Tasmania

DEPARTMENT OF MINES

UNDERGROUND WATER SUPPLY PAPER

No. 2

The Underground Water Resources of the Jericho - Richmond - Bridgewater Area

BY

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Issued under the authority of

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PREFACE.

This publication is the second of the series dealing with the underground water-supplies of Tasmania. It deals with a continuation of the area included under the term "The Midlands of Tasmania," and described in Underground Water-supply Paper No. 1.

A great deal of the general information contained in Underground Water-supply Paper No. 1 has been omitted from this publication, and therefore both should be read in conjunction.

The general geological maps accompanying both publications have been reproduced to the same scale, and can be joined to make one complete map of the combined areas.

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Launceston,
14th December, 1921.

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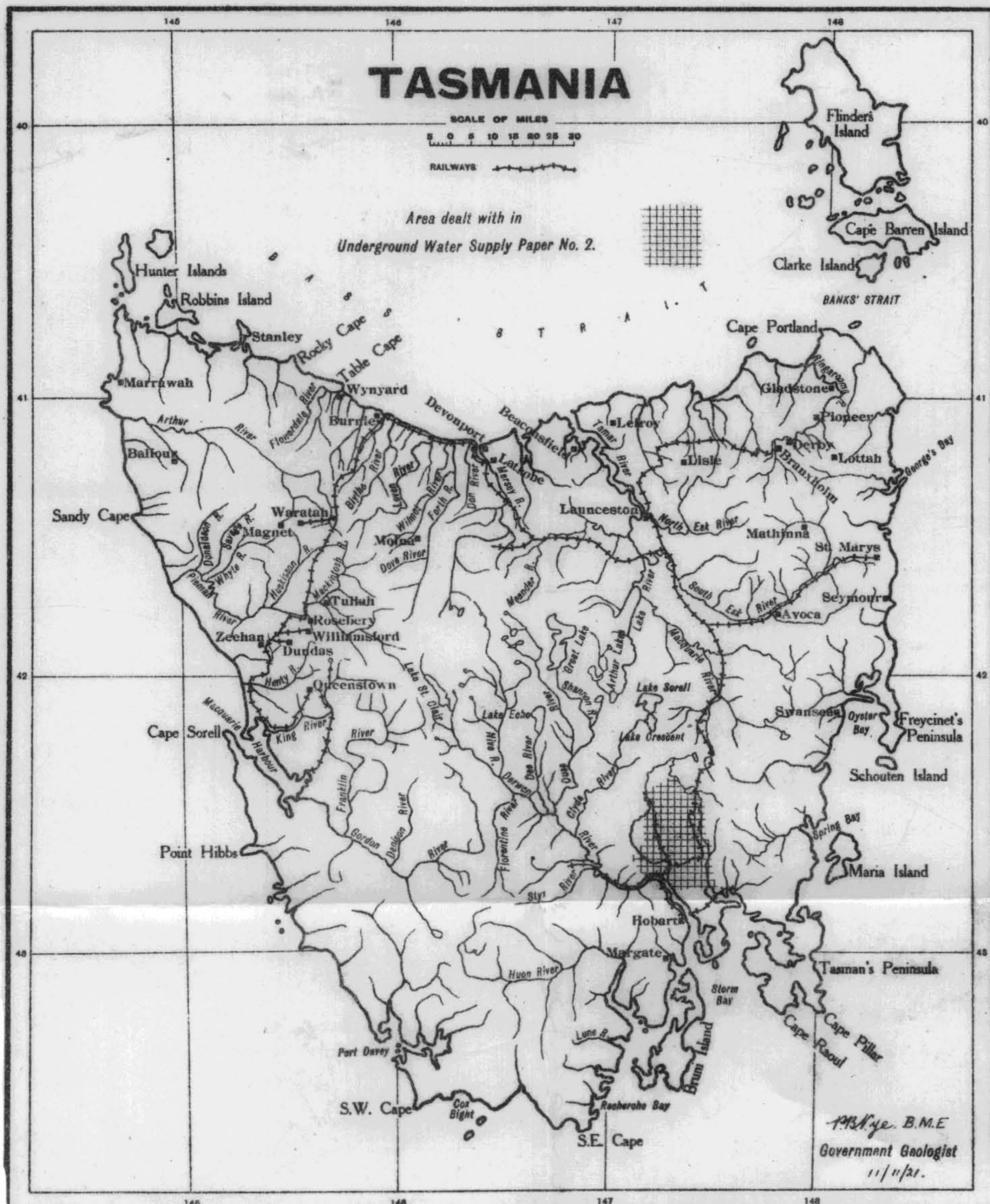

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LOCALITY MAP

5 cm

Summary.

Introduction.—The Jericho-Richmond-Bridgewater area is one with a moderate rainfall (19 to 24 inches), and with no large permanent streams. Additional supplies of water would greatly help the agricultural, pastoral, and orcharding industries of the area, and so this investigation into the possibilities of obtaining supplies of underground water was undertaken.

The district investigated is portion of the County of Monmouth in the south-eastern part of Tasmania, and is approximately that included in the triangle formed by Jericho, Richmond, and Bridgewater. The extent of this district is 370 square miles.

Literature.—A list of the previous literature dealing with the area is given, and it includes publications by Count P. E. Strzelecki, J. Milligan, C. Gould, and R. M. Johnston.

Physiography.—The topography of the area is partly of high relief and partly of low relief. The most elevated portion is around Quoin Mt. (2930 feet), while in the south the country comes down practically to sea-level. The area may be divided into three portions—the valley of the Coal River; the valley of the Jordan River; and the elevated divide between these two drainage systems. This central divide forms the most elevated country in the area, the highest mountains and hills being somewhat to the west of the actual watershed. The area forms portion of the southern drainage system of Tasmania, and is drained by the two south-flowing rivers—the Coal and the Jordan Rivers.

The Coal River flows into the area from the north, and flows in a south to south-easterly direction to empty into the Pittwater, near Richmond. Its main tributaries are the Wallaby Rivulet and the Native Hut Rivulet from the west, and the White Kangaroo Rivulet from the east.

The River Jordan rises in Lake Tiberias, and flows out of the area in a north-westerly direction, but enters it again at Apsley, and from there flows in a south to south-easterly direction to join the River Derwent, east of Bridgewater. Its most important tributaries are from the east, the main ones being the Strathallern Rivulet, Bagdad Rivulet, Green Ponds Rivulet, and Quoin Rivulet.

The topography has been brought about by the ordinary atmospheric and aqueous agencies of denudation, accompanied by the development of the drainage systems. The development of the topography has been greatly influenced by the rock types existing in, and the geological structure of, the area.

The rainfall is moderate, and averages from 19 to 24 inches at the recording stations. The moderate rainfall is due to the "rain-shadow" effect of the elevated country to the west of the area. Other causes are also instrumental in determining the rainfall of this area, which is apparently independent of the altitude.

Geology.—The district is composed essentially of horizontally bedded strata of the Permo-Carboniferous and Trias Jura systems, intruded on a large scale by Upper Mesozoic diabase. The Permo-Carboniferous strata consist of Lower Marine silicious mudstones, sandstones and limestones. The Trias-Jura strata are divisible into at least two series—the lower sandstone series of 600 feet of sandstones, and the felspathic sandstone series of 500 feet of felspathic sandstones with associated mudstones and coal seams. The diabase has intruded the sedimentary strata in the form of a huge, horizontal mass occurring at different levels, and sending up minor intrusions of sills, small dykes, and large dyke-like masses into the overlying strata. Much faulting occurs in the sedimentary strata, and it is very intimately connected with the diabase intrusions. Tertiary sediments, consisting of sands, clays, and gravels, occur to a slight extent, chiefly along the lower part of the Coal River Valley. Tertiary basalt occurs as large surface flows around Richmond and Brighton, and in the former locality it is both interbedded with, and overlying, the Tertiary sediments. Recent deposits of alluvium and hill detritus are forming along the courses of the present streams and their valleys.

Economic Geology.—The source of supplies of underground water is the rain which falls on the surface. Special conditions are necessary for the entrance of the rain-water into the earth, and its storage there to form underground supplies. Such conditions are the existence of porous rocks capable of holding and permitting the passage of water through them, and a geological structure suitable for the storage of water in such rocks.

Porous formations occurring in the area are alluvium, hill detritus, Tertiary sands, Trias-Jura sandstones, and felspathic sandstones.

The geological structure of the area is such that no extensive basin of underground water exists, but there are a number of small local basins containing supplies of underground water.

Such basins are found to exist around the following localities, and are described under these titles—Ringwood, Spring Hill Bottom, Colebrook, Coal River, Middle Tea Tree-Duck Hole Creek, Rekuna, Native Hut Rivulet, Brighton-Back Tea Tree, Pontville-Broadmarsh, Bagdad Valley, Green Valley, Melton Mowbray-Kempton.

The water is not under artesian conditions, and means will have to be adopted to bring the supplies to the surface. Wells, either of the dug type, or drilled by a single form of percussion plant, are the most suitable types for the conditions existing in the area. Pumping by windmills, benzine and kerosene engines operating deep-well and centrifugal pumps will be found to be the best type of power-plants.

The utilisation of the underground supplies is determined mainly by the quality of the water as represented by the nature and amount of the contained mineral substances. The effect of these substances is discussed in relation to the uses of the water, such as irrigation, domestic use, live-stock supplies, and boiler use. The water in existing wells is found to be poor to fair for irrigation; unsuitable for laundry and toilet use; from good to very bad for drinking purposes; suitable for supplies for live-stock; and unsuitable for boiler use. The quality of the water could be improved by treating it with lime and soda ash, which would soften it. This process would render the water more suitable for laundry and toilet purposes, and also for boiler use as regards scale formation.

Before any utilisation of underground water is attempted, it is recommended that the water be sampled and analysed in order to determine its quality for the particular purpose in view. Also, as no information is available as to the yield of the wells, it is recommended that tests be made preparatory to any final decision as to the dimensions of the well and the pumping plant.

It may be confidently anticipated that water obtained from bores will be of superior quality to that in existing wells.

The Underground Water Resources of the Jericho - Richmond - Bridgewater Area.

I.—INTRODUCTION.

(1)—Preliminary Statement.

The Jericho-Richmond-Bridgewater area in which the following investigation was carried out, is subject in a general sense to the same climatic conditions as exist in the Midlands district to the immediate north. There is the same moderate rainfall and lack of permanent streams, which combine to make the area a region of comparative dryness.(1)

Previous geological mapping had shown that considerable areas of Trias-Jura sandstones existed in the Jericho-Richmond-Bridgewater area, and this suggested the probable occurrence of conditions similar to those in the Midlands district, and suitable for the existence of underground water supplies.

Additional water supplies could be used to advantage in the pastoral, agricultural, and orcharding industries, which are practised within the area. Accordingly, this investigation of the possibilities of obtaining supplies of underground water, and their utilisation in the above industries, was carried out.

(2)—General Statement.

The greater portion of the investigations upon which this report is based, was carried out during the period from the 4th April to the 1st August, 1921. A small portion around Melton Mowbray was carried out by Mr. Loftus Hills during the period from the 14th September to the 16th September.

(1) Underground Water-supply Paper No. 1: "The Underground Water Resources of the Midlands," p. 5.

The field work was carried out with the aid of the land-charts, Monmouth No. 1 and 2, which were of great assistance. Numerous topographical features have been added, together with their local names.

Contours at 200 feet intervals are shown on the Geological Sketch Map, and are based on elevations determined from aneroid readings connected with the various points along the railways within the area.

(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 area during his visit. The assistance rendered by Messrs. J. J. O. Stuart, and Mr. J. McShane (Colebrook), P. J. Nichols, and H. Jacobs (Richmond), T. Hannan (Pontville), C. H. Newman, and P. Ling (Bagdad), greatly facilitated the work of this investigation. The writer was accompanied during the earlier portion of this field tr'p by Mr. A. Pearson, as field-assistant, and desires to record the energy and ability displayed, and the splendid services rendered by him.

(4)—Location and Area.

The area dealt with in this report is the central and south-eastern portions of the County of Monmouth, in the south-eastern part of Tasmania. It includes portions of the municipalities of Oatlands, Green Ponds, Brighton, and Richmond; and embraces the districts around Rhyndaston, Colebrook, Campania, Richmond, Bridgewater, Broadmarsh, Brighton, Pontville, Bagdad, Kempton, Melton Mowbray, and Jericho.

The Main Road and Main Line Railway from Hobart to Launceston, and also the Apsley Railway pass through the area.

The area has a maximum length of 24 miles from Jericho in the north to Bridgewater in the south, and a maximum width of 20 miles from near Broadmarsh on the west to Richmond on the east. The area investigated consists of approximately 370 square miles.

II.—LITERATURE.

The amount of geological literature dealing with this area is small.

In 1845, Count P. E. Strzelecki published his book, entitled, "Physical Description of New South Wales and Van Diemen's Land." The description of Tasmania was the result of two years and a half of exploration. The greater part of the area under review is dealt with in the description of the Jerusalem Basin. J. Milligan described the Richmond and Jerusalem Coal Basins in the Proceedings of the Royal Society of Van Diemen's Land, 1849.

In 1869, C. Gould, the then Government Geologist, examined the country along the site of the present Main Line Railway, and wrote a short report, entitled "Coal, South of Oatlands." This report described the country between Rhyndaston and Richmond, with special reference to the coal occurring to the north of Colebrook (Jerusalem).

In 1888, R. M. Johnston, F.L.S., published "The Geology of Tasmania," which contained references to the geology of many parts of the area being discussed.

III.—PHYSIOGRAPHY.

(1)—Topography.

(a) *General Description.*

The topography of the area is in part of high relief, and in part of very low relief. The most elevated part of the area is Quoin Mt., which attains an altitude of 2930 feet above the sea. The northern extremity of the area connects up with the tableland around Oatlands and Jericho at an average elevation of 1400 feet above sea-level, while the southern extremity comes down to sea-level at Pittwater and the River Derwent. The Coal River and its tributaries drain the eastern portion, and the River Jordan and its tributaries drain the western portion of the area.

The area may be divided into the following distinct parts, each of which are separate topographical features, and enable the topography of the area to be easily understood:—

(1) The Valleys of the Coal River and its Tributaries.—In the north of the area the Coal River reaches an elevation of 1000 feet, and the headwaters of its tributaries 1600 feet above sea-level. In the south the Coal River reaches sea-level, and empties into the Pittwater, south of Richmond.

(2) The Valleys of the Jordan River and its Tributaries.—The Jordan River occurs to the north of the area at an elevation of 1400 feet above sea-level, and after a winding course, being for some distance outside the area, ultimately reaches sea-level, where it joins the River Derwent in the south of the area, near Bridgewater.

(3) The Divide between these Two Drainage Systems.—This divide consists of the most elevated country in the area, and traverses the area in a general north-north-west to south-south-east direction. This divide starts off at an elevation of 2200 feet at Flattop in the north, decreases to about 1600 feet to the immediate south, increases to its maximum elevation of 2400 feet at Black Hill and Little Quoin, continues with

> a fairly broken summit at an average elevation of 2000 feet towards Lagoon Tier (1400 feet), from which it decreases to 450 feet at Rekuna, and finally increases to 1000 feet at Gunn's Sugarloaf.

In general the highest country along this central divide occurs to the west of the actual water-parting, *e.g.*, Quoin Mt., Butler's Hill, Mount Dismal, and Flat Rock Tier.

(*b*) *The Mountains and Hills.*

The highest mountain, Mt. Dromedary (3295 feet above sea-level), occurs just outside the south-west corner of the area. The chief mountains of the area are to be found generally along the elevated divide between the Coal and Jordan River systems. The country decreases in elevation from north to south, and the occurrence of mountains and hills is more the result of relative than actual elevations. That is to say, hills with an elevation of, say, 1000 feet in the south appear much more conspicuous than much greater elevations in the north owing to the general higher level of the country in the latter portion of the area. Thus it is difficult to pick out and name the most priminent mountains and hills. Some of the most prominent are:—

	Feet above Sea-level.
Quoin Mt.	2930
Little Quoin	2500
Black Hill	2500
Badger Hill	2440
Flattop	2370
Bisdee's Tier	2350
Butler's Hill	2197
B Mount	2130
Mount Dismal	1800
Gunning's Sugarloaf	1600
Mangalore Tier	1400
Gunner's Quoin	1400
Gunn's Sugarloaf	1000

Numerous other prominent mountains and hills occur, and can be seen in Plate II.

(c) *The Plains.*

The amount of flat and level country in this area is very small, most of the country being hilly and broken The plains which do occur are very limited in extent, and are generally found to be associated with Tertiary basalts and sediments, as at Richmond and Pontville. The plains around Richmond have an average width of one and half to two miles, and extend from Campania to south of Richmond—a distance of six miles. These Richmond plains are formed by Tertiary basalt flows overlying, and in the south interbedded with Tertiary sediments.

The Pontville plains occupy considerable stretches of country around Pontville, Brighton, Tea Tree, and Mangalore. They are composed mainly of Tertiary basalt flows, and also of the old river valleys not entirely covered by the basalt. Small areas of plain country occur along the courses of the streams at certain localities. The only one of these of any size is that around and to the north of Kempton, and traversed by the Green Ponds Rivulet, and its tributaries.

(d) *The Rivers.*

The area forms part of the southern drainage system of Tasmania, and the streams are, therefore, mainly south-flowing ones. Portion of the drainage, chiefly that of the River Jordan and its tributaries, forms part of the much larger system of the River Derwent, while the remainder, mainly that of the Coal River and its tributaries, enters the Pittwater.

The River Derwent is by far the largest river, but only a very short length of its course occurs within the present area. This river enters the area from the west, and then flows in a general southerly direction towards Hobart. It is from a half to one mile wide, and is subject to tidal influences as far upstream as the western boundary of the area.

The River Jordan and Coal River are the only other streams of any size occurring within the area.

The River Jordan has its source at Lake Tiberias, at the northern extremity of the area, and has a general westerly course for several miles. It flows out of the area in a north-westerly direction in the direction of Table Mountain, but afterwards turns southward, and ultimately flows into the area at Apsley. It then flows in a general southerly to south-easterly direction close to, or just outside, the western boundary of the area, and finally empties into the River Derwent, two miles east of Bridgewater. Its main tributaries within the area are from the east, the most important being the Strathallern and Bagdad Rivulets (which unite half a mile above their junction with the Jordan River), the Mangalore Creek, Green Ponds Rivulet, and Quoin Rivulet.

The Strathallern Rivulet has two main heads, one of which rises in the elevated country around Mount Dismal and Flat Rock Tier, while the other rises further to the east on the eastern slopes of Lagoon Tier. The latter flows in a general southerly, and later a south-westerly direction to join the other branch, which has a southerly course, one mile above Tea Tree. The united stream then flows in general westerly direction, and joins the River Jordan between Pontville and Brighton.

The Bagdad Rivulet rises in the elevated country around Quoin Mt. It flows, at first, in a south-westerly, and later a south-easterly, direction to join the Strathallern Rivulet half a mile above its junction with the River Jordan. The only tributary of any size is Brown's Creek, which flows in a westerly direction, and joins the parent stream two miles above Bagdad.

The Mangalore Creek has numerous heads along the southern slopes of Mangalore Tier, and flows in a south-easterly direction to join the River Jordan to the East of Goats' Hill.

The Green Ponds Rivulet has numerous branches in the country to the south and east of Kempton, and flows in a north-westerly direction to join the River Jordan to the south of Melton Mowbray. The Quoin Rivulet is formed by numerous streams rising in the elevated country on the northern slopes of Quoin Mt. and around Black Hill, and flows in a westerly direction to join the River Jordan at Melton Mowbray. A large tributary—the Serpentine Valley—rises in Bisdee's Tier, and flows in a southerly direction joining the Quoin Rivulet three miles above its junction with the River Jordan. Within the area the only tributaries the River Jordan receives from the west are Pritchard's Creek, Limekiln Creek, and Bailey's Creek, all of which rise on the north-eastern flanks of the Mt. Dromedary-Platform Peak Range, and flow north-easterly to join the River Jordan at their respective junctions. The Coal River flows into the area from the north at a point about one mile east of Rhyndaston, and flows in a general south to south-easterly direction, and finally empties into the Pittwater to the south of Richmond.

The largest tributary is the White Kangaroo Rivulet, which flows into the area from the north, and joins the Coal River from the east at a point two and a half miles north-east of Campania. No other eastern tributary of any importance occurs within the area.

The most important of the western tributaries are the Wallaby Rivulet, and the Native Hut Rivulet. The Wallaby Rivulet has several heads—the Coal Mine Rivulet, Hollow Tree Bottom, and Corrigan's Creek—in the high country to the south of Flattop, and flows in a south-easterly direction to join the Coal River, near Bain's Mountain. A main tributary—the Spring Hill Bottom—joins it a mile and a half south of Colebrook.

The Native Hut Rivulet rises in the high country around "B" Mount, and Rung Hill, and flows in a general south-easterly direction to join the Coal River one and a half miles east of Campania.

(e) *Evolution of the Topography.*

As will be seen later,(2) the drainage systems of this area were initiated at the close of the deposition of the Trias-Jura sediments, their elevation, and probably contemporaneous intrusion by the Upper Mesozoic diabase.

It is the ordinary atmospheric and aqueous agencies of denudation, accompanied by the gradual development of the above drainage systems that have been the chief factors in the bringing about of the present topography.

Other factors which have played a part in determining the present topography are:—

(1) Post-diabase Faulting.—The faulting in this area is generally closely associated with the diabase, and probably contemporaneous with it, and post-diabase faulting if it exists, is much subordinate in amount.

