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DEPARTMENT OF MINES

Underground Water Supply
Paper No. 6

THE GROUNDWATER RESOURCES OF THE CYGNET DISTRICT

by

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Preface

The main wealth of the Cygnet District is derived from agriculture, especially apple and pear growing, but the rainfall, though adequate in quantity, is not always evenly distributed through the summer months when water is needed for the maturation of crops. A clear understanding of groundwater conditions is expected to do much to augment the summer water supply. This paper deals with all general aspects of the Groundwater Problem applicable to the Cygnet District and also deals in detail with each of the eight drainage regions into which the district can be divided. Particular attention is paid to the use of geophysical methods in siting bores, and it is expected that these methods will open up new possibilities of tapping useful water supplies in hidden fracture zones in dolerite.

The geology of the District is not treated in detail as it is being dealt with in a separate publication, Bulletin 49: "The Geology and Geophysics of the Cygnet District" to be published shortly.

J. G. SYMONS,

Director of Mines.

(Frontispiece)

Cygnet Region, looking North-East, Grey Mountain in background.

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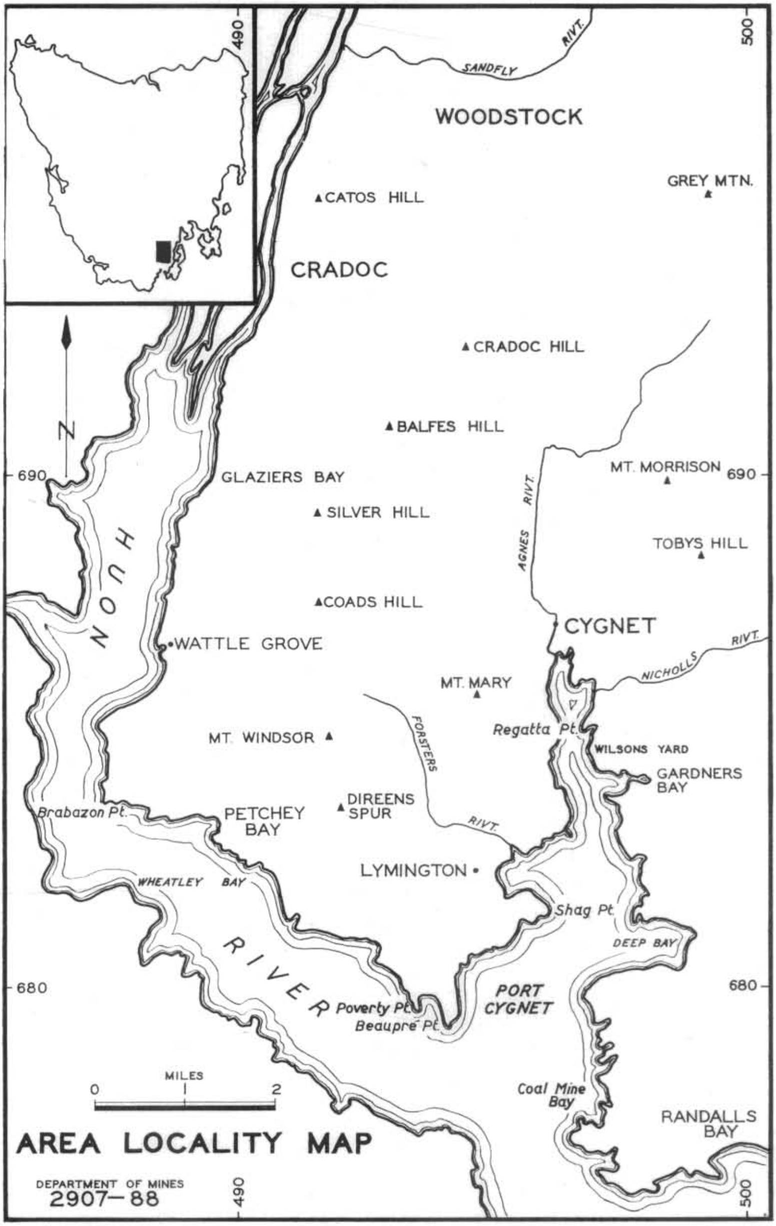

490
500
SANDFLY RIVT.
WOODSTOCK
GREY MTN.
CATOS HILL
CRADOC
CRADOC HILL
BALFES HILL
690
GLAZIERS BAY
MT. MORRISON
SILVER HILL
AGNES RIVT.
TOBYS HILL
HUON
COADS HILL
CYGNET
WATTLE GROVE
NICHOLLS RIVT.
MT. MARY
FORSTERS RIVT.
Regatta Pt.
MT. WINDSOR
WILSONS YARD
GARDNERS BAY
DIREENS SPUR
Brabazon Pt.
PETCHEY BAY
LYMINGTON
WHEATLEY BAY
Shag Pt.
DEEP BAY
RIVER
680
PORT CYGNET
Poverty Pt.
Beaupre Pt.
MILES
0 1 2
Coal Mine Bay
RANDALLS BAY
AREA LOCALITY MAP
DEPARTMENT OF MINES
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FIGURE 1.

5 cm

GROUNDWATER RESOURCES OF THE CYGNET DISTRICT

Abstract

Most groundwater in the Cygnet District occurs in consolidated rocks, and is contained principally in secondary openings. This study includes a discussion of the nature, origin and processes which develop openings in rocks capable of transferring and storing water; the hydrological properties of each formation; the nature of the water table; the cause of bore failure; the reasons for variations in yield from bores; the temperature of the groundwater.

The chemical quality of the water is considered with particular reference to the source and nature of the chemical constituents present, and the utilization of the water. The character of the water from the tillite, Grange Mudstone and Ferntree Formation is described in detail.

The form of the water table, the depth to water, the quality of the water, the nature of water movement and general details with reference to the siting of bores and nature of drilling are described for each of the eight drainage divisions into which the area has been subdivided.

Introduction

LOCATION AND ACCESS

The Cygnet District is that part of Southern Tasmania east of the Huon River, but west of the 500E kiloyard grid line and south of the 700N kiloyard grid line (fig. 1). It is located in the county of Buckingham and includes most of the Municipality of Port Cygnet and the SE part of the Huon Municipality. The area covered is approximately 70 square miles, has a N-S length of 14 miles and a maximum E-W width of 6 miles, and lies between the Grey Mountain-Mt Cygnet divide and the Huon River. Mt Cygnet is a little east of the area.

The principal town within the district is Cygnet but there are many smaller villages. The total population is some 3,000 persons, of whom one third reside in the vicinity of Cygnet.

Access to most parts is excellent, being poorest in the NE, particularly in the vicinity of Grey Mountain.

IMPORTANCE OF GROUNDWATER IN THE DISTRICT

This district is marked by a relative lack of permanent streams with flows adequate for all the agricultural requirements of the area. At present water from dams is the mainstay of supplies but, since such supplies are dependent upon the vagaries of surface water, it is good practice to supplement them with groundwater. Most water is required through the summer when the fruit, the economic mainstay of the district, is beginning to ripen, and surface water becomes almost non-existent. To date relatively few farmers have supplemented their supplies in this way, but with increasing realization of the value of irrigation the need for more bores will become apparent.

