Tasmania

DEPARTMENT OF MINES

UNDERGROUND WATER SUPPLY PAPER

No. 1

The Underground Water Resources of the Midlands

BY

P. B. NYE, B.M.E., Assistant Government Geologist

Issued under the authority of
The Honourable Sir NEIL ELLIOTT LEWIS, K.C.M.G.
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PREFACE.

THIS volume initiates a type of publication which is new to the Geological Survey of Tasmania. Up to the present the publications issued by the Geological Survey of Tasmania have consisted of the following:—

Bulletins: Containing complete descriptions of mining fields.

Reports: Containing less complete descriptions than bulletins.

Mineral Resources: Dealing with the resources of the State in regard to particular metals or minerals.

Records: Containing matter of purely scientific interest, but which it is highly desirable to place on record.

The investigation recently carried out by Mr. P. B. Nye, B.M.E., Assistant Government Geologist, is the first examination into the underground water resources of Tasmania undertaken by the Geological Survey. It is desirable to publish the results of such investigations in the same way as is the practice in the United States, and accordingly a new series of publications is now instituted, namely:—

Underground Water Supply Papers: Containing complete descriptions of the underground water resources of definite regions, and the factors influencing irrigation therein.

This publication is the first of this new series. It will be followed by others as occasion demands the investigation of other areas in regard to underground water-supply and irrigation.

LOFTUS HILLS, M.B.E., M.Sc.,
Government Geologist.

Launceston,
31st March, 1921.

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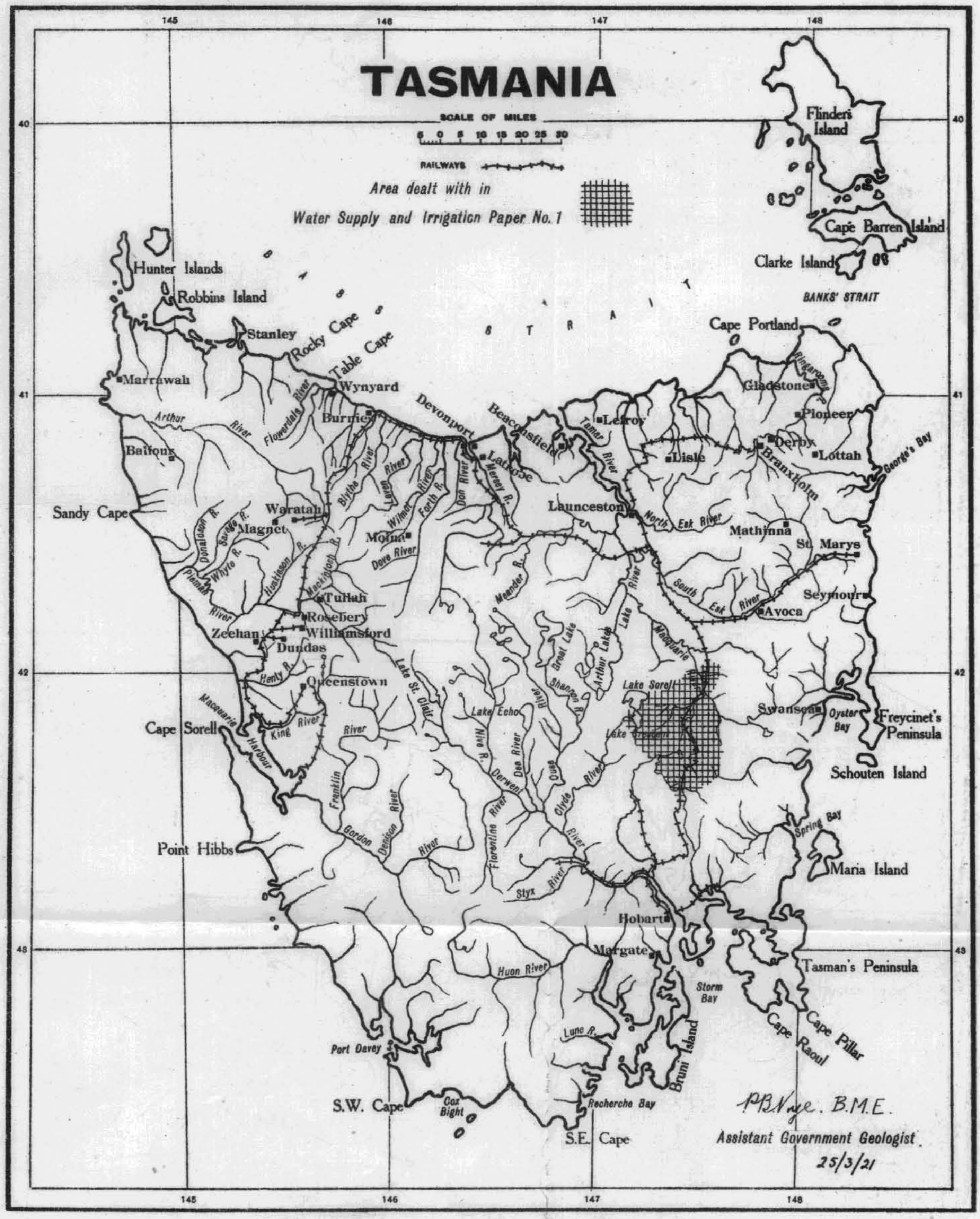

LOCALITY MAP

Photo Algraphed by John Vail Government Printer Hobart Tasmania.

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Summary.

Introduction.—This includes the objects of the Survey, the general manner in which the work was carried out, acknowledgments to the people who rendered assistance in carrying out the field work and the compilation of the bulletin, and the location and area of the district surveyed. The objects of the survey were to determine the possibilities or otherwise of obtaining supplies of underground water, with the view of assisting the agricultural and pastoral pursuits of the district, and also providing a public water-supply for Oatlands. The district surveyed was the greater part of the Midlands, and comprised the country bordering the Main Line Railway from Ross to Rhyndaston, and the main-road from Ross to Jericho, extending from Interlaken on the west, to Kitty's Rivulet on the east. The maximum length was 36 miles, and width 24 miles, the area being 500 square miles.

Literature.—A list of previous literature on the district is given under this head.

Physiography.—Under this title is included a description of the topography of the district: its evolution, its relation to the geology and to the dryness of the district, also its relations to the topography of adjacent regions, meteorology, and vegetation. The district includes both low-lying and much elevated country. The latter includes the Central Plateau (up to 3000 feet), and its eastern edge—the Western Tiers (up to 4000 feet), which occur to the west of the district. A fairly high spur runs easterly between Woodbury and Oatlands. To the north of this we get the low-lying country (600 feet) of the Tunbridge Plains; while to the south occurs the more elevated ground around Oatlands (1400 feet), &c., broken here and there by mountains up to 2400 feet in height.

The district forms a divide between some of the north, south, and east flowing streams of the State. The northern drainage includes the Macquarie River and its tributaries, the Blackman's River, York Rivulet, and Kitty's Rivulet. The southern includes the Coal River, Jordan River, and Clyde River, and the eastern the Little Swanport River. The only lakes of any size are Lakes Sorell and Crescent.

The dryness of the area is due to the fact that the Central Plateau drys and deflects the rain-bearing winds from

the west, and only a moderate rainfall results. Also, as the district acts as a divide, it is the source of many streams, but has no permanent ones. The topography has been brought about by a prolonged period of sub-aerial denudation, and the present features have been determined by the geology and the geological structures of the district. All available rainfall data are given under "Meteorology."

Geology.—The district is composed of generally horizontal strata of the Permo-Carboniferous and Trias-Jura systems, intruded by Upper Mesozoic diabase ("ironstone") and covered in places by Tertiary basalt flows, with alluvium forming along the present stream-courses. The Trias-Jura and diabase formations form about 90 per cent. of the surface, and occur in roughly equal proportions. The Trias-Jura strata consist of normal and felspathic sandstones, with lesser amounts of conglomerates, grits, and mudstones, and the Permo-Carboniferous strata of limestones, calcareous mudstones, and shales. The diabase is younger than these strata, and has intruded them everywhere in a horizontal direction, giving thick masses of diabase at all levels and sending up large dyke-like masses into the over-lying strata. Denudation has removed the bulk of the overlying sedimentary strata, and diabase is now exposed over half the surface, the other half being occupied by mainly Trias-Jura sandstones resting in more or less shallow depressions on the diabase.

Economic Geology.—Underground water is derived from the rainfall, and so the dispersal of the rain and the geology of the country are the important factors. Suitable geological conditions are porous rocks capable of holding and permitting the passage of water through them in large quantities, and a structure such that water will be kept in these rocks in large quantities.

The sandstones and felspathic sandstones of the Midlands are porous (14·6 per cent. and 26·3 per cent.), but the diabase is practically impervious. These two formations occur in equal amounts, and so, as a whole, the Midlands is not favourable for underground water. However, nearly every area of sandstones is a potential source of underground water, and some areas, with the structure given above, form definite basins, the water being held in on every side by diabase. Such basins occur around Oatlands, York Plains, Mt. Pleasant, Tunbridge, Ellenthorpe, and Mike Howe's Marsh.

The quality of the water depends upon the amount and nature of the mineral matter dissolved from the rocks. From the diabase the water will receive carbonates of calcium (lime) and magnesium, and from the sandstones practically nothing except where common salt exists in the latter rocks. The latter mineral seems to occur only around parts of Tunbridge and Ellenthorpe, and apart from these areas the quality of the water should be satisfactory.

The quantity of water depends upon the rainfall, amount of percolation, &c.; but only very approximate results can be obtained by calculation. There will be sufficient water to serve all purposes except irrigation, in which case only a part (about one-eighth) of the agricultural land of the basins can be irrigated.

The water is under sub-artesian conditions, and will not rise to the surface, and so has to be tapped and brought up. Wells either dug or drilled by a simple percussion plant are the types suitable. Pumping will be carried out by deep well and centrifugal pumps, driven by windmills, and benzine and kerosene engines. The chief utilisation of the water will be for agricultural and pastoral purposes. Irrigation is possible for part of the land, and will greatly assist the district by securing good yields from the crops against the more or less uncertain yields by dry-farming methods. Supplies of water for watering stock during dry periods are available if required and developed.

The water, though somewhat hard, is otherwise suitable for household and also for drinking purposes, and a public water-supply for Oatlands could be easily obtained from the Oatlands Basin.

Supplies could be obtained at York Plains for use in the railway locomotive boilers, but it would be advisable to test the water in this locality.

The soils obtained from the various rock-formations are discussed. The soil from the sandstones and felspathic sandstones are the only ones used to any extent for agriculture.

The qualities of the various rocks, &c., as regards road-making materials, are dealt with. Diabase is the best and most widely used material for metalling purposes. An efficient blinding material is needed, in view of the heavy motor traffic. Quartz gravel seems the best at present, but supplies are limited.

The utility of the Trias-Jura sandstones (locally termed "freestone") for building and ornamental work, general constructional work, monumental purposes, and for grindstones, &c., is shown by numerous examples of such work in the past and at present.

The Salt Pans and their crop of salt form an interesting feature of the Midlands, and their origin and formation are described. The salt is regarded as being obtained from either thin beds of salt in the lower series of Trias-Jura sandstones or else heavily impregnated layers in these rocks.

The only deposit of diatomaceous earth so far known in Tasmania is described. It is of impure quality, and the quantity is not large, but it may be found to have a limited use for some purposes.

A deposit of ilmenite is noted from Arthur's Lake, and its possible use as an abrasive of medium hardness is suggested.

Conclusions.—The main conclusions regarding underground water are given, but these are included in the above summary. The quality of the water will be found to be generally suitable for all purposes. The quantity of water is sufficient for all purposes except irrigation, for which it is most needed. Thus it appears that as far as underground water is concerned the district must remain largely a dry-farming one, but a combination of dry-farming and irrigation—water being applied only in the driest period—should be successful, and this would enable a much larger proportion of the district to benefit by the underground water-supplies than would be possible by complete irrigation.

The Underground Water Resources of the Midlands.

I.—INTRODUCTION.

(1)—Preliminary Statement.

The Midlands District, in which this investigation was carried out, is a comparatively dry region, due to the fact that it receives only a moderate rainfall, and has practically no permanent streams.

Additional water-supplies would be welcomed. Accordingly, this investigation into the possibilities of obtaining underground water-supplies was carried out, the specific purposes for which the water would be utilised being—

(*a*) To increase the existing supplies (rainfall and surface waters) in the carrying out of the agricultural and pastoral pursuits of the district.

(*b*) To provide a public water-supply for the township of Oatlands.

Previous geological mapping had shown that considerable areas of Trias-Jura sandstones outcropped in the district, and as sandstones are probably the most favourable of the consolidated rocks (sedimentary), there was every possibility of the existence of a fair-sized artesian or sub-artesian basin.

(2)—General Statement.

The work outlined in this report was carried out during the period from 24th March to 27th September, 1920—a total of six months.

The field work was carried out with the aid of the following land charts:—

Somerset, Nos. 2 and 3.
Monmouth, No. 1.

While these were of great assistance in many ways, they were poor from the point of view of topography. Some of the topographic features have been corrected, and other features not marked on the chart have been added. Local names for such features have in every case been adhered to, and in a few cases only it has been necessary to name previously unnamed features. This is the case mainly with small streams which are regarded locally as starting from springs and not being worthy of names.

The names "Tiers" and "Sugarloaf" are much used in connection with hills, and cause some trouble, especially the latter, as every property contains "The Sugarloaf." When the name of the property owner is added, it helps matters somewhat, but with change of owners the name changes, and the hill becomes known by different names in different parts of the district. As far as possible, the first name for a feature has been adhered to.

The heights above sea-level have been calculated from aneroid readings based on the level of the Main Line Railway at various points between Ross and Rhyndaston.

(3)—Acknowledgments.

The writer desires to express his appreciation of the courtesy and hospitality extended to him, and also of the assistance given to him by many residents of the district during his visit.

The assistance rendered by Messrs. J. Powell (Tunbridge), Terry (Ballochmyle), R. C. Kermode (Mona Vale), H. Gillett (Wetmore), A. W. Burbury (Glenmorey), H. E. R. Oldmeadow (Lowe's Park), A. H. Wrigall (Annandale), J. Powell (Dog's Head), W. Freeman (Woodbury), A. Morrison (Oatlands), C. Burbury (Inglewood), S. Burbury (Fonthill), T. J. Burbury (Park Farm, J. Jones (Bow Hill), W. Rust (Council Clerk, Oatlands), and H. J. Richards (Ross)—greatly facilitated the work of this investigation.

The writer especially wishes to thank Mr. and Mrs. E. E. Powell (Tunbridge), Mr. and Mrs. C. Munnings (The Gables, York Plains), Miss Percy (Oatlands), and Mrs. E. F. Roberts (Ross) for the hospitality extended to him. He also wishes to gratefully acknowledge the assistance rendered to him by Messrs. E. E. Powell (Tunbridge), and R. Gregg (Manager York Plains Coal Mine), while in the field; and also to W. Watt, State Meteorologist, for information *re* rainfall and wind data; and H. H. Scott, Victoria Museum, for examination of the fossils collected. Acknowledgments are also given to Mr. McMahon, of W. Hart and Sons; and J. A. Semple, of Semple and Co., Launceston, for information in connection with pumps and power plants for irrigation purposes.

(4)—Location and Area.

The area dealt with in this bulletin is the greater part of the Midlands district of Tasmania, and includes the districts around Ross, Tunbridge, Woodbury, Antill Ponds, York Plains, Nala, Andover, Parattah, Stonor, Rhyndaston, Jericho. Oatlands, Interlaken, Mt. Pleasant, Mt. Seymour, and Baden.

This area extends from Ross in the north to Rhyndaston in the south; and from Lakes Sorell and Crescent on the west to Kitty's Rivulet (a southern tributary of the Macquarie River) on the east. The Main-road and Main Line Railway from Hobart to Launceston pass through the approximate centre of this area in a northerly direction.

The area investigated has a maximum length of 36 miles from north to south, and a maximum width of 24 miles from east to west, and contains, approximately, 500 square miles of country.

II.—LITERATURE.

The geological literature on this district is very small in amount, owing probably to the almost entire absence of minerals of economic importance. In 1869 C. Gould, Government Geologist, made an examination of the country in the vicinity of the Main Line Railway survey route in connection with the occurrence of coal, and published a short report, entitled "The Midland Coalfields," including an examination of the country south from Oatlands. In 1888 R. M. Johnston, F.L.S., published "The Geology of Tasmania," in which reference is made to the geology of parts of the Midlands, chiefly in connection with coal, and the relation of the diabase and Trias-Jura strata. This work includes papers read before the Royal Society of Tasmania dealing with the same subjects.

In 1902 the late W. H. Twelvetrees, Government Geologist, visited Lake Sorell, and wrote a report entitled "Report on Country on the East Shore of Lake Sorell, and on a Discovery of Coal near Oatlands."

In 1910 "The Catalogue of the Minerals of Tasmania," by W. F. Petterd, was published, and contains references to several minerals from Midland localities, viz.—Randanite (diatomaceous earth), "Inglewood" (Oatlands); halite (common salt), Salt Pans (Tunbridge); quartz (varieties of), Lake Sorell.

In 1918 A. M. Reid, Assistant Government Geologist, made a short examination of the country around the Tunbridge Salt Pans in connection with possibilities of alkali supplies, and wrote a short report.

The only geological map of the district is that in the sketch-map of Tasmania accompanying Johnston's "Geology of Tasmania," and the edition revised by the Geological Survey.

III.—PHYSIOGRAPHY.

(1)—Topography.

(a) *General Description.*

The topography of the district is in parts of very high relief, while in others it is of comparatively low relief. It has been brought about by the denudational action of the present river systems. Its direct relation to the geology of the district is evident, as the most elevated regions are composed of diabase, while the less elevated regions are composed mainly of softer sedimentary rock types.

The district may be divided into the following parts:—

(1) The Central Plateau.—The western portion of the district includes the eastern portion of the Central Plateau of Tasmania. Average altitude of the surface, 2700-2800 feet above sea-level.

(2) The Western Tiers.—These form the eastern edge of the Central Plateau, and towards the north present a steep face at least 2000 feet in height.

(3) The Eastern Spur.—From the Central Plateau a spur runs easterly between Oatlands and Woodbury, apparently in the direction of Fadden's Tier, but east of Kitty's Rivulet it enlarges chiefly in a northerly direction, and connects up with similar ground to the east of Ross.

(4) The Tunbridge Plains.—Altitude 600 feet. North of the Eastern Spur there is a large stretch of comparatively level, low-lying country, with a general slope to the north, broken here and there by high diabase ridges.

(5) South of the Eastern Spur exists a large area of roughly level country (altitude 1400 feet), broken in many places by high diabase ridges.

These five parts are distinct topographic features, and serve for easy understanding of the topography of the Midlands district, viz., very high ground to the west of the area, with a descent to the east, sometimes very abrupt (as in the north), to the Tunbridge Plains, at other times very gradual, as where the Eastern Spur leaves the Tiers, and gradual to the country around Oatlands, the Eastern Spur separating the low-lying Tunbridge Plains from the comparatively low country around Oatlands.

The southern part of the district forms the portion of the east-west divide of Tasmania which separates the north-and-south flowing streams of the State. Towards the east the country also forms part of the divide between the north, south, and east flowing streams. The east-west divide lies generally much to the south of the Eastern Spur.

(*b*) *The Central Plateau.*

The surface of the plateau in this district forms a roughly level plain at an average height above sea-level of 2700 to 2800 feet. Individual mountains, *e.g.*, Mt. Franklin, 3587 feet, and Table Mountain 3596 feet, rise to heights of 800 feet above the ordinary plateau level.

Further west, the general level of the plateau must rise, as the level at the Great Lake is 3350 feet, in comparison with Lake Sorell, 2688 feet, above sea-level.

The edge of the plateau is at a slightly higher level (about 3000 feet) than the Lakes Sorell and Crescent, 2688 feet above sea-level. The plateau is composed mainly of diabase, though formerly it was covered with the Trias-Jura sediments, the latter now occurring only at the southern extremity of Lake Crescent, where they have been preserved by Tertiary basalt flows.

(*c*) *The Mountains.*

The most conspicuous mountains are the Western Tiers, with their abrupt rise from the Tunbridge Plains, and the most elevated are the individual peaks, which rise above the general level of the Tiers.

The following figures show the heights of these features above sea-level:—

	Feet.
Western Tiers—general (about)	3000
Miller's Bluff	3977
Mt. Franklin	3587
Old Man's Head	3355
Table Mountain	3596

From Miller's Bluff to the north of the district, the Tiers run in a direction 30° east of south, as far as Mt. Franklin; then south to Old Man's Head, where they turn south-westerly towards Table Mountain. Here the general height of the ground falls considerably, and no distinct tiers are visible, though high ground appears again to the south at Wood's Quoin, 3033 feet above sea-level.

Towards the north the Western Tiers present a very steep face of about 2000 feet to the Tunbridge Plains, but this steep face does not exist where the Eastern Spur leaves the Tiers, and does not appear again to the south and west.

The Eastern Spur is a high diabase spur running from the Tiers in an easterly direction between Oatlands and Woodbury towards the high country of Fadden's Tier (2144 feet above sea-level). North of York Plains it is 3 to 4 miles wide, but further east it enlarges chiefly in a northerly direction, and connects up with similar country to the east of Ross. The spur connects up with the tiers roughly along the line of the Blackman's River. Here the altitude is 2500 feet, which falls to 2000 feet near Vincent's Hill. A gap occurs at Antill Ponds, and the spur then continues at an altitude of 1800 feet, with no conspicuous peaks, and must rise to the east, where Fadden's Tier is 2144 feet above sea-level.

In the region to the south of the Eastern Spur several conspicuous mountains and hills occur, the chief of which are—Mt. Seymour, 2429 feet above sea-level; Pike's Hill, 2289 feet above sea-level; Murderer's Tier, 2000 feet above sea-level.

Around the York Plains district several peculiarly-shaped hills occur, *e.g.*—Vincent's Hill, 2000 feet above sea-level; Joe Wright's Sugar Loaf, 1855 feet above sea-level; Handsome Sugar Loaf, 1780 feet above sea-level; Mt. Pleasant, 1665 feet above sea-level.

(*d*) *The Plains.*

Small areas of comparatively flat and level country occur in some parts of the district. The northern part of the district has been spoken of as the Tunbridge Plains. These occur around Tunbridge, and extend northwards from the foot of the Eastern Spur in the south to join similar country along the Macquarie River, and from the Western Tiers on the west to what are called the Eastern Tiers and other diabase hills on the east. This stretch of country is not absolutely level and flat, but has a slope to the north, and is broken by high diabase ridges at several localities. Altitude is 600 feet.

Somewhat similar conditions exist around Oatlands and the country to the south of the Eastern Spur, but this country is at a much higher elevation (1400 feet), and is much more broken up by diabase ridges.

(e) *Lakes, Lagoons, and Salt Pans.*

The following table gives some particulars of the lakes of the district:—

TABLE No. 1.

Name.	Shape.	Area (Sq. Miles).	Height Above Sea.	Maximum.		Quality.
				Length.	Width.	
Lake Sorell	Irregular	18·95	2688	5	6	Fresh
Lake Crescent	Roughly elliptical	6·43	2686	3½	2½	Fresh
Lake Tiberias	Roughly triangular	3·93	1450	2½	2½	Very impure
Lake Dulverton	Irregular, long, and narrow	0·95	1322	1½	¾	Very impure

Lakes Sorell and Crescent.—These two lakes are at the present time separated by a strip of alluvium about ½-mile long and ¼-mile wide, but were at a comparatively recent date connected, and formed one lake. Some factor which has caused a lowering of the water-level has caused the separation.

These lakes are situated on the surface of the Central Plateau close to its eastern margin, portion of the north-east shore of Lake Sorell being only ½-mile from the top of the Tiers, while the south end of Lake Crescent is at a less distance.

Lake Sorell is fed by the Mountain River, which flows into it at the northern extremity. The water from Lake Sorell flows through a narrow channel into Lake Crescent, which is given as 2·16 feet lower than Lake Sorell. The overflow from Lake Crescent forms the Clyde River, which eventually flows into the Derwent. The northern extremity of Lake Sorell is bounded by high peaks, *e.g.*, Mt. Franklin, The Cradle, and other prominent hills rising up to 800 feet above the lake, while Table Mt. rises to a similar height at the south-west of Lake Crescent. These features add great beauty to the district, and make Lake Sorell, with its large expanse of water, and these hills rising above it, noted for its scenery. These two lakes occupy depressions in the diabase formed by the denudation of the Trias-Jura sediments which once covered this part of the plateau. Sandstones are to be found at the south of Lake Crescent, where they have been preserved by overlying Tertiary basalt flows. Traces are also to be seen in the pebbles at Diamond Beach, and the sandy stretches which occur around the shores of the lakes, and which could not have been derived from the diabase.

Lake Tiberias or Jericho Lagoon.—This lake is situated to the south of Stonor, and to the west of the Main Line Railway, which runs along the eastern edge of the lake for 2½ miles. The surface of the lake is overgrown with rushes, except for a narrow strip up to 20 yards wide around the shores of the lake.

The only feeder to the lake is a small creek which flows into the north-east corner, while the overflow from the lake at its western extremity forms the Jordan River.

The lake occupies a depression in the Trias-Jura sediments, while the Jordan River for the first 2 miles after it leaves the lake flows through a gorge in diabase. It is this hard diabase mass which has caused the formation of the lake by retarding the corrosion (*i.e.*, deepening of the river-bed) of the Jordan River flowing over it, while in the softer and less resistant sediments up-stream the river was able, not only to corrode its bed, but also to erode or wear away its banks, and thus enlarge its course to the area now occupied by the lake.

Lake Dulverton.—This lake is situated to the east of Oatlands, which has, in fact, been built along its western and south-western shores. Two small creeks flow into it from the south and south-east respectively, while the overflow at the northern extremity forms the Dulverton Rivulet.

The surface of the lake is everywhere visible, but rushes are to be seen, and appear to rise a few inches above the surface.

The lake occupies a depression in Trias-Jura sediments, and was formed similarly to Lake Tiberias, but the diabase bar in this case appears 3 miles downstream, the intervening portion of the rivulet not appearing as a lake at the present time.

Lagoons.—Such small bodies of water are numerous around Tunbridge, especially to the north-west, near Ellenthorpe. They occupy slight depressions in the low-lying sandstone country of the Tunbridge Plains.

The largest is the Salt, or Horseshoe, Lagoon, about $\frac{3}{4}$-mile in length, and averaging $\frac{1}{4}$-mile in width. It is typical of the majority of the lagoons, in that it shows a clear expanse of more or less brackish water not overgrown with rushes. When they dry up they leave a thin white deposit of common salt.

Green, or Bell's, Lagoon is exceptional, in that it is practically covered with green rushes. The well-known Salt Pans around Tunbridge are interesting examples of these lagoons. These are two in number—the Ballochmyle and the Mona Vale Salt Pan—and in dry seasons deposit a layer of salt up to $\frac{1}{2}$-inch thick.

(*f*) *The Rivers.*

It has been seen above that part of the district forms the divide between some of the north, south, and east flowing streams of Tasmania, and thus the river systems are numerous, being seven in number. Of these, two flow to the south, joining the Derwent and really forming part of the larger system of that river. A third flows south into the Pittwater, and a fourth east into the ocean, near

Little Swanport. Of the remaining three, two flow north and form part of the larger system of the Macquarie River—the seventh system.

(1) *Clyde River.*—This river has its source in Lake Crescent, and drains the south-eastern portion of the Central Plateau. It flows in a general southerly direction, and ultimately joins the Derwent near Hamilton.

(2) *Jordan River.*—This river has its source in Lake Tiberias, and then flows in a general north-westerly direction, receiving several small tributaries on the way, to where the Dulverton Rivulet joins it. It turns west for a mile, and is joined by the Green Hill Rivulet, and then flows south-westerly in a series of sharp curves, being joined by the Exe Rivulet. Finally, it flows in a general southerly direction, and empties into the Derwent near Bridgewater.

Of its tributaries, the Dulverton, Green Hill, and Exe Rivulets are the most important.

The Dulverton Rivulet has its source in Lake Dulverton, and flows in a general west-south-westerly direction, to join the Jordan.

The Green Hill Rivulet rises to the west of Mike Howe's Lookout, and flows in a south-easterly direction for the greater part of its length along a diabase sandstone junction.

The Exe Rivulet rises in Table Mountain, and flows south-easterly, passing over in its course a waterfall with a drop of 800 to 1000 feet.

(3) *Coal River.*—This river flows into the area from the south-east in an easterly direction to within 1000 yards of Lake Tiberias, where it turns and flows in a general southerly direction, following a fault-plane for several miles. Ultimately the Coal River empties into Pittwater, near Richmond.

(4) *Litte Swanport River.*—This river rises at the western end of Murderer's Tier, and flows in a general easterly direction, finally reaching the East Coast at Little Swanport.

(5) *The Blackman's River System.*—This system includes the Blackman's River, Millbrook, Curryjong Rivulet, Hook's Creek, and York Rivulet, and their tributaries.

The Blackman's River rises by means of several small heads, about 1½ miles to the south of Lake Crescent, and flows east for 4 miles to Mike Howe's Marsh, then, turning north-east and flowing through a deep gorge in the Eastern Spur, emerges on to the low country of the Tunbridge Plains, across which it flows and joins the Macquarie River at Mona Vale.

The Mill Brook rises well up the face of the Tiers in Racecourse Marsh, and flows in a general north-east direction to join the Blackman's River, 2 miles west of Tunbridge. As tributaries it receives Spring Creek, Blackwood Creek, Vicary's and Flood's Creeks (which unite 1 mile above their junction with the Mill Brook), which come in from the west and north-west respectively.

York Rivulet, or Tin Dish Creek.—This stream rises on the western slopes of Mt. Seymour, and flows in a general northerly direction to join the Blackman's River, 2 miles north of Tunbridge. It has a slightly greater length than the Blackman's River, but contains a less volume of water.

As tributaries it receives the Lightwood and Curryjong Rivulets, the latter being formed by the union of the Curryjong Rivulet, Stringy-bark Creek, and Hook's Creek.

The Lightwood Rivulet rises on the northern slopes of Mt. Seymour, and flows into the York Rivulet at Nala.

The Curryjong Rivulet has numerous heads in the Eastern Spur, and when these unite the stream flows in a north-easterly direction to Woodbury, where it turns east and then north to join the York Rivulet, 2 miles south of Tunbridge.

Stringy-bark Creek rises at Flat-top, and flows down the face of the Eastern Spur with a very steep grade on to the flat country around Woodbury, where it empties into the Curryjong Rivulet.

Hook's Creek rises in Hook's Marsh, and flows in a general northerly direction through St. Peter's Pass and along the Main-road to join the Curryjong half a mile below Antill Ponds.

(6) *Kitty's Rivulet.*—This stream rises in numerous branches in the Mt. Pleasant Estate, and flows in a general northerly direction to join the Macquarie River, 7 miles east of Tunbridge.

(7) *Macquarie River.*—This stream flows into the area from the east, and flows north-easterly, leaving the area to the north-west of Ross. It is easily the largest river in the district, and conservation in Toom's Lake enables the stream to flow all the year round. As the stream approaches Ross it flows through a flood-plain of alluvium up to 1½ mile in width.

The southern tributaries—the Blackman's Rivulet and Kitty's Rivulet—have already been described. From the north and east two tributaries—the Glen Morriston Rivulet and Tacky Creek—join the Macquarie River. The Glen Morriston Rivulet has many branches in the high country east of Ross, and flows generally south-west to join the Macquarie River, 3 miles below the Blackman's River.

Tacky Creek rises 6 miles east of Ross, and flows westerly to join the Macquarie River, 1½ mile above Ross.

The majority of the rivers of the district present features characteristic of topographic youth, though the rock types have a large effect in the causing of such features.

The following table shows the grade of some of the streams of the district, the Mississippi River being included for comparison:—

TABLE No. 2.

River.	Length.	Difference of Level.	Average Grade. (Feet per Mile.)
	Miles.		
Mississippi, U.S.A.	...	...	1
Macquarie River (from Ross to where the water enters the Tamar River)	60	600	10
Jordan River (portion in the district)	16	440	27
Kitty's Rivulet...	10	330	33
York Rivulet	21	700	33
Blackman's River	21	1400	66

This shows the youthful nature of the streams in comparison with the Mississippi River. Of the streams in the district, the Macquarie River is the most mature, while its tributaries and other streams are much less mature.

(*g*) *Evolution of the Topography.*

As will be seen later,(1) the drainage systems of the district came into being as consequent or original ones at the close of the deposition of the Trias-Jura sediments, their elevation and intrusion by the diabase.