(2) Deposition of the Tertiary Sediments.—This deposition occurred along the lower parts of the valleys of the Coal River and Duck Hole Creek, in the vicinity of Richmond, and affected only a comparatively small area.

(2) See below, p. 13.

(3) Extrusion of the Tertiary Basalts.—The only flows of any size are those around Richmond and Bridgewater, Pontville and Brighton.

These three factors have exerted only a small modifying effect on the development of the topography, and, as stated above, it is mainly the ordinary atmospheric and aqueous agencies of denudation with the accompanying development of the drainage systems that have been responsible for the topography.

The river systems, which began as consequent or original, have developed to a very great extent, and now appear largely as superimposed systems. This has been brought about by the removal of much of the Trias-Jura strata, and the establishment of the systems in the underlying Permo-Carboniferous and diabase formations.

(2)—Relation of Topography to Geology.

There have been two main factors in the geology of the district which have been largely instrumental in determining the topographical features of the area, viz.—

(*a*) The geological structure;

(*b*) The rock types—

and these two factors are very closely related. The initiation of the present drainage at the close of the Trias-Jura sedimentation was determined by the constructional slopes of the surface, the latter being the direct result of the geological structure.

At first the streams were carrying out their work of denudation in the soft Trias-Jura strata, but in the course of time the underlying formations of Permo-Carboniferous strata and diabase were reached. The Permo-Carboniferous strata are comparatively soft and easily attacked, but the diabase is very hard and resistant to the attack of the ordinary agents of denudation. The development of the topography then proceeded along the lines of the removal of the soft sedimentary strata from the hard, resistant masses of diabase which underlies and intrudes these strata. These masses of diabase were left rising above the surrounding strata, and now form practically the whole of the mountains and hills occurring within the area, as can be seen in the map and sections in Plates II. and III. respectively.

The streams on reaching a mass of diabase would endeavour to keep in the softer sedimentary strata, and would, if possible, work along the junction of the two formations. Failing this, they have to corrode a course through the hard resistant diabase. When the streams flow over the sedimentary rocks they have generally flat, open valleys, but over diabase the streams have deep, steep-sided gorges.

The Tertiary basalts have played a part in the development of the topography. They occur chiefly as large surface flows which flooded the lower parts of the valley of the former Jordan and Coal Rivers. These basalt flows have formed the plains occurring in those portions of the area, and have slightly retarded the development of these two rivers.

(3)—Relation of the Topography to that of Adjacent Areas.

Any individual area submitted to geological examination seldom forms a topographic unit, and so it is important to connect the area under review with adjacent areas. The present area joins up in the north with the Midlands area described in a previous report(3). The southern portion of the Midlands area consists of a more or less broken tableland with an average elevation of 1400 feet above the sea. This tableland extends a short distance into the present area, and connects up easily with the elevated country at the northern end of the central divide. To the south and south-east of the area occurs the River Derwent and Pittwater, with the low-lying country around the shores of the latter. Between the River Derwent and Pittwater the area connects up with the comparatively high ground of Grass Tree Hill (1778 feet), Mt. Direction (1468 feet), and Mt. Rumney (1236 feet).

To the east the country is much broken and has a maximum elevation at Brown Mountain of 2598 feet. The average elevation to the north-east is about 1400 feet.

To the south-west of the area occurs the elevated country of Mt. Wellington (4166 feet) and Mt. Dromedary (3245 feet), with the valley of the River Derwent between them.

(3) Underground Water-supply Paper No. 1: "The Underground Water Rsources of the Madlands," p. 11.

To the west of the area occurs the high ground between the Jordan and Clyde Rivers, the most prominent points of which are Espie's Craig, Black Tier (2544 feet) and Woods' Quoin (3033 feet).

(4)—Meteorology.

Ten stations at which rainfall measurements are taken exist in this area, and much valuable data has been obtained. One of these stations (Richmond) has records for 37 years, but the others have records extending over lesser periods, those for Apsley extending over only six years.

Table No. 1 gives the records for Apsley, Broadmarsh, Bagdad, Brighton, Colebrook, Kempton, Richmond, Spring Hill (Lovely Banks), and Tea Tree, the figures being supplied by Mr. W. S. Watt, State Meteorologist. The figures for Jericho have been given in a previous publication.(4)

The figures in Table No. 2 are taken from Table No. 1, and show the average annual rainfall of all the stations up to the end of 1920. The approximate elevations of the stations are also included.

Table No. 2.

Average Annual Rainfall.

Station.	Record.	Approximate Elevation.	Average Yearly Rainfall.
	Years.	Feet.	Points.
Bagdad	32	400	2399
Colebrook	9	679	2314
Apsley	6	760	2234
Broadmarsh	13	300	21[illegible]8
Richmond	37	100	2094
Tea Tree	12	250	2082
Spring Hill (Lovely Banks)	20	900	2049
Jericho	13	1270	1963
Kempton	26	700	19.18
Brighton	22	100	19.02

(4) Underground Water-supply Paper No. 1: "The Underground Water Resources of the Midlands," p. 30.

TABLE No. 1.

Bagdad.

Year.	Jan.	Feb.	March.	April.	May.	June.	July.	Aug.	Sept.	Oct.	Nov.	Dec.	Total.
1889	163	257	79	264	90	629	123	69	101	244	442	246	2707
1890	63	343	268	84	137	594	167	281	147	312	206	216	2818
1	250	86	135	126	200	288	300	123	47	251	201	386	2393
2	236	33	149	379	282	185	171	101	88	144	232	171	2171
3	647	16	69	390	288	222	492	151	194	148	203	272	3092
4	191	77	139	220	303	233	273	492	198	203	114	257	2700
5	30	87	366	219	152	149	67	292	398	218	62	246	2286
6	173	159	93	197	158	421	41	374	104	178	61	45	2004
7	308	263	108	104	199	120	204	128	172	197	289	32	2124
8	83	40	103	193	238	169	344	60	182	190	352	94	2048
9	178	38	251	203	177	195	53	101	139	143	201	86	1765
1900	271	100	59	268	85	221	240	178	58	285	27	265	2057
1	532	44	302	319	110	150	83	250	223	515	66	69	2663
2	386	188	133	202	63	224	90	149	305	151	151	301	2343
3	118	411	223	231	241	498	357	73	136	292	273	196	3049
4	263	294	235	10	184	252	79	164	174	141	229	78	2103
5	520	336	155	266	714	45	293	56	190	306	79	208	3168
6	41	65	190	326	122	199	291	94	48	554	196	183	2309
7	301	138	79	130	94	71	203	147	325	367	67	511	2433
8	114	56	266	46	63	128	109	75	225	247	128	62	1519
9	303	121	157	360	199	403	129	209	184	135	144	183	2527
1910	416	30	155	185	151	205	117	202	403	155	107	284	2410
1	69	289	710	183	357	128	110	81	127	207	121	395	2777
2	183	7	259	160	178	334	129	122	353	348	191	265	2529
3	163	28	231	128	26	133	96	161	226	202	202	129	1722
4	30	19	161	312	102	56	199	121	113	40	243	251	1647
5	20	140	169	364	195	156	101	204	127	400	310	15	2201
6	563	240	105	578	73	249	278	296	216	275	442	1398	4713
7	67	146	199	288	250	283	246	168	288	257	145	131	2468
8	96	344	158	178	251	136	233	241	256	265	76	189	2423
9	245	128	223	110	61	342	162	107	135	161	27	149	1850
1920	70	68	127	107	175	260	89	172	150	104	163	250	1735
32 Years' Avge.	222	143	189	223	185	240	183	170	189	239	180	236	2399

Colebrook.

Year.	Jan.	Feb.	March.	April.	May.	June.	July.	Aug	Sept.	Oct.	Nov.	Dec	Total.
1911	—	—	—	—	—	—	—	—	143	162	116	417	—
2	167	15	236	199	133	376	178	128	385	354	235	255	2661
3	133	28	225	182	43	107	110	169	215	181	298	150	1838
4	58	18	156	325	97	74	169	114	72	68	276	221	1648
5	37	182	246	231	275	143	70	149	146	340	315	10	2144
6	543	303	86	498	125	205	285	273	204	211	461	882	4076
7	55	157	181	483	242	392	242	156	322	254	200	130	2814
8	107	199	182	145	259	96	239	223	151	342	95	120	2158
9	174	151	310	127	72	375	189	95	70	189	28	127	1907
1920	68	—	163	164	185	267	71	135	169	99	133	124	1578
9 Years' Avge.	149	117	198	262	159	226	173	160	193	226	227	224	2314.

Apsley.

Year.	Jan.	Feb.	March.	April.	May.	June.	July.	Aug.	Sept.	Oct.	Nov.	Dec.	Total.
1915	66	139	152	434	239	154	105	109	167	291	305	13	2174
6	377	398	45	466	88	168	243	257	238	198	348	810	3636
7	88	172	115	303	201	417	172	129	210	196	254	144	2401
8	94	117	144	190	266	201	250	126	182	273	51	129	2023
9	166	101	196	139	89	426	186	65	99	148	28	73	1716
1920	26	13	101	130	103	212	82	192	196	104	154	142	1455
6 Years' Avge.	136	157	125	277	164	263	173	146	182	202	190	219	2234

Broadmarsh.

Year.	Jan.	Feb.	March.	April.	May.	June.	July.	Aug.	Sept.	Oct.	Nov.	Dec.	Total.
1907	—	152	140	138	87	55	177	154	412	418	109	—	—
8	132	48	224	121	86	134	131	75	217	142	145	66	1521
9	230	96	214	289	244	439	120	220	138	152	145	172	2459
1910	213	15	134	211	160	220	119	218	350	172	106	273	2191
1	49	329	414	194	283	103	122	74	125	199	150	369	2411
2	210	7	227	198	158	415	141	163	474	329	234	243	2799
3	181	49	189	141	57	75	—	—	—	—	—	196	—
4	42	30	130	348	77	65	198	160	115	22	210	246	1643
5	28	107	169	319	223	188	88	128	125	401	309	10	2095
6	434	140	105	523	108	245	214	271	217	174	360	935	3726
7	38	252	188	259	324	272	245	206	144	192	148	64	2332
8	100	325	167	141	274	231	239	164	217	351	84	151	2444
9	266	96	112	179	58	421	180	72	88	129	19	76	1696
1920	56	18	120	60	97	261	56	121	70	100	150	152	1261
13 Years' Avge.	152	116	184	230	166	236	153	156	193	198	177	227	2188

Richmond.

Year.	Jan.	Feb.	March.	April.	May.	June.	July.	Aug.	Sept.	Oct.	Nov.	Dec.	Total.
1884	247	63	52	14	143	162	71	290	150	167	79	473	1911
5	280	141	357	50	95	146	64	77	276	106	560	188	2344
6	389	172	114	266	169	15	91	255	93	170	300	82	2166
7	334	132	209	78	115	230	285	48	233	137	133	93	2027
8	130	2	77	93	83	187	86	134	364	127	128	112	1523
9	253	256	19	348	98	741	144	56	44	244	427	216	2846
1890	121	302	310	99	83	543	229	337	120	182	173	195	2694
1	119	79	110	109	282	189	282	79	27	290	184	432	2244
2	225	11	154	327	202	152	201	63	113	141	152	99	1840
3	513	16	67	305	346	260	516	99	118	121	230	207	2798
4	158	77	147	198	232	148	244	540	124	202	62	278	2410
5	23	134	311	196	87	100	82	238	225	156	21	264	1837
6	120	124	80	102	97	387	81	416	75	144	75	22	1723
7	269	223	92	93	204	77	109	102	139	175	242	7	1732
8	50	4	186	151	269	106	285	77	142	200	247	138	1855
9	275	18	171	162	115	260	49	60	169	103	270	89	1741
1900	259	65	112	233	81	139	191	129	46	187	32	267	1741
1	425	27	296	306	67	161	44	196	205	393	63	41	2224
2	318	265	156	145	65	165	59	82	274	83	86	338	2036
3	96	420	143	243	204	449	252	74	118	233	273	152	2657
4	145	355	302	8	155	200	113	147	215	53	272	40	2005
5	431	348	109	187	639	42	258	34	167	338	84	256	2893
6	24	32	142	185	72	131	227	91	35	495	153	94	1681
7	199	163	84	73	99	86	175	118	213	325	80	472	2087
8	185	37	240	54	13	114	82	42	185	309	70	26	1357
9	289	180	83	424	176	373	112	175	138	77	125	205	2357

1910	211	49	69	182	76	225	92	100	293	157	68	288	1810
1	31	157	459	166	414	124	123	105	102	225	130	294	2330
2	82	111	263	151	140	271	93	61	317	233	136	263	2121
3	129	3	187	185	16	117	94	84	175	156	222	115	1488
4	18	14	123	273	53	36	183	85	80	43	219	150	1274
5	9	195	231	241	218	125	38	159	101	270	212	8	1807
6	522	187	124	509	70	226	266	200	156	283	466	976	3985
7	33	199	188	335	178	311	187	166	272	222	182	169	2442
8	73	216	146	184	236	96	257	208	199	258	103	146	2122
9	208	159	438	96	49	185	157	83	72	116	19	141	1723
1920	60	38	128	151	194	234	92	107	199	43	105	350	1701
37 Years' Avge.	198	134	175	187	158	203	160	144	161	194	172	208.	2094

Tea Trze.

Year.	Jan.	Feb.	March.	April.	May.	June.	July.	Aug.	Sept	Oct.	Nov.	Dec.	Total.
1906	—	—	—	—	—	—	—	—	45	468	185	121	—
7	293	164	53	106	106	85	199	125	229	289	63	537	2249
8	109	53	258	26	18	112	74	54	165	325	128	36	1358
9	285	113	99	319	191	373	104	168	117	81	172	165	2187
1910	218	37	85	181	113	223	87	125	285	168	128	173	1823
1	18	296	459	132	311	138	100	89	97	159	112	273	2184
2	73	5	255	131	176	238	134	61	269	288	149	238	2017
3	105	11	192	163	17	73	98	78	197	152	172	159	1415
4	27	23	111	234	77	36	233	88	104	46	244	194	1417
5	12	120	187	348	175	123	56	157	87	351	195	14	1828
6	526	221	14	572	92	291	271	186	199	251	347	920	3890
7	65	127	170	423	226	327	187	122	349	226	275	100	2597
8	121	390	152	79	187	200	159	184	93	236	46	164	2011
12 Years' Avge.	154	130	170	226	141	185	142	120	183	214	169	248	2082

Spring Hill.

(Mr. E. Bisdee, "Lovely Banks," Melton Mowbray.)

Year.	Jan.	Feb.	March.	April.	May.	June.	July.	Aug.	Sept.	Oct.	Nov.	Dec.	Total.
1901	221	48	313	404	28	226	26	220	290	460	71	60	2365
2	416	275	80	189	26	317	64	94	226	89	58	316	2150
3	20	389	200	280	121	467	297	107	122	254	243	242	2742
4	243	154	218	280	224	175	130	81	130	94	159	48	1656
5	518	384	70	178	281	298	237	—	159	255	39	229	2648
6	2	44	167	360	107	221	315	89	10	503	88	91	1997
7	207	129	28	10	105	62	229	204	305	385	200	401	2265
8	160	39	308	33	36	165	41	57	192	211	115	45	1402
9	348	99	65	327	214	317	66	145	116	94	107	208	2106
1910	205	53	75	213	136	242	65	123	258	189	103	222	1884
1	43	182	325	170	266	120	113	88	99	129	87	338	1960
2	167	8	250	172	122	326	168	57	263	373	190	258	2354
3	151	23	173	150	36	60	77	108	206	131	156	151	1422
4	54	9	155	300	78	71	180	86	78	23	246	175	1455
5	43	101	133	327	245	147	61	112	113	291	213	53	1839
6	399	222	59	432	75	184	203	214	184	234	349	939	3494
7	73	125	125	349	238	359	147	111	308	179	198	231	2443
8	89	221	134	170	267	78	212	123	168	214	58	108	1842
9	131	109	185	94	69	306	163	60	77	141	21	114	1470
1920	47	17	114	138	116	310	75	127	178	68	125	170	1485
20 Years' Avge.	177	132	159	215	140	222	143	110	174	216	141	220	2049

Kempton.

Year.	Jan.	Feb.	March.	April.	May.	June.	July.	Aug.	Sept.	Oct.	Nov.	Dec.	Total.
1894	—	—	—	—	265	185	255	460	152	124	98	117	—
5	—	84	288	168	248	142	114	233	249	128	39	175	1668
6	150	153	41	108	134	550	58	399	79	125	69	87	1903
7	268	231	90	73	206	86	172	108	169	170	274	14	1861
8	75	28	83	146	296	107	245	97	150	201	265	77	1770
9	142	37	179	183	130	231	40	91	116	74	263	73	1559
1900	215	54	59	299	51	173	172	134	62	224	46	221	1710
1	526	32	311	314	68	149	54	206	189	425	44	62	2380
2	355	219	81	163	68	175	35	184	212	90	87	234	1903
3	40	355	164	197	75	688	248	76	115	212	215	145	2530
4	262	175	310	12	184	193	76	141	157	108	185	100	1903
5	421	299	96	196	548	36	222	28	146	277	49	229	2547
6	35	52	136	248	111	146	257	73	26	389	130	116	1719
7	276	102	62	85	87	70	191	128	314	273	46	466	2100
8	94	32	203	25	69	128	76	60	209	174	132	32	1234
9	238	67	78	454	151	261	66	164	83	107	122	192	1983
1910	254	32	54	206	126	190	65	135	226	127	66	185	1666
1	29	174	331	150	262	115	114	80	95	138	91	341	1920
2	174	1	234	129	116	315	164	106	280	270	273	249	2311
3	187	13	161	119	14	69	88	102	142	163	124	142	1794
4	35	14	117	214	62	43	324	81	77	29	216	138	1250
5	15	94	194	276	259	127	73	71	111	348	242	1	1811
6	392	198	91	466	105	169	275	238	202	191	400	1008	3735
7	58	133	108	323	270	287	158	137	266	191	176	121	2228
8	88	216	153	160	250	116	199	88	161	214	73	146	1864
9	156	116	223	119	58	299	123	83	77	144	29	105	1532
1920	42	36	111	94	140	237	102	139	146	83	129	221	1480
26 Years' Avge.	173	113	152	189	150	196	139	130	156	188	146	186	1918

Brighton.

Year.	Jan.	Feb.	March.	April.	May.	June.	July.	Aug.	Sept.	Oct.	Nov.	Dec.	Total.
1899	142	32	164	56	122	158	30	58	124	124	188	68	1266
1900	218	60	47	269	55	128	196	106	38	232	35	240	1624
1	412	49	298	247	89	136	57	201	239	400	45	45	2218
2	327	146	71	186	69	161	47	78	270	113	135	260	1863
3	83	341	195	267	159	364	234	88	113	253	242	136	2475
4	226	212	201	9	185	151	69	125	168	101	232	57	1736
5	458	279	124	217	461	41	262	39	118	237	48	145	2429
6	23	49	134	274	114	164	269	81	41	433	147	170	1899
7	302	116	70	96	90	52	178	121	289	315	81	458	2169
8	102	50	188	74	27	118	131	62	183	212	105	41	1293
9	264	102	146	270	129	319	82	167	144	105	112	207	2047
1910	186	27	68	185	126	204	81	164	370	153	103	211	1878
1	24	219	377	175	294	121	93	75	87	176	116	281	2038
2	101	2	195	165	130	207	124	99	278	286	151	210	1948
3	122	20	189	117	20	64	92	102	188	165	161	146	1386
4	38	18	108	242	72	28	182	104	92	42	191	182	1307
5	19	149	145	294	147	142	61	118	114	307	199	11	1706
6	415	159	50	428	98	213	248	185	148	198	332	973	3447
7	36	70	140	280	200	295	173	202	171	195	161	110	2033
8	127	320	152	189	223	109	193	163	249	235	59	147	2166
9	198	117	224	84	38	287	132	80	92	128	17	140	1537
1920	24	34	98	114	146	230	70	103	131	74	107	256	1387
22 Years' Avge.	175	117	154	193	136	168	136	114	166	204	135	204	1902

The distribution of rainfall throughout the year is shown by the graphs in Plate IV., in which the monthly rainfalls are plotted throughout the year. The graphs are very similar for the various stations, and only a few minor variations are to be detected. These variations, *e.g.*, the October-December part of the graph for Colebrook, and the January-March part of the graph for Apsley, are found where the records extend over only a short number of years, and extraordinary figures, such as the phenomenonally wet years of 1916 and 1917, have an effect on the average which they would not have over a larger number of years. The conclusion to be drawn from the similarity of the graphs is that practically the same set of conditions operates throughout the district in the production of the rainfall. The average graph gives the distribution of the rainfall as follows:—The rainfall for January is about the average, and is followed by a decrease, February being the driest month of the year; there is then an increase to the average again for March, and this continues into April, one of the wettest months; a sharp decrease occurs in May, the rainfall for which is below the average, and then a sharp increase for June, generally the wettest month of the year; this is followed by a decrease for July and August, July being below the average and August the next driest month after February; then comes an increase to September and October, the former having an averange rainfall and the latter being a wet month; November has a rainfall slightly below the average, and December is one of the wettest months.

This distribution is, on the whole similar to that occurring in the Midlands,(5) but there are two points at which variation exists. Firstly, April in this area is a very wet month, whereas in the Midlands this was only markedly so at a few stations, April usually being about the average. Secondly, the dry period following the heavy rains of June in the Midlands occurred in July, whereas in the present area this dry period does not occur until August, July being only slightly below the average.