PURPOSE, SCOPE, AND PERIOD OF THE INVESTIGATION

All water obtained in bores in the Cygnet District is supplied by rocks which are inherently impervious. The occurrence, storage and movement of groundwater in these rocks is controlled by the secondary hydrological properties which have developed as a result of numerous interrelated geological, physical, chemical, climatic and topographic conditions that have affected the rocks at various times since their formation.

Consolidated sedimentary and crystalline rocks are often neglected in groundwater studies in favour of unconsolidated recent deposits. Such deposits are of negligible extent in this district.

With increasing demand for water, the groundwater reserve has begun to be tapped. As a result, it is necessary to develop a better understanding of the processes which have produced the interstices in the rocks, and the manner in which these affect the problem of storage and movement of groundwater, in order to improve success rates.

The principal objects of the study were:—

(i) To provide detailed information on the nature of the water table throughout the district, and to describe any peculiarities and all features which may cause disruption of it;

(ii) to evaluate the effects and nature of the hydrological properties of the rocks; and

(iii) to present information on the chemical character of selected bore waters.

Fieldwork was undertaken at intervals during 1965. The methods and time of investigation of certain aspects of the study, which took place within more restricted periods, are given, where appropriate, in the respective chapters.

PREVIOUS INVESTIGATIONS

The earliest geological mapping undertaken within the district was a regional study in connection with coal resources, by Hills *et al.* (1922). Edwards (1947) published a revised geology in a petrological treatise on the Port Cygnet Alkaline Intrusives which occur in the southern part of the district.

There have been no previous groundwater studies within this district.

ACKNOWLEDGMENTS

The author wishes to acknowledge the geological information provided on the southern part of the district by my colleague, Mr. I. H. Naqvi, and others of the staff of the Department of Mines.

I should also like to thank Mr M. R. Banks, of the Geology Department of the University of Tasmania for his helpful comments and suggestions at various stages of the work.

Acknowledgment is also due to the staff of the C.S.I.R.O. Division of Soils and the Commonwealth Bureau of Meteorology, who so kindly provided information upon request.

The author is also grateful for the co-operation and assistance given by most property and bore owners. Such local people provided considerable information on the behaviour of bores, springs and other groundwater conditions on their properties, and were co-operative in allowing their wells to be used for hydrological observations.

WELL NUMBERING SYSTEM

In order to provide some systematic means of reference to bores the following nomenclature has been used throughout the text. This scheme, if followed, allows any future wells to be catalogued in like manner. All details on the particular wells may be found in the Appendix. Each well is numbered serially within the drainage region in which it is situated, the entire district having been divided into eight drainage regions (fig. 10). The letter or combination of letters which precede the well number is the abbreviation of the name of the Region. For example, C10 was the tenth bore to be drilled in the Cradoc Region.

The letter prefixes are as follows:

Cradoc	C
Cygnet	CG
Glaziers Bay	GB
Lymington	L
Petchey Bay	PB
Wattle Grove	WG

TERMINOLOGY

The following terms are defined below, in order that their use in the text may be fully understood. Unless stated otherwise, the definitions are based on those of Jones (1965).

Porosity relates the total volume of voids a rock contains, and hence the total possible volume of water it may contain, to the total volume of the rock, i.e.,

$$P = \text{vol. voids/vol. rock.}$$

It is normally expressed as a percentage (Amer. Geol. Inst., 1962).

The *permeability* of a rock is its capacity for transmitting a fluid. A *permeable rock* is one having a texture that permits water to move through it perceptibly under the pressure ordinarily found in subsurface water (Meinzer, 1923).

The *specific yield* is the volume of water that a saturated stratum will yield by gravity compared to the volume of the stratum, and is expressed as a percentage (Bateman, 1959, p. 867).

An *aquiclude* is a permeable saturated rock which will not yield groundwater at a sufficient rate to be of local consequence as a source of supply. An *aquifer* is a permeable saturated rock which will yield groundwater at an economic rate. An *aquifuge* is an impermeable rock.

The *piezometric surface* is an imaginary surface defined by the static levels at all points on a given plane in a groundwater body.

Confined groundwater is groundwater occupying the full thickness of an aquifer overlain by an aquifuge or saturated aquiclude.

Unconfined groundwater is groundwater in which the upper surface is formed by surface water or by permeable rock containing air at atmospheric pressure.

A *water bore* is a hole which is drilled, jetted or augered to withdraw or replenish groundwater.

A *spring* is a place of natural discharge of groundwater as a liquid.

Artesian water is groundwater whose static level is above the ground surface. *Sub-artesian water* is groundwater for which the static level is above the upper surface of the groundwater body but below the ground surface.

The *water table* is the surface within a groundwater body at which the hydrostatic pressure is equal to atmospheric pressure.

Geography

TOPOGRAPHY

The topography is generally youthful with moderate relief over the greater part of the area except the NE, where it is high. For ease of discussion the area has been divided into drainage basins by delimiting the major watersheds.

The eastern margin of the area is the Grey Mountain-Mt Cygnet divide which is indented two miles to the east of the area by the basin of Nicholls Rivulet. It then passes south toward the estuary of the Huon River a little east of Randalls Bay. The Grey Mountain (2,723 ft) section of this divide can be seen in the background of Plate 1.

A major N-S divide extends the length of the Cygnet Peninsula. The highest point is Mt Windsor (1,262 ft); other high points are Coads Hill (946 ft), Direens Spur (846 ft) and Silver Hill (805 ft). The elevation decreases northward from Mt Windsor beyond Silver Hill toward Balfes Hill, westward to Brabazon Point and also southward by Direens Spur to Beaupre Point (fig. 1). In the region of Balfes Hill this divide bifurcates into two lower divides. The diminishing height of the mid-peninsula ridge can be seen in Plate 2. North of the peninsula, Cradoc Hill (1,049 ft) forms the key point for the junction of divides: to Grey Mountain in the east, through the hills south of Woodstock to the NW, and to Balfes Hill in the SW. The Cradoc Hill-Grey Mountain connection can be seen in Plate 1.

Balfes Hill is a misnomer, being the name of the connecting ridge between Silver Hill and Cradoc Hill. It can be seen in Plate 2.

The north of the area is defined by a ridge extending from the Huon River north of, and parallel to, the Sandfly Rivulet, toward Kaoota and the Herring Back (2,450 ft) several miles away. This report considers only the lower reaches of the Sandfly Rivulet system.

No one rock type dominates the topography in this area, although that in the NE parts, i.e. east and north of Cradoc, is controlled by dolerite. The ridges and hills in the southern parts of the area are, with the exception of Mt Windsor and Mt Mary which are of syenite porphyry, composed of various sedimentary rocks.

There are very minor regions of lowland within the area. The only lowlying meadows and swamp flats are to be found flanking the Huon River west of Woodstock and near the mouths of the Agnes, Sandfly and Nicholls Rivulets.

DRAINAGE

The principal drainage systems, into which this district has been divided for hydrological discussion, and their streams and rivulets, both perennial and intermittent, are shown on fig. 10.

