat plain already in existence, caused by the previous ice invasion. They thus formed large areas of glacial outwash aprons. It is these masses of rock and gravel strewn by numerous glacial streams over the older glacial valleys that form the great buttongrass plains of Western and South-Western Tasmania.

High up in various parts of the plateaux at about the 4,000 feet level and a little higher are several small cirques, some containing mountain tarns. These are evidently due to glacial action as described in the Field Ranges by Professor Griffith Taylor (Taylor, 1921). On the top of the main plateau there is a very perfectly formed and easily recognisable pair of cirques eating into each side of the quartzite patch before described and nearly cutting it in two, and several lakelets are to be seen to the south-east of the head of the Lake Judd Cirque.

A few other evidences of past glacial action were observed. To the south of Mt. Anne on the face of the quartzite plateau opposite the mountain could be seen four small tarns, the largest of which, as has been mentioned, has been called Smith's Tarn. These are all of glacial origin and are splendid examples of small cirques, Smith's Tarn rivalling the (so-called) Crater Lake on Cradle Mountain. The ice descended by a rock stairway to the basin of the tarn a few hundred feet below it, and thence probably to the valley of the Anne River.

The old moraine from Mt. Mueller noticeable from the Port Davey track is described by Mr. Twelvetrees (Twelvetrees, 1908), and although evidence of glacial action is not otherwise obvious, the glacial theory of the origin of this deposit seems reasonable. There are indications of a young cirque on the south-western corner of the summit of Mt. Mueller, and glacial action would be expected here at an elevation of 3,000 feet at least. Probably ice more resembling an ice cap than a glacier radiated across the spurs and adjacent plains of Mt. Mueller. Mt. Weld and the Snowy Mountains have the altitude and the area to provide névés for glaciers. From information given by some prospectors there is a marked glacial shelf on the eastern side of Mt. Weld on which repose some mountain tarns, and on the Snowy Mountains there are several lakes, one at least of considerable size.

(b) Glacial Epochs in Tasmania.

In the Northern hemisphere it is definitely established that, during Pleistocene times, the ice sheets descended four times over considerable portions of the continents of Europe, Asia, and America. These glacial invasions are known in Switzerland respectively as the Gunz, Mindel, Riss, and Würm ice ages, and are separated by inter-glacial periods of temperate climate. If conditions were similar for both hemispheres—as is the present theory—and if the temperature was sufficiently cold during each of these periods to cause glacial conditions as far north as Tasmania we should find signs of four corresponding invasions amongst our glacial remains.

Recently the Director of the Geological Survey, Mr. Loftus Hills, made the important discovery of the track of a very old glacier in the Pieman Valley. He has told the writer that glacial pavements formerly considered to belong to the Permo-Carboniferous glaciation were really caused by ice during the Pleistocene, but at a date far anterior to the more obvious signs of glaciation on the West Coast range. His opinion was confirmed by Sir T. W. Edgeworth David after a visit in March last year. Later, Mr. Hills has informed the writer that he found signs of two distinct glaciations in the vicinity of Lake Augusta at the head of the Ouse, where one moraine appears superimposed on another, with a peaty deposit from an intervening interglacial period between the two glacial deposits. Observations collected in the National Park indicate the existence of three ice invasions (Lewis, 1921). This idea has now been strengthened by additional data collected around Mt. Anne and the kindly confirmation given by Professor Sir T. W. Edgeworth David, our universal friend and helper.

It now appears that during the Pleistocene times we have traces of three ice invasions. The earliest apparent one was by far the most considerable, and was followed by two later phases. The writer suggests that this would correspond with the Mindel ice sheet of the Northern hemisphere. The size and intensity of this have obscured, if not obliterated, the traces of the Gunz in Tasmania, if any ever existed. The succeeding ice invasions may correspond with the Riss and Würm respectively. This theory is not yet proved, but may be useful as a working hypothesis. The finding of definite traces of interglacial periods between the various morainal deposits is necessary for the proof of the theory.

In the Mt. Anne region, in the National Park, and in Cradle Valley and elsewhere in Western Tasmania, there is every reason to believe that the obvious moraines are deposited on the top of a previously formed glacial topography. The regularity with which lakes appear in pairs, one superimposed on the other with, occasionally, mountain tarns at a greater altitude, the fact that this arrangement is never exceeded, and the definite signs of an older and a newer glaciation mentioned before, are indications that the apparently superimposed deposits are not merely a later phase in a receding cycle of glaciation, but are due to separate invasions. This contention, however, still remains to be proved.