(1) Page 19.

It is the development of this system, accompanied by the ordinary atmospheric and aqueous agencies of denudation, that has been mainly responsible for bringing about the present topography.

Not the slightest evidence of any Quaternary glaciation is to be found, and it is concluded that this part of Tasmania escaped the glaciation of the above period, so common in the western part of the State.

The river systems have developed to such an extent that they are in many places superimposed systems, having denuded the Trias-Jura sediments, and reached the underlying formations of the Permo-Carboniferous series and the diabase, and cut deeply into them.

These drainage systems, which came into being at the close of the deposition of the Trias-Jura sediments, their elevation, intrusion by the diabase and accompanying faulting, were determined by the constructional slopes of the surface brought about by these happenings. The development of these systems has not proceeded without interruption, but has been modified somewhat by later happenings, such as—

(1) Any post-diabase faulting.

(2) The formation of, and the later destruction of, the Launceston Tertiary Lake just to the north of the Midlands district.

(3) The extrusion of the Tertiary basaltic lava flows. The flows along the valley of the former Macquarie River have altered its course, and probably to a large extent, too. If the basalt flows had not occurred to the south of Lake Crescent, it is more than likely that the drainage of this lake would have been along the Blackman's River, and not the Clyde River, as at present.

These modifying influences, however, have had a comparatively small effect, and the present topography is mainly due to the ordinary atmospheric and aqueous agents of denudation and the development of the original drainage systems, which were initiated as described above.

The streams seem to have adjusted themselves by capturing the headwaters of other streams to a very slight extent, the Coal and Jordan Rivers being probably the only example. It seems probable that the Coal River, by headward erosion, has eaten its way towards Stonor and captured the headwaters of the Jordan River. The portion of the Coal River which flows easterly towards Lake Tiberias represents these headwaters, which once flowed through Lake Tiberias, but have now become diverted into the Coal River.

(2)—Relation of the Topography to Geology.

In connecting the topography of the district to the geology, it is found that two main factors have been instrumental in determining the topography of the district, viz.—

(1) The geological structure of the district;
(2) The rock types represented in the district—

and these two factors are so intimately related that it is often hard to separate them, if, indeed, a separation is desired.

Starting off at the close of the Trias-Jura sedimentation, the intrusion of the diabase, and any related earth movements, it was the geological structure of the country which determined the constructional slopes of the surface, and through these the initiation of the drainage systems. At this time the district was covered by the Trias-Jura and underlying Permo-Carboniferous sediments, with diabase intruded into them. The sedimentary rocks were comparatively soft and non-resistant, while the diabase was exceedingly hard and resistant to the ordinary agents of denudation, and so the sedimentary rocks were easily denuded, while the diabase was hard to denude. Thus, in the course of time, the development of the district has practically amounted to the denuding of the sedimentary rocks off the resistant underlying intrusive diabase, and at the present time diabase is exposed over 50 per cent. of the surface, and underlies at no great depth a much larger percentage. Further, the diabase occupies most of the elevated ground of the district, and the sedimentary rocks occupy the lower ground of the district. As regards the streams, they tried to keep their courses in the softer sedimentary rocks, and on coming in contact with the underlying diabase, they chose the junction of the diabase and sedimentary rocks if possible, but failing that they had to corrode a course through the hard resistant diabase. Thus, when the streams are flowing over diabase they generally cut deep, steep-sided gorges, and when over the sedimentary rocks they flow through wide open plains.

The later Tertiary basalt has also played a part in the formation of the present topography. It occurs as dykes and surface flows intruding and overlying both the diabase and the sedimentary rocks. Where the basalt has covered the sedimentary rocks, and there has been a considerable amount of post-basaltic denudation, basalt-capped hills rise to considerable heights above the present surface. Dykes and plugs from which the surrounding rocks have been denuded rise above the surface to a lesser extent. These observations apply to the higher ground of the Plateau and the Eastern Spur, and in close proximity to these. On the Tunbridge Plains, and along the Macquarie River, the basalt occurs exclusively as surface flows. These flows filled the valleys of pre-basaltic streams, and covered a land surface no more than 50 feet above the level of the present streams. The basalt along the Macquarie River filled the valley of the former Macquarie River along part of its course, at any rate. Towards the north the present Macquarie River and the basalt follow different courses, and either—

(1) The basalt flow caused the Macquarie River to alter its course; or

(2) The basalt filled an old tributary flowing almost parallel to the old Macquarie River.

The first is probably the correct solution, and examination of the district to the north would verify or otherwise this theory.

The above shows to what a large extent the geological structure and the nature of the rock types of the district have played their parts in the forming of the present topography.

(3)—The Relation of the Dryness of the Area to the Topography.

The comparative dryness of the district is a direct result of its topography, and is due to the following conditions—

(1) The Central Plateau to the west of the district. The main rain-bearing winds of Tasmania are of a generally westerly nature (south-west to north-west), and these, to reach the district under review, would have to pass over the high ground of the West Coast District, and also of the Central Plateau.

(*a*) These winds, if they do reach the district, will have had most, if not all, of the moisture removed from them.

(*b*) The high ground probably also deflects them to some extent, and the district does not receive the rain-bearing winds it should.

Thus the district is deprived of a large portion of the rain-bearing winds which it should receive, and so has only a moderate rainfall, derived from those from the north, south, and south-east which are not affected by the Central Plateau.

(2) The divide between some of the north, south, and east flowing streams of Tasmania. This feature affects the district, in that though the district contains the sources of many of the streams of Tasmania, yet these streams are only small, and having no great volume of water in them, are dependant on the rainfall for permanency. Thus the district is devoid of large permanent streams. In fact, the Macquarie River is the only permanent stream in the district, and that is mainly due to conservation in Toom's Lake, at the head of the southern branch.

The above two factors, viz., the moderate rainfall and the lack of large permanent streams (both direct results of the topography), make the district one of comparative dryness.

Another factor influential to some extent in causing the dryness of the area is that of dry winds. Apart from the usual proportion of non-rain-bearing winds, some of the "dried" winds from a general westerly direction pass over the district. These do not bring any rain, as they should, but further they must absorb a fair amount of moisture from the soil, thus leaving it drier instead of moister.

(4)—Relation of the Topography to That of Adjacent Regions.

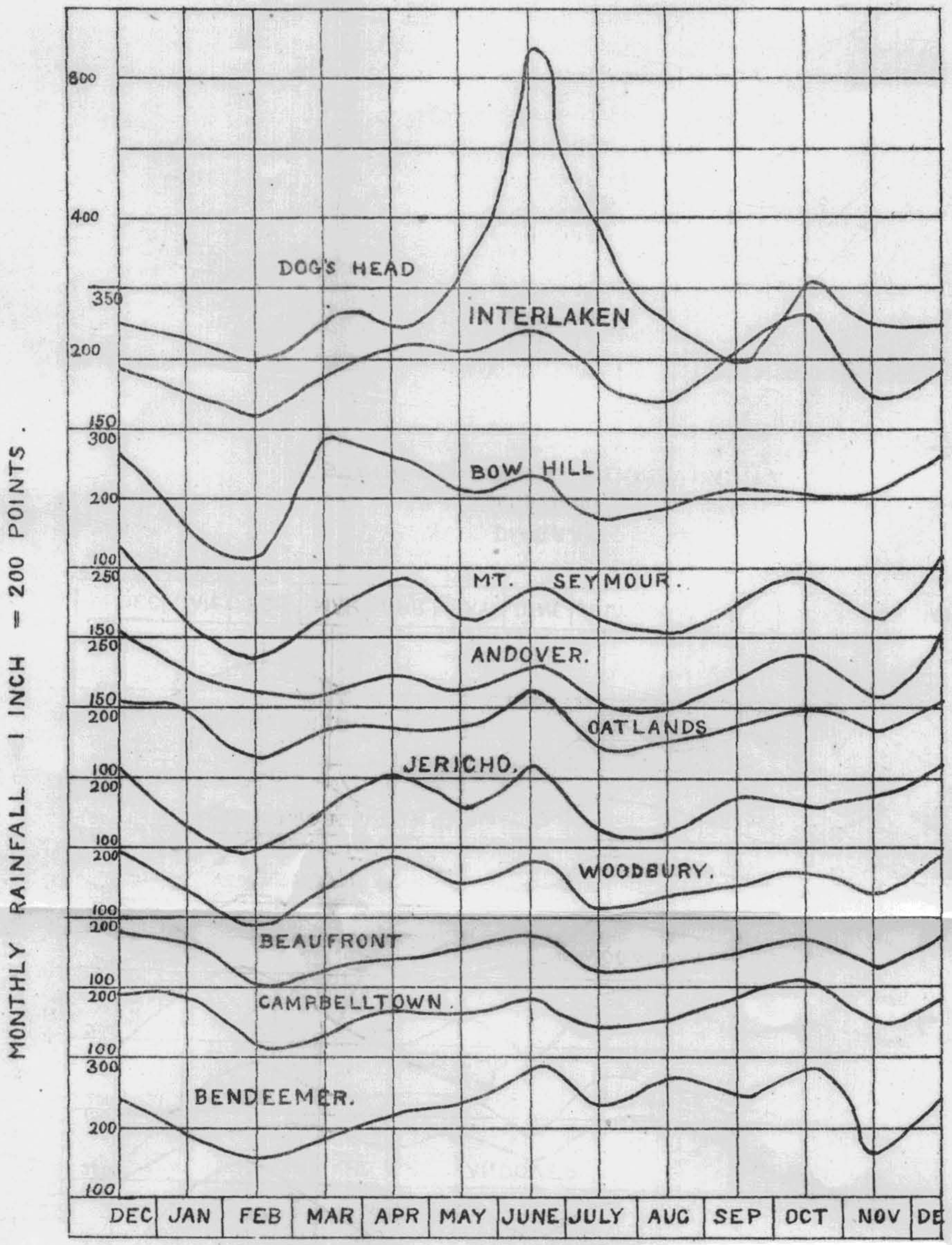
It is important to trace the connection of the topography of the district with that of adjacent regions, as any one single district rarely forms a topographic unit in itself.

To the west and north-west the elevated Central Plateau continues and connects up with the high ground of the West Coast. The Western Tiers, which run roughly north and south in the district, change their direction at Miller's Bluff in the north, and run north-west, and later west. To the south and south-west the Tiers do not exist, though the high ground of the Central Plateau continues in these directions. As part of the district forms the divide between some of the north, south, and east flowing streams of Tasmania, the general tendency of the country is to fall in these directions. To the east this fall must be fairly uniform, because from a hill 2½ miles south-south-east of Murderer's Tier, and at an altitude of 1930 feet, the ocean on the East Coast is distinctly visible on clear days. To the south the fall seems to be steep at first in the vicinity of Rhyndaston, and then more gradual down to the Derwent River. To the north and north-north-west the fall is very gradual from the Tunbridge Plains down to the valley of the Tamar River. To the north-east occurs the elevated region of Ben Lomond and its broken continuation to the north in Mts. Barrow and Arthur.

It is in the Macquarie basin—*i.e.*, the gentle slope to the north of Tunbridge Plains, with the elevated ground to the west (Western Tiers, 4000-4500 feet above sea-level), and to the east (Ben Lomond 5010 feet, Mt. Barrow 4644 feet, and Mt. Arthur 3895 feet above sea-level)—that the chief interest lies. This basin occupies roughly that of the Launceston Tertiary lake, but is somewhat larger in southerly and westerly directions, at any rate; and its surface falls gradually from 663 feet at Tunbridge, down to practically sea-level at Launceston. This area has been spoken of as a "rift valley," (2) and the Western Tiers and the Ben Lomond Range regarded as fault scarps. As will be seen later,(3) the Western Tiers are not regarded as a fault scarp, but are essentially an intrusive junction with sedimentary strata. Undoubtedly faulting and displacements have occurred in the sedimentary strata, but these have occurred away from the Tiers. These may have helped in the initiation of this Macquarie basin or valley, but it is denudation since then that has formed this huge valley. At Ross, beds 300 to 400 feet down in the Permo-Carboniferous strata outcrop, and approximately 1500 to 2000 feet at least of Permo-Carboniferous and Trias-Jura strata have been denuded from above these. This valley,

(2) "The Australian Environment," by Griffith Taylor, D.Sc.
(3) Page 71.

PLATE IV



DIAGRAM

SHOWING

DISTRIBUTION OF THE YEARLY RAINFALL

Photo Algraphed by John Vail Government Printer Hobart Tasmania.

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or a large part of it, was formed in Lower Tertiary times, was then occupied by the Launceston Tertiary lake until the destruction of the latter, and has since been greatly enlarged by further denudation.

Thus it is seen that though faulting may have caused the initiation of this valley, yet denudation has played the greater part in its formation, and it cannot therefore be regarded as a true rift valley.

(5)—METEOROLOGY.

Much valuable rainfall data has been collected for the district, as will be seen from the accompanying table, No. 3, compiled from figures supplied by Mr. W. S. Watt, State Meteorologist. This table gives all the available records for stations in the district, and for several in close proximity to the district, and contains records for 12 stations, some of which date back to 1882, a period of 39 years.

The figures show that the largest rainfall is on the elevated Central Plateau (Dog's Head and Interlaken), where the yearly average approaches 40 inches. For the remainder of the district the rainfall is only moderate, varying from 26 inches at Bow Hill, down to 18 inches to the north at Woodbury and Ross. Table No. 4 shows the minimum and maximum monthly and yearly rainfall data. Of fairly recent years, 1914 stands out as the driest year, with 1919 next. The year 1916 was the wettest, with 1917 next in order.

Going further back, 1908 and 1892 stand out as dry years, in addition to the above.

The distribution of rainfall throughout the year is clearly shown by the accompanying graph in Plate IV., in which the monthly rainfall is plotted. The curves are all very similar for the different stations, showing that the same set of conditions operates throughout the district in the production of the rainfall. At the beginning of the year we have the rainfall of January at or slightly below the average, followed by a large drop to February, the driest month generally of the year. This is followed by a steady rise till June, in general the wettest month of the year; but this rise is in one case (Bow Hill) broken by a heavy rainfall for March, and in others by a fairly heavy rainfall for April. Then comes a sharp fall to July—a fairly dry month—and another steady rise to October—a wet month. This is followed by a sharp fall to November—a comparatively dry month—and a sharp rise again in December, followed by a slight fall down to January.

Thus it is seen that June, October, and December, and in some cases April, are the wettest months; while February, July, and November are the driest months.

Table No. 5 contains the rainfall stations arranged in accordance with their elevation (approximate) above the sea, and shows how closely both the average and maximum annual rainfall follow the same order. The above graph showed that the same set of conditions operated throughout the Midlands, and this table (No. 5) proves that the amount of the rainfall at any particular place is determined by its height above sea-level.

Snow falls during the winter months on the Central Plateau, and is often very heavy, and covers the ground for considerable periods. It falls very occasionally at Oatlands (1332 feet), and never at Tunbridge (663 feet) and Ross (598 feet).

Table No. 3.

Bendeemer.

Year.	Jan.	Feb.	Mar.	April.	May.	June.	July.	Aug.	Sept.	Oct.	Nov.	Dec.	Total.
1899	302	101	332	216	180	353	112	104	248	326	121	241	2636
1900	211	170	152	373	97	348	262	687	54	237	61	305	2957
1	398	15	391	258	113	258	97	276	562	465	87	102	3022
2	371	225	95	97	110	323	130	143	331	62	124	280	2291
3	93	275	407	342	204	415	361	362	250	384	301	231	3625
4	447	445	139	129	268	383	155	202	231	124	204	147	2874
5	324	364	63	319	444	262	261	193	145	277	49	55	2756
6	42	125	99	185	200	503	470	229	391	819	323	81	3467
7	264	190	115	60	214	124	254	435	326	430	93	670	3175
8	59	227	239	25	288	109	152	136	268	161	175	79	1918
9	477	116	161	266	208	311	192	500	125	172	142	237	2907
1910	222	42	74	235	446	365	182	371	456	235	318	404	3350
1	2	267	456	150	248	159	310	64	237	129	43	410	2475
2	144	27	286	216	155	263	295	221	307	437	266	260	2877
3	115	30	263	225	112	68	243	557	190	164	188	231	2386
4	58	10	136	403	145	89	143	50	81	31	127	292	1565
5	31	46	287	278	293	113	278	209	418	368	106	94	2521
6	352	95	39	452	136	299	213	575	161	454	377	738	3891
7	109	232	186	141	348	445	179	254	340	415	282	112	3043
8	223	238	62	213	521	300	314	33	67	255	11	125	2362
9	66	256	28	93	232	476	108	108	43	196	55	119	1780
1920	47	47	136	98	215	493	380	257	344	130	107	185	2439
22 Years' Avge.	198	161	189	222	235	294	231	271	256	290	161	245	2744

Campbell Town.

Year.	Jan.	Feb.	Mar.	April.	May.	June.	July.	Aug.	Sept.	Oct.	Nov.	Dec.	Total.
1885	231	218	264	46	201	195	108	221	147	69	346	301	2347
6	226	161	156	225	175	25	94	252	162	268	169	87	2000
7	299	203	144	243	69	129	295	93	308	229	93	171	2276
8	122	7	3	158	139	289	129	130	275	87	59	141	1539
9	275	113	26	254	123	397	60	156	167	400	530	147	2648
1890	40	210	246	170	120	415	145	204	200	274	...	...	...
1	...	94	66	27	496	90	149	130	69	347	173	695	...
2	255	4	231	265	173	413	143	136	55	148	122	57	2002
3	369	...	1°6	231	280	96	381	234	212	212	16	61	...
4	172	53	133	216	279	161	167	268	273	132	52	224	2130
5	30	...	193	200	86	120	93	254	201	95	12	420	...
6	117	199	104	420	190	197	...	...	...	...	...	...	...
7	240	113	66	21	44	85	75	35	129	131	197	...	1136
8	44	...	16	188	82	130	165	81	150	132	310	97	1395
9	258	45	179	110	210	140	58	78	129	168	60	206	1641
1900	234	64	54	186	40	138	122	259	6	110	21	189	1423
1	257	...	230	275	52	145	75	218	268	311	33	36	1900
2	268	216	47	126	69	162	45	61	162	55	65	247	1523
3	6	158	270	291	193	276	232	196	233	257	138	141	2391
4	273	240	155	14	177	255	105	100	135	80	16	45	1595
5	320	295	55	130	255	100	230	65	155	390	50	95	2140
6	167	59	254	45	226	251	344	110	176	437	200	87	2356
7	206	163	60	58	171	93	161	368	227	366	59	551	2483
8	56	62	277	23	138	75	82	80	171	189	155	67	1375
9	509	121	105	339	134	299	160	284	112	162	168	165	2558
1910	213	28	136	181	330	245	103	194	393	238	129	481	2671
1	3	329	323	70	228	138	233	54	168	48	13	337	1944
2	139	38	169	233	96	233	80	122	190	264	250	296	2110
3	123	20	220	177	24	78	116	328	339	200	156	193	1974
4	58	13	108	201	120	113	158	40	40	38	159	127	1175
5	185	35	165	250	186	259	155	225	284	336	229	50	2359
6	282	166	36	361	89	206	167	327	212	366	391	815	3418
7	123	133	124	410	283	410	208	219	351	369	286	155	3071
8	58	203	80	145	395	261	209	66	151	292	29	163	2052
9	112	188	118	51	181	193	96	83	63	187	142	90	1504
1920	107	38	111	122	184	366	217	178	234	109	93	165	1924
31 Years' Avge.	190	115	140	176	163	193	147	162	188	215	152	191	2034

Beaufront (Ross).

Year.	Jan.	Feb.	Mar.	April.	May.	June.	July.	Aug.	Sept.	Oct.	Nov.	Dec.	Total.
1888	111	5	12	132	120	217	98	152	225	81	58	111	1322
9	288	95	18	259	94	367	78	104	122	298	541	200	2464
1890	58	191	260	96	77	428	108	156	152	189	221	59	1995
1	50	97	86	39	470	137	192	67	41	316	201	392	2088
2	268	5	181	258	150	281	107	103	66	90	117	33	1659
3	383	8	106	186	226	125	231	196	227	118	64	46	1916
4	115	32	128	185	282	100	210	296	228	167	33	157	1933
5	16	60	181	191	84	85	142	145	183	72	7	372	1538
6	84	67	131	160	154	95	103	136	82	76	85	71	1244
7	341	86	77	37	228	81	66	120	47	121	178	...	1382
8	25	13	99	241	66	114	170	110	133	145	247	52	1415
9	184	39	183	107	175	120	52	51	122	152	44	147	1376
1900	396	70	74	172	29	117	152	211	31	133	23	165	1573
1	246	...	279	201	59	164	30	230	228	229	34	22	1722
2	266	221	32	136	61	222	39	99	256	73	61	282	1748
3	43	187	216	222	221	281	149	133	171	385	238	159	2405
4	321	329	174	39	147	168	74	80	131	50	128	76	1717
5	326	266	38	111	371	122	162	58	93	297	44	148	2036
6	30	85	117	41	91	184	227	107	125	401	166	56	1630
7	349	222	48	37	141	69	125	218	144	312	43	573	2281
8	52	113	232	12	87	44	72	65	149	133	167	45	1171
9	463	117	155	266	138	307	86	245	112	142	124	121	2276
1910	237	11	87	184	246	223	90	154	275	161	154	372	2194
1	...	252	383	71	220	105	202	55	159	38	45	314	1844
2	84	30	150	198	100	234	86	85	157	296	187	306	1913
3	130	32	219	190	65	66	64	330	218	107	109	172	1702
4	24	10	103	194	104	65	122	15	59	50	104	163	1013
5	58	50	165	133	142	113	125	141	207	234	128	32	1528
6	267	161	8	313	88	165	139	319	164	260	344	668	2896
7	119	155	128	286	236	319	95	130	271	288	248	127	2402
8	98	218	26	162	325	176	155	59	118	223	96	141	1797
9	112	155	83	64	125	227	71	69	48	147	72	96	1269
1920	112	21	106	120	143	378	178	219	235	81	93	184	1870
33 Years' Avge.	171	103	130	153	159	179	120	141	150	178	134	178	1797

Roseneath (Ross).

Year.	Jan.	Feb.	Mar.	April.	May.	June.	July.	Aug.	Sept.	Oct.	Nov.	Dec.	Total.
1910 to 1915	No record												
1916	247	218	15	319	84	170	146	321	165	309	342	553	2889
7	124	154	157	202	256	317	148	155	292	300	259	126	2490
8	87	165	20	153	382	194	174	45	94	202	45	171	1732
9	108	186	99	60	159	313	82	86	81	145	70	102	1491
1920	110	17	90	117	177	365	221	211	250	72	91	200	1921
5 Years' Avge.	135	148	76	170	212	272	154	164	176	205	161	230	2105

Woodbury.

Year.	Jan.	Feb.	Mar.	April.	May.	June.	July.	Aug.	Sept.	Oct.	Nov.	Dec.	Total.
1908	...	...	...	...	...	...	...	...	...	...	...	35	...
1909	394	125	51	305	111	279	67	213	104	137	101	104	1991
1910	180	38	61	167	224	252	49	106	268	117	152	240	1854
1	9	192	364	135	292	115	91	46	92	103	36	206	1680
2	131	15	188	182	100	222	155	67	154	336	168	230	1948
3	147	19	242	179	20	66	74	201	132	118	142	140	1480
4	44	8	179	171	79	45	135	28	41	37	125	191	1083
5	47	43	145	180	202	73	59	116	210	214	100	22	1411
6	323	138	48	283	48	184	130	327	157	255	403	692	2988
7	108	129	175	268	268	337	110	110	269	223	194	140	2331
8	118	133	49	243	310	135	171	106	76	274	36	83	1734
9	87	155	99	55	102	208	55	54	39	134	31	95	1114
1920	110	30	105	106	96	320	216	247	205	82	93	225	1835
12 Years' Avge.	142	85	142	190	154	186	109	135	147	169	132	197	1787

Jericho.

Year.	Jan.	Feb.	Mar.	April.	May.	June.	July.	Aug.	Sept.	Oct.	Nov.	Dec.	Total.
1907	...	...	...	...	82	79	154	182	259	290	64	484	...
8	96	68	234	78	48	148	44	76	192	273	105	46	1408
9	408	97	57	356	146	283	79	154	124	68	123	255	2150
1910	187	45	53	171	135	244	79	88	268	141	97	214	1722
1	48	252	449	169	294	134	127	85	75	117	70	283	2103
2	105	13	191	204	133	312	195	72	193	278	202	275	2173
3	140	12	218	168	45	76	94	110	148	145	204	158	1518
4	20	7	188	272	55	56	198	82	49	60	231	145	1363
5	29	74	138	330	290	101	62	123	161	227	208	25	1768
6	400	210	53	349	61	248	225	312	195	174	506	884	3617
7	95	165	163	300	268	420	157	129	333	193	225	155	2603
8	141	167	108	156	312	161	162	142	154	281	52	93	1929
9	133	116	176	104	78	322	132	73	107	162	16	134	1553
1920	72	21	71	129	139	277	62	186	292	76	117	176	1618
13 Years' Avge.	136	96	161	208	154	222	122	125	169	169	166	219	1963

Oatlands.

Year.	Jan.	Feb.	Mar.	April.	May.	June.	July.	Aug.	Sept.	Oct.	Nov.	Dec.	Total.
1882	...	...	...	...	...	127	110	247	169	195	235	163	...
3	254	229	487	37	138	155	92	74	143	201	263	221	2294
4	318	94	58	36	105	241	78	294	139	239	99	412	2113
5	282	128	303	34	91	173	48	95	226	145	512	194	2231
6	352	193	125	245	192	44	74	367	159	247	255	91	2344
7	166	162	198	146	115	205	251	76	291	188	107	72	1977
8	89	3	44	94	203	202	20	129	282	135	141	172	1514
9	163	124	18	208	129	871	59	121	123	326	522	273	2937
1890	82	173	362	103	155	452	116	252	101	219	205	128	2348
1	94	92	86	65	314	249	248	89	24	289	180	369	2099
2	246	7	120	209	172	112	161	64	37	131	54	75	1388
3	458	7	78	239	239	182	365	110	157	90	128	67	2120
4	149	13	128	227	223	163	128	338	217	242	30	162	2020
5-8	No records												
9	165	15	251	189	130	144	61	75	151	135	91	106	1513
1900	270	67	167	321	47	183	153	299	56	164	27	168	1922
1	338	24	332	307	95	216	55	283	218	402	52	45	2367
2	288	245	85	132	101	257	72	92	326	65	86	411	2160
3	63	472	223	213	193	427	307	106	228	349	310	165	3056
4	298	299	254	50	124	256	68	126	143	68	198	53	1937
5	409	306	56	183	462	119	184	52	198	315	77	218	2579
6	15	55	93	172	68	142	211	64	163	420	242	93	1738
7	266	211	34	101	87	74	128	223	157	275	80	617	2253
8	61	135	170	43	99	135	62	83	232	227	117	51	1415
9	427	137	106	294	162	301	80	230	103	67	138	191	2236
1910	285	80	69	194	168	273	76	119	309	152	164	365	2254
1	15	265	437	139	350	148	160	69	118	134	60	307	2202
2	104	19	239	231	128	335	235	84	190	290	211	238	2304
3	118	17	260	180	54	101	120	187	172	167	177	170	1723
4	17	4	228	261	100	73	176	70	73	60	173	196	1431
5	54	79	147	284	213	99	88	162	241	224	194	23	1808
6	470	229	64	308	101	238	195	375	203	200	474	840	3697
7	151	155	192	367	305	381	136	157	374	247	267	224	2956
8	129	149	55	186	366	163	235	178	154	308	70	109	2102
9	119	158	172	103	135	296	104	81	67	163	38	140	1576
1920	103	28	88	128	136	303	216	241	263	70	134	288	1998
34 Years' Avge.	200	131	169	177	168	227	140	158	178	205	173	213	2136

Andover.

Year.	Jan.	Feb.	Mar.	April.	May.	June.	July.	Aug.	Sept.	Oct.	Nov.	Dec.	Total.
1900	...	...	...	...	...	...	...	...	4	154	29	162	...
1	634	19	387	298	124	288	98	284	198	375	59	73	2837
2	348	303	76	147	102	262	114	78	400	96	77	522	2525
3	61	397	190	199	281	458	337	110	287	305	251	228	3104
4	284	391	199	56	181	198	72	91	196	75	195	83	2021
5	375	315	120	161	617	99	235	76	187	451	83	164	2883
6	14	85	114	159	80	176	237	122	111	386	205	129	1818
7	285	198	110	123	137	88	153	208	223	185	72	514	2296
8	123	140	179	40	70	63	82	40	201	246	102	50	1336
9	409	88	99	323	202	384	98	199	138	90	160	163	2353
1910	214	72	73	227	130	215	108	65	212	222	119	539	2196
1	35	222	340	140	353	207	189	97	109	112	70	315	2189
2	107	54	234	176	120	337	184	108	227	297	225	242	2311
3	89	35	260	230	54	112	96	199	179	206	309	172	1941
4	59	14	243	329	66	45	164	82	68	10	218	324	1622
5	28	77	200	143	213	90	77	270	184	194	199	28	1703
6	436	527	82	438	82	214	188	354	200	272	412	838	4043
7	129	163	238	319	257	367	118	141	307	279	308	187	2813
8	187	195	85	217	259	167	311	180	162	275	80	103	2221
9	134	193	117	106	147	227	152	65	58	181	23	181	1584
1920	126	12	135	146	97	265	134	315	332	109	111	292	2074
20 Years' Avge.	202	170	174	199	174	213	157	154	199	218	164	257	2293

Mt. Seymour.

Year.	Jan.	Feb.	Mar.	April.	May.	June.	July.	Aug.	Sept.	Oct.	Nov.	Dec.	Total.
1905	...	...	...	...	...	...	...	186	286	461	68	276	...
6	25	105	172	225	114	191	277	98	139	686	162	192	2386
7	219	207	83	162	107	121	176	252	249	276	61	631	2544
8	92	71	260	66	108	229	67	74	257	319	99	54	1696
9	435	163	73	322	202	352	113	264	113	111	145	247	2540
1910	246	64	72	299	189	340	109	114	341	201	120	301	2396
1	50	220	481	158	379	195	152	83	94	119	78	312	2321
2	139	22	204	212	125	318	239	99	298	286	216	320	2478
3	116	26	259	263	73	61	100	158	163	165	315	178	1877
4	29	10	180	335	49	68	257	79	62	80	224	258	1631
5	32	83	161	204	288	115	83	275	195	211	213	20	1880
6	571	307	77	458	111	253	244	326	245	261	459	1046	4358
7	113	169	261	411	327	429	184	116	348	271	220	174	3023
8	146	196	50	140	288	184	221	153	207	363	90	102	2140
9	119	139	286	99	113	304	209	87	139	190	38	152	1875
1920	116	19	133	146	174	274	171	266	285	80	120	186	1970
15 Years' Avge.	163	120	183	233	176	229	173	163	209	241	171	278	2341

Bow Hill.

Year.	Jan.	Feb.	Mar.	April.	May.	June.	July.	Aug.	Sept.	Oct.	Nov.	Dec.	Total.
1910	...	...	...	...	...	...	...	124	400	172	169	332	...
1	32	209	1123	169	340	136	166	91	172	170	60	332	3000
2	118	44	204	243	166	351	258	92	251	380	144	246	2497
3	170	25	269	164	45	86	108	103	178	219	196	201	1764
4	36	7	195	375	77	107	207	98	137	106	335	189	1869
5	58	58	262	504	362	128	91	366	274	269	252	22	2646
6	583	294	109	383	102	269	252	374	239	201	471	958	4235
7	117	177	246	291	276	437	139	255	283	263	330	169	2983
8	155	129	120	203	397	139	300	175	179	172	64	105	2138
9	142	162	233	105	99	400	119	73	109	140	20	142	1744
1920	78	36	122	182	141	296	77	277	266	87	167	205	1934
10 Years' Avge.	149	114	288	262	201	235	172	191	209	201	204	257	2481

Interlaken.