From Table No. 2 it is seen that the yearly rainfall for the various stations in the area does not vary to any great extent. Bagdad has the greatest rainfall with 2399 points, and Brighton the least with 1902 points, the difference being 497 points. Further, it is seen from this table that the amount of rainfall is apparently independent of the

(5) Underground Water-supply Paper No. 1: "The Underground Water Resources of the Midlands," p. 23.

DISTRIBUTION OF THE YEARLY RAINFALL

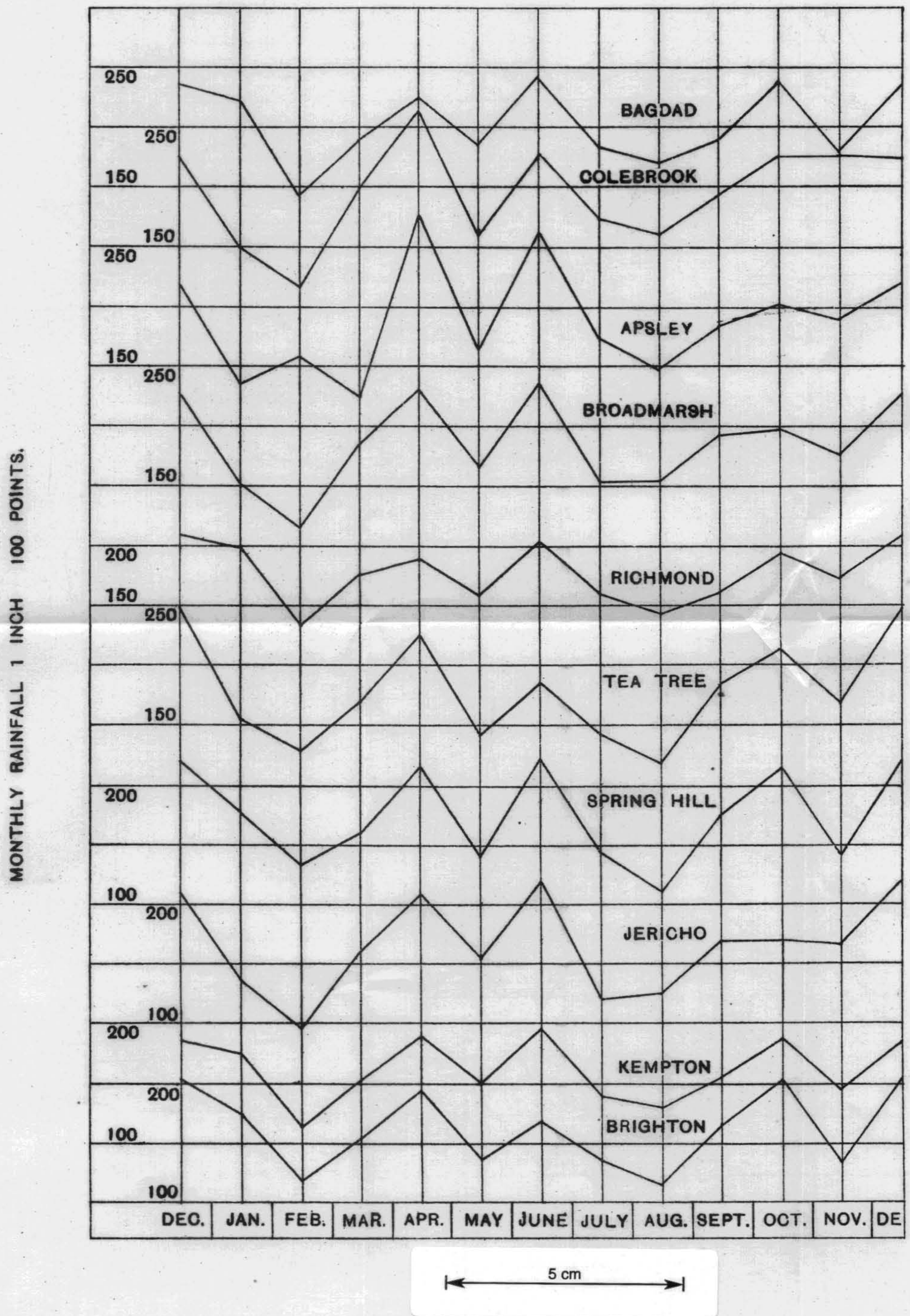

Photo Algraphed by John Vail Government Printer Hobart Tasmania.

elevation of the stations above sea-level. In the Midlands the amount of rainfall at any locality was found to be directly dependent on its elevation.

The general conditions determining the rainfall of the present area and that of the Midlands should be similar. Both areas have only moderate rainfalls, due to the "rain shadow"(6) effect of the elevated country of the Central Plateau and the mountains of the West Coast. This effect is due to the passage of the prevailing rain-bearing winds (south-west to north-west) over these elevated regions, which cause the deposition of most of the contained moisture as rain before reaching the Midlands and the present area. However, while the general conditions are similar, there are differences between the two areas. This is shown by the slight difference between the distributions of the rainfall throughout the year, but more particularly by the fact that the amount of the rainfall is not determined by the elevation as it was in the Midlands.

The stations at Bagdad and Colebrook record the largest rainfalls in the area. Considering the stations south of these two, it is found that the rainfall may be regarded as varying directly with the elevation. North of these two stations the rainfall decreases with increase of elevation (with the exception of Kempton). These facts point to the conclusion that south-south-easterly winds play a large part in determining the amount of rainfall within the area. Bagdad and Colebrook both stand at the head of valleys with a north-north-west to south-south-east trend, which would thus provide easy paths for winds from the south-south-east. The deposition of the moisture from these winds as rain increases steadily until Bagdad and Colebrook are reached, where it is a maximum, and then decreases further inland. The exceptionally low rainfall of Kempton is apparently due to the "rain-shadow" effect of the Quoin Mt.-Constitution Hill range of hills, which occur to the south-east of it.

Thus it is seen that the effects of the south-south-easterly rain-bearing winds are superimposed upon those of the general westerly rain-bearing winds in determining the rainfall within the present area.

(6) "The Australian Environment," by Griffith Taylor, D.Sc.

TABLE No. 3.

Station.	Yearly Rainfall.					Monthly Rainfall.				
	Average.	Maximum.		Minimum.		Average.	Maximum.		Minimum.	
		Points.	Year.	Points.	Year.		Pts.	Month.	Pts.	Month.
Bagdad,		4713	1916	1519	1908		1398	Dec., 1916	7	Feb., 1912
1889-1920	2399	3168	1905	1647	1914	200	710	Mch., 1911	10	April, 1904
Colebrook,		4076	1916	1578	1920		882	Dec., 1916	—	Feb., 1920
1912-1920	2314	2814	1917	1648	1914	193	543	Jan., 1916	10	Dec., 1915
Apsley,		3636	1916	1455	1920		810	Dec., 1916	13	Feb., 1920
1915-1920	2234	2401	1917	1716	1919	186	466	April, 1916	13	Dec., 1915
Broadmarsh		3726	1916	1261	1920		935	Dec., 1916	7	Feb., 1912
1908-1920	2188	2799	1912	1521	1908	182	523	April, 1916	10	Dec., 1915
Richmond,		3985	1916	1274	1914		976	Dec., 1916	2	Feb., 1888
1884-1920	2094	2893	1905	1357	1908	177	741	June, 1889	3	Feb., 1913
Tea Tree,		3890	1916	1358	1908		920	Dec., 1916	5	Feb., 1912
1907-1918	2082	2597	1917	1415	1913	176	572	April, 1916	11	Feb., 1913
Spring Hill,		3494	1916	1402	1908		939	Dec., 1916	2	Jan., 1906
1901-1920	2049	2742	1903	1422	1913	171	518	Jan., 1905	8	Feb., 1912
Jericho,		3617	1916	1363	1914		884	Dec., 1916	7	Feb., 1914
1907-1920	1963	2603	1917	1408	1908	164	506	Nov., 1916	12	Feb., 1913
Kempton,		3735	1916	1234	1908		1008	Dec., 1916	—	Feb., 1895
1895-1920	1918								1	Feb., 1912
		2547	1905	1250	1914	160	688	June, 1903	1	Dec., 1915
Brighton,		3447	1916	1266	1899		973	Dec., 1916	2	Feb., 1912
1899-1920	1902	2475	1903	1293	1908	158	461	May, 1905	11	Dec., 1905

Table No. 3 shows the yearly and monthly maximum and minimum rainfall figures for the years over which records are available. The largest yearly rainfall was 4713 points at Bagdad in 1916, while the smallest does not fall below 1200 points for any part of the area. Of fairly recent years, 1916 stands out as easily the wettest year, with 1917 and 1905 next in order, while 1908 has been the driest, closely followed by 1914. December, 1916, has been in every case the wettest month, and 800 to 1400 points fell throughout the area.

Snow falls occasionally throughout the whole of the area, while the higher localities, Mt. Dromedary and Quoin Mt., have it somewhat more frequently. On July 31 of the present year (1921) from 4 to 6 inches of snow fell throughout the area, and is said to have been the heaviest for many years.

(5)—Vegetation and Timber.

The whole of the surface of the area was formerly covered with a growth of trees and vegetation, but large portions of the area have been cleared for agricultural and pastoral purposes. These cleared portions occur along the valleys of the Jordan and Coal Rivers and their tributaries. The central elevated portion of the area practically retains its original growth of trees and vegetation.

The largest and most common trees are the eucalypts, of which the following species are abundant:—White-gum (*E. viminalis*), blue-gum (*E. globulus*), stringy-bark (*E. obliqua*), peppermint (*E. amygdalina*). These are distributed fairly uniformly throughout the area, but stringy-bark is usually more plentiful on the hills and more elevated portions of the area. The largest trees are found on the more elevated regions, especially on the sides of the gullies and valleys.

Other trees found in the area are silver-wattle (*A. dealbata*), she-oak (*casuarina*), honeysuckle (*banksia*), blackwood and lightwood (*Acacia melanoxylon*), native cherry (*Exocarpus cupressiformis*). In the creeks and gullies shrubs such as kurrajong, dogwood, musk, and tree-ferns are to be found. Bracken-fern, sags, and heath form the bulk of the undergrowth, and are found mainly on the sandy soils. Except in the vicinity of Quoin Mt. the trees are not sufficiently large for sawmilling purposes. One sawmill is in operation at the present time, and is located at Barber's Marsh, to the south of Quoin Mt. The timber of the area is largely drawn upon by the agricultural and pastoral industries, and is used for fencing and rough building purposes. Supplies of sleepers for the railway are also obtained. Considerable quantities of wood are used in the area and sent by rail to Hobart for burning as fuel.

The cleared portions of the area are devoted to agricultural, pastoral, and orcharding purposes. Oats and wheat are the main cereal crops which are grown. Root crops, mainly potatoes and swedes, are also cultivated, chiefly on the virgin sandstone soil. Orcharding and small-fruit growing are practised at various localities, but most intensely around Bagdad.

IV.—GEOLOGY.

(1)—Introduction.

(a) *Summary.*

The oldest rocks occurring in this area are the strata of the Permo-Carboniferous system, and these are followed by the strata of the Trias-Jura system. Both these series of strata have been intruded on a large scale by the Upper Mesozoic diabase. Tertiary deposits occur to a small extent in the south of the area. Basalt occurs in the form of dykes and flows, the latter being in some cases, *e.g.*, at Richmond, interbedded with the Tertiary deposits. Alluvium is forming at certain localities along the courses of the present streams.

The sedimentary (Permo-Carboniferous, Trias-Jura, and Tertiary) strata and igneous (diabase and basalt) formations occupy, roughly, equal proportions of the surface.

Of the sedimentary formations the Trias-Jura strata cover by far the greatest area, followed in order by the Permo-Carboniferous and Tertiary strata. These strata are either horizontal or dipping at only a small angle, the dips in general being purely local. Much disturbance has taken place in these strata, due to faulting closely associated with the intrusive diabase.

Diabase predominates among the igneous formations, and, while occupying half of the surface, it also underlies practically the whole of the area at no great depth.

(b) *Maps and Sections.*

A geological sketch-map of the area is given in Plate II., and shows the boundaries of the various formations occupying the surface. The main topographical features, &c., are indicated, and contours at intervals of 200 feet are shown. Where possible the divisions of the Trias-Jura system, to which the various outcrops of these strata belong, have been indicated. This has been effected by using the letter "L" for the lower sandstone series and "F" for the middle or felspathic sandstone series. It is doubtful whether any of the upper sandstone series outcrop, and none have been indicated.

The basalt, which occurs interbedded with the Tertiary sediments between Campania and Richmond, is exposed in numerous creek and river sections, but no attempt is made to indicate these outcrops owing to the small scale to which the map is drawn.

Geological sketch sections, prepared from the above map, are shown in Plate III., and serve to give a general idea of the geological structure of the area.

(2)—The Sedimentary Rocks.

(a) *The Permo-Carboniferous System.*

The strata of this system outcrop from under those of the Trias-Jura system in only a few localities, and cover about four per cent. of the total area. The main localities where they outcrop are as follow:—

(i) Along the Coal River, 3 miles south-east of Rhyndaston.—These strata appear here on the upthrow side of a fault, and form cliffs along the east bank of the Coal River. About 300 feet of unfossiliferous white mudstones underlie the basal conglomerate of the Trias-Jura system. These strata are thickly bedded with bedding-planes about 2 feet apart, and are lying horizontal.

(ii) On the north-east flanks of Grass Tree Hill, south-west of Richmond.—Here two areas of these strata occur with a fault and an intrusive diabase mass between them. In the higher outcrop 200 feet of slightly fossiliferous mudstones and limestones occur (excellent sections being exposed in the cuttings along the Richmond to Risdon Road) underlying the Trias-Jura strata. These beds are lying horizontal. The other outcrop is on the flat ground at the foot of the hills, and only a few feet are exposed under the basal conglomerate of the Trias-Jura system. These beds dip to the west at 6 degrees.

(iii) In the valley of the Mangalore Creek, west of Mangalore.—In this locality there occur several hundred feet of unfossiliferous mudstones directly underlying the basal conglomerate of the Trias-Jura system. These strata appear to be horizontally bedded, but there is probably a general small dip to the south-west, as the overlying conglomerates occur at lower elevations in that direction.

(iv) North eastern flanks of Mt. Dromedary.—Permo-Carboniferous strata are extensively developed between Mt. Dromedary and Bridgewater. On the flanks of Mt. Dromedary vertical sections of at least 1000 feet of these strata are obtained, but as this is an area with much faulting it may be possible that duplication of beds occur, making the actual thickness less than 1000 feet. These strata consist of horizontally bedded, very fossiliferous limestones, mudstones, and sandstones of marine origin. Where strata immediately underlying the Trias-Jura strata are exposed they consist of unfossiliferous or only slightly fossiliferous white mudstones.

From the above it is seen that the Permo-Carboniferous strata in this area consist of horizontally bedded or low-dipping beds of mudstones, limestones, and sandstones of marine origin. The strata immediately underlying the Trias-Jura basal conglomerates are found to consist of unfossiliferous or very slightly fossiliferous white mudstones to a depth of at least 300 feet. At lower horizons the strata consist of highly fossiliferous limestones, mudstones, and sandstones, several hundred feet of this series being exposed near Mt. Dromedary.

The term "mudstone" used above includes the rock-types other than sandstones and undoubted limestones which are found occurring among the Permo-Carboniferous strata. These mudstones are white, very fine-grained rocks with bedding-planes generally about 1 to 2 feet apart, and vertical jointing prominent. Some are pure white in colour, and these have often been termed limestones and calcareous mudstones. An analysis of one of these pure white types from Mangalore Creek, by Mr. W. D. Reid, Government Assayer, is given below:—

Constituents.	Per Cent.
SiO_2	82·25
Fe_2O_3	1·25
Al_2O_3	12·00
CaO	0·50
MgO	0·44
Ignition Loss	2·80
SO_3	0·55
	99·79

This analysis shows the rock to consist mainly of silica (quartz) with a small proportion of kaolin, the lime content being practically negligible. The rock has been derived from a very fine-grained quartz silt, and may perhaps be best described by terming it a silicious mudstone.

As regards the age of these strata, the following list contains the more important genera, specimens of which were obtained in the area:—

Anthozoa...	Stenopora
Polyzoa	Fenestella, Protoretepora
Brachiopoda...	Spirifera, Productus, Strophalosia
Pelecypoda	Aviculopecten
Gasterpoda	Several genera

These fossils were obtained chiefly from localities to the west of Bridgewater, and on the flanks of Mt. Dromedary, but a few were also obtained from Grass Tree Hill. These forms are all typically Lower Marine Permo-Carboniferous in origin, and prove that the strata containing them belong to this series.

The strata near Bridgewater had been previously assigned to the Lower Marine series.(7)

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

The strata belonging to this system are extensively developed in the area under discussion, and occupy approximately 40 per cent. of the surface. They occur at all elevations from sea-level, at Richmond and along the Derwent, to heights of 2000 feet above the sea in the vicinity of Quoin Mt. The rock-types existing among these strata are numerous, the following types being recognised:—Sandstones, felspathic sandstones, mudstones, shales, grits, and conglomerates. These types have been fully described in a previous report,(8) and a repetition here is unnecessary. These types occur in the above order, sandstones and felspathic sandstones being the predominant types.

The Trias-Jura strata are found either horizontally bedded or dipping at a very small angle. Dips are as a rule purely local, and occur close to faults and diabase

(7) R. M. Johnston, F.L.S.: "Geology of Tasmania," 1888, p. 103.

(8) Underground Water-supply Paper No. 1: "The Underground Water Resources of the Midlands," p. 43.

intrusions. The following divisions of these strata can be made on the evidence available in this area:—

(i) *The Lower Sandstone Series.*—The base of this series consists of conglomerates which, wherever they are exposed, are found to overlie unfossiliferous white mudstones of the Permo-Carboniferous system. These basal conglomerates then pass up through grits into normal sandstones. The exact thickness of this series is difficult of determination, but some sections, *e.g.*, along the Coal River, east of Rhyndaston, show at least 600 feet of these sandstones, and it seems certain that the series attains a thickness of 700 to 800 feet.

(ii) *The Felspathic Sandstone Series.*—This series overlies the sandstone series, but the actual junction is seldom visible. The relation is undoubtedly a conformable one, as the two series have similar dips, and sandstones of the lower sandstone series type occur interbedded with the felspathic sandstones. At some localities, *e.g.*, the northern flanks of Spring Hill Tier, about 200 feet of mudstones appear at the base of this series. Generally this series consists of felspathic sandstones with interbedded mudstones and coal-seams. The thickness of this series is not easy of determination, but probably exceeds 500 feet. A bore(9) at Colebrook proved over 300 feet of felspathic sandstones, while a 500-foot bore(10) at Richmond gave a thickness of 470 feet of these rocks.

(iii) *The Upper Sandstone Series.*—Overlying the felspathic sandstones along part of the Wallaby Rivulet, north of Colebrook, there occur about 20 feet of normal sandstones. These may represent portion of an upper sandstone series, or else an interbedded sandstone bed near the top of the felspathic sandstones, with all of the latter rocks which were overlying it removed. Several other outcrops of sandstones have previously(11) and (12) been referred to this series, but the present investigation has shown that they really belong to the lower sandstone series.

(9) Report of the Secretary for Mines, 1888-89.
(10) Report of the Secretary for Mines, 1891-92, p. 63.
(11) J. Milligan: Proc. Roy. Soc. V.D. Land, 1849.
(12) C. Gould: "Coal, South of Oatlands," 1869.

Age.—These strata are at present classified under the Trias-Jura system, a more definite determination being impossible. Plant remains are fairly plentiful, being found chiefly in the mudstones associated with the felspathic sandstones in general and with the coal-seams in particular. The normal sandstones are poor, as a rule, in organic remains, as are also the felspathic sandstones, but the latter are abundant in masses of silicified wood of all sizes. Following is a list of the forms obtained in this area:—

Phœnicopsis elongatus.
Cladophlebis australis.
Thinnfeldia.

The conditions under which these strata were deposited are those of shallow-water, lacustrine or estuarine conditions. Current bedding is very common in the sandstones, indicating deposition in shallow water subject to variable currents. The organic remains included in these strata are those of land vegetation, no marine organisms being present, thus pointing to deposition under lacustrine or estuarine conditions. Halite (common salt) and epsomite (epsom salt) occur as layers on the floors and roofs of caves in the sandstones in certain localities, *e.g.*, Green Valley, 4 miles west-north-west of Bagdad, and also in the cliffs south of Richmond. These salts have been leached out of the sandstones and deposited in the caves. Thus the sandstones contain appreciable amounts of halite and epsomite at some horizons at least. The deposition of these salts along with sediments takes place in all salt lakes and land-locked estuaries where concentration of these salts under usually arid or sub-arid conditions occurs. The conditions for the felspathic sandstones must have been somewhat different as land vegetation flourished and the coal-seams were formed.

(c) *Tertiary System.*

Strata belonging to this system occur to only a small extent in this area, and are developed chiefly around Richmond. They occur along the lower part of the valley of the Coal River, around the margin of Pittwater, and along the lower portion of Duck Hole Creek. These deposits consist of beds of sands and clays with lesser amounts of conglomerates and gravels. Basalt occurs overlying and interbedded with these deposits, and it has been the source of ferruginous solutions which have discoloured and formed ferruginous concretions in these deposits. Excellent sections are to be be found along the Coal River, and give detailed sections like the following (in descending order from surface to river level):—

8 feet basalt.
2 feet iron-stained sand.
7 feet sand.
5 feet clay.
15 feet sand with ferruginous concretions.