If it will be borne out by future investigations the history of the Pleistocene glaciation in Tasmania will be in general this: The traces of the Gunz glaciation have been obliterated. During perhaps Mindel times a tremendous ice cap covered the western and south-western highlands and the more elevated portion of the central plateau. In the west the ice descended nearly to the sea. It covered, and so protected, the higher mountains, but moved down the valleys and out from the edges of the cap in great glaciers which, as Sir Edgeworth David has informed the writer, have left great outwash deposits in the vicinity of Strahan, and were responsible for the old glacial pavements of the Pieman, and the big terminal moraine seen at 13½ miles from Strahan on the railway track to Zeehan. Lake St. Clair was possibly a cirque formed at the head of a glacier growing from this ice sheet, which then filled the Cuvier Valley and covered the surrounding hills. Farther east, as at Cradle Mt. and Mt. Field, the ice cap covered the summits of the higher ranges but did not reach the bottom to coalesce with ice from neighbouring hills; for example, the Florentine Valley formed a gap of several miles between the ice cap of Mt. Field and the ice in the Vale of Rasselas. On these mountains the ice moved for some distance down the pre-glacial valleys, leaving its imprint on the topography. During this invasion the ice cap spread far out over the central plateau, being responsible for the many lakes and tarns between Cradle Mountain and the Ouse, and most probably responsible directly, or indirectly through the action of the intense cold on the rocks of the plateau, for the origin of the basins in which the Great Lake, Lake Echo, and Lake Sorell lie. It is possible that these are rock basins scooped by the ice sheet, but there is at present no direct evidence to couple their origin with ice action. The small glaciated areas on Mt. Wellington and Ben Lomond possibly belong to this period, and there are indications that many of the mineral-bearing drifts of the north-eastern highlands are glacial outwash fans. The characteristic remains of the possible Mindel glaciation in Tasmania are the broad flat plains throughout the western parts that are generally known as buttongrass plains.

At present we do not know anything about interglacial epochs, but following this period came the invasion by the Riss glacial epoch. Conditions were far less severe than during the Mindel times. The more elevated regions only were affected. Valley glaciers of the Dendritic type (Hobbs, 1910) grew from névés on the ranges and crept a short distance down the mountain valleys. These glaciers are responsible for the great cirques that contribute so much to our finest mountain scenery. As a rule the glaciers did not debouch far from their mountain valleys. They spread great deposits of moraines over the plains surrounding the valley mouths and for some distance up the valleys themselves, where morainal banks frequently dam back fine sheets of water. Between the cirques and U-shaped glacial valleys there still remains much of the older surface showing the rounding effects of the older Mindel ice cap. The glaciers occurred during this period on all mountain ranges in the western half of Tasmania over an elevation of 3,000 feet, and near the coast evidently reached much closer to sea level. The cirques and moraines of Lake Judd, Lake Seal in the National Park, Lake Dove in Cradle Mountain, and all the more striking signs of glacial action belong to this Riss period, which may be termed the cirque-forming period. The rounding effect of the Mindel ice sheet and the cirque-form ing effect of the Riss glaciers have left almost contrary results on our glacial topography.

Following this and clearly superimposed on it come the relics from the Würm glaciation, typified by the mountain tarn. The period of glaciation was this time far less intense than during the Riss period. Only the tops of the more elevated mountains were affected, and the nivation line appears to have rested at an elevation of about 4,000 feet at Cradle Mountain, as evidenced by Lake Wilks, and similarly in the National Park and Mt. Anne, as shown by the elevated tarns at about that height. The duration was only sufficient for very small cirques and rock-scooped basins to be formed. Small hanging or cliff glacierets and horseshoe glaciers grew, but did not travel far or obscure the evidence of the Riss glaciation. One of the best specimens of a moraine the writer has seen, however, lies to the east of Lake Newdigate in the National Park, and is attributable to this period. The distinguishing feature of the Würm glaciation may be said to be the mountain tarn.

A point that warrants passing note here and needs further investigation is the effect of one of these periods of glaciation on the edge of our higher mountains. At about 3,500 feet round the mountains of the centre, south, and north-east of Tasmania run lines of cliffs. The regularity with which these occur suggests that during one of these ice periods, probably the Würm, the nivation layer in the atmosphere rested at this height round the contour of the mountains, and here the intense frost action carved out the lines of cliffs so common near the tops of our mountains, such as the "Organ Pipes" on Mt. Wellington, the Bluffs of Ben Lomond, and the cliffs in which the northern face of the Western Tiers culminates. The concave shape of many high mountain peaks, Mt. Ida and Wyld's Crag for example, may be due to the fact that they protruded their summits into this nivation layer, which has worn a circlet of cliffs round the peak. These cliffs formed the starting point of an ice flow, resembling a collar round the mountain, which descended the slope for some distance before melting. There is ample evidence on Mt. Wellington and on the track to Lake Fenton under Mt. Field East of accumulations of rocks resembling moraines and almost certainly ice borne. At least many of them could not have rolled into their present position, and it is clear that they reached their present position before the present vegetation grew up.