Year.	Jan.	Feb.	Mar.	April.	May.	June.	July.	Aug.	Sept.	Oct.	Nov.	Dec.	Total.
1900	...	...	...	...	...	...	...	...	...	168	30	157	...
1901	359	17	285	240	72	127	90	340	277	421	54	129	2411
2	409	262	62	122	101	234	51	95	255	119	122	297	2129
3	47	311	383	222	139	534	628	209	292	532	280	317	3894
4	350	419	343	141	225	406	158	241	278	145	221	61	2988
5	519	267	87	873	845	249	373	144	398	412	131	281	4579
6	44	109	148	257	94	309	399	142	310	813	463	173	3261
7	160	273	110	171	...	...	...	...	...	...	...	...	...
8	...	...	...	...	...	...	...	...	...	...	...	...	...
9	...	...	...	212	285	324	98	215	111	101	157	186	...
1910	233	...	125	238	203	368	81	190	380	160	140	314	2432
1	...	171	774	173	345	175	170	72	114	164	39	252	2449
2	27	45	236	202	95	332	235	130	256	361	196	240	2355
3	...	...	...	...	...	...	...	...	...	...	...	...	...
4	...	...	...	...	...	...	215	66	92	42	158	215	...
5	50	40	197	378	238	92	87	350	347	292	213	6	2290
6	575	119	62	264	121	298	227	411	199	303	539	897	4015
7	82	227	230	362	342	431	138	176	321	270	284	95	2958
8	181	183	50	215	712	235	225	121	146	259	26	78	2431
9	58	156	176	104	134	283	136	59	66	125	10	120	1427
1920	33	24	107	113	107	256			No record				
19 Years' Avge.	207	166	226	270	262	291	214	191	260	313	194	233	2830

Dog's Head.

Year.	Jan.	Feb.	Mar.	April.	May.	June.	July.	Aug.	Sept.	Oct.	Nov.	Dec.	Total.
1889	333	281	67	182	233	1370	222	211	193	361	852	327	4632
1890	82	658	498	166	295	1381	299	611	287	408	333	189	5207
1	235	138	110	120	427	801	572	187	59	439	280	708	4076
2	310	18	322	606	298	564	250	194	96	410	162	99	3329
3	847	19	103	455	470	654	1357	263	289	372	216	247	5292
4	222	64	296	524	782	321	146	570	479	405	...	...	...
1895 to 1909	No record												
1910	...	...	...	...	...	...	126	203	417	149	261	456	...
1911	31	235	960	125	335	168	236	86	189	154	51	244	2814
1912 to 1915	No record												
1916	...	...	...	...	...	...	...	437	219	358	546	1066	...
7	84	236	226	322	426	553	157	351	311	331	380	187	3564
8	177	185	57	219	488	225	204	253	172	343	48	114	2485
9	82	184	126	103	222	406	219	76	52	187	48	111	1816
1920	59	24	129	129	115	387	315	373	367	138	165	322	2523
10 Years' Avge.	224	198	260	243	331	651	383	261	202	314	253	255	3594

TABLE No. 4.

Station.	Yearly Rainfall.					Monthly Rainfall.				
	Average.	Maximum.		Minimum.		Average.	Maximum.		Minimum.	
		Points.	Year.	Points	Year.		Pts.	Month.	Pts.	Month.
Oatlands,	2136	3697	1916	1388	1892	178	871	June, 1889	3	Feb., 1888
1882-1920		3056	1903	1415	1908		860	Dec., 1916	4	Feb., 1914
Woodbury,	1787	2988	1916	1083	1914	149	692	Dec., 1916	8	Feb., 1914
1909-1920		2331	1917	1114	1919		403	Nov., 1916	9	Jan., 1911
Bow Hill,	2481	4235	1916	1744	1919	207	1123	March, 1911	7	Feb., 1914
1910-1920		3000	1911	1764	1913		958	Dec., 1916	20	Nov., 1919
Dog's Head, 1889-1911,	3594	5292	1893	1816	1919	300	1381	June, 1890	18	Feb., 1892
1916-1920		5007	1890	2485	1918		1370	June, 1889	19	Feb., 1893
Mt. Seymour,	2341	4378	1916	1631	1914	195	1046	Nov., 1906	10	Feb., 1914
1906-1920		3023	1917	1696	1908		686	Dec., 1916	19	Feb., 1920
Ross,	2105	2889	1916	1491	1919	175	553	Dec., 1916	15	March, 1916
1916-1920		2490	1917	1732	1918		382	May, 1918	17	Feb., 1920
Jericho,	1963	3617	1916	1363	1914	164	884	Dec., 1916	7	Feb., 1914
1907-1920		2603	1917	1408	1908		506	Nov., 1916	12	Feb., 1913
Interlaken, 1900-1907,	2830	4579	1905	1427	1919	236	897	Dec., 1916	6	Dec., 1915
1910-1919		4015	1916	2129	1912		873	April, 1905	10	Nov., 1919
Andover,	2293	4043	1916	1336	1908	191	838	Dec., 1916	4	Oct., 1900
1901-1920		3104	1903	1584	1919		634	Jan., 1901	10	Oct., 1914
Ross (Beaufront),	1797	2896	1916	1013	1914	150	668	Dec., 1916	0	Feb., 1901
1888-1920		2464	1889	1171	1908		541	Nov., 1889	0	Jan., 1911
Bendeemer,	2744	3891	1916	1565	1914	229	819	Oct., 1906	2	Jan., 1911
1899-1920		3625	1913	1780	1919		738	Dec., 1916	10	Feb., 1914
Campbell Town,	2034	3418	1916	1136	1897	170	815	Dec., 1916	0	Dec., 1897
1885-1920		3071	1917	1175	1914		695	Dec., 1891	0	Feb., 1898

TABLE NO. 5.

Station.	Record.	Elevation Above Sea.	Yearly Rainfall.	
			Average.	Maximum.
	Years.	Feet.	Points.	Points.
Dog's Head	10	2700	3594	5292
Interlaken	19	2700	2830	4579
Bow Hill	10	1500	2481	4235
Mt. Seymour...	15	1500	2341	4378
Andover	20	1330	2293	4043
Oatlands	34	1330	2136	3697
Jericho...	13	1270	1963	3617
Woodbury	12	808	1787	2988
Beaufront (Ross) ...	33	700	1797	2896

(6)—VEGETATION AND TIMBER.

All the district was probably covered by a growth of trees, but large areas of it have now been practically cleared, and the land devoted to agricultural and pastoral purposes. This applies mainly to the less elevated ground in the vicinity of Ross, Tunbridge, Woodbury, York Plains, Oatlands, and other localities; while the more elevated ground still maintains a fair growth of trees. The commonest trees are white-gum, stringy-bark, peppermint, swamp-gum, and wattle. The timber on the whole is poor, though large trees (mainly stringy-bark) occur at various localities.

The largest trees are to be found on the slopes of the Western Tiers, especially on the sides of creeks and gullies. On the Central Plateau they are small in size, and the same applies to most of the localities in the district. On the summit of Table Mountain they are dwarfed, and average 10 to 12 feet in height. The nature of the soil and underlying rocks plays an important part in the nature of the trees and vegetation.

Diabase should provide a good soil, but there is seldom any depth of it, and the trees are never large. On the less elevated parts the she-oaks seem to be restricted to growth on diabase soil, but whether this is so or the she-oaks have been cleared off sandstone soils it was not possible to determine; but, nevertheless, diabase outcrops could always be picked out from a distance by the she-oaks growing there.

The soil which provides the largest trees is a diabase one with a large admixture of sand in it. This soil, especially on the sides of creeks and gullies, gives growth to tall stringy-bark and white-gum trees. On more level and dry ground this soil is favoured by the peppermint, though they do not reach any size.

The loose sandy soil from the sandstones is much favoured by wattles. The soil does not support many large trees, but is thickly covered by a growth of young wattles and gums, this condition of affairs being probably due to bush fires. Bracken fern and "sags" flourish on this loose sandy soil.

The timber, while unsuitable to the establishment of the timber industry, has, of course, many local uses for farming and pastoral purposes. Chief among its uses are those for fencing (posts, rails, and droppers), building (palings and shingles), and general constructional work like bridges. As firewood, it forms the only source of fuel for the district, and at the present time considerable quantities are railed to Hobart and other places.

IV.—GEOLOGY.

(1)—Introduction.

(a) *Summary.*

Except for a very small outcrop of granite of, probably, Devonian age, the oldest rocks occurring in the district are those of the Permo-Carboniferous system. These are followed by the sediments of the Trias-Jura system, and both these formations are intruded by the Upper Mesozoic diabase. Tertiary basalt occurs as flows, dykes, and plugs in small isolated patches, and in some cases the flows are overlying pre-basaltic river deposits.

Alluvium is forming along the courses of the streams at some places during the present time.

Sedimentary and igneous rock types occupy nearly equal proportions of the surface, with the igneous slightly in excess.

The sedimentary formations are generally horizontally bedded, and while local dips are common, general dips are practically absent. Of these formations the Trias-Jura sediments occupy nearly all the surface, the underlying Permo-Carboniferous being exposed in a few small outcrops only.

Of the igneous rocks, diabase predominates, and occurs throughout the district.

(b) *Maps and Sections.*

The geological sketch-map of the district is to be seen in Plate II. The pre-basaltic and post-basaltic alluvial deposits are not shown on the map, but the localities where they occur are indicated in the descriptions, such a course being adopted because these deposits are of very limited extent, and outcrop over a very small area, especially in the case of the pre-basaltic deposits.

Where possible the Trias-Jura strata are divided into their proper series, these being indicated by the letter "L" for the lower or normal sandstone series, and "F" for the felspathic sandstone series (this series would be considered the upper series in the Midlands, but in correlation with the other districts this would probably have to be altered to middle, and so the use of either "U" or "M" is avoided).

Three geological sketch sections are given in Plate III. These give a good idea of the structure of the country and the relations of the diabase and the intruded sedimentary strata. The relations between the "displacements" of the sediments and the adjacent masses of diabase are also strikingly illustrated.

(2)—The Sedimentary Rocks.

(a) *The Permo-Carboniferous System.*

The rocks of this system outcrop at the following localities:—

(1) Around Ross in the North of the District.—The main types are fine-grained white mudstones (probably calcareous) and limestones, in which marine fossils are abundant. West of Ross a thickness of at least 300 feet of this series is visible, the top underlying the Trias-Jura basal conglomerates, while the base is hidden by alluvium. In the "Pipeclay" cutting, 1 mile north of Ross, a massive bed of white clay at least 10 feet thick underlies the ordinary white mudstones. This clay-bed contains a small number of small water-worn pebbles of quartz, quartzite, quartz schist, and quartz mica schists, arranged in parallel lines along bedding planes.

These strata are generally horizontally bedded, but dips of 6 degrees to the south occur north of Ross, and also around Wetmore Homestead, 3½ miles south of Ross.

(2) Two very small outcrops of white mudstones overlain by conglomerates (both somewhat metamorphosed) occur on the slopes of the Western Tiers near the heads of Vicary's and Blackwood Creeks, along the Tunbridge Interlaken road.

(3) In the extreme south of the district similar strata also occur.

North-east of Baden white mudstones are found associated with overlying conglomerates, both being horizontally bedded.

Along the Coal River, to the east and south-east of Lake Tiberias, very interesting sections of Permo-Carboniferous and Trias-Jura strata are found as the river follows a fault for a couple of miles. The Permo-Carboniferous strata appear on the upthrow side of the fault, where the beds dip in at 6 degrees towards the fault.

At the northern end of the section brown and white mudstones underlie the basal conglomerates of the Trias Jura system. These are thickly bedded with bedding-planes about 2 feet apart, and have developed a remarkable system of prismatic jointing (at right angles to the bedding-planes) similar to that seen in igneous rocks. Going south along the section, there appears, below about 70 feet of the white mudstones, a series of dark-coloured thinly-bedded shales, which are exposed to a depth of 50 to 100 feet at the lowest part of the section.

Thus it is seen that the Permo-Carboniferous strata in the Midlands consist mainly of white mudstones, with lesser amounts of limestones, dark-coloured shales, and clay representing marine sediments. The strata are for the most part horizontally bedded, dips being purely local and occurring in the vicinity of faults and diabase intrusions. The greatest thickness exposed is to the west of Ross, where 300 to 400 feet are found, and the base is not visible.

With regard to the age of these beds, they are to be correlated with the Lower Marine formation of the Permo-Carboniferous system.

Fossils were obtained from two localities, and the following notes were kindly supplied by Mr. H. H. Scott, of the Launceston Museum:

"Locality 2½ miles West-South-West of Ross—

These are all Lower Marine Permo-Carboniferous in origin, and contain specimens of *Rhynchonella spirifera*, *Productus*, the tip of a *Conularia*, and the characteristic polyzoa of this system in about the usual ratio of frequency. A few fragments of internal parts of gastropods are manifested, and also four impressions of caryophylloid corals of seemingly two genera, at least.

Locality 4 Miles West of Ross—

These contain chiefly impressions of *Fenestella*, *Protoretepora*, and the cast of a *Spirifera* (probably *Duodecimcostata*)."

A. M. Reid,(4) Assistant Government Geologist, visited Ross in 1918, and considered these beds to be Permo-Carboniferous.

In a recent paper (5) Prof. T. W. E. David deals with the Carboniferous and "Permo-Carboniferous" rocks,

(4) "Report on the Saline Deposits in the Macquarie Basin, County of Somerset, Tasmania," by A. M. Reid, Assistant Government Geologist.

(5) Reprint from Proc. Royal Society, N.S.W., Vol. LIII.: "Sequence, Glaciation, and Correlation of the Carboniferous Rocks of the Hunter District, N.S.W.," by C. A. Sussmilch, F.G.S., and Prof. T. W. E. Edgeworth David, C.M.G., pp. 303 and 331.

and regards the "Permo-Carboniferous" system from the *Eurydesma cordatum* beds of the Lower Marine series to the top of the Newcastle series as Permian in age. In agreement with this, the "Permo-Carboniferous" system of Tasmania will have to be considered as Permian also.

(*b*) *The Trias-Jura System.*

(1) *Rock Types.*—The rocks of this system are extensively developed in this district, and occupy approximately 40 per cent. of the surface. They occur from elevations of 2700 feet at Lake Crescent, down to 600 feet above sea-level in the vicinity of Ross. These rocks are essentially a series of lacustrine sediments, containing as fossils the remains of land vegetation, with no marine organisms. False bedding is common, and the series was probably deposited in a large shallow lake under somewhat arid conditions. These rocks are generally horizontally bedded, dips (when they do occur) being purely local, though general dips exist at one or two localities for some distance. The local dips are generally found near diabase intrusions and faults. A small, very shallow anticline is visible along the Stringy-bark Creek, 2½ miles south-west of Woodbury. On the north-west bank of the Blackman's River, below the northern end of Flat-top, for a length of 15 yards, sandstones are folded into a series of very steep anticlines and synclines, the disturbing element probably being the neighbouring diabase.

The rock types are numerous, and consist of the following:—

(i) Arenaceous or Siliceous Types:

Conglomerates.—These consist of waterworn quartz and quartzite pebbles in a matrix of coarse quartz sand and grit.

Grits.—These are composed of coarse angular pieces of quartz up to the size of a pea.

Sandstones.—Sandstones are the predominant rock type of this system, and outcrop extensively in the Midlands district. These rocks consist of small grains of quartz (or sand) up to one-sixteenth of an inch in size, with a small proportion of cementing material holding them together, the cement being probably of a clayey nature. White mica is present chiefly along the bedding-planes, and makes a large display when the rock is split along a bedding-plane, though actually the amount of mica present is small. The quartz grains, both in the solid rock and when weathered loose and lying on the surface, glisten very brightly when the sun's rays fall on them, due to the presence of fairly smooth fracture faces, and probably crystal faces also.

The colours of these rock types are variable—white, grey, buff, light-yellow to light-brown, and variegated—the colours being due mainly to the presence or absence of iron compounds.

In texture these rocks are fine, medium, and coarse grained, according to the size of the component grains. The medium to coarse grained types are the most common, and occur plentifully over the district, while the fine-grained ones are less common, and occur mainly in the vicinity of Oatlands.

The sandstones are for the most part massively bedded (*i.e.*, bedding-planes are far apart), but the finer-grained sandstones are often thinly bedded. Current bedding is fairly common.

A remarkable feature of these sandstones is the presence of numerous flat ellipsoidal inclusions of an argillaceous nature. These inclusions are well waterworn or weathered, as all edges are rounded, and probably represent weathered and waterworn fragments of old shales and slates. These inclusions range up to 3 inches long, 2 inches wide, and $\frac{1}{4}$-inch thick, but the usual size is 1 inch by $\frac{1}{2}$-inch by $\frac{1}{8}$-inch.

(ii) Argillaceous:

Felspathic Sandstones.—Next to the sandstone type, the felspathic sandstones are the most plentiful. These rocks are buff, blue, or white in colour, and medium-grained in texture. In the hand specimen they are seen to consist of roughly equal proportions of a white mineral (felspar, fresh or decomposed) and a coloured mineral (blue, dark-green, or brown), quartz being seldom visible.

Under the microscope the rocks are found to consist of the primary minerals, felspar (very much altered), quartz, and a little biotite, with secondary calcite and chlorite. The felspar forms about 80 per cent. of the rock, and is very much decomposed. The ultimate decomposition product is a dark-grey opaque mass of probably kaolin, sometimes with and sometimes without included oxides of iron, and this represents the blue, dark-green, and brownish grains visible in the hand specimens. Some of the felspars are comparatively fresh, and both orthoclase and plagioclase are to be recognised, though a determination of the relative proportions of these is impossible. The quartz consists of clear angular grains, sometimes showing crystal boundaries. Inclusions in the quartz are common, and consist of small crystals of apatite, and possibly tourmaline, along with other very small and unrecognisable inclusions. A few fragmentary flakes of biotite occur, most of which are partly or wholly altered to chlorite.

Secondary calcite occurs to the extent of about 5 per cent. as interstitial matter, being probably derived from the decomposition of the plagioclase felspars.

This rock type is thus seen to consist mainly of decomposed felspar (80 per cent.) and quartz (15 per cent.), and probably had its origin in the denudation of an acid igneous rock, approaching a granite or granodiorite. The name "felspathic sandstone" has been applied to it, as it has previously been called that, the only other name that could be applied to it being "greywacke."

The results of an analysis by W. D. Reid, Government Assayer, of a sample from the north-east slopes of Pike's Hill, east of Jericho, are given below:

Constituents.	Per Cent.
Silica (SiO_2)	65·90
Alumina (Al_2O_3)	12·20
Ferric oxide (Fe_2O_3)	11·00
Lime (CaO)...	1·20
Magnesia (MgO)	0·01
Potash (K_2O)	3·10
Soda (Na_2O)	2·85
Water (H_2O)	3·50
	99·76

These results agree with the above remarks, and prove the rock to consist of mainly fresh and decomposed potash and soda felspars. Secondary calcite was not abundant, while oxides of iron were very abundant in this sample.

The calcite content of the rock is an interesting feature, and, in addition to that seen under the microscope, it is visible in the field in several different ways. Along the main road, ½-mile south of Lemon Hill, the above rock type outcrops and appears pure white, due to the distribution of calcite throughout the rock. At York Plains, Brent's Sugarloaf, and along Flat-top Creek large concretions of calcite are found in the felspathic sandstones. These are flat ellipsoidal masses, occurring parallel to the bedding-planes, and sometimes arranged along these planes in definite lines, being occasionally sufficiently numerous to suggest a limestone bed. The largest concretion seen measured 10 feet in length, and 12 inches to 15 inches in thickness, the usual size being 18 to 24 inches by 6 inches. Definite proof of the concretionary origin of these masses was found on breaking one situated on the east bank of the Flat-top Creek, just north of the Oatlands-Interlaken road. This mass consisted of an external shell of calcite several inches thick, with a kernel of slightly altered, but still unreplaced, felspathic sandstone. Generally the replacement of the original rock was complete, and the concretionary origin of these masses, though suggested, could not be proved. Small veins of calcite occur, sometimes being coloured red or pink, and other times black (at Brent's Sugarloaf), the colour being due presumably to impurities.

Mudstones.—These are not developed to any great extent, but occur mainly with the felspathic sandstones, and particularly with the coal seams. They are composed of clay, being very compact in appearance, and either white or black (due to carbonaceous matter) in colour. They are rendered very "greasy" when wet, and "pug" very easily with water.

(2) *Stratigraphy.*—The rocks of the Trias-Jura system in the Midlands can be divided into two main series—

(i) The Lower, or Sandstone, Series.—The base of this series consists of the basal conglomerates, which rest on the limestones and mudstones of the Permo-Carboniferous system. It then passes up through grits into the normal sandstones of the Trias-Jura system.

Around Ross the basal conglomerates are up to 30 feet in thickness, but along the Coal River they are only 1 foot thick. The grits are not prominent in the area round Ross, but attain a thickness of 50 feet along the Coal River, and then pass gradually into the normal sandstones. Along the Coal River, near the junction of Hunter's Creek, cliff sections show 600 feet of sandstones. The Trias-Jura sediments will extend below the bed of the Coal River for a further 150 feet at least. Above the Coal River sections a small thickness only of sandstones probably exists, as felspathic sandstones come in at about the same level at points around Lake Tiberias and at Pike's Hill.

So, in the Coal River area this lower, or sandstone, series consists of 50 feet of conglomerates and grits, followed by at least 700 feet of the normal sandstone. In other areas the thickness of this series is not determinable.

(ii) The Felspathic Sandstone Series.—This series consists mainly of felspathic sandstones, but also has associated mudstones and coal seams. The mudstones occur as comparatively thin beds throughout the series, and are particularly found forming the floor to the coal seams.

The few outcrops of coal (with the exception probably of that at Mike Howe's Marsh) are all found in the felspathic sandstone series.

A thickness of at least 500 feet of this series is obtained in the York Plains area, and 350 feet at Brent's Sugarloaf, but the base, and its relation to the underlying sandstone series, is not seen in either case. The top of the felspathic sandstone series in both the above localities is represented by a diabase sill. A very intersting conglomerate bed occurs in this series at Brent's Sugarloaf and Mt. Pleasant, and will be a very useful stratigraphical horizon. It occurs near the top of the series in association with a slight unconformity, probably representing a slight period of absence of deposition followed by a renewal under flood conditions. In sections this bed is very thin, and consists of a line of small waterworn pebbles up to 6 inches maximum size, but around the above two hills numerous waterworn pebbles, and boulders up to 18 inches maximum dimension occur, having been weathered out from the conglomerate bed. These pebbles are always well waterworn, and consist mainly of quartz, quartzite, and acid igneous rock types. The interesting pebbles are those which are crowded with lower marine Permo-Carboniferous fossils. These pebbles are all waterworn, and shed from the conglomerate, and form an interesting example of "*remanié*" fossils. These pebbles are in relatively small numbers in comparison with the other pebbles, but it is surprising how easily they can be found on the surface of the ground around these hills.

(iii) Though where visible the top of the felspathic sandstone series is represented by a diabase sill, and no sediments can be proved to exist above the felspathic sandstone series in the Midlands, it seems probable that other sediments did exist, and these may be represented by some of the sandstones which occur high up on the Western Tiers and on the surface of the Central Plateau.

Support is given to this view in a report (6) by C. Gould, who examined the country along the railway-line from Oatlands to Richmond. He separated the sandstones seen in this area into—

(1) An upper division, the dominant type being "a sharp quartzose sandstone, more or less ferruginous, in thin layers, with much false bedding."

(2) A lower division of "bluish-grey sandstone, variegated with dark spots, friable, thickly bedded, alternating with a large proportion of shale and clay."

The lower division corresponds to the felspathic sandstone series, and the upper division may correspond in part (because Gould places the normal sandstones of the Coal River in his upper division, whereas they are part of the lower, or sandstone series, and underlie the felspathic sandstone series) to an upper sandstone series, which overlies the felspathic sandstone series. Gould must have had some definite evidence of a sandstone division overlying the felspathic sandstones, especially as he records pebbles of shale and sandstone as existing at the junction of the two divisions at some localities, and the similarity of the normal sandstone type would naturally lead him to place all the normal sandstones in his upper division.

So, ultimately, the Trias-Jura sediments may be proved to have the following three subdivisions:—

(iii) The Upper Sandstone Series.

(ii) The Middle or Felspathic Sandstone Series.

(i) The Lower Sandstone Series.

(6) "Report on Midland Coal Field," 1869.

(iv) Relation Between the Lower Sandstone and the Felspathic Sandstone Series.—The relation of Series (i) and (ii) appears to be a conformable one. No section is available where the relation can be studied, but everything supports the above relation as being correct. Along the south of the Tunbridge Plains and at York Plains, the felspathic sandstones are clearly at a higher level than the sandstone series. When a comparison can be made betwen the dips of the two series, they are found to be the same (*i.e.*, generally horizontal). At several localities the main rock types of the above series are found to be interbedded with one another, and though it is difficult generally to assign these outcrops to their correct series, it proves that the two rock types are intimately associated with one another, and that the relation of the two main series of these rocks is a conformable one. This interbedding is visible at the following localities:—

(*a*) One mile south-west of Murderer's Tier, and just south of the Oatlands-Inglewood road—here 40 feet of normal sandstones are interbedded in the felspathic sandstone series.

(*b*) Along the Main-road, ½-mile south of Lemon Hill, a section in ascending order shows:—felspathic sandstones, 4 feet of mudstones, sandstones.

(*c*) On the northern slopes of Pike's Hill general sections show in ascending order:—mudstones, felspathic sandstones, and sandstones.

(3) *Age*.—With regard to the age of these beds, the present state of our knowledge is such that the term Trias-Jura must be applied to these beds. The plant remains so far obtained show relationships with those of Triassic, Trias-Jura, Rhætic, and Jurassic systems in other parts of the world, and no characteristic species occur which can assign these beds to any definite system of those mentioned above. For the present, then, the period of sedimentation of these beds is regarded as embracing both the Triassic and Jurassic systems.

A fair collection of plant remains were obtained in this survey, and they are now in the hands of H. H. Scott, of the Launceston Museum, who is now working on them. For the present he supplies the following note:—

"The work of description is far from being completed, and the time problem involved is as follows:—

"It has hitherto been assumed that the so-called 'Trias-Jura' formations of Tasmania are correlated with the Clarence River beds in New South Wales. Fiestmantle admitted that some of the beds might be Jurassic and others Triassic. Tenison Woods listed the Jerusalem basin beds as being Jurassic, and since his day the only fossil I have worked upon (out of the Midlands collection) has been correlated by Seward with similar plants from the Jurassic of South Africa and Siberia. Just what the rest of the evidence will yield, I cannot at present say, but naturally I hope for a definite result, and will hand in my deductions later on. A problem such as this is to be solved rather by an assemblage of cumulative facts, whose mass will amount to the cogency of proof, rather than by the finding of any one fossil, as was so often relied on in times past, hence the need for detailed work."

It is very probable that these strata are to be correlated with the Jurassic rocks of Victoria. Tasmania and Victoria are not very far apart, and the strata in these two States may easily be the result of the same sedimentation, especially as there is a lithological similarity between the rock types of the two areas—normal and felspathic sandstones being the predominant types.

(c) *Pre-Basaltic River Deposits.*

These deposits are visible underlying the Tertiary basalt along the southern bank of the Macquarie River, between Blackman's River and Kitty's Rivulet, and represent the deposits formed along the course of the pre-basaltic Macquarie River. These deposits occur up to a height of 40 feet above the level of the present Macquarie River. The rock types are conglomerates, loosely compacted sandstones, clay, and carbonaceous beds. Of the pebbles in the conglomerates, the most numerous and striking are those of dense black cherty types (metamorphosed Trias-Jura sediments), and fragments of silicified wood. Similar deposits are found under the flat-topped basalt hills around Ballochmyle Homestead, 2 miles north of Tunbridge. Here the included fragments are those of silicified wood, in the form of common and semi-opal.

(d) *Post-Basaltic Deposits.*

Overlying the basalt which occurs to the east of Ross, and extends northwards towards Campbell Town, surface deposits of a sandy nature occur in numerous localities. These deposits are thin, and seldom exceed 10 feet in thickness, and were formed during the disarrangment of the drainage system caused by the flooding of the system by the basalt lava-flows. The adjustment of the drainage practically ended the deposition, but hill talus and wash from adjacent elevated areas are still causing formation of these deposits.

At other localities, *e.g.*, 1 mile north of the junction of the Glen Morriston Rivulet and the Macquarie River, fragments of silicified wood, similar to those in pre-basaltic deposits, occur overlying the basalt, and represent deposits formed immediately after the disarrangement of the drainage.

(*e*) *Recent Deposits.*

(1) *River Alluvium.*—Recent deposits of alluvium are in the process of formation along the courses of the present streams where they are approaching maturity, and flow over areas of the sedimentary rocks. The alluvium is always very dark-coloured, and is composed of weathered products of the adjacent rock formations.

(2) *Wind-Blown Sand.*—The wind is moving the sand formed by the weathering of the sandstones in certain localities in the district. The chief locality is along the eastern shores of Lakes Crescent and Sorell, where deposits of wind-blown sand occur several hundred yards in width, and up to 20 feet in thickness. The sand is derived from the shores, and beds of the lakes when the water-level is low, and represents the remains of former sandstone areas. The general westerly (south-west to north-west) direction of the wind causes these deposits to form along the eastern shores of the lakes.

On portions of the Tunbridge Plains, the wind is starting to shift the sandy soil, but no definite deposits have yet been formed. This occurs chiefly in dry seasons, when the vegetation is scanty and the soil largely exposed.

(3)—The Metamorphic Derivatives.

The metamorphism of the sedimentary rocks is due principally to the intrusion of the Upper Mesozoic diabase, but the Tertiary basalt flows also played a small part.

(a) *Metamorphism Due to the Diabase*

(1) *Permo-Carboniferous System.*—The rocks of this system outcrop over only a small part of the district, and though intruded by diabase no metamorphism is visible in the field, the only effect being probably a slight hardening of the mudstones.

(2) *Trias-Jura System.*—Metamorphism of the rocks of this system is evident in many localities in the district, and is found to be variable in extent and nature, giving rise to the following rock types:—

(i) From the Arenaceous Sediments:

Cherts or Hornstones.—These represent the extreme effect of the metamorphism, and occur adjacent to the diabase mass. The top of a more or less horizontal mass of diabase seems to have a greater metamorphic effect than the steeply rising side of the intrusion, or rather this is suggested by the occurrence of the above rock types in this position.

These rocks are dense, homogeneous-looking rocks, with no signs of any grains or crystal structure in them, generally black in colour, but occasionally light-blue, and on being broken have a very "flinty" fracture and appearance. Horizontal banding can be generally seen, and may correspond with the original horizontal bedding-planes of the rocks.

Under the microscope these rocks have a microcrystalline structure, with a very few larger mineral aggregates. The microcrystalline groundmass consists of, roughly, equal proportions of mineral particles of either quartz or felspar (probably quartz), dark, black spots, which may be oxides of iron, and a greenish substance giving colours the same as the quartz mentioned above. Numerous dark patches stand out from the groundmass, and under high power are seen to consist of larger masses of the green substance along with particles of the black mineral. A few clear areas of quartz are visible standing out from the groundmass. Roughly parallel lines, sometimes of the dark mineral and other times of groundmass material practically free from the dark mineral, are visible in the section.

These types occur at the following localities:—

Three-quarters of a mile south of Antill Ponds, extending from the Main-road for about 3 miles in an easterly direction.

Two and a half miles north of Oatlands.

Four and a half miles west of Woodbury, on the old Tier-road.

Around the heads of the Curryjong Rivulet, and along Flinty Bottom.

One mile north-east of Mt. Pleasant.

Three-quarters of a mile south of Old Man's Head, and $\frac{3}{4}$-mile west of Oatlands-Interlaken road.

Half a mile east of Lake Sorell, at the Diamond Beach and Dog's Head.

Three-quarters of a mile south of Green Sugarloaf, 4 miles east of Ross.

Two miles south-east of junction of Jordan River and Dulverton Rivulet.

Below sill at Brent's Sugarloaf, 5 miles south-east of Tunbrid.

Quartzites.—These represent the less extreme effect of metmorphism above flat-topped diabase intrusions, and probably the extreme effect of steep-sided intrusions. These are generally white, sugary-looking rocks produced by recrystallisation of part or the whole of the original quartz in the sandstone.

Some of the localities where this type is found are—

The Nook, 2 miles west-south-west of Woodbury.

Four miles west of Woodbury.

Near head of Flood's Creek, 8 miles west of Tunbridge.

Eight miles along Tunbridge-Interlaken road.

Two miles east of Tunbridge.

Junction of Junction Creek and Blackman's River.

Altered Sandstones.—These represent the least effect of metamorphism, and include all types, from those almost quartzites to the almost normal sandstone. Slight recrystallisation has probably occurred, and these types differ from the normal sandstone in being much harder and better cemented.

The following localities are a few where good examples of these types occur:—

York Rivulet, 2 miles south-east of Antill Ponds.

Main-road, 2½ miles north of Oatlands.

Three-quarters of a mile south of Old Man's Head.

Coal River, ½-mile north-east of school, near Stonor.