All drainage is toward the Huon River. The flow may be direct or may pass via Port Cygnet (Pl. 2).

Westward drainage from the peninsula ridge passes directly toward the river. Such streams are not normally more than second order and have gradients up to 900 feet in one and a half miles. Many of these streams are intermittent and some are ephemeral due to the steep slope which is very rapidly drained of any water falling upon it.

Eastward drainage from the peninsula ridge is toward Port Cygnet and thence to the Huon River. These streams have similar gradients to those on the western side of the peninsula. It has been observed, however, that the flows of streams in this part of the district (Lymington-Cygnet) are more consistent and that there is a higher percentage of permanent streams.

Drainage from the Nicholls Rivulet-Randalls Bay Region is almost all toward Port Cygnet. There are few streams in this part of the area, and those present are commonly large and perennial, examples being Nicholls Rivulet and Gardners Rivulet. In its upper reaches, Nicholls Rivulet is the source of the town water supply for Cygnet; in its lower reaches, it has developed a minor flood plain (Pl. 16).

Drainage from the Cradoc Hill-Grey Mountain divide is either northward to Sandfly Rivulet or southward to Agnes Rivulet. Both of these drainage systems have marked gradients in their upper reaches. The Sandfly Rivulet has a gradient of 250 feet in five miles in the area under discussion. It flows in alluvial deposits for the last three miles of its course. In contrast, its tributaries in the Woodstock Region may have gradients ranging between 1,000 feet in one mile to 1,000 feet in three miles. As a result all streams flow rapidly after rain has fallen and only those few which are actively supported by groundwater accretions flow perennially. Most of the streams in this part of the area are influent throughout the year and thus only flow when the runoff exceeds infiltration, i.e., only after heavy or continuous rain has fallen.

Drainage throughout the Agnes Rivulet Region is essentially similar to that in the Woodstock Region with the exception that more of the streams are permanent; due solely to the water supplied from the sedimentary block on the southern side of Grey Mountain.

Drainage in the Cradoc Region is very slight, most streams being ephemeral or intermittent. The few permanent streams in this part of the area have exceedingly small flows.

Only three streams within the area generally have flows in excess of one cusec: Sandfly, Agnes and Nicholls Rivulets.

The Huon River, which marks the western and southern limits of the area, is tidal in this part of the State; although the tidal range is small, normally less than one foot, the water is brackish and of little practical value.

CLIMATE

The climate of the district is characterized by cool mild winters, warm summers and frequent weather changes. The summers are humid with thunderstorms common. The prevailing winds are westerlies and pressure systems and fronts pass eastward across the district.

The Commonwealth Bureau of Meteorology maintains two observation stations within the district (Cygnet, Petchey Bay) and two others (Franklin, Geeveston) to the west across the Huon River.

In the district topographic features and climate are closely associated. The undulating nature of the country results in formation of local climates, all of which have common characteristics, but which vary in degree.

Precipitation is distributed throughout the year, and there is little distinction between wet and dry seasons. Table 1 presents the average figures for the four stations mentioned above.

The broad scheme of rainfall within the area is rain slope and rainshadow. There are many minor variations within the area due to its hilly nature, but broadly the area may be divided into three N-S rainfall belts. (i) The land strip extending from the north of the area to Brabazon Point, parallel to and flanking the Huon River, inland to the mid-peninsula ridge and the Cradoc Hill-Woodstock ridge is the windward slope of the prevailing winds. (ii) The

TABLE 1: Average Rainfall Results

Results expressed in points

	Cygnet	*Petchey Bay*	*Franklin*	*Geeveston*
January	200	197	218	261
February	218	204	223	242
March	216	227	240	258
April	352	288	316	348
May	322	249	289	369
June	371	335	350	377
July	278	294	316	327
August	326	324	340	392
September	282	282	324	324
October	370	317	376	379
November	291	257	287	311
December	279	266	307	300
	3,505	3,240	3,585	3,888

belt east of this ridge, from Cradoc Hill to Beaupre Point, lies in the rain shadow of the peninsula ridge. (iii) All rising land east of Cygnet toward the Mt Cygnet-Grey Mountain divide consists of windward slopes with increased rainfall.

As Table 1 shows, the average rainfall within the area is approximately 35 inches. The mean deviation, as a percentage of the average rainfall, is 12-14% in the SE part of the area and 14-16% in the remainder. The maximum rainfall occurs in the region of Grey Mountain and is over 40 inches.

During the summer, temperature and humidity are usually high, and thunder showers are common. These are normally very localized, but may occur in any part of the area. They are not unknown during the winter months. As a result of such showers there may be short periods (10-30 minutes) of intensive precipitation, including hail.

The annual mean temperature for the Huon Valley ranges between 61.9°F and 41.9°F. Frosts may occur at any time between April and November but snow is uncommon in any part of the area except Grey Mountain and the higher ridges.

SOILS

Soils within the area fall within three groups:

(i) alluvial soils,

(ii) soils on the siliceous Permian and Triassic sedimentary rocks, and

(iii) soils on the igneous rocks.

The neutral to alkaline alluvial soils are to be found along the banks of the Huon River north of Cradoc, and in the lower reaches of Agnes, Sandfly and Nicholls Rivulets. There is a large area of deposition at the head of Port Cygnet where Agnes Rivulet has formed a deltaic deposit. These soils are of limited extent, but are well drained due to the light nature of the soil and subsoils. There is often a gravel base to the subsoils (Pl. 16).

Podzols and yellow podzols are developed on the Permian and Triassic rocks which, although essentially siliceous, often contain considerable amounts of feldspar and, in the case of the Permian rocks, many rock fragments. On weathering, clay is produced in some quantity. The soils in the Lower Huon District are commonly duplex rather than gradational. Soils on Triassic sandstone may be very loamy and very well drained. Of those on the Permian rocks, two particular types have been described in the area (Stephens, 1935): the "Huon sand" and the "Lucaston sand". Both types are duplex, grey to yellow in profile with sandy A horizons and clayey B horizons, which are mottled in the case of the latter. There may be a hardpan layer in the upper B horizons. All parts of these soils have highly acid reactions.

Two distinct types of soil occur on the dolerite within this area. These are the grey-brown podzols and brown earths. The former type occurs on the wetter and steeper slopes and has a duplex profile with a sandy A horizon and a yellowish brown B horizon of clay with large numbers of ferruginous concretions. This type of soil is usually thin, less than 2-3 feet thick, with fragments of dolerite throughout. The brown earths are the more common, are also thin, stony and duplex but have loamy A horizons and reddish brown B horizons. Drainage is commonly good in both types since the dolerite, when present, usually forms the hills.

VEGETATION

A large proportion of the district is uncleared land, particularly east of Port Cygnet and Cradoc. In the virgin state the land is lightly timbered with eucalypts and tea-tree. Where the rocks are sedimentary, and in the lower rainfall belts of the western and central parts, much bare soil is exposed since these areas are lightly grassed. In the eastern portions the vegetation is much denser, consisting of varieties of eucalypts, wattle, tea-tree, sassafrass and dog-wood. This area is also heavily grassed. In the region of Grey Mountain there is also some *Bauera*. Most of the SW part of the area has been cleared and utilized for grazing and orcharding. In the northern parts where dolerite is the outcropping rock, vegetation is mainly in the form of an open eucalypt forest with a grass ground cover.