In the immediate vicinity of Richmond the basalt is overlain by 5 feet or more of conglomerates and gravels. The basalt thins out and disappears in the direction of Richmond, and it is replaced by heavy conglomerates containing basalt boulders, which pass up into the ordinary gravels. These deposits are horizontally bedded and are more or less unconsolidated, with the result that they disintegrate very easily, especially in cliff sections, although the basalt protects the cliffs. No organic remains were obtained, and the age and origin of these deposits cannot be definitely stated. Similar deposits, also associated with interbedded and overlying normal basalts, occur in numerous other localities in Tasmania, notably in the Launceston and Derwent basins, and are regarded as Lower Tertiary lacustrine sediments. There is no doubt that these deposits around Richmond are to be correlated with the similar deposits in other parts of Tasmania, and can be regarded as Lower Tertiary lacustrine sediments.

Tertiary deposits also occur to a very small extent around Bridgewater. These consist of conglomerates and gravels, and represent mainly terrestrial accumulations on the old pre-basaltic land surface. Thin layers of gravel also overlie the basalt in a few localities around Bridgewater.

(*d*) *Recent Deposits.*

Alluvium is being formed along the courses of the present streams where they have carved out wide open valleys for themselves and are building up flood plains of this material. On the sides and bottoms of some of the more open valleys accumulations of soil and hill detritus are found. These accumulations are generally not of sufficiently great thickness to be mapped, but they are of importance at some localities, as they give rise to underground water-supplies. The detrital material around Kempton forms a layer over the plains and is of slightly more importance. These deposits are mapped as Recent, but might be more correctly termed Pleistocene.

(3) The Metamorphic Derivatives.

The sedimentary rocks have been intruded on a very large scale by the Upper Mesozoic diabase, and on a much smaller scale by the Tertiary basalt. The Permo-Carboniferous strata occupy only a small portion of the area, and no visible metamorphism in them was observed. The bulk of the metamorphism in the area is found in the Trias-Jura strata, and consists of contact metamorphism at their junction with the the intruding diabase. Various degrees of metamorphism can be detected, and different rock-types have been produced, a full description being given in a previous report.(13) Dark and light coloured cherts or hornstones represent the extreme effect on both the normal and felspathic sandstones. Good examples of these types are to be found along the Tarlington-road, 1½ miles west of Colebrook, and also along the Jericho-road, 3 miles north-west of Colebrook, and in a quarry on the main-road 3¼ miles north-east of Melton Mowbray.

Light coloured, homogeneous quartzites are the product of a lesser metamorphic effect on the normal sandstones. Excellent examples of quartzites are found on the easterly flanks of Gunning's Sugarloaf, north of Campania, and of Butcher's Hill, south of Richmond. Altered sandstones are produced as a result of less extreme metamorphism, and include a range of types from nearly normal rock-types to those approaching the cherts and quartzites.

The cherts are usually found overlying flat-topped masses of diabase, the metamorphic effect being greater here than against the steeply rising portions of a diabase intrusion.

In association with the metamorphism by the diabase, there are sometimes developed masses of quartz, both colourless and coloured, the latter forming red, brown, and yellowish cornelians, and also agates. These are very numerous around Cornelian Hill—a very low hill just south of Bagdad. The basalt flows have caused a slight metamorphism of the underlying soils and rocks. Dense, fine-grained, light-coloured quartzites are the types produced. These are developed on a small scale around the edge of the basalt to the east and south of Pontville Station.

(13) Underground Water-supply Paper No. 1: "The Underground Water Resources of the Midlands," p. 52.

(4)—THE IGNEOUS ROCKS.

(a) *Diabase.*

This rock-type is very extensively developed throughout the area, occupying 55 per cent. of the surface, and underlying at no great depth the remainder of the area.

The occurrences of the diabase in this area are similar to those in the Midlands area to the immediate north, which have already been described in detail,([14]) and will be only briefly dealt with here.

(i) *Petrology.*—The diabase is essentially composed of a plagioclase felspar and light-coloured augite in roughly equal proportions. The mineralogical content is very constant, and the rock varies only in its texture, which depends on the size of the component crystals. Several varieties of texture are to be recognised.

The finest-grained variety is a dense, homogeneous type in which no individual crystals can be recognised in hand specimens. This variety occurs close to the intruded rocks, and is due to the chilling effect of the latter on the intruding magma. The fine to medium grained variety has a very typical doleritic appearance in hand specimens. This variety is very common and occurs where the diabase has not been extensively denuded. The coarse-grained variety has much larger component crystals, and occurs towards the centre of intrusions, being revealed by extensive denudation or by deep gorges cut by streams.

A further very coarse-grained variety occurs to a small extent at certain localities. Crystals appear up to three centimetres in length, but one centimetre is the average. Occasionally this type consists of large porphyritic crystals in a fine ground-mass. This variety is usually found in veins in the ordinary coarse-grained variety, but sometimes assumes larger dimensions. It represents the type produced by the consolidation of the residual magma of the diabase intrusion.

In addition to the above a rather uncommon variety of the diabase occurs in this area at a few localities. This variety is an amygdaloidal, fine-grained, basic rock-type closely resembling a basalt. One outcrop of this rock occurs 3 miles east-north-east of Kempton, where a small area of it overlies felspathic sandstones. It is a much decomposed, amygdaloidal rock, very similar to a decomposed basalt, but it appears to be so intimately associated with normal dia-

(14) Underground Water-supply Paper No. 1: "The Underground Resources of the Midlands," p. 58.

base to the south-east of the outcrop that it is probably an extension of the latter as a small sill into the felspathic sandstones. Another outcrop of a similar rock-type occurs in the bed of the Coal Mine Rivulet, 2½ miles north-west of Colebrook. It is a very much decomposed amygdaloidal rock, and represents either a small sill or the top of a transgressive mass intrusive into the felspathic sandstones of that locality. One mile west of the latter outcrop a small area of a similar rock occurs, and is intimately associated with the normal diabase in the vicinity.

One and a half miles west of Colebrook a quarry has been opened on an amygdaloidal basic rock-type. It is a fine-grained rock resembling the normal diabase, but shows patches of olivine and has numerous white amygdules throughout the rock. The rock occurs as a dyke in the normal Trias-Jura sandstones, and has produced metamorphic effects in the latter exactly similar to those produced by diabase intrusions—cherts, quartzites, and altered sandstones being produced.

(ii) *Relation between the Diabase and the Trias-Jura and Permo-Carboniferous Strata.*—The diabase is found to be everywhere intrusive into these strata in various forms.

Sills are not common, but one can be seen in section in a road cutting on the Campania-road, 4 miles south-east of Colebrook. A very flat sheet of diabase cuts across the bedding-planes at an angle of 5 degrees in a railway cutting to the north of Birmingham Creek between Colebrook and Campania. Excellent sections are visible along the railway between Bagdad and Kempton, and show numerous intrusive contacts between the diabase and the Trias-Jura strata. In some of these the diabase occurs as transgressive masses, but in others it occurs as underlying, more or less, horizontal masses with their upper surface parallel to the bedding of the strata.

Somewhat similar sections to the latter are found along the Main-road to the north-east of Melton Mowbray, being exposed in road cuttings. These sections are described by Mr. Loftus Hills as follows:—"One and a half miles north-east of Melton Mowbray contact of diabase and sandstones occur. The diabase is seen as a flat floor under the sandstone in the road cutting. Going up the road this surface of diabase rises, and the sandstones have a corresponding dip, showing tilting. Within 20 yards the diabase rises to the surface of the cutting. Along the road from this point sandstones and diabase alternate, the latter rising up to the surface and sinking again. It is clear that for half a mile along the road at this locality, the diabase mass is nowhere far below and is covered, where the sandstones occur, only by a thin layer of them." "Two and a half miles north-east of Melton Mowbray the diabase intrusion has arched up the sedimentaries in laccolitic fashion."

A dyke through sandstones can be seen in a railway cutting 1 mile north of Brighton. Sections of numerous transgressive masses are visible along the Main Line Railway at various localities within the area, which can be seen from the geological map in Plate II.

The smaller masses of diabase on the geological map are all typically intrusive dyke-like masses, as is also the case with some of the larger masses. These latter masses join up with the largest diabase masses, which are therefore also intrusive.

Contact metamorphism of the intruded strata, though small in extent, is readily recognised at the diabase boundaries, and the rock-types have been described above.(15)

A consideration of the above facts establishes beyond doubt the intrusive character of the diabase.

(iii) *Age.*—It has been proved above that the diabase is intrusive into, and therefore younger than, the Trias-Jura strata.

Around Richmond the Lower Tertiary strata, with interbedded and overlying basalt, occupy the lower portions of the valley of the Coal River, which has been formed by extensive denudation of Trias-Jura and diabase formations. Thus the age of the diabase is considerably older than Lower Tertiary, in order to allow of extensive denudation before these times. These two limits restrict the age of the diabase to Upper Mesozoic, possibly Upper Jurassic or Lower Cretaceous.

It is probable that the cessation of deposition of the Trias-Jura sediments, their elevation, intrusion by diabase, and faulting are practically contemporaneous events. Thus when a more definite determination of the age of the Trias-Jura strata is accomplished, the age of the diabase should be also fixed.

(iv) *Form of Intrusions.*—The geological mode of occurrence of the diabase is a subject not only of scientific but also economic interest, affecting as it does the structure and extent of the coalfields of the State.

(15) See above, p. 38.

Sills are uncommon in the present area. The position of a 12-foot sill and also a 10-foot flat sheet have been given above.[16] Another probable sill occurs overlying felspathic sandstones between the Coal Mine Rivulet and the Colebrook to Jericho Road. The majority of the small and medium-sized masses of diabase shown on the geological map rise steeply above the surrounding strata and represent small and large dyke-like masses. The remainder of such masses are flat, low-lying masses, being the summits of underlying intrusions only recently exposed by denudation of the overlying strata from above them.

The largest areas of diabase, such as exist about Quoin Mt., Flat-top, Devil's Backbone, Flat Rock Tier,, and Mt. Dismal, Gunner's Quoin, &c., represent huge level-topped masses of intrusive diabase now greatly worn down by denudation.

All these intrusive masses have the appearance of arising from a large underlying mass situated at no very great depth below the surface. This structure is illustrated in the geological sections in Plate III.

These intrusions are found to intrude the Permo-Carboniferous and Trias-Jura strata at all horizons. Around Mt. Dromedary intrusions occur rising to horizons several hundred feet below the summit of the Permo-Carboniferous strata. The main portion of Mt. Dromedary rose to some considerable height in the Trias-Jura strata. The diabase forming Flattop rose to horizons as high as, if not higher than, the summit of the felspathic sandstone series.

Thus in this area it is seen that the form of the diabase intrusion is that of a huge underlying mass of diabase existing at various horizons in the sedimentary strata, and sending up minor intrusions of various characters, including large and small dyke-like masses and sills, into the overlying strata.

(*b*) *Basalt.*

This rock-type is not very extensively developed, and occurs over only about two or three per cent. of the surface. It occurs mainly as surface flows, often of considerable extent, as around Richmond and Brighton.

Two Varieties are recognised in the field.

(i) *Normal Basalt.*—This variety is much the more abundant of the two, and forms the large surface flows

(16) See above, p. 40.

which exist around Richmond and Campania, and also around Bridgewater, Brighton, and Pontville. It is generally a light-coloured, fine-grained, somewhat vesicular basalt, very similar to the basalts along the Macquarie River in the Midlands.(17)

One large flow of this basalt filled the lower portion of the valley of the Coal River from Richmond to above Campania—a distance of 7 to 8 miles, and had a width of 1 to 2 miles. This flow has a thickness of 100 feet towards its northern extremity, but thins out to 8 feet and disappears in the vicinity of Richmond. No definite source could be located, but, judging by the thicknes., the flow originated in the north and flowed southwards down the Coal River valley. Two dykes occur in connection with this flow, but do not appear to be the main source of the basalt. One dyke is seen intruding the felspathic sandstones in a river section east of Richmond. The other is shown in a quarry 2½ miles north of Campania on the road to Colebrook. The strata in the immediate vicinity of these dykes, especially the one near Richmond, are very much disturbed, and have basalt distributed through them. This is in contrast to the clear-cut course taken by diabase dykes. The flow which occurs around Bridgewater, Brighton, and Pontville filled the valley of the former Jordan River and its tributaries—the Strathallern and Bagdad Rivulets—for considerable distances, as can be seen from the geological map (Plate II.). This flow is thickest between Brighton and Bridgewater, and attains a thickness of 100 feet, but decreases in thickness considerably to the north and west.

(ii) *Olivine Basalt*.—This variety is a dense fine-grained basic basalt with porphyritic crystals of olivine distributed through it. It corresponds to the olivine and olivine-ilmenite basalts described in the Midlands.(18) Only very small outcrops of this basalt occur in the present area, the largest being that above the main-road, 2 miles south of Jericho. Other outcrops are situated at the following localities:—

North-west end of Goat's Hill, west of Pontville.

Half a mile west of Pritchard's Creek, north of Mt. Dromedary.

One and a half miles north-west of Campania.

(17) Underground Water-supply Paper No. 1: "The Underground Water Resources of the Midlands," p. 66.

(18) Underground Water-supply Paper No. 1: "The Underground Water Resources of the Midlands," p. 65.

A small outcrop of decomposed, scoriaceous basalt occurs 3 miles south of Colebrook. The rock contains fragments of baked sandstones through which it has been intruded. A yellowish-green decomposition product, probably sulphate of iron, occurs plentifully throughout the rock. Owing to its decomposed nature the relation of this rock with the above two types cannot be determined.

Age.—The normal basalt between Campania and Richmond occurs interbedded in places with the Tertiary sediments which are found along the lower part of the course of the Coal River. The age of these beds has already been discussed,[19] and, while no direct evidence is available, they are considered to be Lower Tertiary in correlation with similar formations in other parts of Tasmania. Normal basalts also occur in association with these areas of Lower Tertiary sediments, and are regarded as practically closing the period of Lower Tertiary sedimentation.

The olivine basalts occupy positions on more elevated country, and have apparently been subjected to a longer period of denudation than have the normal basalts. Thus if any difference in age exists between these two types, the olivine basalts are probably somewhat older than the normal basalts.

(5)—Structural Geology.

As already seen, the area under discussion is composed mainly of strata of the Permo-Carboniferous and Trias-Jura systems intruded on a very large scale by Upper Mesozoic diabase. Tertiary sediments and basalts also occur to a small extent.

The sedimentary strata are lying horizontally or dipping at very small angles, except in some cases in the vicinity of faults and diabase intrusions where larger dips are recorded. Thus these strata have not been subjected to any intense folding such as accompany orogenic or mountain-making movements. The earth movements which have affected the area have been of the nature of direct uplift such as accompany plateau and continent-making (epeirogenic) processes. Much faulting accompanies these latter movements and plays a large part in determining the geological structure of the area.

The forms taken by the diabase intrusions have already been described[20]. These play a very prominent part in

(19) See above, p. 41. (20) See above, pp. 41-42.

the geological structure of the area, as can be seen from the geological sections. (Plate III.)

The faulting in this area is found to be very closely associated with the diabase masses which intrude the sedimentary strata. Faulting is found to have occurred along the line of the diabase, or parallel to and at no great distance from it. No faulting later than, and affecting the diabase was óbserved, and it is concluded that the faulting and intrusion of the diabase were practically contemporaneous events. This relation has been discussed in a previous report.[21]. The best example of this relation between faulting and a diabase intrusion occurs on the north-eastern flanks of Mt. Dromedary. A large dyke-like mass of diabase of varying width runs for about 5 miles, with Trias-Jura strata on the north-east and Permo-Carboniferous strata on the south-west sides. Permo-Carboniferous beds, belonging to horizons hundreds of feet down below the summit of the series, junction with the diabase, and occur to heights of 400 feet above the diabase and Trias-Jura junction on the other side of the dyke. The Trias-Jura beds at the contact represent horizons at least 400 feet above the base of the series. Allowing 600 feet for the depth of the Permo-Carboniferous below the summit of the series, there will be a downthrow to the north-east of at least 1400 feet. Another example of this type of relationship occurs on the north-eastern flank of Grass Tree Hill, west of Richmond, where a downthrow of 600 feet to the north-east is associated with a diabase dyke.

A large fault runs parallel to, and a short distance to the east of, the diabase mass forming Butcher's Hill, south of Richmond. Felspathic sandstones on the east have been dropped to the level of the summit of the Permo-Carboniferous strata, representing a downthrow of about 1000 feet to the east.

Another large fault runs parallel to the Wallaby Rivulet. Here there is a downthrow of 600 feet or more to the south-west, the felspathic sandstone series being faulted down against the lower sandstone series. A number of isolated diabase masses occur along the line of this fault, as can be seen from the geological map (Plate II.). Several other faults closely associated with diabase intrusions occur, and can be seen in the geological map (Plate II.) and sections (Plate III.), but the above examples are sufficient to show the intimate relations between the diabase and the faulting of the sedimentary strata.

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(21) Underground Water-supply Paper No. 1: "The Underground Water Resources of the Midlands," p. 69.

Some very interesting facts in connection with this relationship are revealed in the geological sections. These are illustrated in the two sections in Plate V. From the evidence in the field and the construction of sections from the mapping carried out, there can be no doubt that the diabase has intruded the Permo-Carboniferous and Trias-Jura strata in the form of very thick sheet-like masses, with minor dyke-like intrusions rising from them. These masses, to occupy the positions they do, must necessarily have uplifted all the strata occurring above them. This uplifting has been differential in nature, and huge blocks of the sedimentary strata have been lifted to different levels. It is in this differential uplifting that the diabase and faulting are closely related, and practically contemporaneous. For one block to be lifted relatively to another there would necessarily have to be a greater thickness of diabase beneath the former, and this increase in thickness would undoubtedly take place along the fault plane as shown in Fig. 2 of Plate V. Further, the diabase may actually rise, as a narrow dyke, to much greater heights along the fault plane, as shown in Fig. 1. The section in Fig. 1 is a generalised section taken from the actual occurrences on the flanks of Mt. Dromedary, Grass Tree Hill, and possibly also Butcher's Hill, and which are shown in Section CD (Plate III.). It is interesting to note how these three faults and dykes occur a short distance off a large uprising dyke-like mass. The section in Fig. 2 is a generalised section of occurrences similar to the three described above, but without a narrow diabase dyke following the fault plane. Faults are found to occur in this manner, *e.g.*, south of Bisdee's Tier and a mile east of Broadmarsh, and Fig. 2 may represent the ideal section of such occurrences.

Undoubtedly much more faulting occurs in the area than can be detected owing to the existence of large thicknesses of very similar rock-types. It is only when the throws produced by the faults are sufficiently large to bring different rock-types into contact with one another (as in the above examples) that detection is possible.

(6)—Geological History.

The geological history of this area as represented by the rocks at present exposed at the surface, begins with sediments of the Permo-Carboniferous system.