Fig. 7.

THE SUMMIT OF MT. ANNE.

Fig. 8.

THE TERMINAL PEAKS OF THE NORTHERN OF THE TWO WESTERN SPURS OF MT. ANNE.

(A. N. Lewis, photo.)

(c) Cycle of Glacial Erosion in Tasmania.

There is one further phase of the study of the Pleistocene glaciation in Tasmania that deserves passing mention. As in the case of water-eroded topography, we have in glacial topography a cycle of erosion corresponding to the length of time during which a locality has been subjected to the effects of ice. Professor Hobbs defines the possible classes as follows:—

(1) The youthful channelled or grooved upland.

(2) The adolescent early fretted upland.

(3) The fretted upland of full maturity.

(4) The monumented upland of old age.

In the case of (1), cirques and glacial valleys merely groove the upland, leaving much of the pre-glacial surface still existing and clearly recognisable. In (2) the cirques have extended until they have met, and are separated by a serrated "Comb" ridge representing all that is left of the original surface. In (3) these lateral combs have disappeared leaving glacial horns (e.g., the Matterhorn) standing at the place where the heads of the cirques of the district junction. In (4) even this has disappeared, and all that is left are pairs of twin peaks, or "monuments," which formed that part of the upland which stood at the entrance to the U valleys, these being the last to be affected by the cirque enlargement, which takes place from the head outwards (Hobbs, 1910, 1921).

In Tasmania most of our glaciated areas have reached a stage bordering on the adolescent, early fretted upland. In most areas there is very little pre-glacial upland left. In the case of the National Park there are stretches of preglacial surface a few hundreds of yards across on the Field West and Mt. Mawson ridges and a mile or so on the Field East ridge, where the glaciation has not been so severe, while the Hayes and Newdigate Cirques have eaten into the Rodway ridge until the pre-glacial surface has disappeared, and we see the beginning of the formation of a comb ridge.

On La Pérouse there is a very fine example of a comb ridge. On the Mt. Anne range the process has extended a little farther. The cirques have commenced to cut down the comb ridges between them, and we see rudimentary glacial horns appearing in "Lot's Wife," the cone-shaped pinnacle to the east of Lake Judd, and the summit of Mt. Anne itself. On Cradle Mountain the process has gone still farther until the separating ridges have been quite smoothed out and the main pinnacles of Cradle Mountain and Barn Bluff stand out 1,000 feet above the surrounding cols. These are glacial horns in the making, but the process is far from complete, and it can hardly be called a type of fully mature glacial topography. Doubtless the extremely hard diabase cap of most of our mountains has hindered the development of the glacial cycle as it is hindering the development of the river cycle, and if we had had mountains of soft sedimentary rocks we would probably have had peaks to rival the Matterhorn, in outline if not in altitude. It is the Riss glaciation that has been responsible for the development of this topography. The Mindel ice sheet had more of a rounding effect and the Würm was of too short a duration to have a great effect, although it has accentuated the degree of erosion at the top of the Riss cirques and in many places has completed the formation of the comb ridge.

5. ECONOMIC POSSIBILITIES OF THE AREA.

(a) Mining.

It is difficult at present to see a great future before the district. As settlement extends the eastern part will be absorbed into the cultivated portion of Tasmania, but, short of the discovery of mineral wealth, it is hard to see what use can be made of the bulk of the area. For many years there have been rumours of the existence of gold under Mt. Anne, and the area has been constantly prospected, chiefly by parties from the Huon, but without appreciable results. The quartzites of the area are potential mineral-bearing rocks, but beyond this there appears little justification for hopes of discovery of a great mineral field here. The tiny patch of serpentine on the Weld is the only trace of an occurrence in the district of an igneous rock with which minerals are usually associated. The veins of quartz that traverse this bed of quartzite of Cambro-Ordovician age lying between Mt King William and La Pérouse do not appear to be an indication of the presence of minerals.