(ii) From the Argillaceous Sediments:

Cherts and Hornstones.—These probably occur as the extreme effects of metamorphism of the felspathic sandstones, just as in the case of the normal sandstones. The large development of these types to the south and south-east of Antill Ponds is probably the result of metamorphism of the felspathic sandstones.

Altered Felspathic Sandstones.—These types occur similarly to those of the ordinary sandstones, but are not so common on account of the less occurrence of the felspathic sandstones. This type is represented in an outcrop 1 mile E.S.E. of Andover Railway-station, hardening and alteration of the rock being very noticeable.

Indurated Mudstones.—The effect of metamorphism on the mudstones is to indurate and harden them. In addition, there is generally developed a series of minute cracks or joints in the rock, and on touching or handling a piece it crumbles easily into lumps averaging about ¼-inch in dimensions.

Such types occur at the following localities:—

Along the Main Line Railway, between Antill Ponds and York Plains.

Around Brent's Sugarloaf.

Near the head of Blackman's River.

(*b*) *Metamorphism Due to Basalt.*

This metamorphism is very small in extent and effect, as the flows and dykes occurring are generally of very limited extent.

The rock type produced is always a dense, fine-grained light-coloured quartzite, due to alteration of the original rock, soil, or river deposits over which the flow extended.

These quartzites occur at the following localities:—

East of Ross.

Along the Macquarie River, between the Blackman's River and Kitty's Rivulet.

Don's Battery.

One and a half mile south-west of Parattah.

Half a mile north of Andover Railway-station.

At the last locality metamorphism of the Trias-Jura sandstone has produced a quartzite similar to those formed by the diabase metamorphism.

(4)—Relation Between the Permo-Carboniferous and Trias-Jura Systems.

Up till the present time, the rocks of these systems have been mapped together, and though proof that they were not conformable was lacking, it was believed that a break actually occurred between the two systems. The rocks of these two systems are found to be horizontally bedded or dipping at a low angle, and no difference in the dips of the two systems can be detected, thus making their relation appear conformable.

The following evidence points to a time interval between the two systems, and the existence of a " disconformity " between them in the Midlands.

(*a*) *Evidence in the Field.*

(1) The sudden change of conditions from the deposition of marine limestones and mudstones to that of fresh-water conglomerates passing through grits into normal sandstones.

(2) In the bed of the Coal River, below the school, 2 miles south of Stonor, a section exposed shows the basal conglomerates of the Trias-Jura system, resting on a slightly uneven surface of Permo-Carboniferous mudstone, and further the conglomerate contained a mudstone pebble from the underlying mudstone bed.

(3) The conglomerate bed, already described in the felspathic sandstone series of the Trias-Jura system, contains numerous well-waterworn pebbles of Permo-Carboniferous rocks with typical lower marine fossils.

(4) Thirty yards west of the Main-road, 1 mile north of the White Lagoon, between Ross and Tunbridge, much gravel occurs on the surface, due to weathering of the basal conglomerates of the Trias-Jura system.

A pebble was found in this gravel similar lithologically to the pebbles described in (3) above, and it contained a pentagonal impression described by Mr. H. H. Scott, of the Launceston Museum, as "probably an impression of an encrinital segment," together with some very indistinct traces of polyzoa, typical of the Permo-Carboniferous system.

Summarising the above, we have—

(1) and (2) indicate that a definite break and time interval must have occurred between the two systems. In (1) the change from marine to freshwater sediments could only be brought about by earth movements of an elevational nature. The slight unconformity in (2) is the result of denudation of the Permo-Carboniferous sediments prior to the deposition of the basal conglomerate of the Trias-Jura system.

(3) The presence of pebbles of Permo-Carboniferous rocks in the conglomerate bed in the felspathic sandstone series of the Trias-Jura system means that Permo-Carboniferous rocks outcropped at the land surface of that time, while in the district under discussion Trias-Jura sediments were being deposited on Permo-Carboniferous rocks. This implies differential earth movements at the close of the Permo-Carboniferous period, and the formation of an irregular land surface due to differential earth movements or denudation, or possibly both. Thus, further evidence of a break between the two systems is given in the elevation of the Permo-Carboniferous sediments, their consolidation, and the formation of an irregular land surface of them before the commencement of the Trias-Jura sedimentation.

(4) The occurrence of a pebble of a rock type very similar lithologically to other pebbles of undoubted Permo-Carboniferous age, and with

suggestions of polyzoal organisms, as well as an impression of an encrinital segment, in the basal conglomerate of the Trias-Jura supports the relations of the two systems indicated in (3), and further gives positive proof that a definite break occurred. The above occurrence means that differential earth movements came into play after the deposition of the Permo-Carboniferous sediments, and with or without the agents of denudation produced an uneven land surface of the Permo-Carboniferous strata, and that sufficient time elapsed to allow of consolidation of these strata before the deposition of the basal conglomerate of the Trias-Jura commenced. Thus, a definite unconformity, or, as the strata of the two systems are generally dipping the same amount, a disconformity, occurs between the Permo-Carboniferous and Trias-Jura systems in the Midlands district.

(*b*) *Correlation With Other Localities.*

The fossil contents of the Permo-Carboniferous sediments in this district prove these sediments to be the equivalent of the Lower Marine series of the Permo-Carboniferous system occurring in other parts of Tasmania and in New South Wales. In New South Wales, above the Lower Marine series, there occurs 7000 to 13,000 feet of strata up to the top of the Newcastle series, which is overlain with a slight unconformity by the Triassic sediments. In Tasmania these strata should either be represented between the Lower Marine series of the Permo-Carboniferous and the base of the Trias-Jura system, or else should be negatively represented by an unconformity. As these strata are represented in other parts of Tasmania, it points to a definite unconformity in the Midlands district, thus supporting the conclusion arrived at above.

(5)—The Igneous Rocks.

(*a*) *Granite.*

A very small outcrop of granite has been exposed in a water-hole 3½ miles west of Ross. At the time of the writer's visit the hole was occupied by water, but numerous lumps quarried were available. Reliable information by men who quarried the granite (for samples to ascertain the presence or otherwise of tin) proves that the granite occupies the whole of the water-hole, which is 4 or 5 yards in diameter. It has been suggested that the granite was a boulder in the basal conglomerate of the Permo-Carboniferous, but the writer regards it as the top of an outcrop of solid granite, underlying the above sediments, for the following reasons:—

(1) If it occurred in the Permo-Carboniferous sediments, its horizon would be in the mudstones (Lower Marine), in which no conglomerate has been found in the neighbourhood. A conglomerate bed underlies the mudstones at the Pipeclay Cutting, but there is no indication of this bed near the granite.

(2) In the above conglomerate bed, which is the nearest stratigraphically to the horizon the granite would occupy, the size of the pebbles ranges up to 4 inches (largest dimension), while this boulder of granite would be at least 4 yards (largest dimension), and would need widely different conditions of deposition to be brought into action in a very short distance.

(3) The pebbles in the conglomerate in the Pipeclay Cutting do not yield any composed of granite.

(4) The granite resembles other granites outcropping in Tasmania, and there is no reason why this outcrop should not represent part of the old sea-floor on which the Permo-Carboniferous sediments were deposited.

For these reasons the outcrop is regarded as the top of an outcrop of solid granite (presumably of Devonian age) in correlation with other granites in Tasmania, forming part of the uneven sea-floor on which Permo-Carboniferous sediments were laid down.

In hand specimens the granite is seen to be a coarsely crystalline rock composed of mainly a white felspar and quartz, with a smaller amount of biotite and a little tourmaline.

(*b*) *Diabase.*

Diabase, which occupies a larger proportion of the surface of Tasmania, occurs plentifully in the Midlands, occupying at least 50 per cent. of the surface, and underlying a much greater proportion.

(1) *Relation Between the Diabase and the Permo-Carboniferous and Trias-Jura Strata.*—Formerly different opinions were held as to the relation of the diabase to the Permo-Carboniferous and Trias-Jura systems, but of late years its intrusive nature, and therefore younger age, has been clearly recognised. This is proved to be the case in the Midlands, much direct evidence being available.

(i) Direct intrusions in the form of dykes can be seen in many places.

Sections of intrusive dykes occur at the following localities:—

Quarry on Main-road, 3½ miles south of Ross.

Channel between Grimes' Lagoon and Blackman's River.

Stringy-bark Creek, 1½ mile south-west of Woodbury.

Railway cutting 1½ mile south of Parattah.

Dykes are visible in plan at the following localities:—

On the plains to the north and east of Tunbridge. These are numerous, and are shown on the accompanying map (Plate II.) and sections (Plate III.).

North-west of White Lagoon, 3 miles north of Tunbridge.

North side of Coal Mine Hill.

Three miles south-west of Oatlands.

These dykes can generally be proved to be a connection between two larger diabase masses, or an offshoot from one such mass.

(ii) Small sills occur capping the hills at the following localities:—Mt. Pleasant and Brent's Sugarloaf.

(iii) The larger isolated diabase masses have all the characteristics of large dyke-like masses. They rise high above the surrounding sediments (due to denudation), and sections or outcrops can be found showing diabase at similar levels to the sediments, and clearly intrusive.

Sometimes these masses end in large dykes, which verifies their intrusive nature. As an example, take the Mt. Seymour mass. This contracts into a dyke-like form towards the north, and where cut through by the Lightwood Rivulet the diabase is seen to be definitely intrusive.

Further, the mass to the east of Lake Tiberias can be seen in section in the Coal River, and is clearly seen to be intrusive.

(iv) The contact metamorphism, the rock types of which have already been discussed, gives further proof of the intrusive nature of the diabase. The extent of metamorphism is small, but the effect and the rock types produced are readily recognised.

From the above, it is clearly seen that the diabase is intrusive into the Permo-Carboniferous and Trias-Jura sediments, mainly in the form of large dyke-like masses.

(2) *Petrology.*—In the field three varieties were recognised which were distinguishable in their texture and the size of their component crystals. These probably all have the same composition, and are not absolutely distinct varieties, the three grading into one another. In relation to their mode of occurrence, however, the recognition of these varieties is important. The finest-grained variety, in which individual crystals cannot be recognised in hand specimens, occurs close to the intruded sediments. The medium-grained variety has a typical doleritic appearance in hand specimens, and occurs at most diabase outcrops where denudation has not been extensive. The coarse-grained variety occurs wherever a stream has cut a deep gorge into a diabase mass, or denudation has removed the outer part of a diabase intrusion.

These differences are verified on examination under the microscope, where the rocks are found to be composed of the same minerals—plagioclase felspar and augite—but the difference in size of component crystals is as stated above. Under microscopic examination the coarse-grained variety is found to have a holocrystalline, panidiomorphic, fairly even, medium to coarse texture, with the ophitic structure developed. The component minerals are a basic plagioclase felspar—labradorite to labradorite-bytownite—and a light-coloured augite, the felspar being slightly in excess of the augite. The felspar crystallised first, and the laths are generally wholly or partly enclosed in augite, giving the ophitic structure. Many of the augite crystals are much larger (up to 6 mm.) than the felspar, as though the augite commenced to crystallise before the felspar, which started later, but finished crystallising before the augite. The above examination would suggest that the rock type is a medium-grained gabbro. At present the diabase is regarded as being hyperabyssal, and not Plutonic, and until these relations are settled the correct naming of the rock type as a very coarse dolerite, or a medium-grained gabbro, cannot be applied.

The only analysis available is of a sample from Launceston ([7]), which is as follows:—

SiO_2	52·49
TiO_2	0·62
Al_2O_3	16·44
Fe_2O_3	2·60
FeO	5·30
MnO	trace
MgO	6·18
CaO	11·71
Na_2O	2·06
K_2O	1·09
H_2O under 110° C.	0·15
H_2O	1·42
P_2O_5	trace
	100·06

The above silica percentage shows that the rock is on the border-line between the basic and intermediate groups, 52 per cent. being the arbitrary line. If Plutonic it would place the rock between the gabbros and diorites, to which the term diorite-gabbro is sometimes applied.

(3) *Age.*—(i) Evidence in the Field.—It has been proved above that the diabase is intrusive into, and therefore younger than, the Trias-Jura sediments, so that the lower limit of its age is Trias-Jura.

Along the Macquarie River, north-east of Tunbridge, basalt flows occur overlying diabase, and also river gravels containing waterworn pebbles of metamorphic Trias-Jura sediments. This basalt is found further north along the Launceston Tertiary basin, and is regarded as closing the Lower Tertiary period. To allow of the removal by denudation of the Trias-Jura sediments from the diabase before the basalt flows, considerable time must have elapsed, and this puts the diabase intrusions back to at least very low in the Tertiary period.

Further, in connection with the Launceston Tertiary Basin deposits, R. M. Johnston ([8]) states "it is apparent that the sediments of this ancient Tertiary Lake have levelled up the inequalities of surface of an older valley

([7]) "On an Estatite-Augite-bearing Diabase from Tasmania," by A. Osann, Freiberg. Translated by W. H. Twelvetrees. (Secretary of Mines' Report, 1907, p. 107.)

([8]) "Geology of Tasmania," by R. M. Johnston, F.L.S., p. 268.

occupied by Upper Palæozoic Mesozoic rocks, with their associated intrusive greenstones"; and general observations support this. The lower beds in this basin are regarded as Palæogene or Lower Tertiary in age. Considerable denudation of this area before the deposition of these Tertiary fresh-water sediments commenced, must have occurred, and the diabase intrusions probably took place fairly well back in Mesozoic times to have enabled such denudation to occur before the commencement of Lower Tertiary times.

Thus, in the field the available evidence gives as the lower limit for the age of the diabase Post-Trias-Jura, and as the upper limit Pre-Tertiary, thus restricting it to Upper Jurassic or Cretaceous.

(ii) Correlation with Other Areas.—A. L. du Toit,(9) in a recent publication, correlates the dolerites and diabases of, approximately, similar age and intruding Mesozoic strata throughout the world.

In South Africa itself the dolerites are regarded as dating "from the Rhætic or Lias, the Middle Jurassic at latest." Conditions similar to those in South Africa also occur in the Falkland Islands, Northern Argentine, Uruguay, Paraguay, and Brazil, where dolerites penetrate Permian and Triassic strata.

In Pennsylvania, New Jersey, and Virginia the "Palisade Traps" (of diabase) occur invading the Triassic Newark series.

In conclusion, Du Toit states that "all these approximately synchronous episodes of effusion and injection at or just after the close of the Triassic, accompanied the collapse of great arcs of the earth's crust, and were connected with world-wide movements of advance or retreat of the ocean."

If the Tasmanian diabase intruded into the so-called Trias-Jura strata be correlated with the above, then it would be from the close of the Triassic to Middle Jurassic in age. Much work in connection with the age of our Trias-Jura strata is needed before this can be verified or otherwise. It is very probable that the cessation of deposition of the Trias-Jura sediments, their elevation and intrusion by the diabase, and the majority of the faulting and displacements in the Trias-Jura strata were practically contemporaneous. When the age of the Trias-Jura strata is more definitely fixed, the age of the diabase can be likewise fixed, but

(9) "The Karroo Dolerites of South Africa," by A. L. du Toit, D.Sc., F.G.S.

with the present state of our knowledge it can only be regarded as Upper Mesozoic, possibly Jurassic.

(4) *Nature of the Intrusions.*—Very little field work had been done in connection with the relations of the diabase and other formations, and the conceptions before this examination were as follow:—

(*a*) The Central Plateau, Ben Lomond, and probably some minor features are regarded as being due to huge diabase sills overlying Permo-Carboniferous and Trias-Jura strata.

(*b*) To the west of the Central Plateau the diabase-capped mountains, *e.g.*, Pelion Range, are formed by diabase sills up to 800 feet thick overlying Permo-Carboniferous strata.

(*c*) In the north, midland, east, and south-east parts of the State the diabase is always spoken of as ramifying the strata and forming isolated or ramifying ranges.

In the Midlands it was found that (apart from the Central Plateau) the diabase formed ramifying ranges, due to its intrusion in the form of huge dyke-like masses, which have been left rising hundreds of feet above the surrounding strata, due to the denudation of the adjacent sediments. These must all merge into one another at no very great distance under the present land surface (see sections in Plate III.), and thus represent the higher points of a deep and larger mass of diabase. With regard to sills, the only ones found in the Midlands were two very small ones at Brent's Sugarloaf and Mt. Pleasant.

As regards the Central Plateau, we are dealing with a very large area of diabase, with a fairly level surface and individual peaks rising to a height of 1000 feet above it. The edge, or the portion of it (the Western Tiers) examined in the Midlands shows a solid face of at least 2000 feet of diabase, with the sedimentary strata resting against it, with an intrusive contact. The formerly conceived idea of a sill is thus not supported, unless, of course, the whole 2000 feet (and more) of the diabase forms a huge sill. Thus, in the Midlands we have the Central Plateau occurring as a huge mass of diabase at least 2000 feet thick, and in the remainder the diabase occurring as dyke-like masses uniting in depth into a solid mass. Further, the diabase of the Western Tiers descends easily into the ranges of the lower country by way of the high country around Oatlands and Antill Ponds.

What do these huge intrusions which occur everywhere in a horizontal sense underlying (or else exposed, due to denudation) the strata of the Permo-Carboniferous and Trias-Jura systems, and sending up large dyke-like masses into these strata, represent? Are they sills or sill-like masses extending everywhere in the sedimentary strata and fed by dyke-channels of very much smaller dimensions through the underlying older formations, or are they the summits of intrusions which have intruded the older folded formations and the younger horizontally-bedded strata alike?

The critical test as to how the diabase occurs in the older formations is, of course, an examination of such areas. Up till the present, the diabase has always been found associated intimately with the Permo-Carboniferous and Trias-Jura strata, and seldom with any older strata, but in view of the very small area of Tasmania geologically examined, especially where Pre-Carboniferous, Permo-Carboniferous, and Trias-Jura strata, and diabase occur together, this evidence cannot be given too much prominence.

There is much to be said for the sill form of intrusion fed by narrow dykes. This is the typical form of intrusion of dolerite or diabase into horizontally-bedded sedimentary strata throughout the world, as shown by A. L. du Toit.[10] The great thickness required for the sill is no great objection, as sills occur in South Africa with thicknesses of 1200, 1500, 2000, and 3000 feet; while the Gettysburg sill in Pennsylvania, U.S.A., is fully 2000 feet thick.

The field work does not verify the usual type of sill injection, but points rather to a large and widely-distributed diabase mass intruding the sedimentary strata and sending large minor intrusions into the higher portions of the strata. Whatever the source of supply to this intrusion—whether by narrow dykes through, or a large intrusion into, the older formations—the relations of the diabase and the Permo-Carboniferous and Trias-Jura strata will, when properly investigated, prove a very interesting example of the intrusion of igneous magma into a series of horizontally-bedded strata.

At present it is suggested that the main area of intrusion was part or the whole of the Central Plateau, with subsidiary areas at Ben Lomond, and probably other points. Also that towards the west the true sill type of intrusion predominated, while in the east the diabase everywhere

(10) see above p. 62

ramified the sedimentary strata, sending huge dyke-like masses into it, and the true sill type being subsidiary.

The laccolite origin of many of the elevated diabase masses of Tasmania has been put forward by Stephens.(11) Even if the diabase masses are fed by narrow channels through the older Palæozoic rocks, the typical form of laccolites, viz., large dome-shaped masses of igneous rock with the sedimentary strata arched over the top of them, is missing, and these masses could not be said to be of true lacolithic form. Even an irregular laccolite cannot be said to be a suitable term, and the form of these masses must be left as described above, viz., a huge sill-like mass of diabase extending everywhere in a horizontal sense in the sedimentary strata, and sending minor intrusions into overlying beds.

The top of this horizontal mass seems to occur at different horizons in different localities. Around York Plains and other localities it seems to have "picked up" the sediments somewhere near the horizon of the base of the felspathic sandstone series. Near Ross and in the south of the district this mass exists well down in the Permo-Carboniferous strata. If the diabase really occurs as a horizontal sill-like mass fed by narrow channels, it may have formed at any horizon in the sedimentary strata. Such an occurrence with variable thicknesses of the main mass and variable dimensions of the intrusions extending upwards from it would explain the occurrence of the diabase masses of Tasmania. Otherwise the explanation, though in correlation with other places outside Tasmania it is not so likely, is that the diabase represents the surface of a huge batholith, which has intruded the Trias-Jura, Permo-Carboniferous, and underlying strata alike.

(c) *Basalt.*

This rock type occurs in the form of numerous small patches throughout the district, small dykes and surface flows being represented. The largest flow is that along and parallel to the course of the present Macquarie River, and which, in part at least, filled the valley of a former Macquarie.

(1) *Types.*—In the field three varieties are recognised.

(i) This variety is a very dense basic basalt, generally showing large areas of porphyritic olivine, and to a less extent ilmenite.

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(11) See above.

This rock occurs as small dykes and surface flows, being confined to the surface and edge of the Central Plateau, and on the more elevated ground extending to and around Antill Ponds, York Plains, and Oatlands.

Under the microscope it is found to consist of porphyritic masses of olivine, ilmenite, and a little augite in a very fine groundmass of felspar laths, ilmenite, a little fresh olivine, and a much decomposed mineral (probably both olivine and augite). Limonite is abundant throughout the section as a result of the alteration of the ferro-magnesian minerals. The rock type is a very basic olivine and olivine-ilmenite basalt.

Surface flows of this type occur at Dog's Head Point, Interlaken, east of Lake Sorell, south of Lake Crescent, Pig Tier, Bow Hill, Flat-top, 2 miles south of Flat-top, west and north-west of Oatlands, Coal Mine Hill, ½-mile north of Andover. Dykes occur at Old Man's Head, Young Woman's Head, The Nipples, Vincent's Hill.

The late W. H. Twelvetrees [12] refers to a truncated cone ½-mile east of Diamond Beach. This outcrop very much resembles a truncated cone or a denuded neck of basalt, but it is quite likely that it is merely an isolated denuded patch separated from the other neighbouring flows to the east and north.

(ii) The basalt of the plains around Tunbridge and Ross is quite distinct from the above. It occurs wholly as surface flows, and filled part or the whole of the valley of the Macquarie River of those times.

In hand specimens it is found to be a light-coloured, fine to medium grained rock, generally being slightly vesicular.

Under the microscope it is found to be holocrystalline, even fine-grained, in texture, with the ophitic structure developed to some extent. It consists of laths of plagioclase felspar, grains of augite, and grains and needles of magnetite or ilmenite. Some decomposition has taken place, and limonite and hematite occur to a small extent. The rock type is thus a normal basalt.

These flows are generally 60 to 70 feet thick, but range up to 100 feet in places. No possible source of the basalt was seen in the district, and the flows are due probably to fissure eruptions.

(iii) Basalt flows occur near Rushy Lagoon, and also further east at Johnny's Lagoon, but the latter were not visited.

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(12) "Report on Country on the East Shore of Lake Sorell," by W. H. Twelvetrees, 1902.

In the hand specimen this basalt consists of a light-coloured, very fine-grained, slightly vesicular rock. Under the microscope it has a holocrystalline, even fine-grained, structure, and consists of plagioclase felspar, olivine, augite, and ilmenite or magnetite. The felspar occurs as small laths, while the other constituents occur as roughly equi-dimensional grains.

The rock type is an olivine basalt.

(iv) Three-quarters of a mile east-north-east of Murderer's Tier a very small outcrop of basaltic material occurs. It is a dark-grey, highly vesicular, and scoriaceous-looking rock.

Under the microscope it is found to consist of grains of quartz and felspar (some fresh and some much decomposed) in a dark-coloured groundmass, which is probably slightly devitrified glass. This occurrence of quartz (which, however, may be xenocrysts) in what otherwise might be termed a vesicular, slightly devitrified, basaltic glass is interesting, but renders the task of naming the rock a difficult one.

(2) *Relations of the Types.*—As to the relations of the above types, very little can be said definitely. They occur in distinct parts of the district, and might possibly be regarded as coming from separate magma reservoirs. As regards composition, the basic olivine and olivine-ilmenite basalts of the high country are probably distinct from the more felspathic normal and olivine basalts of the other areas. The two latter (that of Ross and that of Rushy Lagoon) are probably closely related in spite of the fact that olivine occurs in the Rushy Lagoon basalt, because the felspar is easily the predominating mineral in these varieties, and the olivine is subordinate in the Rushy Lagoon type.

(3) *Age.*—The question as to whether these different types can be regarded as being of practically the same age is a difficult one, owing to absence of any definite evidence in the field. If there is any difference, the basic basalts of the high country are probably, from the positions they occupy, the oldest.

These basalts are found overlying or intruding Trias-Jura sediments and diabase, and so are post-diabase in age. The normal basalts of the Macquarie River district are found to the north of the Midlands to overlie the Lower Tertiary Launceston Lake deposits, and are regarded as closing the Lower Tertiary sedimentation. These normal basalts are similar to the newer basalts of Victoria (of probably Pliocene age), and are probably contemporaneous with them.

(6)—Structural Geology.

As already seen, we are dealing in this district with strata of the Permo-Carboniferous and Trias-Jura systems, intruded by Upper Mesozoic diabase, and also by small intrusions and effusions of Tertiary basalt.

The sedimentary strata are either lying horizontally, or else dipping at a very low angle. Thus the earth movements since the deposition of the above strata have been of the nature of epeirogenic—*i.e.*, continent-making—movements, in which the movements are those of direct uplift, and not orogenic—*i.e.*, mountain-making, and accompanied by intense folding—movements. Accompanying such epeirogenic movements there will be much faulting, which will play a large part in the geological structure of the district.

That much displacement of the strata has taken place is soon revealed in the field, as is shown in the accompanying sections (Plate III.). Very little direct faulting was found in the field, but much displacement was found to occur in relation to diabase masses.

A.—Direct faulting was observed at the following localities:—

(1) *Along the Coal River.*—The Coal River for a few miles (to the south-east of Stonor) follows a fault, and some excellent sections are obtained. The fault runs in a north-west to south-east direction, and has a downthrow of at least 200 feet (100 feet is visible, and another 100 feet at least must exist, but owing to the great similarity of the Trias-Jura sandstones the exact amount cannot be determined) to the south-west. The detection of the fault was easy, due to the occurrence of the junction of the Permo-Carboniferous and Trias-Jura strata occurring on the upthrow side.

(2) *Coal Mine Hill, York Plains.*—This hill consists of a block of felspathic sandstone (containing the coal) let down into normal sandstones, the whole being overlain by basalt. A diabase dyke intrudes this let-down block, being parallel to the faulted sides, and joining a large mass of diabase to the north. The direction of the dyke and faults is north-north-west to south-south-east, and the displacement very indefinite, but exceeds 100 feet.

(3) *West of Ross.*—Here a fault runs parallel to the elevated diabase hills to the west of Ross, and takes the form of a horseshoe, with the opening to the east. It is most definite on the south, where the faulted and unfaulted junctions of the Permo-Carboniferous and Trias-Jura are visible, while at other places the limestones are exposed by denudation on both sides of the fault, and it cannot be traced, though it exists. In this southern part the fault runs east and west, and there is a downthrow to the north of 300 feet.

(4) *To the North of White Lagoon.*—A fault similar to that described above follows the diabase to the north and north-west of White Lagoon, but the downthrow does not exceed 100 feet, and in places is very much less (about 20 feet).

No doubt numerous other faults occur, but with the large thicknesses of very similar rock types which occur, particularly sandstones, it is impossible to recognise the faults.

B.—Apart from the above, much displacement, which may be due to faulting (see below), occurs between the strata on opposite sides of diabase masses.

(5) *Mt. Pleasant and Brent's Sugarloaf*, 4½ miles apart, and on opposite sides of the Eastern Spur, are built up of felspathic sandstones containing the conglomerate bed described above,[13] and capped by a diabase sill. These strata are undoubtedly of the same horizon in the Trias-Jura system, yet there is a difference of about 700 feet between them in these two localities.

(6) On the east of the diabase referred to in (3), the junction of the Permo-Carboniferous and Trias-Jura strata is at an elevation of about 1000 feet against the diabase, while on the west of these diabase hills all Trias-Jura strata are seen to a depth of 800 feet and less, so that there is a displacement (downthrow) on the west to the amount of 200 feet at least. The strata on the west must correspond roughly to the downthrow side of the fault on the east.

(7) The more northerly of the two diabase dykes on Ross township has (as shown on the map) Permo-Carboniferous strata on the north and Trias-Jura on the south, thus indicating a displacement to the south, but of unknown magnitude.

C.—The above examples show the very intimate relation of these displacements, and also the faulting with the

(13) See p. 47.

diabase. Post-diabase faulting, no doubt, exists, but the greater part of the faulting is, on the above evidence, contemporaneous with the intrusion of the diabase, and to these two contemporaneous events may be also added the termination of deposition of the Trias-Jura, and the movements, probably elevational, accompanying this. As regards the faulting and intrusion of the diabase, it is generally accepted that the faulting would accompany land movements, and form points of weakness for the intrusion of the diabase, thus giving the above relation. A. L. du Toit,(14) in dealing with the dolerite intrusions of South Africa, states "there is not the slightest evidence, either that the dolerites were produced by the fluxing of the sediments along certain planes, or that the magma slowly stoped its way upwards after the manner of the batholite-forming granites," and "the introduction of each sill must obviously have produced vertical uplift of the strata (overlying), amounting to the thickness of the intrusion at that point measured vertically." Though in Africa the intrusions are mainly of the sheet (horizontal, inclined, curved, and thick) type and dykes, while in Tasmania we have a huge horizontal mass everywhere intruding the sedimentary strata and sending up large dyke-like masses into the higher parts, the conditions are not greatly dissimilar. It thus becomes a question of how much of the displacements, and probably also of the faulting, may not be due to differential uplift by the intruding diabase magma.

This intimate relation of the faulting and displacements, and the diabase, can thus be explained by either one being the cause of the other. Faulting just prior to the intrusion of the diabase would greatly assist the intrusion, and must have occurred, but from the evidence it is apparent that much of the displacement and faulting has been caused by the diabase. Both these factors are related to the earth movements accompanying or causing the intrusion of the diabase at the close of the Trias-Jura period already noted from so many parts of the world, and the whole problem is one in which the separate factors are very intimately related.

D.—The Western Tiers: It has generally been regarded that the Central Plateau was formed by a vast diabase sill overlying Permo-Carboniferous and Trias-Jura strata, and that the scarp of the Western Tiers represents a fault scarp.

(14) "The Karroo Dolerites of South Africa," by A. L. du Toit.

During the recent examination it was found that—

(1) The Tiers represent a solid face of at least 2000 feet of diabase, and that the sedimentary strata do not pass under the Central Plateau.

(2) Wherever the sedimentary strata occur on the Western Tiers, the junction is an intrusive one, the sediments being altered to cherts, quartzites, or types with less metamorphic effect.

(3) The Tiers merge into the high ground of the Eastern Spur, and no possible fault or faults with a downthrow of 2000 feet here exist.

From this it is seen that this portion of the Central Plateau consists of a mass of diabase at least 2000 feet thick, and that its junction with the sediments which existed to the east was an intrusive one. These sediments have now been almost completely removed by denudation, and the eastern edge of this diabase of the Central Plateau is now exposed as a bold scarp forming the Western Tiers.

This is also supported by the fact that no streams cross the Tiers in the Midlands district. If the Tiers had been exposed by faulting, streams would have eaten their way back through the Tiers, and now be draining part of the plateau, which has actually happened to the north-west of the district. The Midlands being at the head of the river systems, denudation has not been so active as lower down the courses of the streams. Accordingly, in the Midlands it has taken longer to remove the sedimentary strata covering the Tiers, and the streams have not yet had much chance to cross them.

Faulting has, however, occurred in the strata to the east of the Tiers. Near the head of the Blackwood Creek, and on the Tunbridge-Interlaken road, two small areas of Permo-Carboniferous rocks, with overlying basal conglomerates of the Trias-Jura system, outcrop on the Western Tiers at an altitude of 1500 feet above sea-level. Trias-Jura sandstones occur both north and south of this up to heights of 1800 feet and more in some localities, but at a lower level on the Tiers, below the above outcrops of Permo-Carboniferous, Trias-Jura sandstones outcrop at altitudes of 1000 to 1200 feet. All these outcrops show signs of metamorphism, so the displacements or faulting were before or contemporaneous with the diabase intrusions. This agrees with the conclusions arrived at above.

The structure and origin of the Western Tiers have an important economic bearing in connection with the coal resources of Tasmania. With the idea of the Central Plateau being formed by a sill overlying Trias-Jura strata, it was possible that the coal measures existed under the plateau, but this cannot be so with the structure given above. There is a possibility, but a very small one, that some of the coal measures strata may exist under the huge horizontal mass of diabase pictured as existing in the Midlands, and of which the Central Plateau forms a part, but this could only be verified by drilling, and the chances are too remote to warrant this.

(7)—Geological History.