PLATE V

GEOLOGICAL SKETCH SECTIONS

LEGEND

- TRIAS-JURA
- PERMO-CARBONIFEROUS
- UPPER MESOZOIC (*Diabase*)

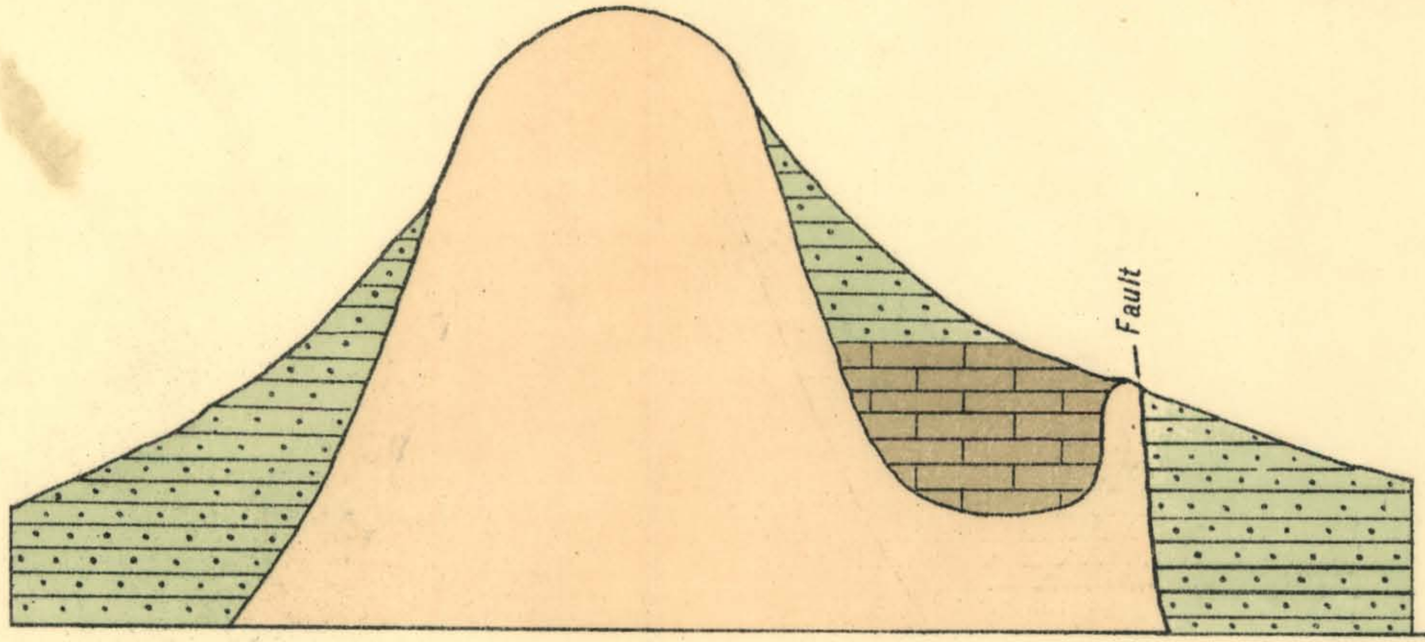

Fig 1

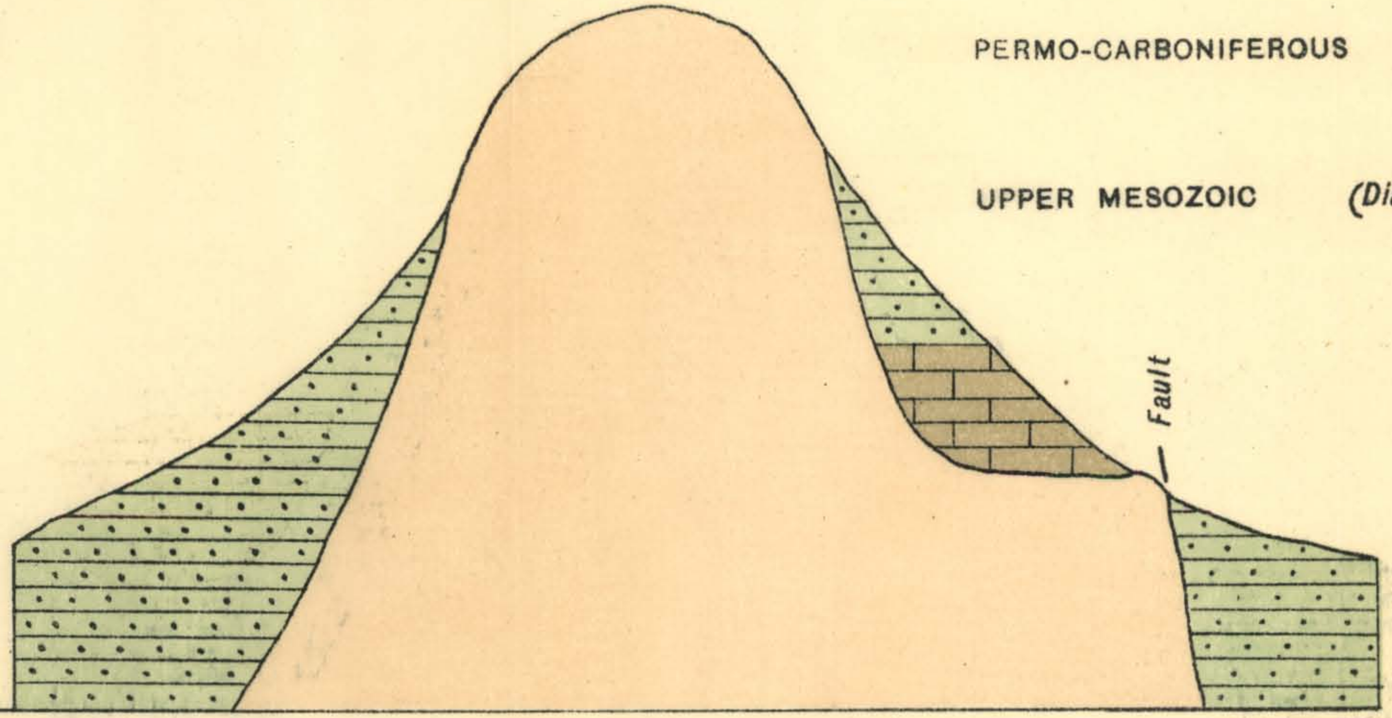

Fig 2

5 cm

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

(*a*) *The Permo-Carboniferous Sedimentation.*—In Tasmania this sedimentation commenced under glacial conditions and the formation of glacial deposits. This was followed by marine conditions and the deposition of limestones, mudstones, and sandstones, constituting the Lower Marine series. Lacustrine or estuarine conditions followed with the formation of the Lower Coal measures. Finally marine conditions were restored and the Upper Marine series deposited.

In the present area several hundred feet of marine fossiliferous mudstones, limestones, and sandstones occur and pass up into about 300 feet of almost unfossiliferous mudstones which underlie the Trias-Jura strata. These represent the Lower Marine series, and if the overlying Lower Coal measures and Upper Marine series were represented in this area they must have been removed by denudation prior to the Trias-Jura sedimentation.

(*b*) *The Trias-Jura Sedimentation.*—Following the Permo-Carboniferous came the Trias-Jura sedimentation, no break or disconformity between the two systems being perceptible in this area. This sedimentation commenced with conglomerates and passed through grits into normal sandstones, up to 700 feet of this series being formed. These sandstones were followed by felspathic sandstones and mudstones, with interbedded coal-seams, a total thickness of 500 to 600 feet being formed. These were probably followed by normal sandstones; but little, if any, of these remain in the area at present.

(*c*) *The Intrusions of Diabase.*— In Upper Mesozoic times igneous activity was developed on a very large scale and diabase intruded the Permo-Carboniferous and Trias-Jura strata, mainly in the form of a horizontal mass or masses, and sending up minor dyke-like masses and sills into the higher portions of the strata. These intrusions were closely connected with much faulting in the strata, and both these events are probably contemporaneous with the cessation of deposition of the Trias-Jura sediments and their elevation by earth movements.

(*d*) *A Cycle of Denudation.*—The intrusion of the diabase was followed by a long period of denudation which, in most portions of the area has continued uninterruptedly up to the present time, and has been mainly responsible for the production of the present topographical features.

In other portions of the area this cycle has been interrupted by the following events.

(*e*) *The Tertiary Sedimentation.*—Sedimentation occurred in Lower Tertiary times along the lower portion of the valley of the Coal River. This sedimentation probably occurred under fresh-water conditions, and has resulted in the formation of a thin series of sands, clays, conglomerates, and gravels.

(*f*) *The Extrusion of the Tertiary Basalts.*—Igneous activity was developed near the close of the Tertiary sedimentation, and outpourings of basaltic lava occurred at various localities. These flows covered all previous formations then exposed at the surface, but towards Richmond they became interbedded close to the top of the Tertiary strata.

(*g*) *The Present Cycle of Denudation.*—Following the basalt extrusions the land surface again became subjected to a period of denudation, which, with the continuation of that described above in (*d*), has produced the present topographical features.

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.[22]

The area under discussion has only a moderate rainfall, varying from 19 inches to 24 inches per annum. Only two streams of any size exist within the area, and these, with their tributaries, flow only during the winter and after periods of heavy rainfall, being at other times a line of water-holes.

The object of the present investigation was to determine the possibilities of obtaining underground water-supplies.

(a) *Surface Water-supply.*

(i) *Lakes and Rivers.*—The only lake in the area is Lake Tiberias, which forms the source of the River Jordan, and has been described in a previous report.[23] The lake is overgrown with rushes, and the quality of the water is very poor. A low dam has been constructed at the locality where the River Jordan flows out of the lake, so as to ensure a regular supply of water in the river along the first few miles of its course. Suggestions have been made that by constructing a much higher dam and conserving the water received by the lake, it would be possible to regulate the flow of the River Jordan throughout its entire length. In this connection the following figures obtained during a previous investigation and taken from the report thereof,[24] will be of interest:—

Area of lake	4 square miles.
Catchment area (exclusive of lake)	8 square miles.
Average annual rainfall	About 20 inches

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

(23) Underground Water-supply Paper No. 1: "The Underground Water Resources of the Midlands," p. 13.

(24) Underground Water-supply Paper No. 1: "The Underground Water Resources of the Midlands," p. 13.

The lake itself will receive a direct precipitation of 20 inches. The catchment area consists of mainly sandstones, with a smaller amount of diabase, and the total run-off will be 40 per cent. of the rainfall. Thus from the 8 square miles of catchment 8 inches of rainfall will enter the lake, and this will be equivalent to 16 inches over the 4 square miles of the lake. The lake will therefore receive 36 inches of water over its surface annually. Evaporation from its surface and absorption by the rushes in the lake will account for a considerable amount of this water, say, 12 inches, which is probably a very moderate estimate of this loss. This would leave an annual conservation of 24 inches over the extent of the lake. The present dam is probably capable of handling somewhere near the maximum amount of water which can be conserved in the lake, and the above calculations show that the rainfall and catchment area are much too small to enable conservation of larger quantities of water by erection of a much higher dam.

The River Jordan is the largest river in the area, but it is not a permanently flowing stream. In the dry seasons the river becomes a series of water-holes, and the quality of the water deteriorates, due to concentration of mineral contents. The above remarks also apply to the tributaries of the Jordan River, the main tributaries being the Strathallern and Bagdad Rivulets. The sole use of the water of this river system is for watering stock and for general farm purposes. Stock are generally watered direct from the streams, but numerous windmills are installed along the streams, chiefly the River Jordan itself, and the water is pumped into tanks at the farm or other required watering points.

The Coal River and its tributaries are the only other streams in the area. These streams are also not permanent, becoming a series of water-holes in the dry seasons. The quality, especially of the Coal River water, is poor. The water is used for watering stock directly, practically no pumping taking place from it.

Thus it is seen that very little use is and can be made from the surface waters of this area.

(ii) *Storage of Rainfall in Tanks*.—This method of obtaining water-supplies is adopted throughout the area, and forms practically the sole source of water for domestic purposes. The drainage from the roofs of houses and other buildings during periods of rainfall is collected in tanks and stored for future use. The quantity which may be collected in this way has been discussed in a previous report.(25)

(b) *Underground Water-supply.*

The general conditions in connection with supplies of underground water have been fully discussed in a previous report,(26) and will be dealt with very briefly in the present one.

(i) *General Geological Considerations.*—Underground water is derived principally from the rainfall, and so the nature of the rocks in, and the geological structure of, any particular district are vital points in determining the existence or otherwise of underground water-supplies.

The rocks must be those which are capable of containing, and also allowing the passage of, considerable quantities of water.

The geological structure of the district must be such that the porous and permeable beds outcrop at the surface, so that they may receive supplies of water directly from the rainfall and also from streams passing over them. The quantity and nature (artesian, sub-artesian, &c.) of the supplies are also dependent on the structure.

(ii) *Dispersal of the Rainfall.*—The rain which falls on the surface of the earth is disposed of by three methods—

- (*a*) Run-off—*i.e.*, the amount of water carried away by surface streams.
- (*b*) Evaporation and Absorption by Vegetation—*i.e.*, that portion of the rainfall which is evaporated from the surface of the earth into the atmosphere, and that which is used by growing vegetation.
- (*c*) Percolation—*i.e.*, the amount of water which soaks through the soil and passes away into the underlying rocks.

It is the percolation which forms the source of the underground water-supplies.

(iii) *Geological Conditions in the Area.*—It has been seen in discussing the geology of the area that it is essentially composed of generally horizontally-bedded strata of the Permo-Carboniferous and Trias-Jura systems, which

(25) Underground Water-supply Paper No. 1: "The Underground Water Resources of the Midlands," p. 75.
(26) Underground Water-supply Paper No. 1: "The Underground Water Resources of the Midlands," p. 76.

have been intruded on a very large scale by diabase. The approximate areas of the surface occupied by the different formations are shown in the following table:—

TABLE No. 4.

Formation.	Per Cent.
Permo-Carboniferous	4
Trias-Jura	35
Diabase	55
Tertiary	1
Basalt	3
Recent	2
	100

Thus it is seen that the area is composed of mainly diabase and Trias-Jura strata.

The Rock Types.—The diabase is an impervious, non-porous rock. It may hold very small quantities of water in joints, but for all practical purposes it may be regarded as a non-water-bearing rock. The Trias-Jura strata consist of sandstones, felspathic sandstones, and mudstones. Of these the normal and felspathic sandstones are very porous rocks, as is shown by the results of porosity tests made by Mr. W. D. Reid, Government Assayer, on samples from the present area, and also from the Midlands. The results are given in the following table:—

TABLE No. 5.

Porosity Tests.

Sample.	Locality.	Per cent.
Sandstone	West shore of Lake Dulverton ...	14.64
Sandstone	Quarry, half-a-mile east of Ross ...	14.58
Sandstone	Quarry, half-a-mile east of Tea Tree	12.12
Felspathic sandstone	East side of Vincent's Hill... ...	26.30
Felspathic sandstone	Colebrook	19.06
Silicious mudstone ...	Mangalore Creek	22.25
Silicious mudstone ...	Mangalore Creek	21.89

Of the remaining formations, which occupy only a small proportion of the surface, the basalt is a non-water-bearing rock, while the Permo-Carboniferous strata, the Tertiary strata, and the recent deposits are capable of yielding supplies of water. The white mudstones of the Permo-Carboniferous system have a porosity of about 21 per cent., and should be capable of holding large quantities of water, though they may not yield the water readily. The Tertiary strata consist mainly of unconsolidated sands and gravels, and should contain considerable quantities of water. The recent alluvium, and also hill detritus, are porous formations, and are capable of holding large amounts of water.

Geological Structure.—The structure of the area is that of horizontally-bedded Permo-Carboniferous and Trias-Jura strata, much faulted and intruded by diabase on a large scale. Differential erosion has left the diabase forming the high country with the softer sedimentary strata occupying depressions between the higher diabase features.

(iv) *Possibilities of Underground Water.*—With the above structure, and with impervious diabase forming more than half of the present surface, there is no possibility of the existence of a large artesian or sub-artesian basin throughout the entire area.

However, all the areas of porous Trias-Jura strata which exist are small local basins which are potential sources of underground water-supplies. Those areas, which are comparatively level and occur along the courses of streams, are the best of these basins. The amount of water in these basins is likely to be greater and the supply more certain than in areas of sandstones, &c., forming more broken country. Also the depth to water is less, and is such that the water can be economically applied for any purposes required.

These local basins are not so completely surrounded by diabase as is the case in the Midlands.(27) This, however, does not affect the water-collecting properties of the porous sandstones, &c., and the formation of basins by these strata. The diabase may have held the water very effectively, but it is not a necessity in the formation of the basins.

Besides the above basins in Trias-Jura strata, water-supplies are also obtainable from the more or less porous formations of alluvium, hill-slip material, Tertiary sediments, and Permo-Carboniferous strata.

The alluvium occurring along the courses of the present streams is generally found to be saturated with water at no

(27) Underground Water-supply Paper No. 1: "The Underground Water Resources of the Midlands," p. 80.

great depth beneath the surface. When sufficient depth of this formation exists a fairly reliable underground water-supply is available.

At the foot of the steep slopes of diabase hills there is often to be found accumulations of soil, decomposed and undecomposed rocks. These have been brought down from the hills above by the agencies of weathering and denudation, and spread over the country at the foot of the hills. This material acts similarly to alluvium in holding water, and when sufficient depth of it exists water-supplies may be obtained from this formation, though they will not be so reliable as the above supplies, and the quantity of water will be smaller.

Though no attempt has been made to obtain water-supplies from Permo-Carboniferous strata, the high porosity of the mudstones show that supplies will probably be obtainable from this source.

(v) *Quantity of Water.*—The sandstone basins in this area are similar to those occurring in the Midlands. The quantity of water in these latter basins was discussed somewhat fully in the report on that area,(28) and only a brief summary of the conclusions which are applicable to the present area will be given here.

The quantity of water entering the underground basins depends upon the rainfall and its dispersal on reaching the earth's surface. The average rainfall over the period of the three consecutive driest years was taken as a safe, reliable figure to use in any calculations. A table was given showing that 75 per cent. of the average annual rainfall agreed very closely with the actual average over the three consecutive driest years, and so could be used in its place.

In considering the dispersal of the rainfall it was found that no figures were available for the run-off, as represented by the discharge of streams or evaporation, and the same absence of data exists in the present area. A comparison of conditions with those of other countries led to the adoption of the following table, as representing the dispersal of the rainfall in the Midlands:—

TABLE No. 6.

Dispersal of the Rainfall.

	Per Cent.
Evaporation	60
Run-off	20
Percolation	20

(28) Underground Water-supply Paper No. 1: "The Underground Water Resources of the Midlands," p. 83.

Using these figures, the quantity of water entering a basin annually, and therefore the maximum amount which can be removed from it in the same period, was calculated to be approximately—

2,900,000 × (rainfall in inches) × (area in square miles) gallons.

These figures are applicable to basins occupied wholly by sandstones and forming more or less complete catchment areas in themselves. As the conditions depart from these, the above figure becomes unreliable.

The above remarks apply to basins formed by Trias-Jura strata, such basins forming the majority of those within the area. As regards basins formed by other porous formations, the same remarks and figures may in a general sense be taken as applicable to these basins also.

(vi) *Quality of the Water.*—The underground water is derived from the rainfall, but does not remain as pure as the rain-water. In its passage over and through the soil and underlying rocks the water dissolves and holds in solution small quantities of organic and mineral matter. The amount of organic matter dissolved is very small unless the water comes in contact with an exceptional source of pollution, such as may exist in the vicinity of a township or farm. The mineral matter is obtained from the soils and rocks the water comes into contact with, and shows a direct relationship with them. Diabase and Trias-Jura strata are the predominating formations, and the mineral matter derivable from these has to be considered. From the diabase, it has been shown in a previous report[29] that bicarbonates of calcium (lime) and magnesium are the substances which will be obtained in any quantities. This is supported by analysis of concretions and segregations formed in the soils and on diabase rocks. These concretions, &c., consist of carbonates of calcium and magnesium deposited from waters containing the bicarbonates of these elements.

From the Trias-Jura strata underground water will obtain small amounts of halite (common salt) and epsomite (epsom salts).

These have been shown to exist in the lower sandstone series,[30] but there is no evidence of them in the felspathic sandstones, although the Colebrook waters contain common

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(29) Underground Water-supply Paper No. 1: "The Underground Water Resources of the Midlands," p. 85.

(30) See above, p. 36.

salt which can only have been derived from the felspathic sandstones. Thus it is seen that the mineral salts likely to occur in the underground waters of the area are bicarbonates of calcium and magnesium, together with sodium chloride and magnesium sulphate. This is verified by the analyses of the waters given in Table 7, which prove that the most plentiful radicles in the waters are those of chloride, bicarbonate, sodium, calcium, and magnesium.

The waters from Colebrook should be typical of those in felspathic sandstones. The Oatlands waters are included as typical of water from normal sandstones. The Kempton waters are from wells sunk in alluvium and drift material, but the underlying rock formation is normal sandstone

The analyses are given in ionic form—that is, stating the radicles present—instead of the form in which theoretical combinations of the radicles to form salts are given. This method is adopted as it is simpler, more useful and practical, and is now coming into general use. In the waters from Bagdad and Oatlands the amounts of the radicles have been calculated from the salts reported in those waters.

Table No. 7.

Analyses of Underground Waters.

(Quantities expressed in parts per million.)

Sample.	Total Solids.	Calcium. (Ca).	Magnesium (Mg).	Sodium. (Na).	Ferric Oxide (Fe_2O_3).	Alumina (Al_2O_3).	Silica (SiO_2).	Carbonate (CO_3).	Bicarbonate (HCO_3).	Sulphate (SO_4).	Chlorine (Cl).	Organic and Volatile Matter (Water of Crystallisation).
I.	571·00	14·31	17·52	166·75	12·14	1·43	14·00	42·95	...	...	282·75	9·29
II.	615·00	53·22	20·64	118·28	2·43	4·42	8·00	132·00	...	36·99	155·16	77·00
III.	969·08	86·33	60·00	93·30	14·00	8·0	30·40	[illegible]3·76	483·6	24·35	188·54	239·57
IV.	3743·83	383·17	148·68	425·39	7·14	71·14	10·85	42·21	523·70	10·64	1544·80	960·00
V.	2681·81	255·08	153·43	224·14	20·00	50·70	4·70	Nil	696·09	2·03	1094·90	750·28
VI.	1301·44	135·77	78·55	80·51	4·14	40·57	9·14	9·65	545·91	11·49	406·62	383·57
VII.	874·29	40·06	...	220·92	...	...	...	59·91	...	...	340·65	...

I. Well-water : Mr. Jones, Oatlands. Analyst, Mr. W. D. Reid, Government Assayer.
II. Well-water : Mr. J. Tremaine, Oatlands. Analyst, Mr. W. D. Reid, Government Assayer.
III. Well-water : Mr. A. J. Wheatley, Kempton Hotel, Kempton. Analyst, Mr W. D. Reid, Government Assayer.
IV. Well-water : Bakery, lower part of Kempton. Analyst, Mr. W. D. Reid, Government Assayer.
V. Well-water : Orchard of Mr. J. J. O. Stuart, "Pineholme," Colebrook. Analyst, Mr. W. D. Reid, Government Assayer.
VI. Well-water : Mr. Evans, Blacksmith's Shop, Colebrook. Analyst, Mr. W. D. Reid, Government Assayer.
VII. Water from Bagdad Rivulet at Bagdad : Dry period at beginning of 1920. Analyst, Mr. Colbourn.

The quality of these waters in relation to the various purposes for which the water may be used will be discussed later.[31]

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

(i) *Introduction.*—It has been shown above[32] that the rock-types existing in, and the geological structure of, the area are suitable for the existence of numerous small local basins containing underground water. All localities where underground supplies are obtainable have been termed "basins," though there is a diversity of structure and general conditions among these basins. Each of these basins is dealt with separately in the following pages, a general description of the location, extent, topography, and geology being given, and the possible uses of the water indicated. Further information in connection with the utilisation of the water is given later.[33]

Any small areas of sandstone not included in the basins, and which are fairly level and have a small creek or drainage channel through them, may be regarded as containing small supplies of underground water.

Where sandstones are found occupying elevated and broken country, such areas are not included and described under the above. Water would be obtainable in these areas, but at much greater and variable depths than in less elevated and more level regions. The sole use of the water would be to obtain supplies for livestock.