HUMAN ACTIVITY

All human activity within the district is geared to some form of primary industry. In the Woodstock, Cradoc and Cygnet Regions there is considerable dairying, but on the whole dairying is subsidiary to orcharding and most of the cleared land is devoted to apples and pears. There is also some timber logging and cutting in the eastern parts of the area, the timber being used by the fruit industry for the manufacture of cases.

General Geology

A detailed account of the geology of the district does not lie within the scope of this study and only a brief description of each formation is given. Prior to the commencement of this study the entire area was mapped geologically (Leaman and Naqvi, 1967). The geology is shown in fig. 10.

The geological formations represented in the area are summarized in Table 2.

TABLE 2. Stratigraphy

System	*Formation*	*Units*	*Thickness feet*
Quaternary		Recent alluvial deposits	10+
		Pleistocene gravels	120
		UNCONFORMITY	
Tertiary		Cemented conglomerate	20+
		UNCONFORMITY	
Cretaceous		Alkaline igneous rocks	
Jurassic		Tholeiitic dolerite	
Triassic		Sandstone, some shale, felds-pathic sandstone	1000—
		DISCONFORMITY	
Permian	Cygnet Coal Measures	Carbonaceous shale	6+
	Ferntree Formation	Coarse siliceous siltstone	600
	Malbina Formation	Quartz sandstone and silt-stone	130
	Grange Mudstone	Fossiliferous marine mudstone	525?
	Faulkner Group	Sandstone and siltstone	70–200
	Bundella Mudstone	Fossiliferous mudstone	250
	Quamby Mudstone	Siliceous mudstone	500
	Tillite	Mudstone, tillite	700+

Permian System

TILLITE

The oldest formation exposed in this area, the tillite, is of unknown total thickness, the maximum known thickness being 700 feet. It is restricted to within a radius of 2-3 miles from Cygnet and consists of pebbly tillitic zones with mudstone horizons. In the tillitic zones there may be up to 50% pebbles in a matrix of rock flour, most pebbles being less than 10 cm across and generally metamorphic in origin. Evidence of bedding is usually absent. Three bores have been drilled in this formation.

QUAMBY MUDSTONE

This formation, 500 feet thick, occurs over much of the central and western portions of the Cygnet Peninsula and also between Gardners Bay and Tobys Hill. At its base is a zone containing pyrite nodules and glendonites. The formation is quite uniform, consisting principally of mudstone and fine siltstone although there are occasional sandy bands. Cementation is complete and the rock is very massive and dense; bedding is normally poorly developed due to a lack of compositional heterogeneity. Near the surface the rock becomes friable and increasingly fractured due to an exfoliation effect. Only one bore has been drilled in this formation to date.

BUNDELLA MUDSTONE

The area of outcrop of this formation is small and restricted to parts of the Lymington, Cygnet, Wattle Grove and Agnes Rivulet Regions. The formation consists of 250 feet of mudstone, siltstone and some sandstone, richly fossiliferous near the base, but becoming more barren toward the top. Bedding is normally well developed. Two bores have been drilled to date.

FAULKNER GROUP

The rocks of this group are limited to an area on the slopes of Tobys Hill, Balfes Hill and near Deep Bay, the largest outcrop being north of Balfes Hill. The group consists of mudstone, siltstone and sandstone which are usually poorly sorted and pebbly. The thickness of the group is also variable, being less than 70 feet on Tobys Hill and more than 200 feet on Balfes Hill. It is very heterogeneous and represents a deltaic deposit, the upper and lower portions of which are marine. In the Balfes Hill area there is some 50 feet of well sorted non marine sandstone. One bore only has been drilled in this formation.

GRANGE MUDSTONE

This formation, of unknown total thickness (>500 ft?), occurs in the Lymington, Agnes Rivulet, Glaziers Bay and Gardners Bay Regions. The formation consists of fossiliferous mudstone throughout with beds 6 inches to one foot thick and fossils usually disposed at the top and bottom of each bed. The formation is fairly uniform but does become finer grained toward the top with a more regular distribution of fossils (as in Pl. 9). No massive limestone phase has been observed within this area. The formation has been extensively drilled.

MALBINA FORMATION

This formation consists of alternating sandstone and siltstone units with a total thickness of about 130 feet. The area of outcrop is very small, being limited to parts of the Lymington and Agnes Rivulet Regions, though small coastal outcrops also occur. The basal member (A) of this formation is a coarse, pebbly, fossiliferous, quartz sandstone, some 30 feet thick, which is overlain by siltstone units (members B, D) although thin sandy zones do occur (Members C, E). Cementing tends to be poorer in the sandy members.

FERNTREE FORMATION

The Ferntree Formation, 600 feet thick, occurs mainly in the Cradoc and Randalls Bay Regions. It is composed of coarse siltstone, sandstone and occasional conglomeratic bands with no particular sequence in the compositional variations. The rock tends to have a banded nature in outcrop, with alternate beds being up to two feet thick and interbedded with more fissile silty zones (Pl. 11). The whole formation is intensively fractured as a result of its competence. It has been extensively drilled.

CYGNET COAL MEASURES

The Cygnet Coal Measures, of negligible thickness, outcrops in the Randalls Bay Region with minor outcrops elsewhere and has not yet been drilled. It consists of carbonaceous shale.

Triassic System

The rocks present probably include the equivalents of the Springs Sandstone and Knocklofty Formation of the Hobart area (Hale, 1962). The Triassic rocks are limited to the Cradoc, Woodstock, NE Agnes Rivulet and Randalls Bay Regions, i.e., the far NE and SE of the district.

Overlying the Cygnet Coal Measures is the Springs Sandstone, the basal portion of which is a well sorted, poorly cemented, friable, feldspathic sandstone. It is very porous, outcrops principally in the Woodstock Region where it is up to 100 feet thick, and has not been drilled. This is overlain by a coarse quartz sandstone in many parts of the north of the district only. It is well cemented, several feet thick and very clean and pure. The grains have substantial regrowths. Plate 10 shows the nature of the basal Triassic rocks when this grit is absent and the normal massive Springs Sandstone overlies feldspathic sandstone.

The basal members are overlain by several hundred feet of well sorted quartz sandstone, with some feldspar, which becomes more micaceous upward.

The maximum thickness of Triassic rocks, as exposed on the southern slope of Grey Mountain, is 1,000 feet, but this section may be faulted. Cementing is variable. No shale has been located in this area, probably a result of poor outcrop. No Triassic rocks have yet been drilled.

Jurassic System

Dolerite outcrops over one third of the district (fig. 2). It is a tholeiitic dolerite emplaced principally as dyke-like bodies. It consists principally of labradorite, clinopyroxenes, iron oxides and mesostasis, the last consisting of quartz and orthoclase. The grain size increases away from the contact zones and may become very porphyritic if the body of material is large enough. Fuller details on the composition and differentiation of the Tasmanian dolerites have been given by Edwards (1942), Dolerite Symposium (1958), McDougall (1962). The stage of differentiation is of note in this context in that it affects the nature of the weathering in a given situation. Near the contacts the dolerite is fine grained and very highly fractured.