The history of this district, as represented by the rocks exposed at the surface at the present time, practically begins with Permo-Carboniferous sediments. The surface on which they were deposited is not exposed to view, except for a very small area of granite of presumably Devonian age outcropping near Ross.

(1) *Pre-Permo-Carboniferous Conditions.*—In common with other parts of Tasmania, this district was probably from the close of deposition of the Silurian sediments and the intrusion of the Devonian granite until the deposition of the basal Permo-Carboniferous sediments, a land surface, and subjected to extensive sub-aerial denudation.

(2) *The Permo-Carboniferous Sedimentation.*—Though not seen in the Midlands, it is found in other parts that this sedimentation commenced under glacial conditions, and then passed into marine conditions (the Lower Marine), changing later into estuarine or lacustrine conditions, and subsequently into marine again (Upper Marine). In the Midlands the Lower Marine series alone is found, the upper formations being either not deposited or removed by denudation.

(3) *Pre-Trias-Jura Conditions.*—In the Midlands a disconformity exists between the Lower Marine series of the Permo-Carboniferous and the basal members of the Trias-Jura. The upper members of the Permo-Carboniferous were, if deposited, removed by denudation before the commencement of deposition of the Trias-Jura sediments. Thus, either at the close of the Lower Marine or the Permo-Carboniferous sedimentation, elevational movements occurred, and the land surface formed was subjected to

denudation until the commencement of the Trias-Jura sedimentation.

(4) *The Trias-Jura Sedimentation.*—This occurred under lacustrine conditions on a somewhat denuded surface of Permo-Carboniferous strata. The deposition commenced with conglomerates and grits passing up into sandstones, and giving a thickness of up to 700 feet of these siliceous types. This was followed by up to 500 feet of felspathic sandstones, and possibly later by normal sandstones again.

(5) *The Diabase Intrusions.*—In Upper Mesozoic times igneous activity was developed, and huge masses of diabase intruded the Permo-Carboniferous and Trias-Jura strata, mainly in the form of a huge horizontal mass, extending everywhere in these strata, and sending up dyke-like masses into the upper parts of them. These intrusions were probably contemporaneous with the cessation of deposition of the Trias-Jura sediments, their elevation and faulting.

(6) *A Period of Denudation.*—Following the intrusions of diabase, there has been in most parts of the district a period of uninterrupted denudation up till the present time, and this has largely produced the present topography, as already dealt with under that heading.

In other parts of the district, and in adjacent regions, this denudation has been interrupted.

(7) *The Launceston Tertiary Basin Sedimentation.*—Prolonged denudation had produced a large basin just to the north of the district, and a lake was formed, resulting in the deposition of several hundred feet of Lower Tertiary sediments.

(8) *The Extrusion of the Tertiary Basalts.*—Following the Lower Tertiary sedimentation came large outpourings of basaltic lava. This extended into the Midlands, where numerous small surface flows and dykes of basalt occur.

(9) *The Present Cycle of Denudation.*—Since the extrusion of the basalt, the land surface has been subjected to an uninterrupted period of denudation, and this, combined with that in (6), has produced the present topography of the surface.

V.—ECONOMIC GEOLOGY.

(1)—WATER-SUPPLY.

The sources of water-supply depend almost wholly on the rainfall, and the consequent springs, rivers, and lakes: and on the geological structure which enables certain rocks to store large supplies of the rain that has percolated through the soil. As these factors are subject to extreme variation, the problem of obtaining wholesome and adequate supplies may be simple or fraught with great difficulty and uncertainty.(15)

As already described above,(16) the greater portion of the Midlands district has a very moderate rainfall, and an absence of permanent streams, thus making the question of surface water-supply a difficult one. As to whether this surface supply could be supplemented by underground supplies was the problem of the present investigation.

(a) *Surface Water-supply.*

(1) *Lakes.*—Lakes Sorell and Crescent form a permanent supply of excellent water suitable for all purposes, but unfortunately they are situated on the Central Plateau, where the population is very scanty. The water in Lake Dulverton would be suitable for domestic purposes after periods of heavy rain, when the lake is full. It has such a small catchment area, however, that it is generally at a low level, and unsuitable for domestic purposes, and is used for the watering of stock.

Lake Tiberias is overgrown with rushes, and is unfit for domestic purposes, but serves for the watering of stock.

(2) *Rivers.*—The Macquarie River is the largest in the Midlands, and by means of storage and regulation in Tooms' Lake, at the head of the southern branch, it is converted into a permanent stream, flowing throughout the year. The township of Ross obtains part of its supplies from the river, the water being pumped into a small reservoir above the town. The Railway Department has established a watering point for its engines at Ross, the water being pumped into a small reservoir at the station. Along

(15) "The Geology of Water-supply," by H. B. Woodward, F.R.S., F.G.S.
(16) See p. 23.

the course of the Macquarie at various places water is led off by means of small channels, and is used on properties several miles downstream. These may have been used originally for agricultural purposes, but are now entirely for pasture or grass lands. The remaining streams have a plentiful supply of water during and after the rainy periods, but soon decrease in volume, and cease running during the dry season. Further, the water in the pools during the dry seasons becomes concentrated in mineral content, derived from the diabase and sandstones, and is unfit for domestic purposes, but is still used for watering stock. Of these streams, the Blackman's River is practically the only one whose waters are used to any extent. At Tunbridge, when this river contains plenty of water, the water is used for domestic purposes. Further, water is pumped by a windmill into storage tanks, from which all the horses of the township are supplied all the year. A windmill also supplies the local hotel with water for domestic purposes during suitable times, and for garden and general purposes.

The water of the other streams is not made use of to any extent, except for an occasional small dam across them, or a small channel taking water off from a point upstream for use at places further downstream. These practices are little used at the present, but apparently had a greater use in the past.

Thus it is seen that, apart from the Macquarie River, the water of the streams is used practically only for watering horses, cattle, and sheep.

(3) *Storage of Rainfall in Tanks*.—This method of obtaining water provides practically the whole source of the water used for domestic purposes throughout the Midlands. The drainage from the roofs of the houses and other buildings during periods of rainfall is run into corrugated iron tanks and stored. With adequate area of roof and sufficient tanks a supply of water to last throughout the year is easily obtained. An inch of rain will yield about half a gallon of water per square foot of horizontal area. The average small house will cover about 500 square feet of ground, and with an average rainfall of, say, 20 inches the annual supply would be 5000 gallons, providing there are sufficient tanks to store the water during the periods of heavy rainfall. This would give a daily supply of about 14 gallons, which, though not large, could, with economy, supply the needs of such a small house. Any additional area provided by outbuildings would, of course, considerably increase this supply.

(b) *Underground Water-supply.*

(1) *General Geological Considerations.*—As the source of underground water is the rainfall, the nature of the rocks and their geological structure play an important part in the existence or otherwise of underground water-supplies.

(a) The first consideration is the nature of the rocks themselves. They must be capable of containing, and also allowing the passage of, considerable quantities of water. These conditions are fulfilled by rocks which are porous and permeable, and also those which have joints, fissures, and other cavities largely devloped in them. The porous and permeable rocks are mainly the siliceous and calcareous rock types (gravels, sands, sandstones, limestones, and chalk); while the highly-jointed, fissured, &c., rock types are the older sedimentaries, igneous rocks, and schists. The first type is much more important as water-bearing rocks than the second, and in addition to their own characteristics, may, and generally do, contain some of those of the second type.

Of the other rock types some are impervious, while others may be absorbent, but do not permit the passage of water through them, and are of no use as water-bearing rocks.

(b) Geological Structure.—The ideal structure for a large underground water-supply or reservoir is that of a basin-shaped or synclinal arrangement (all the beds dipping into a centre) of a series of porous and non-porous beds, with the porous beds outcropping at the surface, so as to receive the rainfall. The water moves into the centre of the basin, where it collects, and can be tapped. Both underlying and overlying impervious layers are included in the above conditions, but are not essential. The underlying impervious layer is not required, a layer thoroughly saturated with water being all that is required. The upper impervious layer saves loss of water by seepage, but is otherwise not essential. A series of porous beds dipping uniformly in one direction—*e.g.*, at Perth, W.A.—fulfil the conditions necessary for the formation of a supply of underground water. The structure of an underground basin will, in general, be found to be between the latter simple one and that of the ideal one described.

The intake to these basins is the area over which the porous beds outcrop and receive a supply of water from the rainfall and streams passing over this area. An outlet from these basins, either on land or below the sea, is necessary, as otherwise the water would become stagnant or heavily mineralised.

For artesian basins—*i.e.*, those in which the water when tapped is under sufficient pressure to rise to the surface and form a flowing well—it is essential that the intake beds outcrop at the surface at a higher level than where they are to be tapped in the basin, in order to give the required pressure to force the water to the surface.

In sub-artesian basins the water may be under pressure, but not sufficient to make it rise above the surface of the ground.

Apart from such large and specialised supplies of underground water, which will be formed by the above structures, the formation of underground water-supplies is generally as follows:—Part of the rainfall soaks through the soil, and will continue in its downward movement while the rocks are porous or channels exist in the way of joints, &c. Finally, it becomes stopped by non-porous or impervious beds or formations, and then saturates all the porous rocks above this level. These porous rocks become saturated up to a certain level, called the "water-table" or "plane of saturation," which is the level at which water will stand in wells sunk in these rocks. The depth of the water-table below the surface varies from place to place, but the table follows the surface of the earth in a modified manner. The depth also varies with the seasons, approaching the surface in wet periods and retreating from it in dry seasons.

Springs, seepage, and soakage are formed as the result of movements of underground water, depending largely on the geological structure. The water which has passed underground reaches the surface again, due to a variety of reasons, and emerges forming springs, seepage, and soakage.

(2) *Rainfall and Its Dispersal After Reaching the Surface of the Earth.*—The rainfall on the surface of the earth is disposed of in three ways, and is divided into the three following parts:—

(*a*) Run-off—*i.e.*, the water which is carried away by surface streams.

(*b*) Evaporation and Absorption by Vegetation.—A large amount of the rain is evaporated from the surface of the earth back into the atmosphere, and a further amount is used to supply the needs of the growing vegetation.

(*c*) Percolation—*i.e.*, the amount of water which soaks through the soil and saturates the underlying porous strata or rocks if they exist.

The run-off is not entirely independent, because a proportion of the percolation reaches the surface again in the form of springs, and adds to the run-off. Thus there is a "direct" run-off and a "total" run-off, the "total" being equal to the "direct" augmented by that portion of the percolation which appears as springs, &c. Care is needed in dealing with these, depending on the particular problem in hand. In problems of surface water-supply the total run-off would be considered, while with underground water problems, where large quantities of water are being used, the portion of the percolation which increases the run-off would be reduced considerably, if not completely, and the direct run-off and percolation would be considered.

These factors vary considerably with the conditions existing at the part of the earth's surface under consideration, the factors on which they depend being amount of rainfall, climate, nature and properties of the soil and underlying rocks, character of the vegetation, elevation and amount of slope of the surface, character of the rainfall, &c. It is the relative amounts of run-off, evaporation, and percolation which affect the question of water-supply as regards the quantity of water, and these vary with the above conditions.

(3) *Geological Conditions in the Midlands.*—As seen in discussing the geology of the district, the Midlands is composed of horizontally-bedded strata of the Permo-Carboniferous and Trias-Jura systems, intruded on a large scale by diabase. The following table shows the approximate relative areas occupied by the different rocks and formations at the surface:—

	Per Cent.
Permo-Carboniferous	1
Trias-Jura	40
Diabase	50
Basalt	5
Recent	4
	100

The basalt and alluvial overlie a greater area of Trias-Jura than diabase, so it gives almost equal proportions of Trias-Jura strata and diabase constituting the surface of the Midlands; so in considering underground water we have to deal mainly with these formations.

(*a*) The Rock Types.—The Trias-Jura strata consist mainly of sandstones and felspathic sandstones. The latter form the upper strata in this district, and they have been largely removed by denudation, and the former outcrop much in excess of the latter. Sandstones are among the best of the water-bearing rocks, and these are no exception to the rule. Tests of their porosity were made by the Government Assayer, Mr. W. D. Reid, and the results given were as under:—

Sample.	Percentage Porosity by Volume.
I.	14·64
II.	14·58
III.	26·30

I. Sandstone: West shore of Lake Dulverton.
II. Sandstone: Quarry of H. J. Richards, half-mile east of Ross.
III. Felspathic Sandstone: East side of Vincent's Hill.

The diabase is a practically impervious rock, and the only water it could hold would be that in cracks and joints, which are not large or very numerous, so it is essentially a non-water-bearing rock.

(*b*) Geological Structure.—The structure of the Midlands is that of horizontally-bedded porous Trias-Jura strata intruded by a huge horizontal mass of diabase sending up large dyke-like masses in the higher strata. The greater part of the Trias-Jura strata have been removed by denudation, leaving the structure of the Midlands at the present time as that of comparatively small and isolated areas of Trias-Jura strata resting on diabase (see accompanying map and sections). These areas are more or less completely surrounded by the dyke-like masses of diabase, which stand high above the Trias-Jura strata, due to differential erosion, and the areas of Trias-Jura strata occupy roughly basin-shaped depressions in the diabase.

(4) *Possibilities of Underground Water:*

Artesian.—The above structure of small isolated basins of porous Trias-Jura strata resting on impervious diabase, with each of these formations occurring over 50 per cent. of the surface, is absolutely unsuitable for the existence of a large artesian basin in the Midlands, and such a basin cannot exist.

Sub-artesian.—The above remarks also apply to the existence of a possible large sub-artesian basin in the Midlands.

Local Basins.—The small areas of porous Trias-Jura strata are small potential sources of underground water. The rainfall and streams flowing over them will saturate these strata up to a certain level, and as these basins are more or less completely surrounded and underlain by impervious diabase, the water in these basins is held rather efficiently. Diabase is generally to be found on the downstream side of streams flowing through these basins. As this locality is the lowest ground in the basin, it would be the natural outlet for the waters of the basin and the diabase. This acts as an underground dam. This is not altogether a desirable feature, because, though the water will be held very efficiently in the basin, there must be some stagnation produced below the level of the diabase dam, with resulting bad effect on the quality of the water.

These basins are generally quite distinct from ea other, and will be dealt with separately later on.(17)

(5) *Rainfall in the Midlands.*—In attempting to arrive at the quantity of underground water, the amount of rainfall to be taken into account is an important point. It varies, of course, from a minimum in dry years to a maximum in wet years, and it is necessary to arrive at a safe and reliable figure to use.

The mean average rainfall over a period of consecutive dry years is the figure adopted, three being the usual number of years taken; but occasionally rainfall data show that it is necessary to extend this period to a greater number of years. The table (No. 6) given below shows figures for the average of different periods of consecutive dry years, and how they agree with figures calculated by the formula of Bennie.(18)

For the Midlands the rainfall taken will be the average of the three consecutive driest years, and 75 per cent. of the average annual rainfall will be used.

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(17) See p. 88.

(18) Institute of Civil Engineers. Vol. CIX., Part III.

Table No. 6.

Station.	No. Years for Average.	Average Annual Rainfall.	Bennie's Driest Year = 60% of Normal.	Actual Driest Year.	Date.	Bennie's Average of Two Consec. Driest Years; 69% of Normal.	Actual Average of Two Driest Years.	Bennie's Average of Three Consec. Driest Years: 75% of Normal.	Actual Average of Three Consecutive Driest Years.
Bendeemer	22	2756	1654	1565 1780	1914 1919	1902	1975 2386 1913 1565 1914	2067	2153 2386 1913 1565 1914 2521 1915
Mt. Seymour ...	15	2371	1423	1631 1696	1914 1908	1666	1776 1870 1913 1681 1914	1778	1810 1870 1913 1681 1914 1880 1915
Andover	20	2308	1385	1336 1622	1908 1914	1593	1669 1634 1914 1703 1915	1731	1793 1941 1913 1634 1914 1703 1915
Oatlands	34	2140	1284	1388 1415 1431	1892 1908 1914	1477	1562 1693 1913 1431 1914	1605	1550 1518 1913 1363 1914 1768 1915
Quorn Hall (Campbell Tn.)	31	2035	1221	1136 1175 1375	1897 1914 1908	1404	1266 1136 1897 1395 1898	1526	1390 1136 1897 1395 1898 1641 1899
Jericho	13	1992	1195	1363 1408 1659	1914 1908 1892	1374	1440 1518 1913 1363 1914	1494	1550 1518 1913 1363 1914 1768 1915
Beaufront (Ross)	33	1799	1079	1013 1171 1344 1382 1415	1914 1908 1896 1897 1898	1241	1357 1702 1913 1013 1914	1350	1380 1344 1896 1382 1897 1415 1898 1414 1702 1913 1013 1914 1528 1915
Woodbury...	12	1783	1069	1083 1114	1914 1919	1230	1250 1083 1914 1417 1915	1337	1327 1480 1913 1083 1914 1417 1915

The figures headed "Bennie," &c., are calculated in accordance with his formula for finding the driest year, the average of two consecutive driest years, and the average of three consecutive driest years. The figures above show a close agreement between the actual and calculated amounts.

The years 1913 and 1914 and 1913, 1914, 1915 were the driest periods of two and three years respectively. The Beaufront (Ross) and Campbell Town records show that 1896, 1897, 1898 were also very dry, but Oatlands unfortunately had no observer during those years.

(6) *Dispersal of the Rainfall.*—No figures are available for the Midlands for the discharge of streams; evaporation, &c., and so comparison has to be made with other countries for data as to the relative amounts of run-off, evaporation, and percolation.

H. B. Woodward [19] quotes various figures for Great Britain. The total run-off for the Thames at Staines and the Seine at Paris has been estimated at from one-fourth to one-third of the rainfall. For the world in general an extreme variation of from 3 per cent. and less to 75 per cent. is noted, but the average is reckoned as not more than one-fifth of the rainfall. Out of an average yearly rainfall of 30 inches in Britain, the evaporation is reckoned as from 10 to 18 inches, and generally taken at 14 inches. The amount that may percolate is estimated at one-fourth or one-fifth of the rainfall.

The following mean annual data in Table No. 7 are given with regard to the Thames Basin for 1883-1902:—

TABLE No. 7.

	Inches.	Per Cent. of Rainfall.
Rainfall (over whole of basin)... ...	26·12	—
Total run-off...	7·74	29·6
Evaporation	15·02	57·5
Percolation	+3·36	+12·9

(19) "The Geology of Water-supply," by H. B. Woodward, F.R.S., F.G.S.

Finally, the following table (No. 8) is given as a general approximate method for the dispersal of the rain in Britain:—

TABLE No. 8.

	Per Cent. of Rainfall.
Evaporation and absorption	$8/14 = 57{\cdot}2$
Direct run-off	$2\frac{1}{2}/14 = 17{\cdot}8$
Percolation...	$3\frac{1}{2}/14 = 25{\cdot}0$

The conditions in the Midlands are not the same as those of the Thames Basin or other parts of Britain, but they can be taken as roughly analogous. The Midlands is at a generally greater altitude, and has a warmer and drier climate than the Thames Basin. In this latter basin the rocks are a series of clays, sands, chalk, and limestones; while in the Midlands we have sandstones and diabase. On sandstone areas the percolation will be considerable and the run-off small, while on the diabase the percolation will be negligible and the run-off large. On the whole, these conditions will have the effect of slightly increasing the evaporation, and possibly the run-off, with a consequent decrease of the percolation; and for the areas of sandstones in the Midlands the following figures will be adopted:—

	Per Cent.
Evaporation...	60
Run-off	20
Percolation	20

(7) *Quantity of Water*.—Any calculations as to the quantity of underground water can only be regarded as very approximate, especially when there is a complete absence of local data as to stream discharge and evaporation. Some of the small basins in the Midlands are almost ideal, and calculations of quantity could be reliably applied if local data were available.

These basins are not being drawn on to any extent at present, practically not at all; and they will contain their maximum amount of water, which will vary with the seasons and the rainfall. This amount depends on the configuration of the diabase in which the sandstone rests, which could only be determined by boring, but it is not of much importance, the amount of water capable of entering the basin yearly being the important figure. If the water in a basin at any one time was relied on, the supply would soon give out, and in cases of underground water-supplies, care must be taken that a greater quantity than the annual intake is not removed, otherwise supplies would dwindle, and become unreliable.

At present all the surplus water above the level of saturation or the water table comes to the surface again as springs, seepage, and soakage, and joins the run-off. With supplies being drawn, the amount of water capable of entering the basins is that part of the rainfall over th total drainage area of the basin which percolates into the basin, and therefore

= (percolation) × (rainfall) × (catchment area)

1 inch of rainfall on a square mile = 2,323,200 cubic feet of water

and for the Midlands the percolation = 20 per cent.

annual amount of water entering a basin = $\frac{20}{100}$ × 2,323,200 × (rainfall in inches) × (catchment area in square miles)

cubic feet

= 464,640 × (rainfall in inches) × (catchment area in square miles)

cubic feet

or 2,900,00 × (rainfall in inches) × (catchment area in square miles) gallons.

This figure will apply where the drainage area and the basin are practically the same size, and where the area is occupied mainly by sandstones. As the conditions depart from these the application of the above formula becomes unreliable, and should not be utilised.

(8) *Quality of the Water.*—The underground water, though derived from rainfall—the purest water obtainable in nature—soon loses this pureness. In its passage over and through the soil and underlying rocks, it dissolves and holds in solution small quantities of organic and mineral matter. Providing the water does not come into contact with polluting materials, the amount of organic matter dissolved will be small. The nature and amount of dissolved mineral matter depends on the rocks the water traverses, and will determine the suitability or

otherwise of the water for various purposes. The analysis of the diabase given above ([20]) shows that the soluble salts which may be derived from this rock are those of calcium (lime), magnesium, iron, sodium and potassium, mainly in the form of carbonates. The iron seems to remain in the soil or at the surface in the form of "buckshot gravel," and the amounts of sodium and potassium are relatively small, so that the chief salts in the water will be those of calcium and magnesium. White incrustations are left on the stones in stream-channels when the streams dry up, and also white concretions are very numerous in the soil at several localities. Some of the latter were determined by Mr. W. D. Reid, Government Assayer, with the following results:—

	I.	II.	III.	IV.	V.
Silica (SiO_2)	9·66	5·50	22·30	17·26	10·60
Alumina (Al_2O_3)	3·20	3·75	5·76	12·29	9·76
Ferric oxide (Fe_2O_3)...	4·00	0·25	3·28	3·71	3·00
Calcium carbonate ($CaCO_3$)...	79·78	85·31	66·03	56·47	51·58
Magnesium carbonate ($MgCO_3$)...	1·56	3·26	0·15	7·56	23·00
Water (H_2O)	0·58	0·60	0·56	0·80	0·40
	98·78	98·67	98·08	98·09	98·34

I. Concretions in Soil: Three miles south-east of Tunbridge.

II. Incrustation on Diabase: Creek, seven miles south-east of Tunbridge.

III. Concretions in Soil: Southern shore of Ballochmyle salt pan.

IV. Concretions in Soil: Stringy-bark Creek, two miles south-west of Woodbury.

V. Large Segregations in Soil: Two and a half miles west of Woodbury.

These analyses show that the main mineral substance deposited from waters which have derived minerals from the diabase, is calcium carbonate, and to a much less extent magnesium carbonate. The waters themselves will contain a greater proportion of magnesium salts relative to calcium salts, because the calcium salts are much less soluble, and more readily deposited as incrustations, concretions, &c. Thus, these analyses support the above

([20]) See p. 61.

statement that the main constituents derived from the diabase by circulating waters are carbonates of calcium and magnesium.

The Trias-Jura sandstones are regarded as being deposited under lacustrine conditions, and should consist of mainly quartz grains (or sand), with a small amount of clay and muscovite (white mica), and so should be practically free of mineral matter which would yield soluble salts capable of being dissolved by the underground water. However, the salt pans of the Tunbridge Plains suggest the possible presence of salt in these sandstones. The late Mr. W. H. Twelvetrees,[21] Government Geologist, states "the saliferous sandstone of the Midlands. Several salt pans occur," &c., and regards the salt in these pans as obtained from the sandstones. He also states: "Saliferous sandstone exists also near Richmond, on the Coal River, 3 miles east of Colebrook, and reappears south of the town." The writer saw no evidence of the sandstones being saliferous in the Midlands, though he regarded the salt of the salt pans as coming from the Trias-Jura sandstones.[22] The Richmond occurrence proves definitely that the sandstones may be saliferous at some localities, and that the sandstones were probably deposited under somewhat arid conditions, and may be saliferous at certain localities and horizons. This will affect the quality of the underground water where the sandstones are saliferous, which apparently is not common. The analyses of water from two wells in Oatlands are given below, and both contain chlorine, so that it appears that, though not highly saliferous, all the sandstones probably contain very small amounts of common salt.

The mineral matter derived from the felspathic sandstones is probably very small in amount, but may consist of carbonates of sodium, potassium, and calcium. There is no available evidence for the existence or otherwise of common salt in these rocks.

Thus the mineral salts existing in the underground water of the Midlands are likely to be carbonates of calcium and magnesium (from the diabase), and sodium chloride (from the sandstones). The firstnamed salts are likely to be present in all the waters, but the latter salt is only likely to be present in any quantity where the sandstones are highly saliferous. It will be the quan-

(21) Secretary of Mines' Report, 1908, p. 144.
(22) See p. 129.

tity of these substances present which will determine the suitability or otherwise of the water for various purposes.

The structure of the basins which exist probably prevents absolutely free circulation of the waters, and some concentration of mineral matter in the water may occur. Absolute stagnation should only occur in depth, and in the upper levels of the water-supply there should be sufficient circulation to prevent any great concentration of mineral matter.

ANALYSES OF WELL WATERS FROM OATLANDS.

(By W. D. Reid, Government Assayer.)

	I.	II.
	Grains per Gallon.	Grains per Gallon.
Total solids	43·05	39·97
Sodium chloride...	17·90	29·67
Sodium sulphate...	3·83	—
Magnesium chloride...	—	2·41
Magnesium carbonate	5·01	2·12
Calcium carbonate...	9·30	2·50
Ferric oxide	0·17	0·85
Alumina	0·31	0·10
Silica	0·56	0·98
Volatile matter	5·39	0·65

I. Water from well at residence of Mr. J. Tremaine, Oatlands.

II. Water from well at residence of Mr. Jones, Oatlands.

The second water is regarded as the best in Oatlands at present, and the analysis verifies the fact that it is a good water. This water apparently has little contact with diabase, and must pass almost entirely over and through sandstones to explain the low calcium and magnesium content, and the high chlorine content.

The first water is regarded as one of the hard waters of Oatlands, and was taken as a typical sample of these waters. A small amount of surplus rain-water enters this well at times, but will have little or no effect on the quality. This water is probably a more average water, and contains much higher proportions of calcium and magnesium, and a lower proportion of chlorine, than the other water.

(c) *The Underground Water Resources of the Midlands.*

As already indicated,[23] geology and the structure of the Midlands is such that there exists a number of small local basins of underground water. These occur around Oatlands, Tunbridge, York Plains, Mt. Pleasant, Ellenthorpe, and Mike Howe's Marsh, and will be dealt with below. While these basins will be found to be the main sources of supply, every area where the unaltered sandstones outcrop at the surface is a possible source of underground water. The springs, seepages, and soakages which occur to some extent in the Midlands are also part of the underground water resources of the Midlands.

(1) The Underground Water Basins.

These will be described, and the main features of each, along with all the information which can be given as regards the quantity and quality of the water, will be dealt with. Maps of the more important of these basins are given in the accompanying plates, V., VI., and VII. On these maps it will be observed that the area given as suitable for obtaining supplies of water does not include all the porous sandstones in the vicinity of the particular basin.

(i) The sandstones near the diabase, which generally occurs around the basins, may not attain a great depth, and as they are above the general level of the basin, the movement of the underground will be away from them, and the supply of water will be unreliable. Hence these areas are not included with the suitable areas.

(ii) The sandstones may form elevated and broken country, and apart from the fact that these areas are not cultivated, and do not need water for irrigation, the depth to water would very likely be too great to enable it to be economically used for irrigation.

(*a*) *The Oatlands Basin (Plate V.).*—This basin occurs around Oatlands and Lake Dulverton, and may be said to consist of all the level ground in that vicinity, and has as boundaries the hills, which close it in on practically every side. It has a catchment area of about 23 square miles, 16 of which are composed of sandstones and 7 of diabase. Lake Dulverton occupies, roughly, the centre of

(23) See p. 79.

this area, and is fed by two creeks (both known locally as Bacon's Creek), from the south and south-east respectively, Previously to the damming of the lake the overflow formed the Dulverton Rivulet, which stream for its surface supplies has now to depend on the four south-flowing creeks, which enter it to the west of the lake. The Dulverton Rivulet receives much underground water by soakage, as the water-table intersects the surface of the ground along the course of this stream.

Geology.—As shown in Plate V., this basin consists of a flat area of sandstones surrounded by hills of diabase on practically every side. The sandstones extend to the south and east from Parattah, but diabase must occur at no great depth, and the limit of the basin may be taken as that shown. This includes all the area from which the drainage is into the lake, and also probably that in which the movement of the underground water is towards Lake Dulverton and Dulverton Rivulet. Diabase occurs to the west, and acts as an effective dam to the underground water in that direction, and the surplus water soaks out along the Dulverton Rivulet as mentioned above, this rivulet leaving the area through a small gorge cut in the diabase.

Quantity.—The average rainfall for Oatlands is 21·40 inches, and the calculated average for three consecutive dry years is 75 per cent. of this, or 16·05 inches, the actual figure for the three years 1913, 1914, 1915 being 15·05 inches. The catchment area is about 23 square miles, so that the annual amount of underground water available

$$= 2{,}900{,}000 \times 16{\cdot}05 \times 23 \text{ gallons}$$
$$= 1{,}000{,}000{,}000 \text{ gallons approximately.}$$

Quality.—The water is not regarded at the present time with much favour, chiefly on account of its hardness, and rain-water collected in tanks has replaced the well-water. That the well-water had a considerable use in the past is evident from the fact that upwards of 50 wells exist in the township, and the early settlers must have been dependent to a large extent on the wells for their water-supplies. Apart from the necessity of obtaining water-supply, these wells in such great numbers prove that the water must have been of at least fair quality, otherwise the wells would not have been sunk, and it seems certain that deterioration in the quality of the water has occurred. That this is so can be sometimes established for individual wells as far as their history can be obtained from local inhabitants and people connected with them for a number of years. Apart from the factors discussed in the general consideration of quality, another factor coming into operation is that of human inhabitation of the area, which may affect the quality of the water very seriously. Some of these wells have been in existence up to 70 and 80 years, and have not been cleaned out, which is readily understood when it is realised that ordinary baling with windlass and bucket will not lower the water sufficiently to enable cleaning operations to be carried out, and pumping by mechanical means being costly, was not resorted to. Thus at the present time the wells contain an accumulation of old buckets, and other articles, rubbish, dust, &c., either dropped in, blown in by the wind, or washed in by the rain on the surface, being rendered possible by insufficient protection of the surface portion of the well. There is also the very serious pollution which may have occurred by surface or underground leakage of sewage into the wells.

That good water has existed and still exists is shown by the following facts:—The well considered as yielding the best water in Oatlands is that at the residence of Mr. Jones, Stanley-street, known originally as Solomon's Well, and which always yielded water of good quality. When supplies of tank water in the township fail, considerable quantities of water are carted from this well for household purposes. The well at the Kentish Hotel, corner of High and Church streets, yields water capable of being used for all purposes. The wells at the residences of Mr. E. Bishop, High-street, and Mrs. Taylor, Stanley-street, are also said to contain good water. The well at the old brewery was apparently suitable for brewery purposes in those days.

In connection with the deterioration of water in a well, that of Mr. W. Dickenson is a good example. This well has been in existence at least 70 years, and was regarded as equally as good as Solomon's Well, much water being carted from it. At the present it is regarded as giving hard water, due no doubt mainly to not having been cleaned out during its 70 years of existence.

An interesting case occurs in connection with the well at the house of E. Bishop, and another not more than 12 yards from it, where the firstmentioned well is yielding good water and the other one hard water. These wells are sunk to the same depth, and have the same depth of water in them, so they are apparently in the same strata, and there should be no difference in the water they yield, so that it suggests a different degree of cleanliness of the two wells.

The above discussion suggests that originally the quality of the water must have been at least fair, in some cases being exceptionally good, while in the majority it was probably slightly hard, though otherwise satisfactory. As tanks came into use the wells became neglected, and, in the absence of cleaning, the water became harder and of poorer quality. Further, the water was sometimes used for rough cleansing purposes at or even over the well, the dirty water running back into the well, which would hardly improve the quality of the water in that well, and possibly the neighbouring ones also.