(ii) *The Ringwood Basin.*—This basin is located along that portion of the Colebrook to Jericho Road to the west and north-west of Flat-top. It consists of a narrow strip of country 5 miles long and half a mile wide. The south-eastern portion is drained by the headwaters of Hollow Tree Bottom, and the north-western by an unnamed tributary of the Jordan River. The basin has an average elevation of 1600 feet, while the hills to the east and west rise to heights up to 2400 feet above sea-level.

This basin is composed mainly of normal sandstones, but felspathic sandstones also outcrop in a number of localities. The surface is covered with a good depth of soil and alluvium. The surrounding hills are mainly composed of diabase, except for a length of about 2 miles on the west, where they are composed of normal sandstones.

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(31) See below, pp. 73-86. (32) See above, p. 53.
(33) See below, pp. 73-86.

There are no wells in the area at present, and the water is not utilised. The quality of the water should be equally as good as the average underground water in the district. The basin has a catchment area of 4 to 5 square miles, and the quantity of water entering the basin will not be large. There would be sufficient to irrigate only a small portion of the land in the basin. The water will form a valuable supply for the watering of stock in connection with the pastoral pursuits of the district.

(iii) *The Spring Hill Bottom Basin.*—This basin is located around the valley of the Spring Hill Bottom Creek, to the south-west of Colebrook, and has an extent of about 5 square miles, with a catchment area of 9 square miles. It is drained by the Spring Hill Bottom Creek and its numerous small tributaries. The lowest part of the basin is at an elevation of 600 feet, while the surrounding hills rise to various heights, those to the west being the highest and rising to elevations of 2400 feet above sea-level.

This basin is composed of normal sandstones, with much smaller amounts of felspathic sandstones and mudstones of the Trias-Jura system. Diabase occurs forming the hills which limit the basin chiefly to the east and west.

No attempts have been made to develop the underground water-supplies of this basin. The quality should be similar to that of other underground waters of the district. The quantity should be sufficient to assist in a general way the agricultural and orcharding pursuits of the area, and to enable irrigation of portion of the area devoted to these industries to be carried on. Supplies for livestock could also be made available.

(iv) *The Colebrook Basin.*—This basin is located in the vicinity of the township of Colebrook, and covers an area of about 10 square miles, including parts of the valleys of the Wallaby Rivulet and Coal River. The lowest country in the basin is at an elevation of 600 feet above sea-level, and occurs along the valleys of the above streams. Between the two valleys the country rises to heights of 1200 feet, while the hills bordering the basin rise to elevations of 800 to 1200 feet above sea-level.

The main portion of this basin is composed of normal sandstones of the lower sandstone series of the Trias-Jura system. Along and to the west of the Wallaby Rivulet felspathic sandstones occur as a result of faulting which has lowered them against the normal sandstones to the east. To the east of the Coal River, near Brandy Bottom, a small area of Permo-Carboniferous strata outcrop, and are exposed as the result of the Coal River following a fault for a short distance. Thick accumulations of alluvium and soil occur at Brandy Bottom and along the valley of the Wallaby Rivulet. Small intrusions of diabase occur within the basin, and also form the greater portion of the boundaries of the basin.

The most important portion of this basin occurs along the Wallaby Rivulet. Numerous wells have been sunk in the felspathic sandstones of this vicinity, and water-supplies have been obtained. The shaft of the Tasma Coal Mine was sunk in these strata, and considerable quantities of water had to be baled during the working of this mine. Owing to the removal of the water from the mine the water-level in the wells in the immediate vicinity has been lowered during periods of working. The water in these wells has been used for general farm purposes, but very little use is now made of it. Analyses of the water from two wells have been given above,(34) and the quality of the water is fully discussed(35) in connection with the purposes to which it might be applied. It is poor for irrigation purposes, suitable for supplies for livestock, and medium to bad for drinking purposes.

The water could be utilised for irrigation purposes, but great care would be necessary in selecting the type of soil to be irrigated, and also in choosing only well-drained land, otherwise artificial drainage would be required. The quantity would be sufficient to irrigate only a small portion of the available agricultural land in the Wallaby Rivulet valley. Supplies for watering livestock could be readily obtained.

Another important portion of the basin, where supplies could be readily obtained at shallow depths, is the alluvial flats which form Brandy Bottom. Watering points for stock could be conveniently established in these flats. The quality and quantity of the water might also be suitable for the irrigation of a portion of the agricultural land of these flats.

Between the two portions of the basin discussed above there occurs an area of elevated sandstone country in which water-supplies would be obtainable. The greater portion of this area is devoted to pastoral purposes, and in this connection watering points for the stock could be established. The quality of the water should be suitable for irrigation purposes, but the quantity would be sufficient

(34) See above, p. 58. (35) See below, pp. 73-86.

for irrigation of only a small portion of the land used for agricultural pursuits.

(v) *The Coal River Basin.*—This basin is located along the course of the Coal River from about 5 miles above Campania down to its mouth, where it joins Pitt Water. It coincides with the valley of the Coal River, and has a length of 12 miles and an average width of 1 to 2 miles. The elevation of the country near the mouth of the river is about 100 feet, while in the extreme north it is 400 feet above sea-level. The hills on either side rise to heights varying from 600 to 1600 feet above sea-level.

The geology of this basin is varied, and the formations outcropping at the surface are numerous. Normal sandstones of the Trias-Jura system occupy a considerable portion of this surface. Felspathic sandstones outcrop to a slight extent in the extreme north and south of the valley. Diabase occurs along both sides of the valley, and also to a limited extent in the floor of the valley. Tertiary sediments cover the floor of the valley from Campania to Pitt Water. Tertiary basalt overlies these sediments around and to the north of Campania, and is interbedded with them between Richmond and Campania. Alluvium occurs to a small extent along the course of the Coal River.

All localities along this valley are not favourable for obtaining water-supplies. Water will not be obtained where the surface is occupied by diabase and thick flows of basalt. It will be readily obtained in areas of sandstones, though in steeply rising sandstone country the depth to water may be excessive. In Tertiary sediments and the recent alluvium supplies should be easily obtained. Where the basalt flows are thin supplies could be obtained in the underlying strata, such as Trias-Jura sandstones and Tertiary sediments.

The quantity of water obtainable from this basin will not be very large, especially in the northern portion. Between Campania and Richmond there should be larger quantities, but much will depend upon the thickness of the basalt as to whether it can be economically exploited for irrigation purposes. There will be found to be more than sufficient supplies in all parts of the basin for watering stock and for general farm purposes.

(vi) *The Middle Tea Tree-Duck Hole Creek Basin.*—This basin is situated to the west of the township of Richmond, and includes the valley known as Middle Tea Tree and also that of the Duck Hole Creek. The extent of this basin is about 9 square miles.

The Duck Hole Creek drains the south-western portion of the basin, while the unnamed creek which flows into the Coal River at Richmond drains the Middle Tea Tree and the north-eastern portion of the area. The country in the basin is at an average elevation of 100 feet, while the hills around rise to heights of 600 to 1000 feet above sea-level.

The geology of this basin is varied, as many formations occupy the surface. Trias-Jura sandstones are the most plentiful and outcrop over or underlie the greater portion of the basin. Permo-Carboniferous mudstones outcrop to the west of the area, while Tertiary sediments occur to the south. Large portions of the area, especially to the north, have thick accumulations of soil over them. Diabase hills form the limits of the basin in nearly every direction.

Several wells exist in this basin, chiefly to the north along the Middle Tea Tree. Surface water-supplies are very scarce in this locality, and the underground supplies have been developed for general farm purposes and for watering stock. These wells have been sunk in thick accumulations of diabase soil and detritus from the hills, and the quality of the water is generally very poor. The water from some of the wells is said to be injurious to vegetation, while that from other wells has no harmful effect. The supplies are used for livestock and general farm purposes. Several wells occur within a half to one mile to the south-west of Richmond. One well is provided with a windmill, tank, and trough, while another has a hand-pump and trough, and they provide excellent watering points for stock.

No development of the underground supplies has taken place in the main portion of the basin. The quality of the water should be such that the water could be utilised for irrigation purposes, but it would be advisable to sample and test the water before use. The quantity should be sufficient to enable irrigation of a portion of the cultivated land to be carried out. Supplies for livestock could be readily obtained, as they are in the portions of the basin mentioned above.

(vii) *The Rekuna Basin*.—This basin is located in the vicinity of Rekuna, on the Hobart to Launceston Railway, between Brighton and Campania. The extent of this basin is about 5 square miles, and it has a catchment area of 8 square miles.

The basin is drained by a main tributary of the Strathallern Rivulet. The comparatively level and low-lying portions of the area have an average elevation of 500 feet, while the surrounding hills rise from heights of 600 to 1400 feet above sea-level. The basin consists of normal sandstones of the lower Trias-Jura series. Alluvium and thick accumulations of soil cover the surface along the courses of the streams. Diabase occurs chiefly to the south and west, and forms the boundaries of the basin in these directions.

A few wells are in existence in this area, mainly in the south-western portion. Several occur well up on the flanks of the diabase hills to the north-west of the railway-line. These have been sunk in the thick accumulations of diabase soil and detritus derived from the hills above, and are used in conjunction with the orcharding carried out on these slopes. Another well has been sunk three-quarters of a mile to the south-east of the railway-line. It is in sandstone country, and the water-level is within 10 feet of the surface, the water being used apparently to water stock.

No development has taken place in the main portion of the basin as regards its water-supply. The quality should be the same as in other parts of the district, and the quantity is sufficient to irrigate part of the cultivated land in the basin. Supplies could be made available for the watering of stock.

(viii) *The Native Hut Rivulet Basins.*—Three small underground water basins occur along the course of the Native Hut Rivulet between its source and the locality where it flows into the valley of the Coal River near Campania.

The first of these basins occurs at the headwaters of this stream to the south of "B" Mount, and has an extent of about 1 square mile. The level of the stream is 1000 feet at its lowest point, while the hills rise to heights of from 1400 to 2000 feet above sea-level. This basin is composed of normal Trias-Jura sandstones, and is completely surrounded by hills of diabase. The supplies in this basin have not been developed. They could be applied to the watering of stock when surface supplies fail, and might also be used to a slight extent to assist the raising of root crops, chiefly potatoes, which takes place on the virgin sandy soil of this basin.

(ix) *The Native Corners Basin.*—This basin occurs around the locality known as Native Corners, situated along the Native Hut Rivulet, 4 miles north-west of Campania, and has an extent of 1¼ square miles.

The country along the rivulet has an average level of about 700 feet, while the surrounding hills rise to heights of 1600 feet above sea-level.

The greater portion of the basin consists of normal sandstones, but a narrow strip of felspathic sandstones is exposed along the course of the stream. Diabase hills surround the basin almost completely, except on the north. The sandstone country extends to the north, but it is hilly and broken, and it is of little use even for grazing. Water-supplies could be obtained in it if required, but it is not included in the present basin.

No attempts have been made to develop the underground water up to the present. The water should be of average quality, and could be used to irrigate a portion of the cultivated land of the basin which is devoted to the raising of cereal crops. Supplies could also be made available for the watering of stock.

Another small basin occurs along the Native Hut Rivulet, 1 mile north-west of Campania. Its extent is about half a square mile.

The basin has an average altitude of 300 feet, while the surrounding hills rise to heights of 600 feet.

Normal sandstones form the main portion, while alluvium occurs along the course of the stream. Diabase occurs to the east, while high, broken sandstone occurs to the west and is not included in the basin.

The land in the basin is almost wholly devoted to agricultural purposes, but the water-supplies would be sufficient to irrigate only a small portion of this area. Supplies could be developed for the watering of stock and general farm purposes.

(x) *The Brighton-Back Tea Tree Basin.*—This basin comprises a portion of the country extending from the River Jordan, south of the township of Brighton, easterly towards the valley known as Back Tea Tree. It has an extent of about 5 square miles, and a somewhat larger catchment area.

The River Jordan flows through the basin at an elevation not exceeding 100 feet above sea-level. The average altitude of the land in the basin is 300 feet. The hills within and to the north of the basin rise to heights of 600 and 800 feet, while those to the west rise to 1400 feet above the sea. The greater portion of the drainage is to the west into the River Jordan and Herdsman's Cove, by means of small creeks, such as Cove Creek and Gage Brook. A small portion of the drainage is to the east into the Tea Tree Rivulet.

Normal sandstones of the lower sandstone series of the Trias-Jura system outcrop over the main portion of the basin. On the higher sandstone country shales and mudstones occur, and indicate the former presence of the felspathic sandstone series overlying the basin. Diabase occurs to a large extent and forms the hills surrounding the basin on nearly every side.

No development of the underground water-supplies of this basin has taken place. The main industry in the district is pastoral, sheep being raised for wool-growing purposes. Agriculture is carried out to a much less extent, while orcharding is practised to a slight extent in the north-eastern corner of the district. The surface of the basin has a good fall to the Jordan River, and the quality of the underground water should be equal to the average quality of underground waters in other parts of the area, and should be suitable for pastoral and agricultural purposes. The quantity of water should be sufficient for all pastoral and general farmyard purposes, such as watering stock, &c. In addition, there should be water available to irrigate a small portion of the agricultural land.

(xi) *The Pontville-Broadmarsh Basin.*—This basin is located along the River Jordan between Broadmarsh and Pontville, and consists of a strip of country about 8 miles long and averaging 1 to 1½ miles wide.

The River Jordan flows through the area, and receives numerous tributaries, mainly from the south. The average elevation of the country along the river is 100 to 200 feet. The hills on the north rise to heights of 800 feet, while those to the south are the foothills of Mt Dromedary, and rise to greater elevations above the sea.

The geology of this basin is varied. Sandstones of the Lower Trias-Jura series occupy most of the surface. Recent alluvial deposits occur along the course of the river at numerous localities. Tertiary basalt flows extend over the surface around and to the west of Pontville. Generally the alluvium and basalt are found overlying Trias-Jura sandstones. Permo-Carboniferous strata occur to a slight extent near Broadmarsh. Diabase hills occur practically continuously along the north and south sides of the basin, and form the boundaries in these directions.

Water will be obtainable in the sandstones and the alluvium in this basin. Also where basalt occurs overlying sandstones, wells sunk through the basalt will obtain supplies in the underlying sandstones. Such wells will, however, only be practicable where the thickness of the basalt flow is not too great—as at the western extremity of its flow.

A few wells have been sunk in this basin, but very little use has been made of the underground supplies. One well has been sunk on the Brighton Racecourse through basalt into the underlying sandstones, and a watering point established for the horses from the resulting supply. Another well exists in the sandstones, 2 miles west of Pontville, the water being used for general farm purposes and also to water a small vegetable garden. Numerous windmills are used to pump water, but the supplies are drawn from the river. Agriculture, pastoral, and orcharding are the industries carried on in this basin. The quality of the water should be similar to that in other parts of the district, and suitable for the above purposes. The quantity is sufficient to provide supplies to assist the above industries in a general way, and also to enable irrigation of portion of the cultivated land to be carried out. Watering points for livestock could be established to a much greater extent than at present.

(xii) *The Bagdad Valley Basin.*—This basin is located along the Bagdad Rivulet, and extends from the foot of Constitution Hill to the vicinity of Pontville Railway-station. This strip of country has a length of about 5 miles, and a width averaging from a half to 1 mile.

The average elevation of the land along the rivulet is 300 to 400 feet, while the hills to the east and west rise to heights of from 600 to 1400 feet above sea-level.

The surface of this valley is occupied mainly by deposits of recent alluvium along the Bagdad Rivulet, and by accumulations of soil and hill detritus along the flanks. Trias-Jura sandstones outcrop at several localities on the flanks of the hills and towards the bottom of the valley, and form the greater portion of the underlying rock formations of the valley. A small area of Permo-Carboniferous mudstones outcrop towards the south-western extremity. Diabase hills form the sides of the valley.

Very few wells are in existence in this basin, though windmills are employed pumping water from water-holes and pot-holes near the rivulet. One well has been sunk on the southern slopes of a hill 2 miles north of Bagdad Station, and at an elevation of several hundred feet above the stream. It is situated in diabase detritus from the hill above, and water was struck at 70 feet. No use is made of the water.

An analysis of water taken from the Bagdad Rivulet during the exceedingly dry spell in January and February of 1920 has been given above.[36] The quality of the underground water should be slightly better than the surface water in dry periods, as it is not subject to the great evaporation and concentration that the latter is.

The quality of the surface water is discussed later,[37] and is shown to be fair for irrigation purposes and medium for drinking purposes. Assuming the underground water to be of similar quality, it would be possible to use it for irrigation purposes in connection with the orcharding industry, for which the Bagdad Valley is noted. The quantity of water would not be sufficient to irrigate all the available land, but only a portion of it. Even if used during only very dry periods, the result would be very beneficial to the orcharding industry.

(xiii) *The Green Valley Basin.*—An area of 10 square miles of normal Trias-Jura sandstones occur to the north-west of Bagdad. They form a fairly level stretch of country at an average elevation of 1200 feet above sea-level, which is broken by numerous small creeks with gorge-like courses. Portion of the drainage is to the east into the Bagdad Rivulet system, and the remainder is directly into the River Jordan to the west.

Water-supplies could be obtained at any locality within this district. On the elevated portions the soil is, as a rule, very sandy and useless for agricultural purposes, and is very poor for grazing purposes, so that supplies are not likely to be required. Everywhere along the streams, where they open out sufficiently and the soil is suitable, agriculture and the growing of small fruits are carried out. Water-supplies are readily obtainable at shallow depths in such localities. A few shallow wells are in existence at present, and are used for watering stock, but a much greater development of the water-supplies for this purpose should be possible. The quality of the water should be similar to that in other sandstone regions, and should be more or less suitable for irrigation purposes. Deposits of common salt and epsom salts occur in caves in the district, so that some of the sandstones must have a fairly high content of these minerals, and it would be advisable to have the waters tested before use.

(xiv) *The Melton Mowbray-Kempton Basin.*—This basin is situated around and to the north and east of the townships of Melton Mowbray and Kempton. It has an extent of about 20 square miles, and a catchment area of at least

(36) See above, p. 57. (37) See below, pp. 72-86.

30 square miles, exclusive of that of the River Jordan outside the boundaries of the basin.

The drainage of this basin is into the River Jordan, which flows through the western extremity. Of the numerous tributaries of the River Jordan, the Quoin Rivulet, with its largest tributary the Serpentine Valley, and the Green Ponds Rivulet are the most important streams. The less elevated country in the basin occurs along the streams, 600 feet being the average elevation along the River Jordan. The basin is surrounded by hills, and forms almost a complete drainage system in itself. The hills on the west rise to heights of 1000 feet, those on the south to 1400 feet, those on the north to 2000 feet and over, while those on the east in the vicinity of Quoin Mt. rise to 2800 feet above sea-level. The country within the basin is, as a rule, gently undulating, except where broken by higher diabase ridges, and rises more or less gradually to the north, east, and south.

The main portion of the basin is composed of normal sandstones of the lower series of the Trias-Jura system. Felspathic sandstones and mudstones occur on the more elevated ground to the north and south of the basin. Alluvium has been formed along the lower portions of the Quoin and Green Ponds Rivulets, and portion of course of the River Jordan. The level country around Kempton has a covering of detrital material derived from the surrounding hills. Diabase occurs to a large extent and forms hills within, and also those surrounding the basin.

Water should be obtainable from the alluvium and detrital material, and also from the Trias-Jura sandstones and felspathic sandstones. Wells are numerous in the township of Kempton, where they have been sunk to obtain domestic supplies. These wells occur in alluvium and detrital material, and yield water of variable quality. The water obtained from the low-lying parts is regarded as being very bad in quality compared with that in the more elevated parts of the township, and this relationship is supported by the analyses[38] of the waters from these two localities. The water of better quality, such as that from the Kempton Hotel, is fair for irrigation purposes, good for drinking purposes, good for livestock, and unsuitable for boiler use in its natural state. It is very hard for toilet and laundry use, but could be rendered fairly soft by treatment.

[38] See above, p. 57.

The water of worse quality is useless for practically all purposes. It is poor for irrigation, but could be used where great care is exercised in the selection of the soil and the drainage of the land to be irrigated. It might also be used for livestock where no other supplies are available.

The quality of the water in other parts of the basin in the vicinity of Kempton and in the alluvium and detrital material should be similar to those discussed above. The greater portion of the water-supplies of the basin will be obtained from Trias-Jura sandstones, and the water from these rocks should be generally of better average quality than those from the wells of Kempton.

(xv) *The Mangalore Creek Basin.*—This basin forms portion of the valley of the Mangalore Creek and its numerous small tributaries, and is situated to the west of Pontville and Mangalore. It has an extent of about 5 square miles, and a catchment of 8 square miles.

The lowest land in the basin occurs at elevations of 200 to 400 feet above the sea, while the hills to the north (Mangalore Tier) rise to 1400 feet, and those on the remaining sides to heights of 600 feet above sea-level. The Mangalore Creek drains the greater portion of the basin, and joins the River Jordan 2 miles west of Pontville.

This basin is composed mainly of Permo-Carboniferous mudstones, while the overlying grits and sandstones of the Lower Trias-Jura series are developed to only a slight extent. Diabase occurs plentifully and forms the hills surrounding the basin on nearly every side.

No wells have been sunk in this basin, and very little information can be given as to the underground water. The mudstones have a high porosity, and should contain considerable quantities of water, although they may not yield the water very freely. The quality is an unknown factor, and analyses of samples of the water would be advisable before any utilisation is attempted. If the water proves of suitable quality, supplies could be developed for watering stock, and also possibly to irrigate a small portion of the cultivated land in the basin.

(xvi) *Springs.*—Springs occur at various localities throughout the area, and several of the most important will be briefly discussed.