The locality has been well prospected. The western slopes of Mt. Anne would be easy to examine, and it is reasonable to suppose that they have been well searched. A lode there would be difficult to miss if a prospector investigated the faces of the main spurs. In the Weld Valley, on the other hand, the country is most densely covered with jungle and cannot have been at all thoroughly investigated, while the presence of a little serpentine is a hopeful sign. If mineral wealth exists here the eastern slopes of Mt. Anne, the western slopes of the Jubilee, and the gorge of the Weld between seems to be the most likely location. Although little hope in this respect can be held out the area warrants, and would possibly repay, a detailed investigation by the Geological Survey.

Mr. Renison Bell reported the existence of gold somewhere in the area, but exactly where he located it cannot be ascertained. He evidently did not consider the find of much value. On 2nd February, 1897, Henry Judd and Michael Gallagher lodged an application for a reward claim for gold reported to have been found on the north bank of the large western branch of the Weld. Their corner peg blaze is still distinguishable at the end of the old track up the creek, as indicated on the sketch plan attached to this paper. However, the applicants did not pay the fees and the block was never surveyed. The application lapsed, and apparently was not considered of value by the applicants. There is also a corner peg blaze on the old Weld track just above the patch of serpentine, but no application for a lease of this or any other spot in the area has been lodged with the Mines Department.

At the mouth of the Weld a reward claim for nickel and cobalt was awarded to H. E. Evenden in 1920. A little work has been done here and the lease is still effective, but apparently nothing is being done towards extended operations. The minerals here were obtained from the alluvial flat described above, just at its upper border. If the river has cut through any old lodes, minerals may exist in this flat. Some of the small boulders removed from a small shaft on this claim bore close resemblance to flint, and Mr. Gilbert Rigg, of the Electrolytic Zinc Ltd., who was good enough to have some pieces analysed, considered the specimens were true flint. Some specimens were then submitted to the Geological Survey, but the Director reports that although they bear a close resemblance to flint they are only a form of chalcedony. Some deposits of a very pure clay also occur near the mouth of the Weld. On the Styx a claim has been taken up for lithographic stone.

(b) Agricultural.

Agriculturally the area does not appear to have great possibilities. The lower third of the Weld Valley possesses fair soil of a nature and depth common in diabase and mudstone country in Southern Tasmania, and the sandstone higher on the hills indicates that somewhat better soil exists there. The entrance to the Weld Valley over the river flats and quartzites is unpromising, but there appears to be some ten miles or so of country which is at least no worse than the majority of the Huon district. There is some similar country around Mt. Mueller and doubtless on the flanks of the Snowy Mountains, all of which will warrant opening up as facilities are pushed farther out.

But the quartzite country that composes most of the area is very poor. The hard siliceous rock weathers very slowly, and with the heavy rainfall that exists there steep hillsides are washed bare before soil can accumulate to any depth, and will only support buttongrass and small flowers. Around the head waters of the Styx and Weld soil from this quartzite and the limestone deposits there has accumulated to a considerable depth and now supports a luxuriant forest growth. Much of this land will probably support agricultural crops when its turn comes to be opened up, and the heavy rainfall will assist cultivation, but when the forests are removed it is doubtful whether the shallow soil will not be washed away.

The timber in the Weld Valley appeared poor and patchy although there are good quantities of Beech (*F. cunninghami*). On the south-west of Mt. Mueller there is a fine but small area of Yellow Gum (*E. gunnii*) and mountain peppermint (*E. coccifera*). The lower slopes of Mt. Mueller will yield quantities of valuable timber for the Tyenna mills, and the Weld Valley possesses enough to make it worth while protecting until it can be milled, but it is not a preeminent timber area.

The western half of the area is at present valueless. Half has been scraped bare of soil by recent glaciation and the other half strewn with outwash gravels consisting largely of small angular chips of quartzite. The utilisation of the great buttongrass swamps of the west is one of the most pressing problems at present. It would pay the Government handsomely to institute research work into their possibilities and requirements for cultivation, but without systematic scientific research every effort to use them will be wasted, and it would be certainly a leap in the dark to spend money on them in, for example, planting exotic pines, without knowing more about them than we do at present.

Should this area ever be used it is to be hoped that the possibility of canalising the Huon and joining it by a canal via Lake Pedder to the Serpentine and thence to the Gordon will not be overlooked. This should prove quite possible, and on the surface appears the cheapest way of providing transport facilities to the back country here.

Mt. Anne when opened up will prove one of the foremost scenic areas of our island, and probably its most promising future appears to lie in its being made accessible for ordinary tourists.

APPENDIX (A.)

(Extract from account by H. Judd, 1898.)

Contributed by Major L. F. Giblin.