In view of the fact that Oatlands requires a public water-supply, the quality of the underground water is an important factor. The analyses of the water from two wells in Oatlands are given above,[23] and show that the quality of the water is very good.

(*b*) *The York Plains-Mt. Pleasant Basin (Plate VI.).*—This basin occurs in the vicinity of York Plains, Nala, east of Andover, and part of the Mt. Pleasant Closer Settlement Estate. This basin does not form one continuous basin, but consists of three separate ones more or less distinct from one another. These have been included in the above basin for convenience of mapping, but will be described separately. In general these basins are separated by masses of diabase, but at a few points by elevated masses of felspathic sandstones.

The York Plains Basin includes all the less elevated land along the Main Line Railway and the York Rivulet and its tributaries from near Andover in the south to several miles north of York Plains Station in the north. This basin covers an area of about 7 square miles, and by means of the York Rivulet and its tributaries receives the drainage of 33 square miles (including its own 7 square miles) of country.

The Mt. Pleasant Basin includes an area of 5·7 square miles of country to the east of Mt. Pleasant and the Handsome Sugarloaf, forming the best portion of the Mt. Pleasant Closer Settlement Estate. Numerous creeks rise in this locality and form the main headwaters of Kitty's Rivulet, and the basin receives the drainage of 20 square miles of country.

([23]) See p. 87.

Another small basin occurs around the headwaters of the Lightwood Rivulet and the Little Swanport River. It covers an area of $1\frac{3}{4}$ square mile, and receives the drainage from about 6 square miles of country.

Geology.—These basins consist of comparatively flat and low-lying areas of felspathic sandstone resting in depressions of the diabase and more or less completely surrounded by diabase hills. Diabase occurs on the down-stream side of these basins, and acts as a barrier to the movement of the underground water in this direction.

Quantity of Water.—The conditions are not so favourable for entering into the calculation of amount of underground water available per annum as they are with the Oatlands basin. The area of the basin and the catchment which drains into it differ greatly, and as the latter in general contains much diabase the percolation would be lower than 20 per cent. for the whole catchment. Or if the area of the basin be taken and the percolation taken as normal (20 per cent.), then the amount of water entering the basin by means of streams becomes very indefinite. Thus, with conditions being very indefinite, calculations would be very approximate, and are better not attempted.

Quality of Water.—Nothing can be said on this matter, as no wells exist anywhere in the above basin. Seepage occurs at numerous points, and small surface pits are occasionally dug near these, the water being used to water stock. No evidence of any salt exists in the felspathic sandstones, and the water should be free from this mineral. Calcium and magnesium salts will exist in the water, as in the Oatlands basin.

Present Utilisation.—Except for a few shallow pot-holes, which hold mainly surface water, no wells exist in these basins, and the underground water is not utilised.

(c) *The Tunbridge Basin (Plate VII.)*.—This basin occurs to the east of Tunbridge, and practically coincides with all the comparatively flat and low-lying country there known as the Tunbridge or Salt Pan Plains. The Blackman's River and York Rivulet enter from the west and south respectively, and unite and empty into the Macquarie just to the north of the basin. The basin covers an area of 18 square miles, exclusive of the two diabase masses enclosed in it. It has a direct drainage area of 50 square miles, apart from the large areas drained by the York Rivulet, Curryjong Rivulet, Blackman's River, and their tributaries, before entering the basin.

Geology.—This basin consists of horizontally-bedded sandstones of the Lower Trias-Jura series, with overlying felspathic sandstones coming in to a small extent towards the south. Permo-Carboniferous strata occur to the north and north-west of the area. This area of sandstones, &c., is surrounded by high hills of diabase on every side except the north-east. Here basalt-flows occur, overlying river deposits, which in turn probably overlie Trias-Jura sandstones.

Quantity of Water.—The conditions are too indefinite, especially as regards the amount of water entering the basin by means of surface streams and the proportion of this absorbed, for calculations to be entered into.

Quality of Water.—Only three wells have been sunk in this basin, and these are on the edges and do not give a good idea of the quality of the water. The well at Glenmorey is in felspathic sandstones near the bed of the unnamed creek flowing past Brent's Sugarloaf, and gives water of very good quality.

The other wells are both in thick accumulations of diabase soil, which occurs in places between Tunbridge and Woodbury. One is situated at the residence of J. O. Powell, Tunbridge, and though not used now, had a large use for nearly all purposes in the past. The water from this well is said to have been "mineralised," but the amount of mineral matter could not have been excessive, seeing it was so largely used. The other well is situated just off the main-road to the south of the Tunbridge township boundary. Conflicting accounts of its quality are given, but it was used very little, and apparently contained much soluble salts.

As regards the quality of the water in the main part of the basin, nothing can be said definitely, and the presence of the white concretions in the soil at one locality already described,(24) and the occurrence of the salt pans are not very favourable to the existence of good-quality water in the parts of the basin where these occur. The water in the area where the white concretions occur would, as a result of the bad drainage, be too heavily charged with mineral matter to be of good quality. If the water were in continuous use it would increase in purity, but could not be used locally on account of the bad drainage, though the withdrawal of quantities of water would probably improve the drainage somewhat.

(24) See p. 85.

The salt pans are discussed later,[25] and the conclusion arrived at that the salt is derived from the Trias-Jura strata, probably occurring as thin beds in the latter. The purity of the water in the Tunbridge basin will depend on whether these salt deposits are local or else more or less distributed throughout the sandstones of the Tunbridge plains. The salt is restricted mainly to the Mona Vale and Ballochmyle salt pans, and so there is some localisation of the salt, but as small amounts occur on most of the lagoons on the Tunbridge and Ellenthorpe plains it is evident that the salt is in very small quantities, distributed throughout the sandstones.

Thus, the quality of the underground water is doubtful, and can only be ascertained by actual drilling, and testing of the water obtained. Around the edges of the basin, and in localities where the level of the water-table is above that where the salt occurs and the direction of movement of the underground water is towards the latter, there is every chance of obtaining good-quality water, provided that pumping does not lower the water-table sufficiently to cause the water from the salt area to move towards the well.

Present Utilisation.—As indicated above, only three wells occur in the basin. The one situated to the south of Tunbridge township has had little or no use. The one at the residence of J. O. Powell was formerly used for general farmyard purposes, such as watering stock, &c., and even for washing clothes, but these uses have now been discontinued.

The well at Glenmorey, belonging to A. Burbury, is of recent construction, and yields water of good quality. It is at present used for general farm purposes, but is shortly to be utilised to irrigate an orchard.

(*d*) *The Ellenthorpe Basin.*—This basin occurs in the north-west corner of the district around the Ellenthorpe property, to the west and south of the Hanging Sugarloaf. No plate is given for this basin, as the whole of the probable area was not examined. The part examined may be taken as that area mapped as Trias-Jura, and covering about 13 square miles. This area is dotted with lagoons, and the drainage is to the south, eventually joining the Mill Brook. Some of these lagoons leave a thin layer of salt on the beds, but do not yield crystals as the salt pans do, being comparable with the White Lagoon rather than

(25) See p. 129.

the salt pans. The unexamined area to the north is part of the drainage system of the Isis River, which flows northwards.

Geology.—This basin is similar geologically to the Tunbridge basin, in that it consists of sandstones of the Lower Trias-Jura series, which are more or less surrounded by diabase hills. To the north of the basin Permo-Carboniferous strata occur, and as flat country seems to persist for a considerable distance northwards along the foot of the Tiers, there is the probability of a large basin existing in that direction.

Quality.—Owing to the conditions being similar to those of the Tunbridge basin, the same doubt as to the quality of the water as regards common salt must exist, and the quality of the water could only be established by drilling.

Present Utilisation.—No wells exist in this basin, and the water is not utilised at present.

(*e*) *Mike Howe's Marsh Basin.*—This basin occurs along the upper part of the Blackman's River, and includes the alluvial flat known as Mike Howe's Marsh. No map is given of the basin, but it may be taken as consisting of the area of Trias-Jura strata mapped in that locality on the geological sketch-map (Plate II.). These sandstones cover an area of 9 square miles, but only that portion of the basin around Mike Howe's Marsh, and the comparatively low-lying part along the road to Oatlands, would be suitable for obtaining water at shallow depths, the remainder being elevated and broken country and unsuitable for such purposes.

Geology.—The geology of this basin is that typical of previous basins, viz., an area of porous sandstones resting upon and surrounded by diabase. These sandstones are capped by basalt at Flat-top, and rise high above the surrounding country to the south and east, but this does not affect the typical structure of the basin.

Quality.—No wells exist in this basin, as there is a fair supply of water in the Blackman's River, and the underground water is not needed. This area receives a plentiful rainfall, and as the basin seems to be well drained, the quality of the water should be good.

Present Utilisation.—As mentioned above, there is no call for underground water in this area, and no attempts have been made to utilise the water.

(2) Other Sources.

Apart from the sandstones occupying the basins described above, other areas, both large and small, of sandstones exist, as shown by the geological sketch-map. These may lack the structure of the basins, or else may be too small to warrant special description, and are not included with the basins.

(*a*) Large areas of sandstones occur along the Exe Rivulet and to the south-east of Parattah. These form elevated and broken country, with streams cut deeply into them, and lack the structure typical of the basins. Water will occur underground in these areas, but the depth to water will be very variable and much greater than in the basins. As the main object of this investigation was water for irrigation, and the depth to water would be prohibitive for irrigation on economic lines, these areas are not described along with the basins, but nevertheless the water exists, and could be obtained by drilling to depths greater than those necessary in the basins. This also holds for other areas of sandstones occurring under similar conditions.

(*b*) Numerous small areas of sandstones occur throughout the Midlands, and are potential sources of underground water-supply, and will be dealt with in a general manner.

These sandstone areas are generally low-lying, and may occur between diabase hills, as is the case with the larger basins. A small stream or drainage channel generally exists in such areas, and forms a black alluvial flat.

The conditions are similar to those existing for the basins, and it may be taken that supplies of underground water occurs in such localities. The quantity will vary with the area of sandstones, &c., and may be determined very approximately by the figures already given. The quality will be similar to that discussed for the basins.

Such small sources of water may exist anywhere where the necessary conditions are fulfilled, but are most plentiful in the stretch of country to the south-east of Oatlands. These areas can be picked out by the areas of sandstones (Trias-Jura) shown on the geological sketch-map (Plate II.).

(3) Springs, Seepage, and Soakage.

These occur in parts of the Midlands district, but the quantity of water available in this form is small. They are formed in several ways.

(*a*) Rainfall on diabase soil may percolate into the soil and decomposed rock, but when this water comes into contact with the solid rock it is largely forced to move over the surface of this rock. Springs formed by this cause are numerous on the face of the Tiers along the Oatlands-Interlaken road and in that vicinity. The quantity of water flowing is small, and besides forming small supplies of water for stock, has no other use.

(*b*) The movement of underground water in the porous sandstones may be directed to the surface of the ground again by various causes. Half a mile to the south of Parattah the movement of the water in the sandstones is arrested by an underlying intrusion of diabase, and the water is forced to move along the surface of the latter, and reaches the surface where the diabase outcrops. The Railway Department has made two excavations to catch this soakage, and pipe it by gravitation to Parattah station, and use the water in the locomotive boilers. Springs, &c., are caused by less porous beds in the sandstones causing the water to move along them and reach the surface. Also by the water-table cutting the surface of the ground, due to the configuration of the latter. It is difficult to distinguish the cause of the springs in sandstone country, and they may be due to either of the above reasons. Springs, &c., are numerous in the sandstone country to the east and south-east of Parattah, and form the only supplies of water for watering stock and other farm purposes. These also occur near Oatlands, and one just to the north of the township is conserved to a slight extent and piped into a trough for watering horses, &c. Springs are also numerous in the high sandstone country of Flat-top and around the south of Lake Crescent, the water of which is probably the source of the springs in this locality. Soakages occur in many of the small alluvial flats throughout the district along drainage slopes. Pot-holes and excavations are often made at these points, and serve as watering places for stock.

(*d*) *Method of Obtaining Supplies.*

The water in basins and other underground resources of the Midlands is not under artesian conditions, and so will not rise to the surface when tapped by wells. Means have to be adopted to bring the water-supplies, made available by wells, to the surface. Dug wells are the only type so far used in the Midlands, the water being raised by windlass, rope, and bucket in the majority of cases, and occasionally by windmill and pump. In modern practice, bored and drilled wells have largely displaced dug wells, a small power plant and pump being used to bring the water to the surface.

(1) Selection of Type of Well.

The type of well to be sunk depends on many factors. Apart from the purposes for which the water is to be used (which will be considered under that subject),[26] the following are the main factors [27] bearing on this question:—

(*a*) *Character of the Materials.*—This will affect the selection of the type of well in two ways. Firstly, the question as to whether the materials in the well yield the water readily or otherwise. The materials we are concerned with in the Midlands are sandstones and felspathic sandstones, with porosities of 14·6 per cent. and 26·3 per cent. respectively, and these rocks should yield the water fairly readily. This means that the diameter and depth of the wells need not be large, as excessive storage is not required with materials which yield water readily. Secondly, the character of the materials will largely determine the method of sinking to be employed. The sandstones, though they are solid rocks, are easily broken, and are quite suitable for the sinking of dug wells. Boring by hand methods would not be possible, except for small bores, which would be unsuitable for water-supply. Of the various drilling methods, the percussive method is the one that recommends itself, and a simple form of percussion plant would be the most suitable.

(*b*) *Depth to Water.*—The greatest depth to water during the writer's examination of the Oatlands wells was 30 feet, but the depth of the water-table from the surface varies with the seasons and years, and during the dry summer of 1919-1920 the water-table dropped to 46 feet below the surface at some places. The depth to water is therefore not great, and is favourable to any type of well, but it represents the conditions under which dug wells can be used. The greater the depth to water the more favourable do the circumstances become for drilled, instead of dug, wells.

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(26) See p. 107.
(27) United States Geological Survey Water-supply Paper No. 255, p. 32.

(*c*) *Amount of Water Required.*—As the amount of water required approaches the annual amount entering the basin, the deeper the well or wells would have to be in order to make use of the water stored in the basin, to enable pumping of large amounts of water to be carried out continuously over dry periods. Thus, the greater the amount of water required, the deeper the well has to be, and so dug wells would give place to drilled wells, dug wells being only favoured for shallow depths.

(*d*) *Relative Cost of Different Types.*—Of the various types of drilled wells, those drilled by standard percussion methods are the cheapest, the calyx and diamond methods being used only when cores are required. The following figure was given by the Water Conservation and Irrigation Commission of New South Wales, in which State practically the whole of the drilling for artesian water is carried out with the standard cable plant, using percussion tools. The present cost in that State is £1 16s. to £2 per foot, up to depths of 3000 feet. The less the depth the cheaper is the cost per foot, and for the shallow depths required in the Midlands the above figures would be reduced somewhat. The Department of Mines, Victoria, carries out most of its boring with the Victoria boring machine, which can be used either as a rotative or percussive machine, using calyx bits or percussion tools. This machine is used largely in boring for coal in their rocks of Jurassic age, which are similar to our Trias-Jura rocks.

The following table (No. 9) shows the cost per foot with this type of machine:—

TABLE No. 9.

Year.	Cost per Foot.
	s. d.
1901	13 3
2	12 5
3	12 4
4	14 5
5	10 10
6	13 4
7	13 2
8	8 3
9	12 3
1910	7 4
1	8 8
2	9 3
3	8 4

No figures have been published since 1913, but the Secretary of Mines, Victoria, in a recent letter gives the cost at 8s. per foot, so apparently, in spite of increased cost of material and labour, improvements in plant and operating of same have counteracted these increased costs and kept the cost of boring at 8s. per foot.

In connection with the boring to shallow depths (up to 500 feet), as would be required in the Midlands, the Secretary of Mines, Victoria, states: " A simplified form of the Victorian machine, as adopted by Mr. Stanley Hunter, our Engineer for Boring, for work in France, would probably be suitable, and cost considerably lower than the standard type of Victoria plant."

The above figures refer to straight-out boring, and a bore for water has to be lined with casing and finished properly.

The present price of casing, as charged at Sydney by importing firms, is—

	Per Foot.	
	s.	d.
10-inch casing	25	0
8-inch casing	16	8
$6\frac{3}{8}$-inch casing	12	6

The Victorian figures are for about a 4-inch hole, and the cost of a 6-inch hole would very likely be somewhat greater. A 6-inch well, drilled, cased, and finished, would cost at least 20s. 6d. per foot, and would probably be 25s. to 30s. per foot if machines and operatives as efficient as the Victorian ones were available.

Dug wells can be sunk very cheaply in soft materials, and to shallow depths. Wells to 60 or 70 feet in the Midlands would have to deal with water from 30 feet downwards, and the cost of sinking would exceed £2 per foot, and the cost of a finished 5-foot diameter circular well would very likely exceed £3 per foot.

(*e*) *Safety of Well.*—Providing the water at its source is pure, the safety of the well depends upon its construction, which will protect the well from entrance of contaminating liquids and solids.

Any type of well can be made more or less safe, depending on the amount of work and finish put into it, but the small-bored well, with its tight-fitting iron casing, is much more efficient from the point of view of protection, and the tendency of modern practice is to the use of such wells. A dangerous type of well is that of the combined dug and drilled type, on account of its fancied safety, which does not exist, unless the dug part is very efficiently protected.

(*f*) *Conclusions.*—The materials with which we are concerned in the Midlands admit the possibility of either dug or drilled wells; in the latter case a simple drilling-machine with percussion tools being favoured.

The sandstones yield water freely, and only in cases where large amounts of water are required would either the dug or drilled well have an advantage over the other, deep-drilled wells then being favoured. As regards depth to water, the drilled has no advantage over the dug, as this depth is not excessive. Considering the safety of the well as regards purity of the water, the drilled well has much in its favour above the dug well. It is the cost, however, which is generally the deciding factor. For very shallow depths in soft materials the dug well is the cheapest, but otherwise the drilled wells are the cheapest. There is, however, the initial cost of plant to be considered, which is considerable in the case of drilling-machines, and very small with dug wells; and in view of the absence of drilling-machines in Tasmania this point must have considerable weight.

With machines of the Victoria type, or a simplified form thereof, and also skilled operatives of these machines available, wells drilled by these would be the best and cheapest from nearly every point of view, and is the type recommended. Unless such machines are introduced, it seems as though the less satisfactorily dug well would have to be utilised.

(2) Type of Pumping Plant.

This is more a matter for the mechanical engineer, but something will be said on this subject, and also in connection with the power to operate it.

Where the depth to water, and quantity of water available, are such that during pumping the level of the water will not sink below 28 feet from the surface, any type of pump situated on the surface of the ground may be used. The 28-feet is the maximum length of suction-pipe which can be used with ordinary pumps. The same result can, of course, be obtained with deeper water, by building a pump chamber underground, so that the suction head does not exceed 28 feet. The common types of pump are the reciprocating and centrifugal pumps.

Reciprocating pumps are those in which a piston moves to and fro in a cylinder, water being admitted behind the piston and forced out on the return stroke. These may be single or double acting, and are most suitable for high lifts.

Centrifugal pumps consist of a series of rotating vanes in a casing, water being drawn in at the centre of the vanes and discharged at the circumference when the vanes are driven at a sufficiently high speed. They are suitable for small heads, and must be run compound for larger heads. Having no valves, they do not get out of order easily, which is a great advantage. As high speeds are necessary, these pumps can be directly coupled to electric motors. When the depth at which water can be pumped exceeds 28 feet, and the plant is situated on the surface, pumps on the principle of the "plunger and draw-lift" have to be used. These are reciprocating, and consist of a cylinder and piston or plunger, situated well down in the well, and worked by a rod connected to the motive power on the surface. These types are used on windmills, no matter what the depth to water, and are referred to as deep-well pumps and deep-well cylinder pumps. With dug wells, other methods of raising water can be adopted, such as windlass, rope, and bucket; continuous chain, with small elevator buckets; continuous chain and canvas belt; hand pumps, &c.

(3) Power Plant.

Power is obtained from many sources, such as wind, steam, gas, oil, and electricity, and the selection of a particular type of power plant depends upon many circumstances, cost of installation and running being the main factors, as well as quantity of water required and use to which it is to be put.

(*a*) *Windmills.*—These are largely used for pumping from shallow wells, their advantage being that they use the energy of the wind supplied free by Nature, the cost of running being simply that of lubrication and repairs. The greatest disadvantage is that they are entirely dependent on the wind, and may not be available when required. Further, they do not develop much power, and would only be suitable for wells with small yields and no great depth to water. The following tables from the Department of Agriculture Year-book U.S.A., 1917, show how much water the windmills can handle:—

TABLE NO. 10.

Work Done by a Twelve-Foot Windmill.

Velocity of Wind.	Height Water was Lifted.	Quantity of Water Pumped per Hour.
Miles per Hour.	Feet.	Gallons.
6	56	89·76
8	56	269·28
10	56	501·16
12	56	718·08
17	56	1271·60
18	56	1353·88

The lift and quantity are dependent on each other, and if one is increased the other will decrease in about the same ratio, and *vice versa*. It will be noticed that the quantity of water pumped increases at a much greater rate than the wind velocity, *e.g.*, if the velocity is increased from 6 to 12 miles (doubled) per hour, the quantity of water is increased from 89·76 to 718·08 (eight times), while for from 6 to 18 (trebled) the quantity of water is increased 15 times.

TABLE NO. 11.

Work Done by Windmills of Different Sizes.

Size and Type.	Time	Average Wind Velocity.	Height Water was Lifted.	Quantity of Water Pumped.	
	Days.	Miles per Hour.	Feet.	Gallons.	Acre-Feet.
16-foot, direct stroke ...	45¼	12·98	56	752,967	2·31
14-foot, back-geared ...	45¼	12·98	56	666,991	2·05
13-foot, back-geared ...	45¼	12·98	56	502,207	1·54
12-foot, back-geared ...	45¼	12·98	56	408,854	1·25

No data with regard to wind are available for the Midlands, and the data for Hobart are given in Table No. 12. The conditions for these two localities are not the same, but the figures will give some indication of the wind likely to be met with in the Midlands, and it is the belief of the writer that the velocities are higher in the Midlands.

TABLE No. 12.

	Jan.	Feb.	Mar.	April.	May.	June.	July.	Aug.	Sept.	Oct.	Nov.	Dec.	Average.
Total miles for month	5984	4365	4788	4750	4677	4632	4628	4905	5768	5847	5745	5738	—
Miles per day	193	155·9	154·4	158·3	150·9	154·1	152·5	158·2	192·3	191·5	191·5	185·1	169·1
Miles per hour	8·0	6·5	6·4	6·5	6·3	6·4	6·4	6·5	8·0	8·0	8·0	7·6	7·05
Maximum miles per day	500	393	406	432	411	569	396	459	516	468	508	375	—

The average velocity is 7 miles per hour, and from Table 10 this would, operating a 12-foot mill, only give about 200 gallons per hour. Winds with velocities about the average exist and give larger results. The present practice in the Midlands and adjacent parts of Tasmania is to use an 8 or 10 foot mill on a 20 to 30 foot tower, and this will yield with suitable pump at least 500 gallons per hour and up to 1000 gallons per hour. These results will be obtained from winds with above the average velocity, and indicate velocities of about 10 to 12 miles per hour. Over continuous periods the velocity would be nearer 7 miles per hour, and the yield nearer 200-500 gallons per hour.

(*b*) *Steam* as a source of power is not greatly favoured for small supplies of water. The plant requires a good deal of attention, and has to be started some time before pumping can be initiated. Good to fair quality coal is needed as a fuel, and such coal supplies do not exist in the Midlands.

(*c*) *Gas* is a very useful source of power, but as there are no gas companies to supply it in the Midlands, small producer gas plants would have to be installed. These plants can use hard coal, coke, charcoal, or wood. Coke or charcoal is generally found to be the best, though wood is very suitable, but only with the proper type of producer. Producer plants and gas-engine provide the cheapest source of power available (except probably hydro-electricity), and are easy to handle.

(*d*) *Oil Fuels* for use in internal combustion engines are very convenient sources of power. These engines can be started and pumping commenced almost at once, and practically no attention is necessary during the running.

(*e*) *Electric Current* for use in motors is generally a cheap and very convenient power to use. No current is available in the Midlands at the present time.

(*f*) *Conclusions.*—The following conclusions are arrived at, taking into consideration the conditions existing in the Midlands:—For small quantities of water, windmills will be mostly used, and possibly supplemented by a small power plant. Internal combustion engines using petrol or similar fuel will be found to be the most convenient power to use apart from the windmills. If considerable quantities of water are to be used or a central power-station erected, producer gas plants with, in the latter case, generation of electricity, will be found to be the most economical source of power.

(4) Depth of Well.

This depth depends on the depth of the water-table and the fluctuation which it undergoes at the locality where the well is sunk. To enable a supply of water to always be available in the well, the well should be sunk below the greatest depth of the water-table in dry seasons. Except for the Oatlands basin no information can be given as to this figure, and as it varies in different localities, experience alone will determine it. During this investigation the greatest depth to water in the Oatlands wells was 30 feet, but during the dry summer of 1919-20 this increased to 46 feet in some of the wells. Under these circumstances the depth of a dug well would be 66 feet at least (allowing 20 feet below the water-table for storage) and of a drilled well at least 76 feet (allowing 30 feet for storage below the water-table). If large quantities of water are to be pumped these depths would have to be increased so that the water stored in the basin could be taken advantage of to enable pumping to be carried out over dry periods. Pumping from a well withdraws the water from around the well, and produces an artificial lowering of the water-table, causing it to slope in towards the well from all directions. By increasing the depths of the well the gradient of the water-table is prevented from becoming too small, in which case water could not enter the well. Thus the deepening ensures a supply of water for the well.

The modern practice where large quantities of water are required for, say, irrigation purposes, is to increase the number of wells rather than have a deep well where the cost of pumping is excessive.

(5) Size of Well.

The standard sizes for drilled wells are 6-inch, 8-inch, and 10-inch diameter. Very deep wells start off with one of the larger sizes and end with the 6-inch. For the conditions in the Midlands of small depths only one size will be needed in a well. The smallest, 6-inch diameter, will probably be favoured, but it must be remembered that the larger ones, though slightly more expensive, will have greater storage capacity and be better for pumping purposes. The size will be largely determined by the rate at which the wells yield water, about which little can be said, as large quantities of water have not been pumped from any of the wells. The greater the difference between the rate at which the water makes into the well and the rate at which it is to be pumped, the larger must be the diameter and depth of the well, so as to provide larger storage capacity and also increase the rate at which the water makes. Experience will be necessary to determine the yield of the wells before the dimensions of a well for a particular amount of water can be determined.

The dug wells in the Oatlands district are all circular, and are 4 to 5 feet in diameter. This is quite a suitable size, and the circular type is convenient in the sandstone, which stands well and does not need support.

(e) *Utilisation of the Underground Water Supplies.*

Little use has so far been made of the underground water supplies of the Midlands district. The obtaining of supplies of water for drinking and household purposes has been the greatest effort in this direction, with the result that over 50 wells exist around Oatlands. The collection of rain-water in tanks has now mainly displaced the use of well-water for these purposes, on account of the varying hardness of the latter, and, apart from the few wells yielding good-quality water for drinking and household purposes, the water is used for odd purposes only.

The purposes of any other wells in the Midlands have been mainly to obtain supplies for watering stock.

A much greater use of the underground water is possible in the future, and is dealt with in the following pages. Pumping of the water and irrigation of the land would greatly assist agriculture. Watering places for stock could be obtained by well-sinking and pumping of the water, and would help the pastoral industry. Though the water is somewhat hard, a public supply could be installed for Oatlands. There is also the possibility of suitable supplies for use in the locomotive boilers of the Railway Department.

(1) Irrigation.

(*a*) *Introduction.*—Agriculture is carried out in the Midlands mainly round the following localities, which are given, together with their average yearly rainfall and their minimum rainfall:—

TABLE No. 13.

Locality.	Average Rainfall.	Minimum Rainfall.
	Points.	Points.
Oatlands	2136	1388
York Plains	—	—
Mt. Pleasant	2100	2000
Woodbury	1787	1083
Tunbridge	Similar to Woodbury and Ross	
Ross	1797	1013
Jericho	1963	1363

In districts where the average rainfall is 20 inches or more, agriculture can in general be successfully practised without irrigation, good crops and a good quality of hardy cereals, like oats, being obtained. Of the above, Oatlands and the parts of York Plains and Mt. Pleasant Estate adjacent to Mt. Pleasant are the localities above the 20-inch rainfall.

The other localities have rainfalls between 15 and 20 inches, under which conditions dry-farming can be carried out with more or less success, depending on the total rainfall and its distribution throughout the year. The graphs in Plate IV. show the distribution throughout the year, and prove that June is a very wet month, July a dry one, and from August to October there is a steady increase in the monthly rainfall, from a low one in July to a high one in October—a wet month—followed by November, being a dry, and December, a wet, month. Sowing is performed from March to July, the early sowing being carried out on fallowed land. If water could be supplied to the crops during the comparatively dry period, between July and September, and during November, it would do much to increase the agricultural production of the Midlands.

To accomplish this by taking proper advantage of all the water which falls as rain the following methods are available:—

(i) Proper Method of Tillage Which Will Enable the Soil to Store the Moisture Most Efficiently.—The best results are obtained in the Midlands by letting the land lie fallow for one year and making an early sowing the next year. This is largely due to the fact that the moisture of two years is conserved in the soil, but while yielding a good crop, this method means that only half the land is producing each year. However, with the known conditions of rainfall as given above, the farmers could determine the best method of tillage under these conditions to conserve the moisture in the soil.

(ii) Conservation of Surface Waters and Irrigation.—These projects have to be carried out on a large co-operative scale, and are costly, and have not so far been undertaken. Ideas have been entertained of bringing the waters of Lakes Sorell and Crescent down to the low-lying parts of the Midlands. This certainly suggests itself as the best source of water, but it has already been reported on, and apparently condemned. Water could be stored along the courses of some of the streams of the district, but no attempts have been made in this direction.

(iii) Utilisation of Underground Water and Irrigation.—This has not been attempted in the Midlands up to the present time, though lately Mr. A. Burbury, of Glenmorey, near Tunbridge, has sunk a shallow well 12 feet deep, and obtained a good supply of water, with which by pumping with a windmill, he intends to irrigate an orchard. This, however, is the first and only attempt, apart from a few cases where a small quantity of well and spring water has been pumped by windmills for use in small flower and vegetable gardens. That considerable quantities of water exist has already been discussed, and generally its quality may be taken as suitable for agriculture. The question of the utilisation of this underground water will now be discussed more fully.

(*b*) *Conditions Determining the Use of Underground Water for Irrigation.*—The principal conditions determining the use of underground water for irrigation are [28]—

Depth to the Water Table.—This affects the question, in that the deeper the well has to be, the greater the distance the water has to be lifted, and the greater the cost of pumping. The depth to water is not great in the Midlands, being generally less than 30 feet, and seldom, if ever, greater than 50 feet. Generally it may be taken that the distance to lift the water does not affect the question of cost until it is over 50 feet to water, while the

[28] United States Geological Survey Water-supply Paper 343, p. 213.

upper limit is that at which it becomes too costly to lift the water for irrigation purposes, say about 100 feet; but this figure will, of course, vary with such factors as yield and nature of crop, and price obtained, &c. This condition is, therefore, in the Midlands quite suitable to the utilisation of the water by pumping for irrigation purposes.

Quantity of Water.—The quantity of water in the different basins has already been discussed.[29] There is sufficient water available to irrigate part at least of the agricultural land in the Midlands, but whether it will be enough to irrigate much of the agricultural land depends on the amount of water required to be put on the land to irrigate it, which can only be determined by actual trials and experience.

Generally it may be taken for the underground basins that about 3 inches of the rainfall will enter the basin by percolation from the rainfall and drainage entering the basin from other areas. The amount of water applied for irrigation may be in the vicinity of 4 inches per acre per month during the period July to October, and 1 foot per acre or more during November, depending upon the length of the dry spell which occurs about that month. This would mean at least 2 feet per acre would be required, so that no more than one-eighth part of the land could be irrigated. However, all the land in the basins is not suitable, and some has to be reserved for other purposes, so this proportion is not so low as it appears.

It is probable also that a combined method of dry-farming and irrigation could be evolved, water being added in very dry periods only. The adoption of such a method would allow of the utilisation of a much larger proportion of the agricultural land than by straight-out irrigation.