Cretaceous System

The alkaline rocks, which have been shown to be Cretaceous in age (Leaman and Naqvi, 1967), may be grouped into two main classes on the mode of occurrence: (i) as dyke rocks, and (ii) as large homogeneous masses.

The dyke rocks occur principally in the area of the Cygnet Peninsula, although some are to be found near Tobys Hill, Cradoc Hill and Nicholls Rivulet. These rocks are very variable in composition, normally hard and massive and only a few feet wide. Details of their composition may be found in Edwards (1947). The occurrence of the rocks differs in each locality and is affected by the nature of the intruded rocks and the composition of the dyke. In many cases the dykes stand out as resistant bodies, e.g. Plate 8, but elsewhere the converse is true. A dyke of the latter type was detected in the Lymington Region by the resistivity method (fig. 4).

The homogeneous masses are composed of syenite porphyry or banatite and occur in four localities (fig. 10). The largest mass lies between Regatta Point and Mt Windsor, with smaller subsidiary masses east of Brabazon Point, Wattle Grove and Glaziers Bay. These masses of material are very uniform in composition and it has been suggested (Leaman and Naqvi, 1967) that they form part of a denuded asymmetrical laccolith.

Tertiary Period

Rock of this age occurs in only three localities, two near Deep Bay and one north of Beaupre Point on Port Cygnet. All are very limited outcrops, situated near the coast. The rock is hard, massive and very siliceous, and consists of pebbles cemented together.

Quaternary Period

Pleistocene Gravels

These gravels consist principally of quartz or quartzitic pebbles of various sizes in a sandy matrix which usually accounts for half of the material. Less than 3% of the pebbles are derived from Permian sedimentary rocks or Jurassic dolerite. These gravels are to be found on the banks of the Huon River, with the largest deposits at Randalls Bay and north of Beaupre Point. Smaller deposits occur near Petchey Bay, Glaziers Bay and Cradoc. The deposits in the vicinity of Randalls Bay and Beaupre Point may extend from sea level to 100-120 feet, whereas those in the Cradoc area are normally less than 75-100 feet. Cementing is non-existent. There are occasional clay bands, which are usually dark in colour. Plate 5 shows part of the deposit at Beaupre Point.

Recent Alluvial Deposits

These deposits include gravels and alluvium in stream valleys. There is normally up to five feet of alluvium overlying an unknown thickness of gravels, commonly composed of a large number of dolerite pebbles.

Structural Geology

Several aspects of the geological structure in this district are of importance with respect to the hydrology. In summary these are:—

(*a*) Extensive faulting,

(*b*) Doming of the sediments in the area,

(*c*) Form of the dolerite intrusion, and

(*d*) Form of the alkaline intrusion.

It is thought (Leaman and Naqvi, 1967) that the faulting and doming in this area may be related to the dolerite intrusion. All the major faults are shown in fig. 2. Nearly all faulting within the district can be shown to be pre-dolerite in age and to have been produced in a purely tensional environment. The faulting is probably related dynamically to the formation of the dome.

The dome can be best observed in the sedimentary block of the Cygnet Peninsula zone which is entirely surrounded by dolerite (fig. 2). It is asymmetrical, dips being steeper to the west. The general order of the dips is 10°.

Most dolerite occurs as large dyke-like masses. Evidence for sills exists in the NE. Smaller plug-like bodies also occur within the sedimentary block which forms the Cygnet Peninsula (e.g., fig. 9).

The alkaline rocks were emplaced in two ways: (1) as dykes, and (2) as an asymmetrical laccolith. The dykes are distributed throughout the Cygnet Peninsula and tend to have a radial distribution with respect to the point(s) of intrusion. The laccolith of syenite porphyry has been deeply eroded and only four outcrops remain. Each outcrop represents only the lower part of the original body. Thus the thin coatings of material on the western side of the mid-peninsula ridge represent the basal skin of the laccolith. The body of material west of Regatta Point rises from the base of the laccolith into the thickest part of the original body. The alkaline material in these bodies was intruded along the northern surface of a dolerite wedge beneath the centre of the peninsula (for details, see Leaman and Naqvi, 1967).

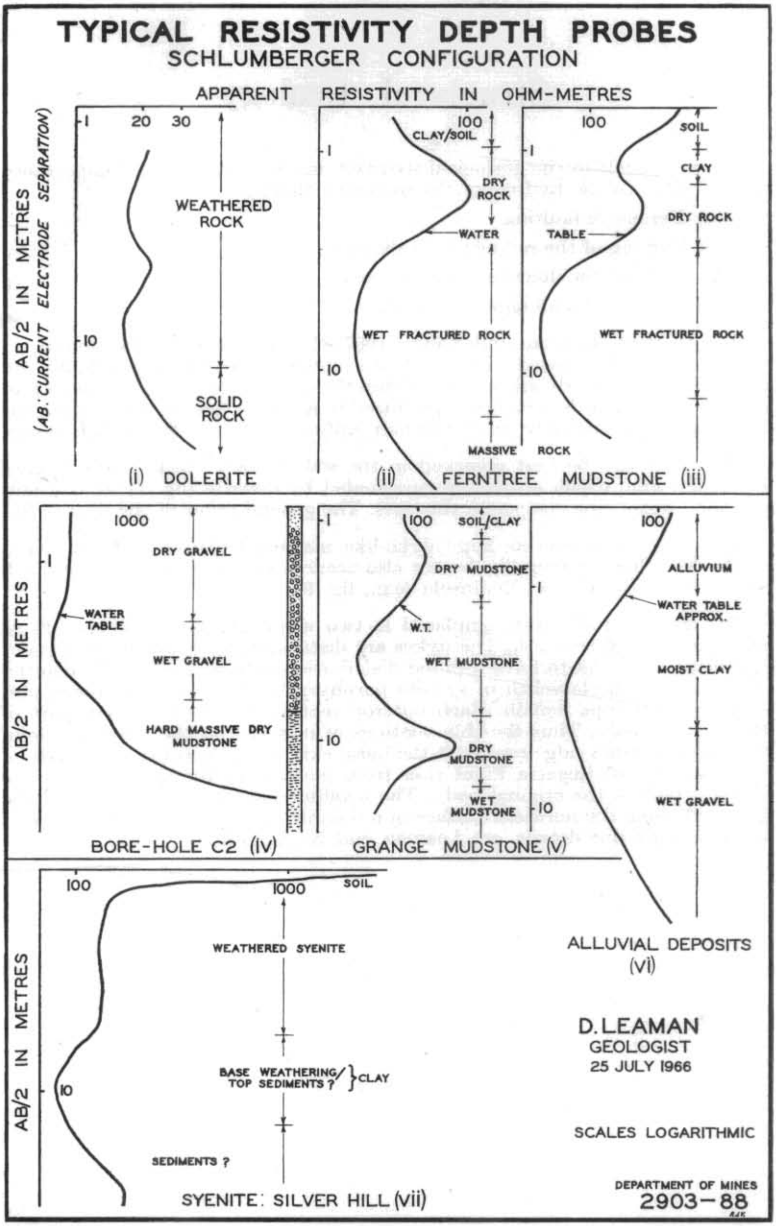
TYPICAL RESISTIVITY DEPTH PROBES
SCHLUMBERGER CONFIGURATION
APPARENT RESISTIVITY IN OHM-METRES
AB/2 IN METRES (AB: CURRENT ELECTRODE SEPARATION)
WEATHERED ROCK
SOLID ROCK
(i) DOLERITE
CLAY/SOIL
DRY ROCK
WATER
WET FRACTURED ROCK
MASSIVE ROCK
(ii) FERNTREE MUDSTONE (iii)
SOIL
CLAY
DRY ROCK
TABLE
WET FRACTURED ROCK
AB/2 IN METRES
DRY GRAVEL
WATER TABLE
WET GRAVEL
HARD MASSIVE DRY MUDSTONE
BORE-HOLE C2 (IV)
SOIL/CLAY
DRY MUDSTONE
W.T.
WET MUDSTONE
DRY MUDSTONE
WET MUDSTONE
GRANGE MUDSTONE (V)
ALLUVIUM
WATER TABLE APPROX.
MOIST CLAY
WET GRAVEL
ALLUVIAL DEPOSITS (vi)
AB/2 IN METRES
SOIL
WEATHERED SYENITE
BASE WEATHERING/ TOP SEDIMENTS ? } CLAY
SEDIMENTS ?
SYENITE: SILVER HILL (vii)
D. LEAMAN
GEOLOGIST
25 JULY 1966
SCALES LOGARITHMIC
DEPARTMENT OF MINES
2903—88