Two springs occur in the Tarlington district to the west of Colebrook, one being 1½ and the other 2½ miles distant from the latter township. The water from these springs has been conducted by pipe-lines to Colebrook, where it has been treated and used in the railway-locomotive boilers. The nearer spring was the first to be used. It gave the quantity of water required, but was very hard. The other spring (Stainer's Spring) yields a much softer water, but the quantity was hardly sufficient, and a mixture of the two waters has to be used to give the required amount (about 15,000 gallons per day).

A small but apparently permanent spring occurs on the track along the north-eastern flank of Black Hill, 3 miles west of Colebrook.

Two small permanent springs occur in the vicinity of Richmond. One is situated half a mile to the north-west in the limestone deposits(39) of that locality. The flow is small, and is used for watering stock. The other occurs three-quarters of a mile south of Richmond, on the flanks of Butcher's Hill. The water is collected in a tank and piped by gravitation to the Lowlands homestead, several watering points for stock being provided *en route*.

Springs are numerous along the hills to the west of Kempton.

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

The underground water in the area has to be made available by means of suitable wells. When tapped, the water is not under artesian conditions, and arrangements have to be made to bring the water to the surface.

(i) *Selection of Type of Well.*—This has been fully discussed in a previous report,(40) consideration being given to the factors on which the selection depends, and the conclusions arrived at are given below. The conditions are suitable for dug wells and drilled wells, the drilling in the latter case being carried out by machines of the Victoria type, or a simplified form thereof. For shallow wells in soft materials like alluvium and hill-slip material, dug wells would be the type most likely to be used, being cheap and very easily sunk. For wells in sandstones and felspathic sandstones the decision between the above two types will vary with the depth, purpose for which the well is intended, &c. For the deeper wells and those to be used for township or domestic supplies the drilled wells will be found to be the cheaper and most secure type. The tendency of modern practice is towards the use of drilled wells whenever

(39) See above, p. 42.

(40) Underground Water-supply Paper No. 1: "The Underground Water Resources of the Midlands," p. 98.

possible, and of course compatible with economy, utility, &c.

(ii) *Type of Pumping Plant.*—Centrifugal and deep-well cylinder pumps are the common types used in connection with pumping from wells.

Centrifugal pumps are most suitable for small discharge heads. They are very efficient, can be coupled direct to electric motor, and have no valves to get out of order. They have to be installed within 28 feet of the depth at which the water is to be pumped, and so are only suitable for dug wells or drilled wells in which the top portions are enlarged for their installation.

Deep-well cylinder pumps can be worked with large discharge heads. They can be used with any type of well, but are specially suited for drilled wells with depths to water-level greater than 28 feet. The pump can be installed near the water-level and operated by power from the surface. This type is always used in conjunction with windmills.

With dug wells, other methods, such as windlass, rope, and bucket, hand-pumps, &c., are often used to obtain small quantities of water.

(iii) *Type of Power Plant.*—This subject has been fully dealt with in a previous report,(41) and will not be repeated here; but the conclusions arrived at, together with any modifications due to special conditions in the present area, are given below.

When only small quantities of water are required, windmills are the cheapest and most convenient power plant to use. Tables showing the wind data for Hobart, and the work which can be performed by windmills, are given in the above report. For short periods 8 or 10 foot mills on 20 to 30 foot towers are capable of delivering 500 to 1000 gallons per hour, but for extended periods the average yield will be nearer 200 to 500 gallons per hour. When small but continuous quantities are required the windmills can be supplemented by small internal combustion engines which will be called upon in periods of little or no wind.

For larger plants internal combustion engines, using benzine and kerosene, will be the most convenient ones to use. The southern portions of the area are in close proximity to the hydro-electric transmission-line from the Great Lake to Hobart, and may possibly at some future

(41) Underground Water-supply Paper No. 1: "The Underground Water Resources of the Midlands," p. 102.

date be supplied with electric power. If this takes place, then electric motors driven from this source are recommended as probably the cheapest and most convenient power, especially in conjunction with centrifugal pumps.

(iv) *Size and Depth of Well.*—These dimensions depend on various conditions, including the quantity of water required and the yield of the wells. The well must have sufficient storage capacity, and the water must enter the well at a sufficient rate to enable the required amount of water to be pumped from it over extended periods. The greater the size and depth of the well the greater is its capacity, and also its area of wall surface through which water can enter the well as it is removed by pumping.

The depth should exceed the maximum depth to the water-table liable to occur in very dry seasons, by amounts of 20 or 30 feet or more, depending on the size, yield, and quantity of water required. Rather than have a very deep well, the tendency in modern practice is to increase the number of wells, as the cost of pumping becomes excessive with deep wells for irrigation, &c.

The standard sizes for drilled wells are 6-inch, 8-inch, and 10-inch diameter, the particular size required being determined by the yield and quantity of water to be pumped. Dug wells in the Trias-Jura sandstones and felspathic sandstones are made circular, being 4 to 5 feet in diameter. These materials stand well, and the walls do not need lining, except near the surface, and the circular shape is very convenient. For dug wells in other materials, *e.g.*, alluvium and hill-slip material, both circular and rectangular shapes are used, and stone and timber linings respectively are necessary.

(e) *Utilisation of the Underground Water-supplies.*

The underground water-supplies of the area have been developed to only a very slight extent up to the present time. The greatest development has taken place around Kempton and Colebrook, where numerous wells have been sunk, and the resultant supplies utilised for general household and farm purposes. With the installation of tanks and the collection of rain-water, the use of the underground supplies for household purposes has been discontinued, except for rough cleansing purposes, &c. The wells which have been sunk on farms and sheep-stations yield supplies which are used for the watering of stock and also for general farm purposes if suitably located.

That a much greater use of the supplies is possible will be seen in the following discussion, in which the use of the water for irrigation, domestic purposes, livestock, and boiler water is dealt with.

It is of interest to note the extent to which underground water is utilised for irrigation purposes in other countries. Brown[42] states:—" It has been estimated that of the 44,000,000 acres under irrigation in British India in 1903, 13,000,000 acres were irrigated from wells, of which there were probably 2,500,000. In Egypt well-irrigation has less importance, and will have less and less as the canal system becomes more perfect. There are some 30,000 wells still used for irrigation in Lower and Upper Egypt. In California there are about 150,000 acres served by wells."

It may also be noted[43] that the first irrigation scheme to be undertaken in Queensland is in connection with underground water. This is the Inkerman irrigation scheme, where the present area included in the operations of the scheme is 22,000 acres, though it may probably be extended to 50,000 acres.

(i) Irrigation.

(*a*) *Introduction.*—Agriculture and orcharding are carried out to a considerable extent at various localities within the area with a very fair amount of success. It has been seen in discussing the meteorology[44] that the rainfall throughout the area varies from 19 to 24 inches per annum. In districts with an annual rainfall of this amount agriculture can generally be practised with a fair degree of success without irrigation. The conditions are, however, approaching those under which dry-farming methods of cultivation have to be resorted to. The success or otherwise of these methods is dependent upon the total rainfall and its distribution throughout the year. This distribution is clearly shown in the graphs in Plate IV.[45] The sowing period is from March to June, but as early a sowing as possible is effected; while the main growing period is between August and November. A reference to the graphs shows that the rainfall during the latter period is as fol-

(42) Sir Hanbury Brown, K.C.M.G.: "Irrigation—Its Principles and Practice," p. 43.

(43) Bulletin No. 1, Water-supply Department, Queensland: "Irrigation Activities," 1919-20, H. Eklund, A.S.M.B., M.I.E.

(44) Page 25, &c.

(45) Page 25, &c.

lows:—August is a dry month, September about the average, October a wet month, and November about the average rainfall. Under these circumstances there is no doubt that the addition of water to the crops by irrigation during the months of August, September, November, and possibly October, would greatly assist the growing of those crops and yield much greater returns to the grower.

In orchards the growing period is from September until about the end of February, and, in addition to the above period from August to November, the distribution of the rainfall in the months of December, January, and February has to be considered. December is a wet month, while January is about the average, and February is the driest month of the year. The addition of water during possibly September and November, but certainly during the dry period of January and February, would undoubtedly benefit the growing of the fruit.

The above remarks in connection with orcharding applies with equal if not greater force to the growth of small fruits.

It is thus seen that the agricultural and orcharding pursuits of the area would benefit greatly if supplies of water were available for irrigation purposes. These supplies are obtainable by conservation of surface waters and the utilisation of the underground water resources.

(*b*) *Conditions Determining the Use of Underground Water for Irrigation.*—These have been fully discussed in a previous report(46) on the Midlands. The factors in the present area, such as depth to the water-table, quantity of water, nature of the soils, topography, and drainage, are similar to those existing in the Midlands, and will not be further discussed. It may be stated, however, that these conditions are generally favourable to the utilisation of the underground water for irrigation purposes. The quantity of water available is sufficient to irrigate only a portion of the area, but much will depend upon the amount of water which has to be applied to the land. A combination of dry-farming and irrigation could, no doubt, be evolved, irrigation being carried out in dry periods only. With such a method a greater portion of the agricultural land would be benefited by the utilisation of the underground water-supplies.

(46) Underground Water-supply Paper No. 1: "The Underground Water Resources of the Midlands," p. 109.

The quality of the water has also been discussed in the above report, but will be further dealt with below.

(c) *Quality*.—It has been pointed out above[47] that the underground water contains mineral substances in solution, and the analyses prove these to be chiefly sodium, calcium, magnesium, chloride, bicarbonate, carbonate, and sulphate. Small amounts of these substances are necessary to the growth and development of vegetation, but excessive amounts are injurious to plant-life. When water containing substances such as the above is used for irrigation, evaporation will result in deposition of salts in the soil, while continued evaporation may lead to such a concentration of these salts that the soil will be rendered useless for growth of vegetation. The salts most injurious to vegetation are those of sodium and potassium, known as the alkalies, and reported together as sodium in the analyses. The various salts of the alkalies are not equally harmful, and the relative harmfulness has been found by investigation[48] to be as follows:—Sodium as carbonate, 10; sodium as sodium chloride, 5; sodium as sodium sulphate, 1.

Magnesium salts are injurious to a much less extent; white alkali—a mixture of chlorides and sulphates of sodium and magnesium. Calcium salts are not injurious to vegetation owing to their low solubility in water, on account of which they do not enter into concentrated soil solutions.

In order to facilitate the comparison of waters to be used for irrigation, Stabler[49] has deduced formulæ for determining the " alkali coefficient " from the results of a chemical analysis. This coefficient is " a purely arbitrary quantity and may be defined as the depth in inches of water which, on evaporation, would yield sufficient alkali to render a 4-foot depth of soil injurious to the most sensitive crops. Whether injury would actually result from the application of such a water to any particular piece of land, however, depends upon methods of irrigating, the crops grown, the character of the soil, drainage conditions, and it should be clearly understood that the alkali coefficient in no way takes account of such conditions."

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(47) Page 55.

(48) United States Geological Survey Water-supply Paper No. 274, p. 178.

(49) H. Stabler: United States Gological Survey Water-supply Paper No. 274, p. 178

These formulæ are—

(*a*) When Na − 0·65 Cl is zero or negative—

$$\text{Alkali coefficient, } k = \frac{2040}{Cl}$$

(*b*) When Na − 0·65 Cl is positive but not greater than 0·48 SO_4—

$$\text{Alkali coefficient, } k = \frac{6620}{Na + 2{\cdot}6\ Cl}$$

(*c*) When Na − 0·65 Cl − 0·48 SO_4 is positive—

$$\text{Alkali coefficient } k = \frac{662}{Na - 0{\cdot}32\ Cl - 0{\cdot}43\ SO_4}$$

In the above formulæ Na, Cl, and SO_4 represent respectively the quantities, in parts per million, of sodium, chloride, and sulphate, as determined by analysis.

A classification based upon the alkali coefficient has been drawn up by Stabler, who states:—(50) "The following aproximate classification, which is based on ordinary irrigation practice in the United States, indicates in a very general way the customary limitations in the use of waters having various alkali coefficients:—

TABLE No. 8.

Classification of Irrigation Waters.

Alkali Coefficient	Class.	Remarks.
More than 18...	Good	Have been used successfully for many years without special care to prevent alkali accumulation
18 to 6... ...	Fair	Special care to prevent gradual alkali accumulation has generally been found necessary, except on loose soil with free drainage
5·9 to 1·2 ...	Poor	Care in selection of soils has been found to be imperative, and artificial drainage has frequently been found necessary
Less than 1·2	Bad	Practically valueless for irrigation

(50) H. Stabler: United States Geological Water-supply Paper No. 274, p. 179.

Applying the above formulæ and classification to the analyses of the waters in Table No. 7([51]), the following results are obtained:—

TABLE NO. 9.

Sample.	Formula Applicable.	Alkali Coefficient.	Class.
I.	(a)	7·2	Fair
II.	(b)	12·6	Fair
III.	(a)	10·8	Fair
IV.	(a)	1·3	Poor
V.	(a)	5·0	Poor
VI.	(a)	1·9	Poor
VII.	(a)	6·0	Fair

It is thus seen that some of the waters so far tested are of fair quality for irrigation purposes, while others are poor for these purposes. Such waters can, however, be used for irrigation providing that care is taken in the selection of the soil and in the drainage of the land. Soils with loose texture are those best adapted to the use of such waters. The drainage of the land should be as free as possible, and if this does not exist naturally, then the drainage should be improved by artificials means.

It must be borne in mind that the quality of the water which will be obtained from bores in constant use will be superior to any so far available for testing.

(*d*) *Type of Irrigation System, Plant, &c.*—The conditions for determining the selection of a system, plant, &c., for utilising underground water for irrigation are practically the same in the present area as they were in Midlands. The type of system, plant, &c., required is fully dealt with in the previous report on that area([52]) in connection with the following particulars:—

Type of Irrigation System.
Type of Well.
Type of Pump and Power Plant.
Storage and Distribution.
Examples of Pumps and Plants Required.

The above applies to the present area, with the one exception of the possible use of electricity for power purposes

(52) Underground Water-supply Paper No. 1: "The Underground Water Resources of the Midlands," p. 113.

owing to the passage of the Hydro-Electric transmission-line through the southern portion of the area. If this power were made available it would be convenient, efficient, and cheap, and could be used as already indicated.([53])

(*e*) *Economic Considerations.*—Providing the quality of the water is suitable and the quantity sufficient, the question of the use of underground water for irrigation becomes one of finance. Irrigation with underground water is expensive, and to be profitable the extra income produced as a result of irrigation must exceed the annual cost of the irrigation.

The annual cost consists of the following items:—

Interest on Capital Expenditure.—This expenditure will include the cost of the wells, pumps, engines, grading the land, and all the storage and distribution arrangements.

Depreciation and Repairs.—The pumping plants generally remain idle outside the irrigation periods, and the amount that should be allowed for depreciation is difficult of determination. The plants should be well protected and cared for during such periods, otherwise the depreciation may be greater than in periods of working. Up to 12½ per cent. is the figure recommended by American experience.

Running Costs.—These costs will include the cost of power, lubrication, and labour in operating the pumping plant and distributing the water.

Taxes.—All these items should be very carefully considered before any large expenditure is undertaken, otherwise financial failure may result.

As regards the increased yield from crops as a result of irrigation, such a subject is better dealt with by agriculturists. However, as the result of irrigation in America it is known that with efficient management irrigation can be made a profitable enterprise.

(ii) *Domestic Use.*—The utility of underground water for domestic use depends upon the nature and amount of the dissolved mineral substances. The amount of mineral substances which may be present without impairing the quality of the water depends entirely on the specific substances present.

(*a*) Drinking and Culinary Use.—It is impossible to give even an approximate classification of waters for these purposes. A classification based on total solids is unsatisfactory, as so much depends upon the substances present. Alkali carbonates are the most objectionable substances,

([53]) Page 71.

while alkali chlorides (mainly common salt) and sulphates (Glauber salt) are also objectionable. The following table, based on experience in America, indicates the quality of water as affected by the above substances (expressed in parts per million): —

TABLE No. 10.

	Good.	Medium.	Poor.	Bad.	Thoroughly Bad.
Total Solids	0 to 1000	1000 to 1500	1500 to 2500	2500 to 4000	4000 and over
Alkali Carbonates ...	0 to 200	...	200 to 300	...	300 and over
Chlorides (in form of common salt)	0 to 300	...	300 to 600	600 to 1000	1000 and over
Sulphates (in form of Glauber salt)	0 to 400	...	400 to 1500	...	1500 and over

Salts of calcium and magnesium are less objectionable and have no harmful effects when present in moderate amounts. Magnesium sulphate, however, becomes objectionable when present in considerable quantities.

Reference to the analyses[54] shows that the objectionable features in some of the waters of the area are the amount of total solids and the chlorine content. The following table indicates in a general way the quality of these waters:—

TABLE No. 11.

Sample.	Quality.	Remarks.
I.	Good	Total solids and chlorine content low
II.	Good	Total solids and chlorine content low
III.	Good	Total solids moderate. Chlorine content low
IV.	Very bad	Total solids and chlorine content excessive
V.	Bad	Total solids and chlorine content high
VI.	Medium	Total solids and chlorine content moderate
VII.	Medium	Total solids and chlorine content moderate

(*b*) Laundry and Toilet Use.—Waters used for these purposes should be "soft," *i.e.*, capable of readily forming a lather with soap, and not "hard," *i.e.*, consuming much soap before it will form a lather. Salts of calcium and magnesium are mainly responsible for the production of hardness in waters, because they decompose soap and form curdy, insoluble compounds, and so prevent the soap forming a lather with the water until all of these elements have been precipitated. The bicarbonates and carbonates of these elements cause "temporary" hardness, which can be destroyed by boiling. Hardness that cannot be removed by boiling is termed "permanent," and is due to the sulphates and chlorides of the above elements.

The addition of slaked lime in sufficient quantity will convert the bicarbonates into carbonates, and cause the precipitation of equivalent amounts of calcium and magnesium as carbonates. Further addition of soda-ash (carbonate of soda) will remove any excess of calcium and magnesium, precipitating them as carbonates. The addition of these substances will thus have the effect of greatly reducing the hardness of the water, and consequently decreasing the consumption of soap used in connection with such waters.

Sodium and potassium salts do not decompose soap, and need to be present in much greater quantities than those usually found in underground waters before they prevent the soap readily forming a lather. In connection with the amount of hardness as produced by calcium, magnesium, bicarbonate, carbonate, and sulphate, which renders water

(54) Page 57.

unsuitable for laundry purposes, the available information is very small. Waters are termed "hard," "soft," &c., in relation to other waters in the same district, and would probably be classified differently in other districts. Waring[55] states that "200 parts per million of calcium and magnesium render a water noticeably hard." Parker states that[56] "in Kansas the waters that are generally called hard contain over 300 parts of bicarbonate radicle, or over 40 parts of sulphate radicle, in equilibrium with calcium and magnesium." Dole states that[57] "in New England, water, to be considered soft, must have much less than 100 parts per million of total hardness, and water containing 30 or 40 parts of sulphate would not be used." Dole also quotes Whipple as stating[58] "that one pound of ordinary soap will soften only about 24 gallons of water having a total hardness of 200 parts per million." Thus it is seen that a water with a total hardness of 200 parts per million requires much soap to soften it before a lather can be formed. This would be a costly operation, and it would be much more economical to soften such a water with lime or soda-ash, or both, before use.

The analyses[59] show that the waters from Kempton and Colebrook contain considerable quantities of calcium, magnesium, and bicarbonate radicles, and smaller quantities of sulphate. These waters will all be very hard, but to a varying degree. In the following table the hardness of the better quality waters is given, and was obtained by calculation from the amounts of calcium and magnesium as given in the analyses:—

TABLE No. 12.

Table of Hardness.

(Expressed as parts per million of calcium carbonate).

Sample.	Calcium (Ca).	Magnesium (Mg).	Hardness.
I.	14·31	17·52	107
II.	53·22	20·64	217
III.	86·33	60·00	465
VI.	135·77	78·55	662

(55) United States Geological Survey Water-supply Paper No. 338, p. 21.
(56) United States Geological Survey Water-supply Paper No. 273, p. 15.
(57) United States Geological Survey Water-supply Paper No. 254, p. 234.
(58) United States Geological Survey Water-supply Paper No. 254, p. 237.
(59) Page 57.

Thus it is seen that the waters already tested are all hard, and that to be economically used for laundry and toilet use they would need to be softened by preliminary treatment with lime and soda-ash. It is of course possible that the water to be obtained regularly from deep bores will not be as hard as that at present available for testing.

(iii) *Supplies for Livestock.*—Animals can drink waters containing more dissolved substances than can human beings, but the nature of the dissolved substances is the main consideration in determining the use of waters for the above purposes.

Of the substances present in the underground waters of the area, common salt is the most objectionable. Waters containing up to 1000 parts per million are considered satisfactory, but those containing over 1000 parts should only be given to stock when no other supplies are available. The great majority of the underground waters of the area would be suitable for supplies for stock. The well-water from the well of Mr. J. Stuart, Colebrook, containing 1094 parts per million of chloride, is given to, and drunk by, sheep. The water in the lower parts of Kempton contains 1544 parts of chlorine, and should not be used if other supplies are available.

A very much greater use could be made of the underground water supplies for the above purpose than is carried out at the present time. Dug wells could be sunk where watering points are required and underground supplies exist. The erection of a small windmill with storage tank and trough would result in an efficient watering point at which supplies would be always available for the stock.

(iv) *Boiler Use.*—Probably the only utilisation of the underground water-supplies for this purpose would be in connection with the railway locomotives which traverse the area.