Quality of the Water.—This has been discussed at some length already,[30] and the deductions and assays show that the bulk of the dissolved solids consist of carbonates of calcium and magnesium, with perhaps sodium chloride present. The most injurious salts are those of sodium, in the order of carbonate (black alkali), chloride (common salt), and sulphate. Of these, the chloride is the only one likely to be present in any quantity, and that will be confined to parts of Tunbridge and Ellenthorpe Basins. The manner in which this will affect the use of the water

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(29) See p. 89. (30) See p. 84.

can be seen by the following figures: (31) " Water that contains less than 100 parts of chlorine per million, and less than 400 parts of white alkali per million, can be used indefinitely without injury to crops on soil not impregnated with alkali from other sources. Water that contains between 100 and 300 parts of chlorine, and less than 1000 parts of white alkali, can be successfully used on soil that does not contain excessive alkali from other sources, and has fair drainage, provided precautions are taken to prevent accumulation of alkali. Water containing between 300 and 1000 parts of chlorine, or more than 1000 parts of total white alkali, is poor for irrigation, and can probably be successfully used only where effective drainage to remove alkali is possible."

Magnesium salts are injurious to a much less extent, and are chiefly so in white alkali—a mixture of chlorides and sulphates of sodium and magnesium. Chlorides and sodium (except at Tunbridge and Ellenthorpe), and sulphates, are not present in appreciable quantities, and so white alkali will not exist. Calcium salts are not injurious to plants, chiefly on account of their low solubility, which means that they do not enter into concentrated soil solutions. Thus, it is seen that the dissolved solids in the underground water, except perhaps around Tunbridge and Ellenthorpe, will not have an injurious effect on the vegetation, and would be suitable for irrigation purposes. The surface waters will have much the same composition as the underground waters, and these have proved suitable in any cases where used, thus supporting the above.

Nature of the Soils.—(32) The agricultural lands are found on the areas of Trias-Jura sandstones and felspathic sandstones, and these provide very fair soils, which should be suitable for irrigation. What little irrigation by surface waters has been carried out has proved that the soil will respond readily to irrigation.

Though the conditions are somewhat dry in the Midlands, they are far from being arid, and none of the alkali soil characteristic of such regions occurs.

Topography and Drainage.—The agricultural lands are the fairly-level tracts of Trias-Jura sediments enclosed wholly or partly by a ring of diabase hills, and the topography of these tracts is suitable for irrigation purposes.

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(31) United States Geological Survey Water-supply Paper 343, p. 137.
(32) See p. 111.

The question of drainage is a very important one in considering irrigation with underground waters. These waters contain a certain amount of dissolved mineral salts, and with bad drainage the water is kept near the surface, with the result that evaporation of the water concentrates the mineral salts in the soil, which injure, if not totally destroy, the fertility of the soil. In the Midlands the drainage is, on the whole, good, but the effect of bad drainage can be readily seen at one small locality at least. This locality occurs 2 miles south east of Tunbridge. An unnamed creek comes from the Black Tier, and flows past Brent's Sugarloaf, and more or less loses itself in an alluvial flat. A small lagoon appears further on, but the stream does not form again. The underground drainage, which should take place towards the York Rivulet, is largely restricted, owing to the presence of diabase at very shallow depths causing the bad drainage. At parts of this alluvial flat the soil is barren of vegetation, and the largest barren area is stated to be steadily increasing in size. The soil of these barren areas is full of white concretions, which were assayed by Mr. W. D. Reid, Government Assayer, the results being given above.(33)

These concretions have been formed by the process described above, and show conclusively how bad drainage affects the fertility of the soil, and the necessity of choosing well-drained ground for irrigation purposes. As already stated, the drainage in the Midlands appears to be generally good, and the badly-drained localities will be easily picked out by the features described above, viz., areas of black soil free, or nearly so, from vegetation, and with numerous whitish concretions in the soil.

Thus, it is seen that the conditions for the utilisation of the underground water of the Midlands are very favourable.

(c) *Type of Irrigation Systems.*—Irrigation with surface waters means the establishment generally of large and costly projects on a co-operative scale, but with underground waters the problem is essentially different. Each landholder or farmer should develop his own supply by sinking wells on his property, installing a pumping plant, reservoirs, and distributing systems. This method means that a maximum supply can be obtained with a minimum lowering of the water, and the water will have to be lifted the least distance, and also there will be a

(33) See p. 85.

smaller loss of water in distributing it. The initial cost of the plant, and the interest thereof, would not be excessive, especially when the figures for irrigation with surface waters are considered. Such systems are specially adapted for the conditions in the Midlands, where the agricultural land and underground water basins coincide, and other conditions are very favourable.

In connection with co-operation, it might be feasible to have a central power station, *e.g.*, for generating electricity, this power then being distributed and used by motors to drive the pumping plants. The success or otherwise of this would depend on the number of farmers involved, and would in the Midlands probably only be successful where the district is thickly populated and heavily cultivated, as around York Plains and the Mt. Pleasant Closer Settlement.

(*d*) *Type of Well.*—This has already been discussed generally,(34) and wells drilled by a simple percussion plant selected as the most suitable type for the Midlands. In irrigation, however, some controlling factors—*e.g.*, safety of water-supply as regards purity, do not carry so much weight. Further, large quantities of water are required over considerable periods, and dug wells provide excellent storage for such purposes. In spite of such factors, the modern practice in other countries, especially America, where much irrigation by underground waters is carried out, is the use of drilled, and not dug, wells. Groups of wells are drilled to increase a yield which is too small.

(*e*) *Type of Pump and Power Plant.*—Windmills working deep-well cylinder pumps will be largely used where the quantity of water to be handled is not large. These would be suitable for any depth to water likely to be met with in the Midlands and could be run cheaply. Windmills have an advantage over other plants in that they can be run outside of the crop-growing period at very little cost, and the water pumped on the land and conserved there by tillage. This could be done by other plants, of course, but the cost would be prohibitive.

Apart from windmills, deep-well cylinder pumps can be driven by other power. They would be suitable for high lifts and fairly small yields, and would be very efficient while in good order.

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(34) See p. 98.

Centrifugal pumps driven by oil engines are the best for pumping water for irrigation. Only low lifts are required, and this is the condition under which these pumps work. For small depths to water horizontal centrifugal would be used but for other depths vertical centrifugal would be necessary. In the absence of electricity in the Midlands, oil engines will be the best method of driving these pumps, benzine being used up to 2 or 3 horsepower, and kerosene for larger powers.

(*f*) *Storage and Distribution.*—With small pumping plants it is very desirable, if not necessary, to provide some storage capacity for the water. It is stated[35] that "A means of storing water . . . should be resorted to in every instance where the flow is less than 600 gallons per minute. The reason for recommending a reservoir for flows up to this amount is that with small streams used direct from the pumps the loss in conveyance in ditches is excessive and the loss in application to the land is large, since a small stream will saturate a spot, and a large amount of water will sink into the soil in this spot instead of spreading over a large area and moistening the surface. Further, much more labour is required to irrigate with a smal stream than with a large one."

Cement-lined reservoirs are the best but expensive, while earth reservoirs can generally be made sufficiently watertight, provided the soil is not too porous, and can be constructed by the farmers themselves with little expense.

The site of the reservoir should be fixed on ground sufficiently high to enable water to be conducted from it by gravity to the area to be irrigated. The water is distributed over the land to be irrigated by means of drains or ditches dug where required and provided with gates, &c., so that the water can be directed to any desired part of the land. The land has to be levelled and the ditches located and constructed so that the water can be put on the land most easily and efficiently. In preparing and levelling the land care should be taken to keep the soil at the surface as much as possible. The soil and subsoil are generally productive to some distance below the surface, but the surface soil naturally contains the elements, &c., essential to growth of vegetation and should be kept at the surface for growing the crops.

Concrete pipes would be more efficient for distributing the water as they would save loss in application to the land

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(35) Farmers' Bulletin (U.S. Department of Agriculture) No. 394.

and also leave more land available for cultivation. The first cost would be greater but could be reduced by the farmers making the pipes themselves in position, which is a simple matter. In any case the more economical working of the system would probably more than compensate for the heavier initial expenditure.

(*g*) *Examples of Pumps and Plants Required.*—The growing period in the Midlands lasts from July or August till December, and irrigation would probably be applied over a period of about five months. Pumping could be carried out continuously, but it is troublesome, and not generally attempted. Experience in America has shown that 10 hours a day for 20 days a month is the average pumping time, and this, carried out for five months, gives a total of 1200 hours for the season.

Assuming that the pumps are installed at the depth of the water-table during dry periods about 40 feet, the pumps will have a discharge head of about 60 feet.

The folowing table (No. 14) shows the plant, cost, &c., required to handle different bodies of water. An acre-foot is the amount of water required to cover an acre to the depth of one foot, and is a convenient unit in irrigation. Ten acre-feet, say, will be 1 foot on 10 acres, 6 inches on 20 acres, 2 feet on 5 acres, and so on.

TABLE No. 14.

Quantity.		Pump.	Engine.	Cost of Pump and Engine.	Fuel Consumption per 8 hours.	Cost: Benzine 4/3 gal., Kerosene 2/9 gal.	Cost per Acre-Foot.
Acre-Feet	Gallons per Hour.			£ s. d.	Gal.	s. d.	£ s. d.
5	1089	5-in. cylinder	2-h.p. benzine	70 0 0	$\frac{3}{4}$	3 2	4 15 0
—	—	1-in. centrifugal	2-h.p. benzine	54 10 0	$\frac{3}{4}$	3 2	4 15 0
10	2178	$1\frac{1}{2}$-in. centrifugal	3-h.p. benzine	82 10 0	$1\frac{1}{4}$	5 4	4 0 0
			3-h.p. kerosene	90 0 0	$1\frac{1}{4}$	3 5	2 11 4
20	4356	2-in. centrifugal	3-h.p. benzine	85 10 0	$1\frac{1}{4}$	5 4	4 0 0
			3-h.p. kerosene	93 0 0	$1\frac{1}{4}$	3 5	2 11 4
30	6534	3-in. centrifugal	6-h.p. kerosene	168 0 0	$2\frac{1}{4}$	6 2	1 10 10
80	16,000	4-in. centrifugal	9-h.p. kerosene	290 0 0	4	11 0	1 0 7

(2) Drinking and Household Purposes.

In the early days of the Oatlands settlement the underground water in the Oatlands basin was largely made use of for these purposes, and practically every house had its own well and water-supply. As already stated, the use of this water has been largely abandoned, and rainwater stored in tanks is used. The township has grown to a considerable size, and a public water-supply is greatly needed. The streams in the neighbourhood are merely small creeks, which do not contain much water. Some of these have been investigated, but presumably without any satisfactory results as regards a surface supply, and thoughts were turned to the possibility of a water-supply from underground resources.

(*a*) *Quality*.—This is the most important factor in the question of a public water-supply, and the quality of the water in the underground basins and that of Oatlands in particular has already been discussed.(36) The amount and nature of the dissolved mineral material determines the quality. The dissolved mineral matter is mainly carbonates of calcium and magnesium, which have no injurious effects, and sodium chloride, which is likely to be injurious if present in any quantity. It is stated(37) that " water containing up to 2000 parts of total solids per 1,000,000 are generally considered satisfactory for drinking, and where the proportion of calcium is high and that of chlorine low, waters containing 2500 parts or more may be considered satisfactory.

Water that contains 250 to 300 parts per million of chlorine in the form of common salt has a slightly salty taste, and water containing larger amounts is corespondingly more salty. With no other salts in great abundance, the following generalisations hold good. Water containing less than 300 parts of chlorine are considered good; those containing between 300 and 600 are considered rather poor, but are used for drinking and culinary purposes; those containing between 600 and 1000 are considered bad, but are used for drinking and cooking purposes in cases of necessity."

(36) See p. 89.

(37) United States Geological Survey Water-supply Paper No. 343.

Converting the analyses of the well waters from grains per gallon to parts per million, the results are:—

	Jones' Well.	Tremaine's Well.
Total solids	571	615
Sodium chloride	424	256
Chlorine	257	156

Thus it is seen that both as regards total solids and chlorine (the only objectionable constituent in the Midlands water) the waters of Oatlands, as shown by analyses, are very good in quality for drinking and cooking purposes. As regards the calcium and magnesium, they are present as carbonates, and render the water "hard" for washing purposes. Soda ash would have to be added to soften such waters.

(*b*) *Quantity Required.*—Experience has shown that 50 gallons of water per head of population per day is an abundant supply for the needs of even a large family and household. The population of Oatlands is not more than 800 people and a daily supply of 40,000 gallons should more than meet requirements.

(*c*) *Type and Size of Well.*—The drilled well is the type to be recommended for water-supply for household purposes on account of its greater safety as regards purity of the water.

Assuming pumping to be carried out over 12 hours a day, the yield of the well would have to be, roughly, 3000 gallons per hour. No particulars are available as to the rate at which the Oatlands wells make water, and a preliminary pumping test on a neighbouring well would be the most satisfactory way of settling the question. It is an important question in deciding on the size of well, because sufficient storage for the rate at which water makes in the well would have to be provided to enable continuous pumping to be carried out. The water may not make at the rate of 3000 gallons an hour, and even an 8-inch or 10-inch drilled well might not provide sufficient storage to enable pumping at this rate to be carried out over 12 hours a day. It would then become a case of perhaps 2 drilled wells or a dug well, which is to be avoided if possible. As stated above, a preliminary pumping test on a neighbouring deep well is highly desirable to settle the question definitely.

If found that the water makes at a sufficiently fast rate for a drilled well to be employed, one of the larger sizes would be preferred, to provide pumping facilities in the well for a deep well cylinder pump to deal with 3000 gallons an hour. As to the depth of the well, it also largely depends upon the rate at which the water makes in the well. If the rate is not great, extra storage can be provided by deepening the well, but this must not be too great, as the cost of pumping then becomes excessive With the water making somewhere about 2000 gallons per hour, the depth of the well would need to be at least 20 feet below the water-table in a dry summer—say 50 feet below the surface—so that the well would need to be 70 to 80 feet deep at least, but 100 feet would probably be necessary in view of the quantity of water required.

(*d*) *Type of Pump and Power Plant.*—To take full advantage of the safety of the drilled type of well, a deep-well cylinder pump will have to be used and operated by an engine on the surface. An alternative is to make the well of the combined dug and drilled type, with the pump at the bottom of the dug part, but this takes away the greater part of the security of the well. In the latter case any type of pump could be used, being operated from the surface, but centrifugal pumps would have to be two or three stage pumps to deal with the comparatively large heads. A deep-well cylinder pump driven by an oil-engine on the surface, and capable of handling 3000 gallons an hour, is regarded as the best plant. A suitable plant would be a 7-inch pump driven by a 4-5 horsepower engine. Pumps of this size are not generally kept in stock by engineering firms, and would have to be made on order, so no figures as to costs can be given here.

It will be noted that a pump of this size would need at least a 10-inch drilled well to enable its instalment to be carried out.

(*e*) *Site of Well.*—The main considerations in siting the well are that it should be some distance from the edge of the basin to obtain a reliable supply, and that it should be away from possible areas of contamination. With regard to the latter the "safety distance," *i.e.*, the distance from a source of contamination at which a well may be sunk with safety for sandstones such as occur around Oatlands, is regarded as 125 to 150 feet.([38])

([38]) **United States Geological Survey Water-supply Paper No. 255, p. 42.**

The site favoured is on the hill to the south of the main part of Oatlands, situated near Dudley-street, between High and Marlborough streets. This is not thickly populated, and should be free from contaminating sources. Though situated on a hill the depth to water is no greater than elsewhere in the basin, as the water-table follows the surface very closely. The direction of movement of the underground water is towards the main part of the town, and even with heavy pumping this movement would probably still exist, and little if any movement would occur from the main part of the town towards the well-site. This should render the well free from possible contamination from the more thickly populated part of the town, and also from Lake Dulverton.

(*f*) *Storage and Distribution.*—A reservoir would be necessary to hold a supply of water for several days, in case of a breakdown of the plant. Additional pressure would also be desired, and the reservoir would be probably best situated on the hills to the north of the township. This and other matters, such as distribution, are rather for the civil engineer, and will be left in his hands.

(3) Pastoral Purposes.

If required, the underground water could be used to form supplies for watering-places for sheep, cable, and horses.

Dug wells, with a small windmill plant erected on them, would provide an ample supply of water. As regards the quality of the water, live stock can drink water containing more dissolved solids than human beings, and from the evidence available the water will be quite suitable for animals. Common salt is the most undesirable constituent, and water containing more than 1000 parts of salts per 1,000,000 parts should not be given to stock. Such amounts would only exist near the Salt Pans, and here care would have to be taken with the quality of the water.

The quality of the underground water would probably be much superior to the surface water existing in holes and stream beds during dry summers, and which becomes very concentrated in mineral matter, mainly salts of calcium and magnesium.

(4) Boiler Water.

Supplies of water for use in locomotive boilers of the Railway Department are not abundant in the Midlands, and the underground water might be utilised in this direction. The watering point at Parattah obtains its supply from an underground source in the form of a seepage [39] to the south of the station.

The most suitable point for underground water along the Main Line from Ross to Rhyndaston would be York Plains. The station is situated on a suitable part of the York Plains Basin, and water could be obtained quite close to the station, and at no great depth, probably 20 feet. Nothing can be said as regards the quality of the water of this basin, but it could easily be tested by a shallow shaft on bore. The quality would probably not be as good as that obtained at Parattah, as the water in the latter case does not have a long passage underground, and does not form part of a basin. Assuming the dissolved solids to be similar to those in other basins, they will be mainly bicarbonates of calcium and magnesium. These will form a boiler scale of calcium carbonate and magnesium oxide, but the amount and nature will depend on the quantity of the dissolved solids present.

It is recommended that a test shaft or bore be put down, and the water tested as regards its usefulness for boiler purposes.

(2)—Soils.

(a) *Introduction.*

No soil map has been prepared of the district, as this would involve a much more detailed examination than that possible in the time, but for the Midlands it may be taken that the soil map would agree fairly well with the geological map. The soils are derived generally from the underlying rocks, and so where a rock is shown as outcropping, it may be taken that the soil at that locality is that typical of the underlying rock. The soils typical of the various rocks and formations will be described below, but in addition to these distinct types there will be many intermediate types found near the junction of two different rocks or formations; *e.g.*, with a high diabase ridge rising above an area of low-lying sandstones, there will be many transitional types between the pure diabase soil on the ridge, and that of pure sandstone soil on the plain, some distance from the ridge. Allowance will have to be made for such conditions in using the geological map as a soil map.

([39]) See p. 97.

Samples of typical soils were taken, and results obtained from these will be given, but except in a general way the value of these must not be over-estimated, as they are single samples. Proper and efficient sampling of the whole of the soil is a large undertaking, and would be undertaken solely by the Soil Survey of the Agricultural Department.

(b) Diabase Soil.

This soil is formed directly from the weathering and disintegration of the diabase, and is a dark, reddish, heavy soil. The diabase is generally found occupying the hills, ridges, &c., and no soil accumulates to any extent, but even on comparatively level areas the depth of soil is small, and not suitable for agricultural purposes. The exception is to the south of Tunbridge, where a large depth of decomposed diabase, and probably drift material from neighbouring hills, has accumulated. This, however, is very stony, and is not worked. The diabase soil was sampled to the west of the Main Line Railway at Tunbridge, giving the following section:—

0″ — 6″	Dark-red heavy soil.
6″ — 12″	Dark-red clayey subsoil.
12″ — 18″	Light-brown material, containing much calcareous (lime) matter and pieces of rock. This passes through decomposed rock into fresh diabase at depth.

This section shows the small thickness of soil, and the underlying clay subsoil which holds the moisture near the surface, rendering it waterlogged in wet periods, and soon becoming dry in dry periods. To these conditions—the small depth of soil and the clayey nature of soil and subsoil with above results—is due the fact that the diabase soil is unfitted for cultivation. In only too very small paddocks in Tunbridge is diabase soil used for cultivation.

(c) Basalt Soil.

This soil is formed by the weathering and disintegration of the basalt, and is a black heavy soil. The largest area of basalt occurs along the Macquarie River, and is the only locality where this soil could be utilised. Here the true basalt soil is very thin and rocky, and is not suitable for cultivation on this account. A sample was taken just to the east of the Main-road, $1\frac{1}{4}$ miles north of Ross, and gave the following section:—

0″ — 6″ Heavy black soil.
6″ — 14″ Light-coloured reddish-brown clay, with pieces of rock.

Then solid basalt.

Thus the basalt soil suffers from the same drawbacks, being thin, and with a stiff clay subsoil, which tends to waterlogging in wet periods and dryness in dry periods. The only areas of true basalt soil cultivated are a small paddock at Ballochmyle homestead, near Tunbridge, and another area about $2\frac{1}{2}$ miles north-west of Oatlands.

(*d*) *Limestone and Mudstone Soil.*

This soil is formed by weathering and disintegration of the limestone and mudstone, and is a light-brownish soil, somewhat of the nature of a marl. The depth of soil is very variable, often being many feet in depth, but the average is generally quite suitable for agriculture. A sample was taken above the Main road, 1 mile north of Ross, and gave the following section:—

0″ — 10″ Light-brownish soil.
10″ — 18″ Light-brown subsoil, rendered gravelly by fragments of the limestone.

This soil occurs around Ross, but not in large quantities, and is little used for agricultural purposes.

(*e*) *Sandstone Soil.*

This soil is formed by the weathering and disintegration of the Trias-Jura sandstones, and is generally a light-coloured sandy soil. With continued tillage this appears to lose much of its sandy nature, and becomes more of a loamy nature, due to the bringing up of some subsoil, which would contain more clay than the soil. Except on very steep hills this soil is always of good depth, and suitable for agriculture.

A section of the Golf Links, Oatlands, showed—

0″ — 9″ Dark-coloured sandy soil.
9″ — 24″ Light-yellow sandy subsoil, passing through the decomposed rock into solid rock.

This soil is extensively developed in the Midlands, and is largely used for agriculture, especially around Oatlands. Owing to its porous nature, it requires more rainfall than the other soils, and if it receives this, then a very good yield is obtained from this soil.

(*f*) *Felspathic Sandstone Soil.*

This soil is derived from the weathering and disintegration of the felspathic sandstones, and is a dark-coloured loamy soil. The depth of soil is variable, but apart from steep slopes there is generally a good depth for agricultural purposes. The following sample was taken on the flank of Mt. Pleasant, and while representative of the nature of the soil is not of the depth, the section being—

0″ — 4″ Dark-coloured loamy soil.
4″ — 12″ Light-coloured subsoil, being practically decomposed rock.

This soil occurs around York Plains, the Mt. Pleasant Closer Settlement Estate, "Glenmorey," on the Tunbridge Plains," and on most of the flats between Lemon Hill and Jericho. It is heavily cultivated on the Mt. Pleasant Estate, and gives good results, and is probably the best soil occurring in the Midlands.

(*g*) *Alluvial Soil.*

This soil is formed over the deposits of alluvium formed along the courses of the present streams, and which represents material derived from all parts along the courses of the streams. It consists of a dark, somewhat heavy, clayey soil, and being composed of particles of all other materials in the district, should be the best soil.

A section of the alluvium along the Macquarie River, near the bridge at Ross, showed—

0″ — 12″ Black, heavy soil.
12″ — 21″ Black, very clayey subsoil.

This soil is little used for agriculture, probably on account of its heavy nature, and the clayey subsoil, which tends to produce water logging.

(*h*) *Chemical Nature of the Soils.*

Some idea can be obtained of the possibility of the existence of plant foods in the soil from the composition of the rocks from which they are derived. All the soils will be poor, as regards phosphorus content, as the rocks themselves contain only traces of phosphates.

Lime should be abundant in most of the soils. The diabase, basalt, and Permo-Carboniferous limestones and mudstones should give soils containing much lime in a suitable form for plants. The felspathic sandstone soil should contain some lime, while the normal sandstone is probably very poor in lime.

Potash is likely to be most abundant in the felspathic sandstone soil, as the rock contains over 3 per cent. potash (K_2O). The diabase and basalt soils should contain a little potash, while the other soils are likely to be very poor.

(*i*) *Conclusions.*

Thus, it is seen that though several types of soil exist in the Midlands, only two—the sandstone and felspathic sandstones—are used to any extent. As regards the others, the conditions are such as to render them unsuitable for agricultural purposes, and they are used for pastoral purposes only.

(3)—Road-making Materials.

Excellent opportunities were afforded during this field trip for observing the properties and efficiency of the various rocks and formations in connection with road-making.

(*a*) *Foundations.*

All kinds of rock have been used for this purpose, depending on the formation nearest at hand, and diabase, basalt, sandstones, and limestone appear in the foundations. These materials have all answered the purpose, but there is no doubt that diabase is the most suitable, followed by the others in the above order.

(*b*) *Metal.*

As above, all materials have been used, depending upon circumstances, but with a much more varying degree of success.

Diabase stands far ahead of all other rocks present, and is almost wholly adopted in the Midlands. It is hard, tough, and resistant, but does not polish with wear. It outcrops over 50 per cent. of the area, and so is generally conveniently at hand, if not actually right on the spot for road-making. Best results seem to be obtained with metal up to about 2½ inches in size, when a good surface is obtained.

Basalt would be a fairly good material to use, but it is not extensively developed in the Midlands, and has not been available for the majority of the road sites. It would act somewhat like the diabase, but is not so hard or tough, and powders more easily, thus being worn quicker than the diabase, and yielding more dust and mud. Basalt is used around Ross with good results.

Hornstone (Flints).—These metamorphic derivatives are sometimes used when they occur close to roads, but do not form a good metal. They are hard, but flake readily, and the life of the metal would not be great, and in addition it always has sharp edges due to the flaking. This latter condition is not desirable, as it, amongst other things, plays havoc with motor tyres.

Sandstones.—These rocks are used on secondary roads where diabase is not conveniently at hand. They are too soft, and crush easily under traffic, and the metal has a short life. Sometimes they yield stretches of road with a fine smooth surface, but also give patches of loose sand, which is a serious disadvantage.

Limestone.—This rock is used to a small extent around Ross, but is not very suitable. It is very soft, and powders easily, thus wearing away quickly, and yielding much dust. It also forms a glaring white surface, very trying to the eyes.

(c) *Blinding.*

The question of blinding has become a very important one in road-making, on account of the greatly increased volume of motor traffic. Unless the metalled surface is well protected, the binding material is soon removed from between the pieces of metal, which become loose, and the surface of the road becomes destroyed and wears away.

Soil and Subsoil.—These are often applied, especially in repair work, diabase soil being generally used. Too much of this is generally used, and forms wet, slippery patches in wet weather, and hard ridges in dry weather. This material seems to be fairly efficient, but has not a very long life.

Screenings from crushing of diabase are used when available, and would form a more efficient blinding material than the soil.

Buckshot Gravel.—Besides being used for blinding purposes, this material is used for making less important roads, but it is only suitable for light traffic. As a blinding material it is not too successful, as it is very easily thrown off the road by motor vehicles, and the metal is quickly exposed.

Quartz Gravel.—This material is derived from the basal conglomerate of the Trias-Jura, and occurs at the surface between Tunbridge and Ross, due to weathering of the conglomerate. It has been used on the Main-road, in that vicinity, and, as far as appearances go at present, forms easily the most efficient blinding material.

(4)—Building, Monumental, and Other Materials.

The normal sandstone of the Trias-Jura system has had, and still has, an extensive use for these purposes. In the past the great majority of the houses and buildings in the Midlands were constructed of this sandstone, or, as it is locally termed, "freestone," but during recent years wood and bricks have largely taken its place. The main factors which influenced its use were its availability, as it was right on the spot where required, the ease with which it could be quarried and blocks of convenient size easily obtained, and its comparative cheapness in the days of cheap labour. Quarries were opened up wherever the stone was required, but at present Ross and Oatlands are the two main places where it is quarried.

(a) *Building Stones.*

These sandstones have already ([40]) been described at some length. They owe their utility to the factors that they are easily quarried, provide blocks of almost any size, and are very easily dressed, and also worked for ornamental purposes. They have a pleasing appearance, and resist the weather very well (some buildings in the Mid-

([40]) See p. 44.

lands are at least 70 years old, and are little the worse for wear). One slight disadvantage is the presence of the clay pellets already discussed.[41] These disfigure the stone slightly, but not to a very serious extent. These sandstones are somewhat soft, and should not be used for floors, stairs, &c., where the amount of wear is large, as their life would be comparatively short.

Similar stones exist in many parts of Tasmania, and have been largely used for building purposes in the cities of Hobart and Launceston, where a good idea of their value and uses as a building stone can be obtained. Their use for ornamental purposes is illustrated, among other places, by the Public Buildings in Launceston. The Oatlands stone is a fine-grained buff-coloured sandstone, and is largely used in that locality.

A variety of stone exists at Ross, and is slightly superior to the Oatlands stone. It is coarser in grain, and gives a variety of colours—white, grey, brown, and variegated. The most common are the brown (buff to brownish-yellow) and the variegated (marked by bands of different colour). The white and grey are not so common, unfortunately, as the white is easily the best type of stone. This stone occurs on a sandstone ridge at Ross which is 1 mile to 1¼ mile long, and ¼-mile to ½-mile wide, and runs in a south-easterly direction from the Ross bridge. The beds dip into the hill at angles of 5 degrees to 10 degrees, and make work in large quarries more difficult and expensive than usual.

As a splendid example of what can be done with these sandstones of the Midlands and other parts of Tasmania, there stands the homestead of the former Mt. Seymour Estate, 3 miles south-east of Parattah. This house was built of picked stone from the Midlands, and to a less extent from other districts, and has a fine appearance.

(b) *Monumental Stones.*

The cemeteries in the Midlands bear testimony to the utility of the sandstones for these purposes, as the tombstones, headstones, and sidestones are almost entirely made from the sandstones. Tombstones dating back to 1835 are found in good order, even although uncared for, and often lying on the ground.

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(41) See p. 44.

Once again, it is the ease of obtaining blocks of suitable size, and dressing, carving, and figuring them, which determines the use of these stones.

Both the Oatlands and Ross stones are used for these purposes. Of the Ross stones, the brown and variegated stones have been mainly used, and some very striking results can be obtained with the latter.

(c) *Grindstones, &c.*

These are made from the Ross stones, which are much more suitable than those of Oatlands, and a large output of grindstones is maintained at Ross. The brown stone is used at present, but judging from appearances the white and grey stones would be superior to the brown. These grindstones are made in any size up to 6 feet diameter, and are largely exported to the mainland. Scythestones are also made from these sandstones.

(d) *Constructional Purposes.*

Apart from general building purposes, the sandstones could be used for constructional work in connection with bridges, &c. The well-known bridge at Ross, built in 1836, is built entirely of sandstone, and shows the possibility of this stone.

(5)—Salt Pans and Salt.

This material is obtained from the salt pans and lagoons of the Salt Pan or Tunbridge Plains and the Ellenthorpe Plains. Numerous saline lagoons occur in these two localities, and have been the subject of much interest and speculation. It is stated that the salt lagoons were often the subject of much contention among the aboriginals, and were the scenes of fierce tribal warfare.

(a) *Literature.*

In 1889 Mr. Joseph Barwick(42) reported in a letter to the Royal Society of Tasmania some particulars about these salt lagoons.

(42) Proc. Royal Society of Tasmania, 1889.

In the Mines Department Circular No. 2 (1917) by the late W. H. Twelvetrees, Government Geologist, these salt lagoons are discussed, chiefly in connection with the possibility of their association with petroleum supplies. In December, 1918, Mr. A. M. Reid, Assistant Government Geologist, made a short examination of the salt pans to ascertain their suitability or otherwise as a source of alkali. Mr. Reid concluded that the lagoons are "sinks" produced by the action of carbonated waters on Permo-Carboniferous limestones, and that the salt is derived from the Mesozoic sandstones, the concentration in the lagoons being due to deposition and later evaporation of saline alluvium formed in pre-lagoon times by overflowing rivers.

(*b*) *General Description.*

As mentioned above, numerous saline lagoons occur on the plains around Tunbridge and Ellenthorpe. These lagoons are shallow depressions in the comparatively level country of these plains, and contain water during wet periods, while the majority dry up during dry periods. Those containing just a little salt will, on drying, leave merely a trace of a white coating of salt behind them, while the few containing much salt leave a nice crop of salt crystals behind them. Some dry up very occasionally, possibly once in a lifetime, and may or may not leave a good crop of crystals. The largest lagoon is the Salt, or Horseshoe Lagoon, on the Ellenthorpe Plains, which covers about 100 acres, while the smallest occupies no more than 1 acre. The lagoon at present known as Grimes' Lagoon is larger, and covers about 300-400 acres, but it is somewhat different from the others. This lagoon was not known to the early settlers as a lagoon, but was agricultural land known as the "Woolshed Paddocks," and was cultivated, but a flood in the Blackman's River entered and changed it into a lagoon, which it was probably also in different times previous to white settlement.