FIGURE 3.

General Hydrology

METHODS OF INVESTIGATION

Borehole Data

All borehole data, as provided from drillers' logs and yield tests, are given in the Appendix. Generally there are insufficient bores within the district to enable statistical conclusions to be made, but recent level measurements in the Cradoc Region, where numerous bores are available, has permitted a more complete analysis of the hydrological conditions there.

Geophysical Methods

Geophysical methods have not yet been used in the selection of bore sites. However, for the purposes of this study, the author undertook the experimental use of the electrical resistivity method to determine the locations of structural traps (including faults and dykes), the depth of weathering, depth of the water table and character of particular formations. The method was shown to be of great value and its use in other parts of this State is recommended. The depth probe method was used almost exclusively. The electrode line was kept, as far as possible, parallel to the strike of the formations to be investigated in order to eliminate the minor variations in resistivity near the electrodes and avoid unnecessary irregularities which may complicate curves, making interpretation difficult. The constant separation method was used in the Lymington Region to detect faults, dykes and conducting zones.

The Schlumberger configuration was used for all depth probes. The various aspects of the application and usefulness of the method are indicated where appropriate. Drill hole control on the method has been provided where possible.

The resistivity of a given formation may be exceedingly variable due to resistivity being a function of the following factors:

(i) porosity, or open space due to fracturing,
(ii) disposition of the pores or openings,
(iii) resistivity of the water contained in the formation,
(iv) degree of saturation, and
(v) resistivity of the mineral grains.

This last factor is of little significance if the rock is saturated, since the resistivity of a saturated formation is a linear function of its porosity and the resistivity of the water contained in its pores or other openings. The resistivity is only partly related to permeability since permeability is a function of porosity, grain arrangement and the size of the openings present. It is evident that the resistivity of any particular formation in an area varies according to its total porosity and indirectly as its permeability, and therein lies the diagnostic value of this method as regards the water-bearing properties of rocks.

Fig. 3 shows some typical resistivity depth probe curves obtained in this district. Each curve is discussed in the appropriate place. Fig. 4 shows a resistivity profile.

Field Observation

Detailed observations have been made on the nature and location of springs and seepages, the attitude, frequency and size of joints and other openings in formations within the area, and the relation of these features to the contained water.

5 cm

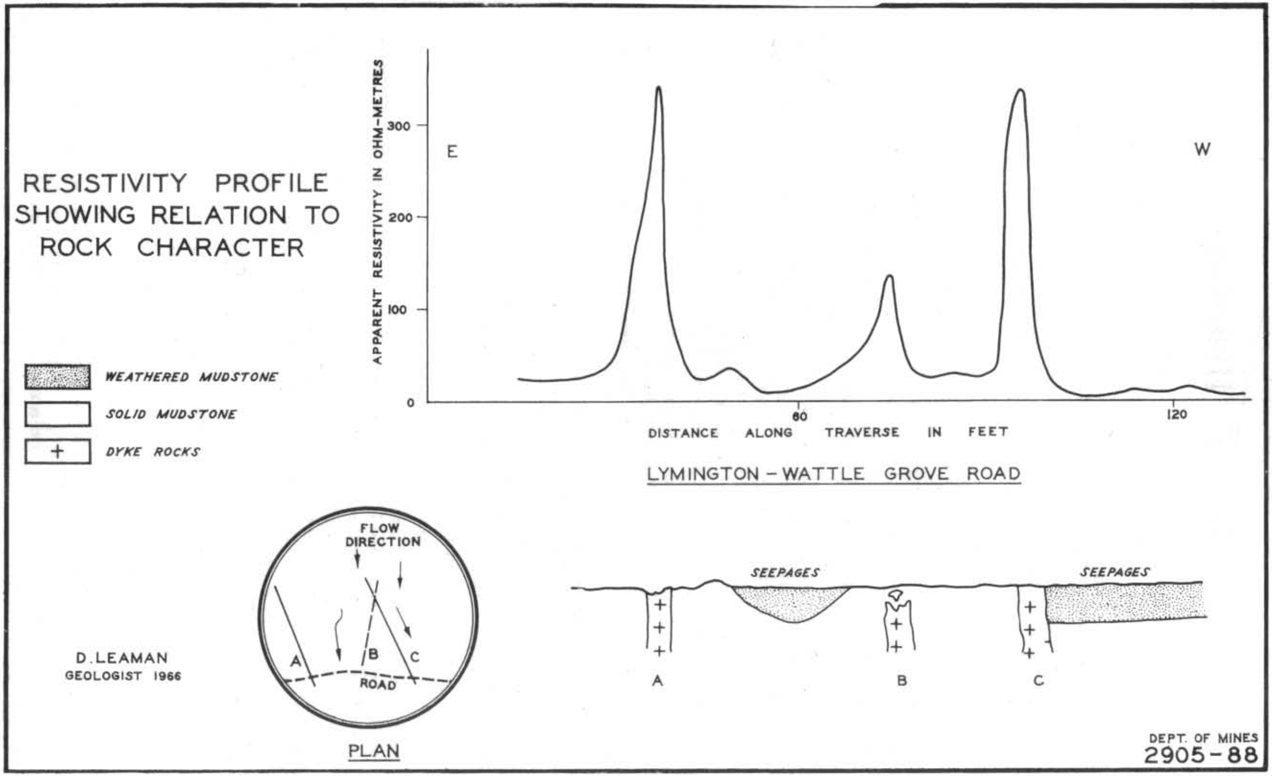
RESISTIVITY PROFILE SHOWING RELATION TO ROCK CHARACTER
APPARENT RESISTIVITY IN OHM-METRES
300
200
100
0
E
W
60
120
DISTANCE ALONG TRAVERSE IN FEET
LYMINGTON - WATTLE GROVE ROAD
WEATHERED MUDSTONE
SOLID MUDSTONE
DYKE ROCKS
FLOW DIRECTION
A
B
C
ROAD
PLAN
SEEPAGES
SEEPAGES
A
B
C
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FIGURE 4.