You pass on up the same river [Weld] until you come under the northern end of the Weld Mountain, which is very high and rugged, and here you hear the sound of a distant waterfall. The next object you see is Mt. Ann, which has a pinnacle of rock, which takes many different forms as you go round the mount, which is 5,020 feet high. Upon the southern side there is a stream of water that flows over a ledge of rock upon the top of the mount into space. So very high is it that it is thrashed into vapour before it can get to the earth, and has the appearance of a floss of silk floating about in the air by the change of wind. In this way the forest is watered by a vapour from it. At the western end of Mt. Ann you enter a small belt of low gum trees, then comes before you one of the most enchanting sights that anyone ever wished to behold.

This mountain has been burst open by some great power in Nature, leaving it with perpendicular walls of over 4,000 feet high upon three sides, and filled up with a beautiful lake called Lake Judd, discovered in 1880. This lake is about one and a half miles long and half a mile broad; perhaps it is larger, as I had no means of measuring it. The beauty here cannot be exaggerated. As you look into the water you at once see all the surrounding beauty of these high walls, with their rugged rocks and lovely spots of all sorts of green and dead reflected in the water below, with the dropping water from the snow above. When I first found this lake I was upon the top of the mountain, and came suddenly upon the edge of the large vault below, which made me tremble with fear, as I was in snow at the time, December. Opposite to this, westerly, is another opening between two mountains, and as you enter it you come to where the sides of the hill are broken back and a miniature lake in the centre. Proceeding further a new sight bursts into view, and you find that the inner part of the high mountain is thrown back on every side, opening out the bowels of the earth to view, with hundreds of different strata of rock of all sorts and thickness one above the other down to the slate formation. In the centre of this great amphitheatre, with its ledges of rocks to sit upon is a large lake in the centre and a conical-shaped rock of different coloured slate, polished smooth by the fallen rain and storms of passing time. Here you can sit and study geology from Hugh Miller's book of nature, as I call it, with all the quiet that surrounds thought in such places.

APPENDIX (B.).

EXPLANATION OF PLATES AND TEXT FIGURES.

PLATE I.—Sketch of the area described. The scale is approximately 8 miles to the inch. The scale and details must be taken as very approximate.

ERRATA.—In Legend for Ordovician Limestones read Silurian Limestones, and for Cambrian read Cambro-Ordovician.

Text figure is a sketch across the area described from east to west made looking south from the side of Mount Field East.

PLATE II., Fig. 1.—Shows the Mount Anne Range from the west. It is taken from the edge of the Huon Plains looking up the large cirque between the two western outliers, seen on both sides of the picture. The summit of Mt. Anne is at the left (north) end of the range. An easy ascent can be made up the spur seen on the right of the picture.

PLATE II., Fig 2.—Looking north-west at the Anne Range from the foothills of Mt. Weld. "Lot's Wife" is seen on the right of the range, and the summit of Mt. Anne is the next peak to the left. One of the two south-eastern cirques is seen in the centre of the picture. The valley in the foreground is that of the western branch of the Weld. Judd's Reward Claim is in the valley at the extreme right of the picture. This photo was taken from the farthest point reached by the party in 1921.

PLATE III.—Sketch plan of Mt. Anne showing the location of the more important features. The relative positions of the south-eastern features are very approximate.

PLATE IV., Fig. 3.—Looking south from the south end of the Mt. Anne Plateau. Smith's Tarn can be seen in the centre of the opposite ridge. The south-east end of the Arthur Range is in the background.

PLATE IV., Fig. 4.—The Huon Plains looking west from the southern of the two western spurs of Mt. Anne. The Huon runs in the line of scrub in the far distance. Lake Pedder lies at the back of the prominent hill on the right centre. The ranges in the background are the southern terminals of the Frankland Range. The mountain in the background on the left is Mt. Giblin.

PLATE V., Fig. 5.—Looking east from near the summit of Mt. Anne down the large cirque on the east of the summit. "Lot's Wife" is in the centre, and the Snowy Mountains in the background, with the Weld Valley in between.

PLATE V., Fig. 6.—The south-western end of Lake Judd taken from the Mt. Anne Plateau. Mt. Picton is in the distance in the centre, and Precipitous Bluff is the conical mountain to its left.

PLATE VI., Fig. 7.—The top of Mt. Anne looking across the western cirque from the top of the second spur, the quartzite of which can be seen in the foreground. The light patches on Mt. Anne are slopes of Diabase talus.

PLATE VI., Fig. 8.—The terminal peaks of the northern of the two western spurs of Mt. Anne. Cirques separate these peaks, which are glacial monuments in an early stage of development.

(Photos by the writer.)

APPENDIX (C.).

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