Watering points have been established within the area at Brighton, Colebrook, and Rhyndaston. The supplies at Brighton are obtained from the River Jordan, while those at Colebrook are obtained from two springs[60] situated several miles from the township. Water-softening plants are established at these two places, and the water is treated before being used. The watering point at Rhyndaston obtains its supply from a spring, but is only used when

(60) Page 69.

necessary. The use of underground water for boiler purposes is determined by the nature and amount of mineral substances contained by the water, and how they behave in regard to scale formation, corrosion, and foaming. Stabler[61] has deduced formulæ and coefficients to express the properties of waters in relation to these factors, and has introduced classifications in accordance with these coefficients. These formulæ, &c., are used in the following discussion upon some of the underground waters of the area. Where symbols such as Al, Fe, Ca, Mg, Na. K, CO_3, HCO_3, Cl, SO_4, H are used, they represent respectively the following radicles (expressed in parts per million):—Aluminium, iron, calcium, magnesium, sodium, potassium, carbonate, bicarbonate, chloride, sulphate, and hydrogen; while Sm and Cm represent suspended and colloidal matter respectively.

(*a*) Foaming and Priming.—Foaming is caused by masses of bubbles on the surface of, and also above, the water in a boiler. The chief cause of foaming is a large concentration of dissolved substances in the boiler water. These substances increase the surface tension of the water, and thus makes it more difficult for the steam bubbles to break on reaching the surface of the water. Suspended matter also causes foaming, but not to such an extent as the dissolved substances. As practically all the salts of other elements are precipitated under the conditions existing in boilers, it is usual to consider foaming to be due to the salts of potassium and sodium, and the foaming tendency to be directly proportionate to the concentration of these salts.

The "foaming coefficient" (f) $= 2{\cdot}7$ Na $+ 2$ K.

An approximate classification is as follows:—

Non-foaming; f not greater than 60.
Semi-foaming; f between 60 and 200.
Foaming; f. greater than 200.

A non-foaming water is defined as one that can be used in a locomotive boiler throughout one week's work without foaming; a semi-foaming as one that cannot be used for a week without foaming, but does not need a complete water change more often than every two days; and a foaming water as one that cannot be used as long as two days in a locomotive boiler without blowing off or changing water to prevent foaming.

(61) United States Geological Survey Water-supply Paper No. 274, p. 171.

Applying the above formula to some of the waters whose analyses have been given, the following results are obtained :—

Sample.	(Sodium and Potassium) in terms of Sodium.	f.	Classification.
III.	93·30	251·9	Foaming
VI.	80·51	217·3	Foaming

Priming consists of water being carried from the boiler to the engine along with the steam. It is largely a matter of the design and working of boilers. Foaming will, however, greatly increase the tendency for priming to take place, owing to the difficulty with which the steam separates from the water during excessive foaming.

(*b*) Corrosion.—Corrosion or "pitting" of the internal surface of a boiler is due to the action of acids on the iron of the boiler. The acids are mainly derived by chemical actions during the steam-raising process in the boiler, basic radicles being deposited as scale and leaving an excess of acid radicles in solution. If these acids are in excess of the amount necessary to decompose the carbonates and bicarbonates in solution or in the scale, they attack the iron of the boiler. The action of acids upon iron will liberate hydrogen, and the amount of hydrogen formed may be taken as a measure of the corrosion which occurs. On this assumption Stabler has obtained the following formula :—

Coefficient of corrosion (c)—

$$= H + {\cdot}1116\ Al + {\cdot}0361\ Fe + {\cdot}0828\ Mg - {\cdot}0336\ CO_3 - {\cdot}0165\ HCO_3.$$

A classification based upon this coefficient is as follows :—

Corrosive: If c be positive the water will certainly corrode the boiler.

Non-corrosive: If c + 0·0503 Ca be negative, no corrosion will occur on account of the mineral constituents of the water.

Semi-corrosive: If c be negative, but c + ·0503 Ca be positive, corrosion may or may not occur, the probability of corrosive action varying directly with the value of the expression (c + ·0503 Ca).

Applying this formula and classification to the better quality waters so far available from Kempton and Colebrook, the following results are obtained:—

Sample.	c.	c + ·0503 Ca.	Classification.
III.	−3·318	+1·024	Semi-corrosive
VI.	−3·244	+3·585	Semi-corrosive

(*c*) Scale Formation.—Scale and sludge are formed in boilers, due to the waters used containing suspended and dissolved substances. The heating of the water to a high temperature causes many of these substances to be precipitated and so form a scale. The suspended matter becomes deposited, while the dissolved substances may be precipitated as a result of decreased solubility, concentration above saturation point, and chemical actions.

The iron, aluminium, and magnesium are precipitated as hydroxides, and appear in the scale as oxides, but magnesium also occurs partly as the carbonate. Calcium is precipitated both as carbonate and sulphate. Bicarbonates are decomposed and the normal carbonates formed and precipitated. Calcium sulphate is precipitated owing to its decreased solubility with increased temperature and pressure.

Scale is produced as a result of these actions, and the amount may be determined from the following formula based on these actions:—

Scale (Sc) in lbs. per 1000 gallons of water—

$$= \cdot 00833\ Sm + \cdot 00833\ Cm + \cdot 0107\ Fe + \cdot 0157\ Al + \cdot 0138\ Mg + \cdot 0246\ Ca.$$

The classification using this index is as follows:—

Very little scale	Sc. not more than 1.
Little scale	Sc. between 1 and 2.
Much scale...	Sc. between 2 and 4.
Very much scale	Sc. more than 4.

Applying these to the better quality water at present available from Kempton and Colebrook, the following results are obtained:—

Sample.	Scale.		Classification.
	Parts per million	Lbs./1000 gallons.	
III.	405·45	3·37	Gives much scale
VI.	584·63	4·87	Gives very much scale

It is seen, therefore, that the waters discussed above as available for testing at present are foaming, semi-corrosive, and give much scale, and are of little use for boiler purposes. The waters could be improved in quality as regards scale formation by a water-softening process involving the addition of lime and soda-ash. The addition of the soda-ash would, however, add to the soluble material left in the water, and increase the tendency for foaming. It must be remembered, however, that the water which is to be obtained by boring and constant pumping will probably be of better quality than any of the above results show.

(2)—Soils.

(a) *Introduction.*

The geological map (Plate II.) does not show the soils which occupy the surface, but deals with the underlying rock formations. This map can, however, be used as a soil map with a fair degree of accuracy, the soils derived from the various rocks being read in place of the rocks themselves.

There is, however, a much greater variation in the soils which could only be shown on a soil map prepared as a result of a detailed soil survey.

The soils typical of the various rocks and formations from which they have been derived have been fully described in the report on the Midlands.(62) The descriptions will not be repeated, but the soils will be dealt with generally and the purposes to which they are applied will be indicated.

(62) Underground Water-supply Paper No. 1: "The Underground Water Resources of the Midlands," p. 121.

(b) *Diabase Soil.*

This is a dark-red, heavy soil with a close, clayey sub-soil. In general only a small thickness occurs on elevated diabase country, and such regions are devoted solely to pastoral purposes, forming the best pastoral land in the area. Where the soil is sufficiently thick, as at the foot of diabase hills, it forms a very good soil, and has an extensive use. Orcharding is carried out on this soil at Colebrook and Bagdad, with very good results at the latter locality. Agriculture is carried out on this soil at numerous localities throughout the area, wherever the thickness is suitable

(c) *Basalt Soil.*

Basalt forms a black soil of excellent quality where a sufficient depth of it occurs. Basalt occurs around Campania and Brighton, but in general has yielded only a very thin layer of soil useless for agricultural purposes. A good thickness of soil exists on the Campania Estate, and forms probably the best agricultural land in the area. A mixture of basalt and Tertiary gravel soil is used between Campania and Richmond, but with somewhat poorer results.

(d) *Silicious Mudstone Soil.*

The soil derived from the Permo-Carboniferous strata (mainly silicious mudstones) is very light-coloured, and is generally of very poor quality. On the flanks of Mt. Dromedary it is used to a fair extent for orcharding, and to a smaller extent for agricultural purposes. This soil is also used to a slight extent for agriculture in the valley of the Mangalore Creek, but there is usually a mixture of other soils, such as alluvial, with it where it is used. Outside of these localities the soil is poor even for grazing purposes.

(e) *Sandstone Soil.*

The soil derived from the Trias-Jura sandstones is a light-coloured, loose, sandy soil, and is extensively used for various purposes throughout the area. Around Spring Hill Bottom this soil is used for orcharding, potato-growing, and also for agriculture. The same applies to a few other localities, but the main use of this soil is for agricultural purposes. All sandstone areas do not produce good soils, and the soil on elevated, broken country is often very sandy and poor. Bracken and heath abound on such land, which is poor even for grazing purposes.

(*f*) *Felspathic Sandstone Soil.*

This soil is of a dark loamy nature and of very good quality. It is developed to only a small extent in the area, mainly along and to the south of the Wallaby Rivulet, but also around Constitution Hill and to the north-east of Melton Mowbray. It is most suitable, and is used for agricultural purposes. Along the Wallaby Rivulet it is more or less mixed with alluvial and diabase soil, and is used for orcharding.

(*g*) *Alluvial Soil.*

This soil occurs on the alluvial flats which have been formed along many of the streams within the area. It is a heavy black soil, and when well drained produces land of very fair quality. Along the Wallaby Rivulet and the Bagdad Rivulet, especially the latter, this soil is used for orcharding purposes with very good results. Its main use is, however, for agricultural purposes, although it is often well-grassed and used for pastoral purposes.

(3)—Road-making Materials.

Splendid oportunities to observe and compare the values of the various rock-types and formations occurring in the area for road-making purposes existed during the present investigation. The rock-types and formations are the same as those existing in the Midlands area to the immediate north, and which have been discussed as regards their road-making properties in the report on that area.(63) The same general remarks apply to the present area, and will not be repeated here. A short description of the local conditions need only be given.

Diabase is easily the most valuable and widely used of the various rock-types. This is due to the excellent physical properties which it possesses for the above purposes, and also to its widespread distribution throughout the area. Practically the whole of the main-road from Hobart to Launceston and other first-class roads within the area are metalled with diabase.

(63) Underground **Water-supply Paper No. 1: "The Underground Water Resources of the Midlands," p. 125.**

Basalt possesses characteristics almost as good as those of diabase for road-making purposes, but its occurrence within the area is limited. It has been used to a large extent on the main-road between Bridgewater and Pontville, with very satisfactory results. Basalt has also been used on portion of the Pontville-Broadmarsh-road, the Brighton-Tea Tree-road, and on the main-road to the south of Jericho.

Mudstone.—The white mudstones of the Permo-Carboniferous system are used for road-making where these strata outcrop. They are not suitable for the making of roads which have to stand heavy traffic, as they are too soft and crush easily, thus causing the surface to wear quickly. For roads subject to only light traffic they are much more suitable, and form an excellent surface. The best example of a road constructed with this material is that portion of the Richmond to Risdon-road which crosses Grass Tree Hill. This material is largely used on the roads on the eastern flanks of Mt. Dromedary and along the north side of the River Derwent west of Birdgewater. It is also used on the roads on the east bank of the Coal River, in the vicinity of Brandy Bottom, east of Colebrook.

Sandstone.—The normal sandstones of the Trias-Jura system are largely used for road-making. This occurs on the roads crossing large tracts of sandstone country, especially those of lesser importance. This material crushes very easily, and the road metal has a very short life, leaving a mass of loose sand in its place. It is thus of very poor quality, but is used under the above conditions.

(4)—Building and Monumental Stone.

The normal sandstone, locally termed "freestone," of the Trias-Jura system has had a very extensive use in the past for building, monumental, and constructional purposes. At the present time the use of this stone is restricted almost solely to monumental work.

These sandstones occupy about 35 per cent. of the present surface and are widely distributed throughout the area, thus being conveniently at hand when required for the above purposes. They are easily quarried, and blocks of any desired size can be obtained, while dressing and working of the stones are comparatively easy. It is these factors which have mainly determined the extensive use of these stones.

Building Stones.—Practically all the houses and churches in the older townships, such as Richmond and Pontville, have been built of "freestone." This also applies to a less extent to such townships as Kempton, Melton Mowbray, Colebrook, Bagdad, and Bridgewater. All the old churches and larger country houses have also been built of this stone.

Quarries exist in the vicinity of the above localities, having been opened up to meet the local requirements. One large quarry, 2 miles east of Tea Tree, is still worked at intervals to supply building stone required in Hobart. The stone produced in this quarry is a grey to white stone of very good appearance.

Monumental Stone.—The great majority of the tombstones, headstones, and sidestones erected in the cemeteries throughout the area are constructed of sandstone. The buff, brown, and variegated stones are most used.

Constructional Stone.—The sandstones are also used for constructional purposes, such as the building of bridges and culverts. The bridge by means of which the main-road crosses the River Jordan at Pontville has its abutments and pillars built with sandstone, and showing an example of very fine workmanship.

The road bridge at Richmond across the Coal River is constructed wholly of sandstone.

The sandstones have also been largely used in the construction of culverts and small bridges along the railway-lines within the area.

(5)—Limestone.

Beds of fairly pure limestone occur in the Permo-Carboniferous strata around the flanks of Mt. Dromedary. The limestone has been quarried and burnt for lime for some considerable time on the south side of the River Derwent near Bridgewater, and is reported to give satisfactory results. An attempt is about to be made to burn the limestone on the north side of the river 4 miles west of Bridgewater.

Lime has been produced from a deposit of limestone situated about 1 mile north-west of Richmond. This deposit has been formed as a result of the deposition of calcite from mineral solutions derived from the diabase hills to the west. Two large mounds have been built up by this material, which also underlies much of the surface in the vicinity of these mounds. These mounds have been formed where the mineral solutions have reached the surface and formed springs. A spring still issues from the larger mound, and the process of building is still going on, but no spring now exists in connection with the smaller mound to the south. The mineral solutions are formed by rain-water on the hills percolating underground and dissolving bicarbonates of calcium and magnesium in their passage through and over the diabase. When these solutions approach the surface again the carbonates, mainly of calcium, are deposited and form deposits described above. The quality of these deposits varies, some portions being very pure and others being impure, due to the inclusion of fragments of decomposed diabase and other foreign material. This material has been burnt in a kiln built close to the deposit, wood being used as fuel. The lime produced was used locally in Richmond, and is reported to have been very good in quality.

(6)—Reported Occurrences of Gold.

Gold has been reported to occur at a few localities in the vicinity of Richmond and Campania, and mining operations have been carried out in the past to a slight extent in search of the precious metal. In one case a company was formed, a tunnel was driven into a hill, and a battery erected. The first crushing did not yield any gold, and the operations ceased. These workings were situated on the eastern flanks of Gunning's Sugarloaf, 1½ miles north of Campania.

These occurrences are associated with metamorphosed Trias-Jura sandstones, and are found close to the intrusive diabase. The sandstones have been altered to dense fine-grained quartzites, which in places are similar to homogeneous masses of quartz, and it was the latter no doubt which originated the search for gold, as it was mistaken for reef quartz.

It is doubtful whether any gold occurred in association with these quartzites, because, though reported, further work revealed no trace of the metal. The amount of gold in the original sandstones would be infinitesimal even supposing any existed. The gold, if present in the quartzites, would be more likely to be introduced during the metamorphism of the sandstones by the intrusive diabase. Though ore-bodies have been found in association with diabase (or dolerite) of similar age in other parts of the world, none have so far been reported in association with the diabase of Tasmania, except for specimens obtained from a bore near Lawrenny. One specimen had a content of 14 dwt. 16 gr. of gold 16 dwt. 7 gr. of silver, but the other specimens contained only traces of gold and silver.

The metamorphism of the Trias-Jura sediments by the diabase is small in extent and strongly suggestive of the action of heat alone. No evidence of solutions or gases accompanying the intrusions is obtainable, and it is hardly possible that gold was introduced in the quartzites by these means. Further, this " dry " nature of the diabase intrusions is unfavourable to the existence of ore-bodies generally in association with the diabase.

VI.—CONCLUSIONS.

This geological investigation of the Jericho-Richmond-Bridgewater area has shown that the rock-types occurring in, and the geological structure of, the area are such that no extensive basin of artesian or sub-artesian water exists. There are, however, a number of small local basins in which supplies of underground water exist. These supplies occur mainly in the Trias-Jura sandstones and felspathic sandstones, but also in other porous formations such as alluvium, hill detritus, Tertiary sands, and Permo-Carboniferous mudstones. The quality of the water is determined by the nature and amount of the contained mineral substances. The water so far available for testing is shown to be poor to fair for irrigation purposes; good to very bad for drinking; unsuitable for laundry and toilet use; suitable for supplies for livestock; unsuitable for boiler use. The hardness of the water could be destroyed by treatment with lime and soda-ash, and the water rendered suitable for laundry and toilet purposes, and also, from the point of view of scale formation, for boiler use. It may be expected, however, that the quality of the water ultimately obtained by boring and pumping will be superior to this.

The quantity of water should be more than sufficient for all purposes except irrigation. As regards irrigation, assuming that about 3 inches of the rainfall is available in the underground supplies, and that 2 feet of water will be applied to the land for irrigation, then only one-eighth of the available land can be irrigated. With a combination of irrigation and ordinary methods of farming, a much greater proportion of the agricultural land could be irrigated in this manner.

Wells, either dug or drilled by a simple form of percussion plant, will be necessary to make available these underground supplies, the above types being recommended. Pumping by windmills, benzine and kerosene engines, and possibly electric motors operating deep-well and centrifugal pumps, is recommended as the best pumping plants.

No information is available as to the yield of the wells, and it is recommended that tests of existing wells should be made before any decision is made as to the size, type of well, and other particulars in connection with an installation of a pumping plant.

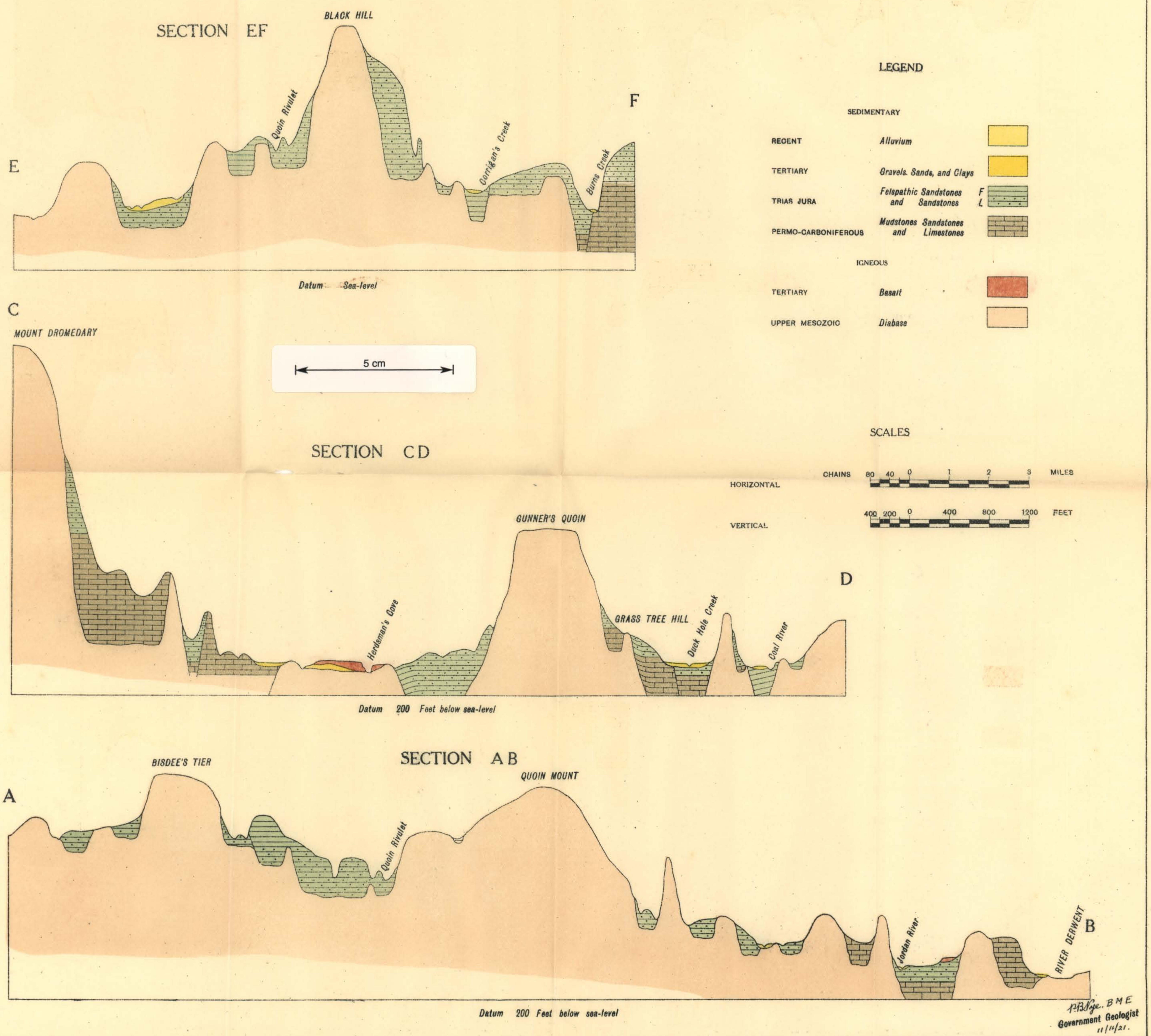
Where wells are sunk in localities where the quality of the water has not been determined, it is recommended that the water be analysed before being used for any specific purpose.

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

Geological Survey Office, Launceston,
11th November, 1921.

Government Geologist
11/11/21.

GEOLOGICAL SKETCH SECTIONS



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