Observations were also made on water levels in wells, the effects of pumping—particularly for extended periods—and the quality of the water. Selected water samples were subsequently analysed.

HYDROLOGICAL PROPERTIES OF ROCK UNITS

The vacant spaces which groundwater may occupy within rocks are termed hydrological characters or properties of that rock. The more spaces there are, the greater will be the storage capacity of the rock; the better the interconnection, the higher the permeability and thus more ease of movement. It should be noted that as all water moves under the influence of gravity, all openings should be of such a size that molecular forces do not exceed gravitational forces; the limiting size for free motion is regarded as capillary because in sub-capillary openings water is held too tightly by molecular forces to move under the influence of gravity.

Nature and Origin of Hydrological Properties

PRIMARY HYDROLOGICAL PROPERTIES

The primary or syngenetic hydrological characters are inherent characteristics which are formed at the same time as the rock. Generally, primary hydrological properties are less important than secondary properties which are more numerous near the surface in the zone from which most groundwater is collected.

IGNEOUS ROCKS

Many kinds of interstices may be developed during the process of solidification. Most primary cavities in crystalline igneous rocks are developed as a result of gas content but, since the dolerite and alkaline rocks were apparently lacking in volatiles, no cavities of this type have been formed. The only type of primary interstices to be expected in rocks in this district are intercrystal and intracrystal spaces which give these rocks their porosity (0.5-1%). The resistivity of unaltered rock, which may also be regarded as a primary property, is of the order of 1,000-10,000 ohm-metres.

SEDIMENTARY ROCKS

The sedimentary rocks contain many more hydrological properties of primary origin than do the igneous rocks and may be divided into two groups, consolidated and unconsolidated.

Consolidated Rocks

These have a considerably higher porosity than the igneous rocks. Results are available for Triassic sandstone only (14-26%, Nye, 1921). It should be noted that a high porosity does not imply high specific yield, particularly in the case of the finer grained rocks since the grain size and atomic forces are such that water within pore spaces is strongly held.

It has been shown (van Wyk, 1963) that other primary structures such as bedding or planes of stratification and the contacts between layers of sandstone and shale may have very little effect on permeability. This is because no interstices necessarily exist in these zones in the technically unaffected state.

The resistivity of unaltered rock, a further primary property, is also useful since divergence from this state may be reflected in the value of resistivity for the rock. Only two results are given since it is believed that in most cases weathered rock was being measured: for the Grange Mudstone the value is 1000+ ohm-metres and for the Ferntree Formation, 2000+ ohm-metres.

Unconsolidated Rocks

These differ considerably from the consolidated rocks. Porosity is normally very much higher, therefore, cementing being absent, permeability is also high and these deposits freely yield any water they may contain. These comments apply only to sand and gravel, since clay deposits are little different from mudstone.

SECONDARY HYDROLOGICAL PROPERTIES

Secondary or epigenetic hydrological properties were formed at some stage after the formation of the rock. They are important because they control the occurrence, storage and movement of groundwater in most rocks of the district.

Secondary hydrological properties are developed as a result of the action of complex geological, physical, chemical, organic and climatic conditions that have affected the rocks after their formation. These properties may be developed in two stages: (1) Formation of openings by physical or geological processes, and (2) The modification of these and primary openings by the action of circulating water and weathering. The more important processes that have affected the hydrological properties of rocks are discussed below.

NEAR SURFACE PHENOMENA

Although the following processes are only operative near the surface and may have no direct influence on the yields of bores, they are nevertheless of great importance because they are responsible for the countless joints and fissures to be found near the surface, which not only accelerate weathering and soil formation, but affect the infiltration capacity of the rock below. These processes include elastic response, thermal changes, frost action and organic activity.

Elastic response results from the unloading of rocks by uplift and erosion. Low angle joints develop approximately parallel to the ground surface (Ellis, 1906; Hills, 1963) and are called sheeting. Such joints can be clearly seen in the syenite porphyry (Pl. 3). These joints are normally best developed in the igneous rocks, where their separation increases with depth. They are about one foot apart near the surface. The effect in sedimentary rocks, particularly the strongly laminated formations, is to cause partings along bedding where there is an abrupt change of rock character.

Thermal expansion during the day and contraction at night serves to disintegrate the rocks. This effect is particularly noticeable with reference to the igneous rocks.

Frost action is limited throughout most of the district. However, in the elevated points to the east it may be significant, especially in the igneous rocks.

Organic activity contributes greatly to the development of cavities, particularly the enlargement of pre-existing interstices. Tree roots may extend 50 feet below the surface in some localities, and worms, ants, small rodents and the like also contribute an incalculable amount to such development.

DEEP SEATED PHENOMENA

Hydrologically, the more important geological changes in the rocks of the area are faulting, jointing and igneous intrusion effects. These features are of more profound significance in that they persist to considerable depth and need not be confined to a zone near or above the water table. The storage capacity and ability of rocks to yield water is determined by the extent, pattern, size, openness, continuity and interconnection of the openings produced. Such openings may be modified by weathering.

Jointing

All consolidated rocks within the district are broken by joints, undoubtedly the most important and most abundant of all the hydrological interstices that such a rock can contain. Joints may be associated with faulting, igneous intrusion or epeirogeny. While joints of the first two types do exist and are of local importance, they are of far less overall importance than joints produced as a result of epeirogeny. All bores at present obtaining water in this district receive their supplies from joints, either one or two in 60 feet of bore below the water table.

Faulting

Faults within this district are principally Jurassic in age and may be related to the intrusion of the dolerite. Faults may influence groundwater occurrence in three ways. Firstly, they affect the distribution and position of aquifers; secondly, they may act as underground dams; thirdly, they act as conduits to flow.

Whether faults act as dams or conduits depends on the character of the faulted rock. Dams may be developed if an impermeable bed is faulted against an aquifer, or if decomposition in the fault zone produces clay minerals which effectively seal off the rocks along the fault zone. If the faulted rocks are brittle and the weathering products do not include large amounts of clay, the fault zone may remain open enabling it to transfer large quantities of water. The term fault zone refers to the actual zone of breakage as well as the zone about this in which joints resulting from the faulting are developed. There are commonly large numbers of small joints associated with faults in competent rocks.

Most of the formations in this area tend to seal off by weathering the fracture system associated with faults. Notable exceptions are the Malbina Formation and the Ferntree Formation. Two bores, C7 and C8, have been placed near a fault zone. It should be noted that drilling in such a zone increases the chance of success but does not mean that the yield will be abnormal.