The lagoons are generally very shallow, but some—*e.g.*, Green or Bell's Lagoon—exceed 6 feet in depth. Of the numerous lagoons only two—the Mona Vale and the Balochmyle Salt Pans—produce a good crop of salt crystals. Township Lagoon is reported as drying-up occasionally and giving a crop of salt crystals. These two salt pans yield salt during February and March during dry summers, but not every year, as the lightest shower is sufficient to destroy the crystals, and they may not form again. Mona Vale Salt Pan yields the crystals more readily than Ballochmyle, and the crystals are coarser. When the crystals occur there is stated to be up to $\frac{1}{4}$-inch to $\frac{1}{2}$-inch of crystals, a few inches of brine, and several inches of fine black slimy mud. Ridges cross the layer of salt in all directions, caused by the stress due to growth of the crystals.

(c) *Origin of the Depressions and Lagoons.*

Apart from the lagoons, numerous "black bottoms," as they are called, occur in the Midlands. Many of these are definitely alluvial flats formed by creeks, both on diabase and sandstone, and other formations, but these do not give rise to lagoons. There is another class of "bottom" restricted to sandstone areas, and occurring more or less plentifully on all sandstone outcrops in the Midlands. These may be anything in size from $\frac{1}{4}$-acre, or even less, up to the size of the large lagoons, and may or may not contain water. These are mere shallow depressions in the surface of the ground, and may be found at any elevation. Wind is probably the start of these small depressions, the loose sandy soil from the sandstones being easily moved by the wind. Fine sand, organic matter, &c., gets washed into this depression, and forms a black deposit in it, and soon renders the depression capable of holding water. Small amounts of soluble salts will accumulate by concentration of the water, and these act readily on the cement of the sandstones, and provide large quantities of loose sand for removal by the wind. Continuance of these conditions will result in the growth of the depression, and it may ultimately become a fair-sized lagoon.

That water with salts in solution readily attacks the cement of the sandstones is seen wherever such water is allowed to be in contact with the sandstones used for building purposes, the latter being quickly destroyed. It is also to be noted that where the salt occurs in the Midlands the depressions and lagoons are numerous, and much larger than in other places, proving that such action as pictured above actually occurs. A. M. Reid pictures the lagoons as due to limestone "sinks" in the Permo-Carboniferous rocks. These lagoons all occur in the Lower Trias-Jura series, and while the Permo-Carboniferous strata may occur at no great depth, neither the latter nor the basal Trias-Jura conglomerate are visible in the vicinity of the lagoons. The limestone, marl, &c., found in the vicinity of the salt pans and on barren patches of soil around Tunbridge is derived from the diabase, and not from the Permo-Carboniferous strata. Secondary deposits of calcite, as well as the nodules in the soil, already discussed, are derived by concentration of underground waters, which have leached calcareous and other materials from the diabase. Thus the formation of these lagoons by limestone "sinks" is not possible, as the Permo-Carboniferous limestone does not occur sufficiently close to the surface to enable such action to take place.

(d) *Origin of the Salt.*

The source of the salt is to be sought for in one of the rock formations in the vicinity of the lagoons, viz., Permo-Carboniferous, Trias-Jura, diabase, and basalt.

Diabase.—Though the salt of the ocean has been derived from the continued decomposition of all the igneous rocks which have been exposed at the surface of the earth, the amount in plutonic and hypabyssal rocks, such as diabase, is very small, and never gives rise to deposits of salt, except through the medium of the ocean. Further, diabase is just as plentiful in other parts of Tasmania, and the conditions are similar, but no salt deposits occur in association with the diabase.

Basalt.—Salt may be obtained by the leaching of volcanic rocks, but it is seldom that deposits of salt are formed from this source. Further, though basalt covers part of the Tunbridge Plains, and may have extended over practically all of them, no sign of it exists at Ellenthorpe, and so the basalt could not possibly have been the source of the salt in both places.

Permo-Carboniferous Strata.—These were deposited under marine conditions, and probably contain some salt, but as they are nowhere in close association with the lagoons they cannot be regarded as a likely source.

Trias-Jura Sandstones.—The lagoons and pans occur in close association with these rocks at both Tunbridge and Ellenthorpe, and suggest that these sandstones form the source of the salt. No indications of salt in these strata were found elsewhere in the Midlands, but it is reported in other districts. The late Mr. W. H. Twelvetrees [43]

[43] Report of Secretary for Mines 1908.

states: "Saliferous sandstone exists also near Richmond, on the Coal River, 3 miles east of Colebrook, and reappears south of the town." Unofficial reports of the existence of salts in sandstones in other parts of the island also exist.

Thus, it is definitely established that some, at least, of the Trias-Jura sandstones are saliferous, due to the accumulation of these deposits under somewhat arid conditions. The waters in which these sediments accumulated either became very concentrated and deposited thin layers of salt, or else dried up much like the present salt pans do, and deposited crystals in this manner, and it is likely that thin layers of salt occur in the Trias-Jura strata.

Thus, the source of the salt is proved to be the sandstones of the Trias-Jura period.

As to the concentration of the salt in the lagoons and pans, A. M. Reid believes most of it to have been derived from saline alluvium deposited by overflowing rivers in pre-lagoon times, this representing a concentration of salt from the sandstones. Though the drainage of the Tunbridge Plains and the Macquarie Basin was much disturbed during and immediately succeeding the outpourings of basalt, there is not the slightest evidence of any lake or river deposits resulting from this or any other cause on the Tunbridge Plains, and the existence of the saline alluvium is very doubtful.

As seen above, the sandstones will at certain horizons contain either thin beds of salt, or be heavily impregnated with salt. The present surface of the ground is close to one of these horizons at Tunbridge and Ellenthorpe, and the lagoons and pans obtain their salt directly from such layers.

(e) *Quantity.*

The Mona Vale and Ballochmyle salt pans are practically the only producers of salt

The Mona Vale pan covers about 10 acres, and is productive of salt in sufficient quantity to be gathered over, perhaps, 5 acres. It is stated that ¼-inch to ½-inch of salt usually appears on it.

Taking the average of, say, ¼-inch of salt over the 5 acres, and the crystallised salt as averaging 100 lb. per cubic foot, this pan would yield, approximately, 200 tons of salt.

The Ballochmyle pan covers about 15 acres, and taking ¼-inch of salt over 7 acres, this would give a yield of 280 tons.

The above figures are all approximate, and are only intended to give an idea of the amount on these pans. The question as to whether such a quantity could be taken off the pans year after year is an important one. The salt is gathered locally by the people for various farm and household purposes, but the total quantity removed in this way cannot be great. In the past considerable quant ties were bagged at the pans and sent to the cities, but no idea of these can be obtained. Apparently the amounts so far removed have not affected the pans, but the removal of the full crop each year is another matter, and the renewal of the salt would depend on the source. If, as put forward above, small layers of salt or sandstones impregnated with salt occur in the vicinity, there would be some possibility of a fairly reliable supply of salt. Before attempting to gather the salt in such quantities, either through the medium of the salt pans or otherwise, the actual mode of occurrence of the salt and the extent of such deposits would have to be determined by shallow boring. One such bore was actually put down over 20 years ago, but no trace or record is now available.

(*f*) *Present Uses.*

The salt is used solelv at the present time for farm purposes, such as curing meat, &c. For the latter it is said to be very suitable, and on account of the rich colour it gives the meat, is alleged to contain nitre, which is utterly disproved by the analysis carried out by W. D. Reid, Government Assayer, and given below:—

	Per Cent.
Sodium chloride...	99·51
Magnesium chloride	0·49

This analysis shows the remarkable purity of the salt crystals obtained from these pans.

Samples of the salt seen are pure white incomplete crystals, and the analysis shows that they are practically pure salt, and there is no reason why this salt should not be used for cooking and table purposes. The small amount of magnesium chloride present, and experience since the samples were obtained, prove that the salt will not become moist in wet weather, so the salt could be made into a fine table salt.

(g) Possible Connection with Petroleum.

The possible connection of these salt pans with petroleum deposits has been discussed in the Mines Department Circular No. 2, entitled "The Search for Petroleum in Tasmania," and doubt was expressed as to any connection. This has been verified during the present investigation, as no trace or indication of petroleum was met with. The full thickness of the Trias-Jura strata represented in the Midlands was examined, and no possible source of petroleum exists in these strata.

(6)—Diatomaceous Earth.

This substance is known by several names, such as diatomaceous earth, infusorial earth, tripolite, kieselguhr, and randanite, some of which may be appropriate for particular varieties, but the first may be applied to all. It is derived from the fact that this material is formed by the accumulation of deposits of microscopic particles of silica secreted by small plants called diatoms living in small freshwater lakes, and which are unaffected when the plants die and decay. The purity depends on how much foreign material, such as sand and clay, collects with the deposit

The only deposit of diatomaceous earth recorded for Tasmania up to the present occurs in the Midlands at a locality just south of the Andover-Inglewood road, at a point 4 miles east of Andover railway-station. A shaft was put down some years ago into the deposit, but was filled up at the time of the writer's visit. Mr. C. Burbury, of "Inglewood," gave the writer the information that the top 3 feet of the shaft was in surface soil and limonite concretions, with the following 6 feet in the diatomaceous earth, and the bottom still in this material. The deposit occupies a shallow depression in a surface of diabase, and was formed in an ancient pond existing there. The depression covers, roughly, one acre, so that the quantity available is not great, but similar depressions occur in the vicinity, and might, on investigation, be proved to contain diatomaceous earth.

Messrs. Burbury forwarded a sample to the Imperial Institute, London, for examination, and the following extract is taken from their report, dated 22nd November, 1915:—"The kieselguhr is of dark-cream colour, and poor texture, and consists of diatoms, which appear to be in a pulverised condition, and contaminated with clay. Kieselguhr of better quality than this is readily obtained in Great Britain."

The quality of the diatomaceous earth is thus poor, and at present of no use. Pure diatomaceous earth has numerous uses in the different industries, but until a demand arises for which no great purity is required the above deposit will be of no commercial importance.

(7)—Ilmenite (Titaniferous Iron).

This mineral is composed of oxides of iron and titanium, and is a common accessory mineral in many igneous rocks. By weathering of the rocks, this mineral becomes concentrated in beds of rivers and lakes, forming "black sand," so commonly mistaken for sacciterite (oxide of tin).

Though not within the district examined, the writer was informed of a considerable deposit of this material at the upper Arthur's Lake, by Mr. Askin Morrison, of St. Peter's Pass, Oatlands. The mineral is to be seen at the southern end of this lake, where it is shallow, and exposes the bottom during dry periods, and probably covers the whole of the lake bed. When dry the bed is said to consist of alternately black (ilmenite) and yellow (quartz) sand ridges, about 4 feet apart, and these are probably due to concentration by the waves or wind, which easily remove the light quartz sand from the much heavier ilmenite.

The sample seen consisted of fine "black sand," the amount of ilmenite predominating largely over the quartz sand. The quartz could be readily removed by ordinary concentrating tables or by electro-magnetic separation, leaving a clear concentrate of fine ilmenite. The hardness of this mineral is 5 to 6, and it would be suitable for an abrasive agent of medium hardness. As there are probably considerable quantities of the material available, easily obtained by bagging during dry periods, and the ease with which it could be concentrated, the deposit may prove on investigation to be a useful source of abrasive of medium hardness.

The origin of this ilmenite is either from the diabase or basalt. Only diabase is mapped as occurring around the lakes. but the writer's experience in the Midlands was that the diabase yielded very small quantities, if any, of ilmenite, while the basalt contained a much greater amount, and so it is possible that unmapped areas of basalt may occur around the lakes.

A sample of the mineral washed clean from the sand present was assayèd by W. D. Reid, Government Assayer, and gave 25·74 per cent. of titanium. Ilmenite corresponding to the formula $FeOTi_2$ contains 31 per cent. titanium, and so there is an excess of iron in the mineral compared with the above formula.

VI.—CONCLUSION.

This investigation of the Midlands has shown that the geology and geological structure are such that while no extensive basin of artesian or sub-artesian water exists, yet there were found to be a number of definite local basins and other smaller sources of sub-artesian water. These basins occur around Oatlands, York Plains, Mt. Pleasant, Tunbridge, Ellenthorpe, and Mike Howe's Marsh. The other smaller sources occur wherever comparatively flat and low-lying areas of unaltered Trias-Jura sandstones and felspathic sandstones are to be found.

The general quality of the water, apart from certain localities of the Tunbridge and Ellenthorpe Basins, is regarded as being very satisfactory for most purposes.

The quantity of water is sufficient for all purposes other than irrigation, in which case the quantity is sufficient to irrigate only a part (roughly, one-eighth) of the available agricultural land in these basins.

Wells, either dug or drilled by a simple form of percussion plant, will be used to tap these water supplies. Pumping will be carried out by windmills, and benzine and kerosene engines, operating deep-well or centrifugal pumps. The chief utilisation of the underground water will be for agricultural and pastoral purposes. Irrigation is possible for part of the land, and would greatly assist the present methods of dry farming, and make the possibilities of good crops very great.

Supplies of water for stock during the dry periods are available in this underground water, and would greatly assist the pastoral industry.

A public water-supply for Oatlands could be obtained from the Oatlands Basin. The water would be somewhat "hard," but otherwise satisfactory. The hardness could be largely or wholly destroyed by addition of soda ash, and it might be possible to include this in the water-supply scheme. Supplies of water for use in locomotive boilers could be obtained at York Plains, but it would be advisable to test the water first.

In arriving at the size and type of well in any installation, the possible yield of the well is an important point, of which no idea can be obtained at present, and it is recommended that tests of some of the existing wells be made prior to attempting to fix the size and type of well, especially for larger quantities of water.

P. B. NYE, B.M.E.,
Assistant Government Geologist

Geological Survey Office, Launceston,
25th March, 1921.


PLATE II
GEOLOGICAL
SKETCH MAP
OF
THE MIDLANDS
LEGEND
SEDIMENTARY
RECENT River Alluvium Windblown Sand
TRIAS JURA Sandstones and Mudstones
PERMO-CARBONIFEROUS Limestones and Mudstones
IGNEOUS
TERTIARY Basalt
UPPER MESOZOIC Diabase
DEVONIAN Granite
CHARACTERISTICS
Roads
Railways
Contour Lines 200'
Geological Boundaries
Strike and Dip of Strata
Faults
Stations
Trig. Points
Township Reserves
SCALE
CHAINS 80 40 0 1 2 3 4 5 MILES
N
AUBURN
River Isis
RUNG HILL
Green Creek
Gavin's Creek
THE WESTERN TIERS
MOUNT FRANKLIN
LAKE SORELL
DOG'S HEAD POINT
DIAMOND BEACH
TO THE GREAT LAKE
INTERLAKEN
CENTRAL PLATEAU
LAKE CRESCENT
HARRISON'S LOOK-OUT
CLYDE RIVER
OLD MAN'S HEAD
YOUNG WOMAN'S HEAD
TO BOTHWELL
TABLE MOUNTAIN
Waterfall
Tent Marsh
MIKE HOWE'S LOOK-OUT
BOGMAN HILL
Exe Rivulet
JORDAN RIVER
MOUNT ANSTEY
JERICHO
TO HOBART
PIKE'S HILL
STONOR
LAKE TIBERIAS OF JERICHO LAGOON
Aaron's Marsh
Hunter's Swamp
Hunter's Creek
RHYNDASTON
TO HOBART
COAL RIVER
BADEN
TO WOODSDALE
TO TUNNACK
PARATTAH
ANDOVER
MOUNT SEYMOUR
LAKE DULVERTON
OATLANDS
Dulverton Rivulet
LEMON HILL
Flat Top Creek
YORK PLAINS
HANDSOME SUGARLOAF
NALA
MUNDERERS TIER
Johnny's Lagoon
Rushy Lagoon
Stony Lagoon
Crown Lagoon
LITTLE SWANPORT RIVER
MOUNT PLEASANT
Hook's Marsh
VINCENT'S HILL
THE NIPPLES
FLAT-TOP
Mike Howe's Marsh
BLACKMAN'S RIVER
THE NOOK
BIG ENFIELD
ANTILL PONDS
WOODBURY
BALD HILL
BLACK TIER
KITTY'S CORNER
BRENT'S SUGARLOAF
Township Lagoon
TUNBRIDGE
York Rivulet
Mona Vale Salt Pan
Balochmyle Salt Pan
ONE TREE HILL
SEDLITZ TIER
MACQUARIE RIVER
Grimes Lagoon
DON'S BATTERY
White Lagoon
TOWER HILL
Glen Morriston
Johnson's Bottom
ANSTEY'S HILL
Bell's Bottom
TAYLOR'S HILL
GREEN SUGARLOAF
ROCKY HILL
Tacky Creek
ROSS
COLLEGE HILL
THE BLUFF
Green Lagoon
Salt Lagoon
BLACK SUGARLOAF TIER
Flood's Creek
Bowling Green Marsh
BARLOW'S TIER
Racecourse Marsh
HANGING SUGARLOAF
TO CRESSY
MACQUARIE RIVER
MOUNT AUGUSTA
TO LAUNCESTON
THE EASTERN TIERS
R.B. Nye. B.M.E.
Assistant Government Geologist
25/3/21

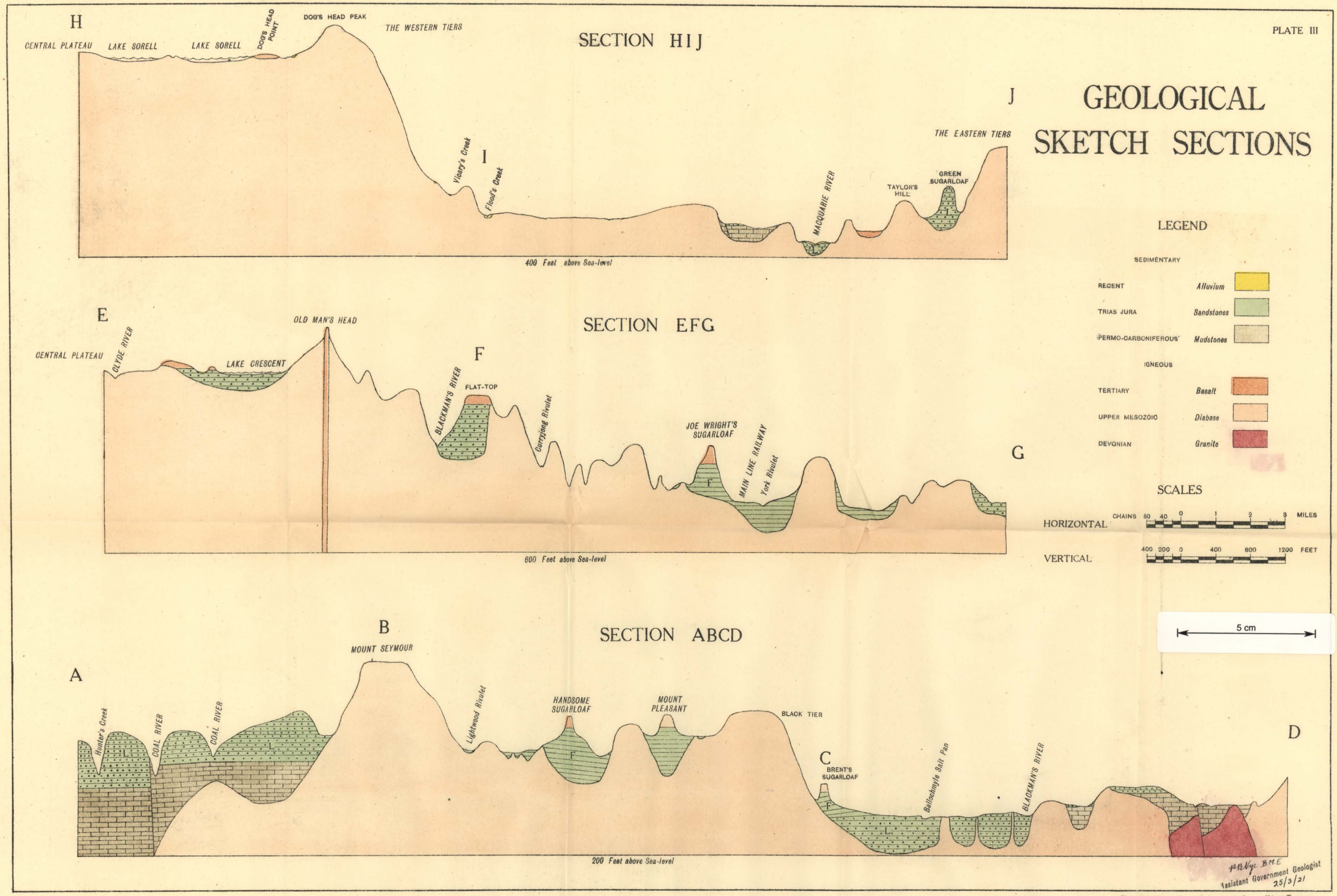

Photo Algraphed by John Vail, Government Printer Hobart Tasmania.

PLATE V

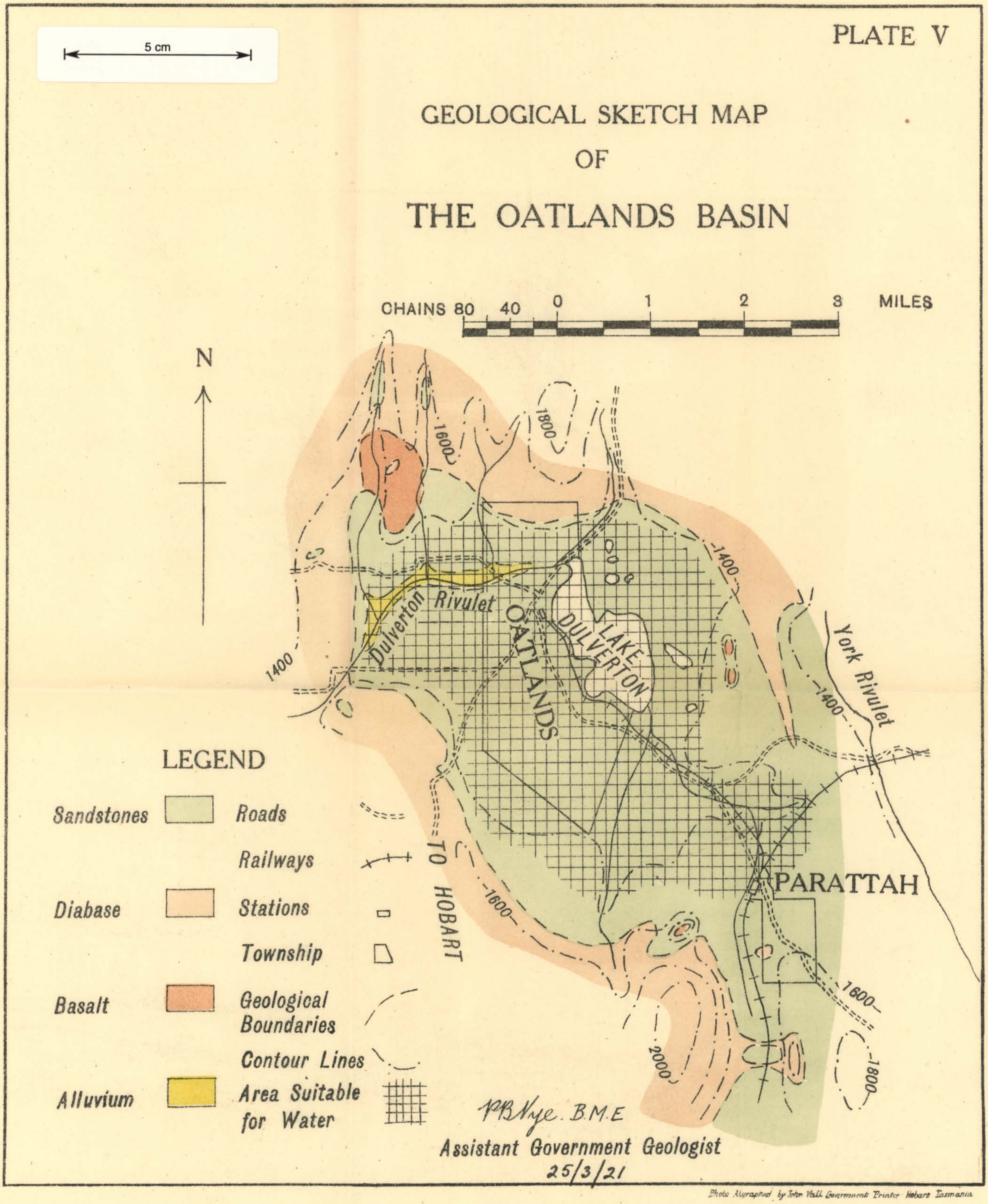

Photo Lithographed by John Vail Government Printer Hobart Tasmania

PLATE VI

GEOLOGICAL SKETCH MAP OF THE YORK PLAINS—MOUNT PLEASANT BASIN

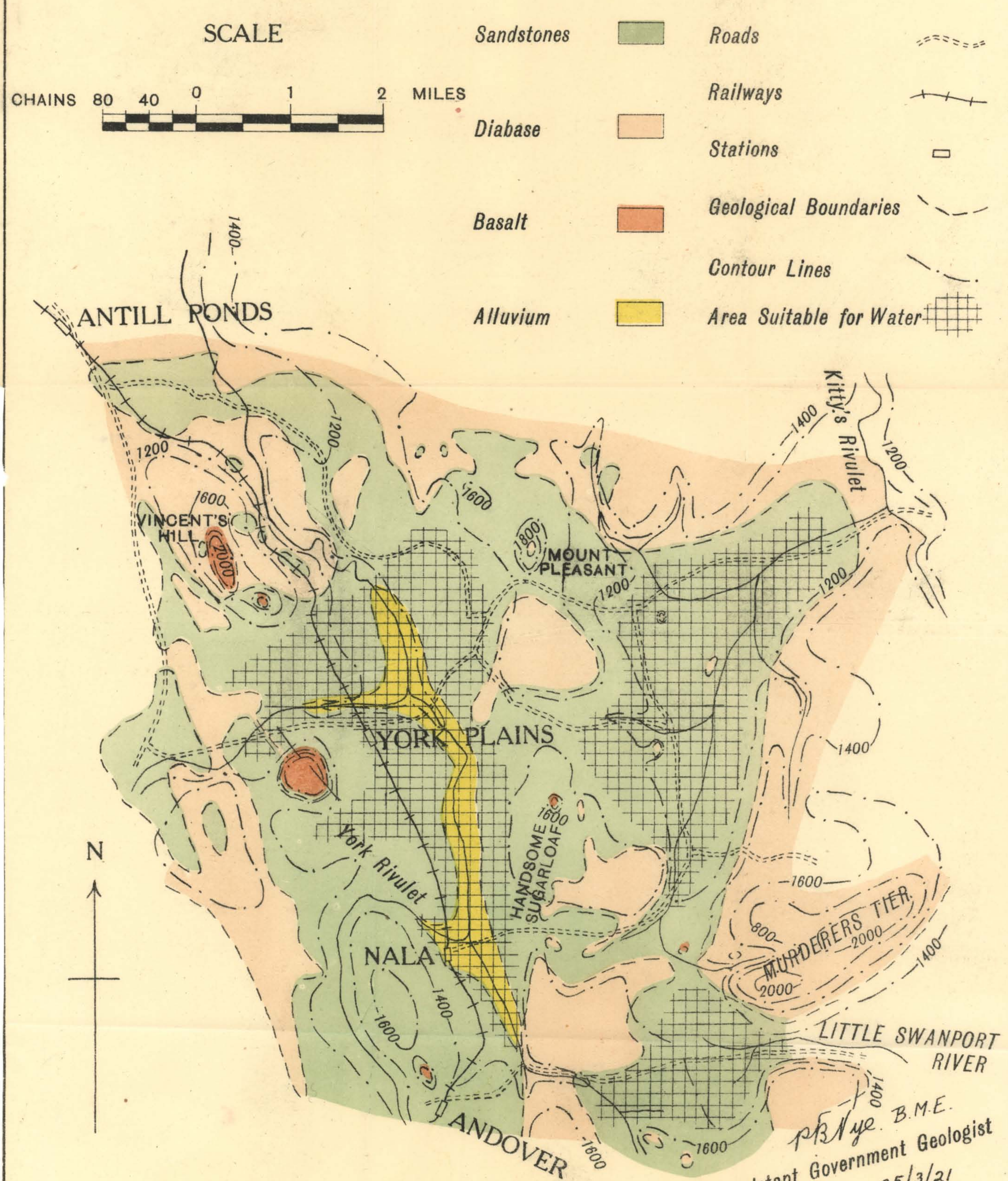

Photo Algraphed by John Vail, Government Printer, Hobart, Tasmania.

PLATE VII

GEOLOGICAL SKETCH MAP OF THE TUNBRIDGE BASIN

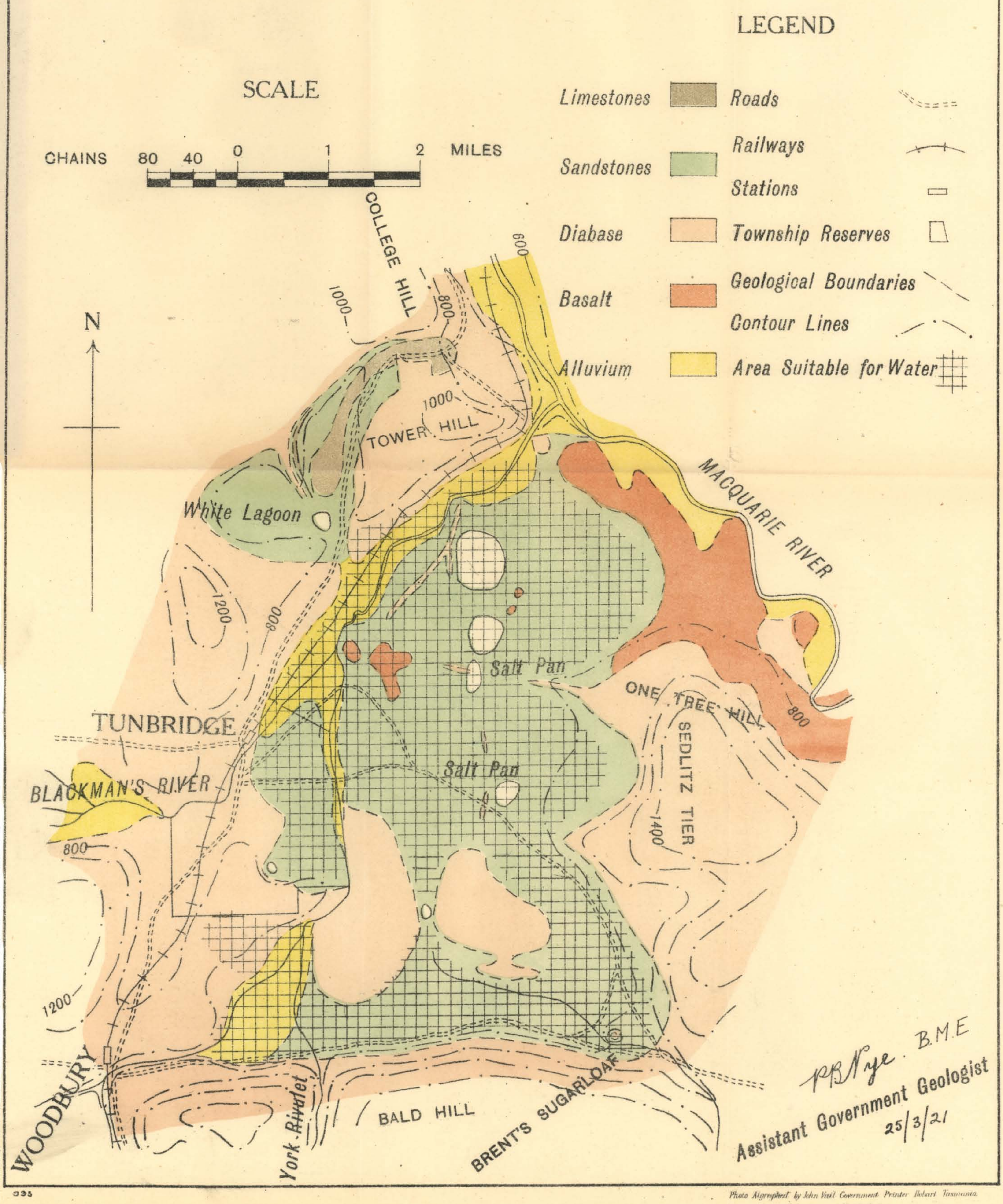

Photo Algraphed by John Vail Government Printer Hobart Tasmania