Dolerite Intrusion

The effect of dolerite intrusion on the sedimentary rocks of this area is generally minimal. As a result of intrusion the rocks in the contact zone are hornfelsed, producing chert and quartzite. In all cases there is a hardening effect. As a result of this thermal metamorphism the porosity of the sediments is decreased, but the permeability of the rocks may be increased due to the development of many joints in the contact zone. This is equally true of the chilled margin of the dolerite (Pl. 7). There is usually negligible crushing, tilting or other disruption of the rocks near the contact.

Van Wyk (1963) showed that most successful bores in the Karroo rocks of South Africa are placed in the contact zone of dolerite intrusions. This amply supports the above observation. Bores placed to strike contact zones should aim to strike this zone 15-30 feet below the water table. If the hole is too shallow, it may fail by not striking sufficient water-bearing fractures, or if too deep by the closure of joints with depth.

It should be noted that the contact zone, even of large dolerite masses, is quite narrow. The actual width of the contact zone depends on the thermal susceptibility of the intruded formation and its position relative to the dolerite intrusion. Rocks with high calcium content, e.g., Grange Mudstone, are particularly affected and the contact zone may be more than 20 feet wide. Rocks situated toward the roof of an intrusive body are more likely to be affected than those on the sides.

Two sets of tension joints may be developed in the dolerite and adjoining contact zone during cooling, i.e., columnar joints perpendicular to the contact and planar joints parallel to it. These joints are more closely spaced near the contact, where they are very numerous, very fine and closely interwoven. Only a small proportion are capillary or super-capillary. The columnar joints are best developed in the dolerite, and the planar in the baked sedimentary rock, although both types of joint may occur on either side of the contact zone. The effects of weathering and circulating water are most important in making these joints of hydrological value. Plate 7 shows the nature of the joints in a dolerite contact zone.

Alkaline Intrusion

The metamorphic effects of this intrusion are less important than those of the dolerite intrusion. The amount of baking associated with the laccolith and dykes is normally slight. Only in two localities, on the east side of Port Cygnet opposite Regatta Point and in the valley of Forsters Rivulet between Mt Mary and Mt Windsor, is the baking pronounced. In these localities the rock intruded is tillite and the metamorphism is such that the included pebbles show reaction haloes. This metamorphism is probably due to the concentration of superheated fluids at the time of intrusion. Elsewhere, occasional dykes may affect the sediments extensively, as at the Lymington Jetty. Plate 8 shows the metamorphic effect of a sanidine tinguaite dyke on Grange Mudstone. It is quite common to find no chilled margin to dykes or any joints induced by the chilling effect as is clearly seen in Plate 8. The effect of intrusion of alkaline dyke rocks into dolerite is negligible.

EFFECTS OF WEATHERING AND CIRCULATING WATER

Weathering is the second stage in the development of secondary hydrological properties. It is a selective and self-intensifying process, and as a result of its action water is able to circulate more freely.

Weathering begins by incipient alteration along joints and gradually proceeds to rot the rock between them. If there is a high density of joints in any particular locality, basins of decomposition may develop. These features are the most important source of groundwater in igneous rocks (Enslin, 1943; van Wyk, 1963). In rocks less susceptible to weathering, i.e., most sedimentary rocks, or where the joints are further apart, the process is usually confined to alteration along joints. There are many variations between these extremes. The Grange Mudstone is one of the most susceptible formations to circulating water.

Depth of Weathering

Little information is available on this matter within the district. Normally, weathering extends to the water table and we may expect to find its effects to the depth of the lowest level of the water table. It should be realized that groundwater circulation, which assists alteration, may extend to considerable depths in many formations or rock zones of high permeability such as master joints or fractures. This is deemed unlikely here from a review of the temperature of the water.

Resistivity soundings in dolerite, of which that shown in fig. 3 is typical, indicate a maximum depth of weathering of 50 feet. This figure is most closely approached in the dolerite between Glaziers Bay and Wattle Grove. The depth of weathering in the dolerite near Gardners Bay is up to 30 feet. In these instances weathering may extend 15-20 feet below the present water table. This depth of weathering is only achieved in favourable conditions—many joints with access to circulating waters—and many resistant zones, with depth of weathering less than 3 feet, may occur between these basins of decomposition.

Little is known about the sedimentary rocks, but certainly no basins of decomposition of the magnitude described for the dolerite are present. The maximum depth of weathering is usually about 15 feet. Small basins of decomposition were detected in Grange Mudstone using resistivity methods (fig. 4) but were not deep enough to be of hydrological significance. Most weathering in sedimentary rocks is confined to the immediate vicinity of any openings.

Lateral Extent of Weathering

Besides proceeding vertically, weathering also acts laterally, particularly along any zones accessible or susceptible to the processes of weathering. Near the surface the result is a continuous mantle of decomposed rock and soil. At depth, groundwater conditions may limit the extent of weathering.

In the case of igneous rocks, basins of decomposition are developed. Contact zones of dykes may be susceptible to weathering with the result that a linear belt of decomposed material is developed; alternatively the sediment beside the dyke may be more decomposed (Pl. 8) due to increased circulation caused by damming. This is well shown in fig. 4. The section faces southward toward the source of water. Water from the west of the section is impounded by dyke C and forced to travel in the sedimentary rock beside it. The result is a belt of deeply weathered mudstone, which is indicated by the very low resistivity and lack of outcrop. Unweathered mudstone, such as near dyke A where there is an outcrop, has a considerably higher resistivity. The drop in resistivity between dykes A and B indicates a smaller basin of decomposition. Seepages were observed in both zones classed as deeply weathered on the basis of the resistivity results. The distance between dykes A and B increases up slope and that between dykes B and C decreases up slope. This means that dykes B and C intersect near the section and as a result the sedimentary rock between them does not pass water from upslope as does that between dykes A and B which act as a funnel. While dykes A and C outcrop strongly at the surface, dyke B does not and could only be detected by resistivity. Dyke B is a rare case in which the dyke rock is more deeply weathered than the intruded rock, and it may itself act as a conduit to water if weathered deeply enough.

Effects of Weathering on Hydrological Properties

Weathering may increase the porosity, specific yield and permeability of a formation to such an extent that it may be an excellent supplier, whereas in its unaltered state it was unproductive.

The joints, fractures, partings and other interstices, possible or existent, which a rock contains in a closed or disconnected state are usually opened by weathering. This increases the porosity of the rock, whether igneous or sedimentary. The extreme condition is the resultant soil. The more openings that are developed, the more likelihood of their being connected. If they are open and connected, the rock will be a potential water bearer and, if the interstices are capillary or larger, a supplier.

However, should the weathering be extreme, in which case the texture of the rock is destroyed, then although water is present the rock may be incapable of yielding it.

The weathering of rocks, because it increases the porosity and interconnection of interstices, increases the storage capacity of the rocks. This is a most important aspect of the hydrology of consolidated rocks since pumping may deplete the storage of a fracture system due to the extremely rapid flow of water through the rock. For optimum satisfaction of a bore, there should be an hydraulic connection between a lake or stream, or unconsolidated material which lies below the water table.

Water-bearing characteristics of rock units

PERMIAN SYSTEM

TILLITE

The porosity of the formation is small, with most pore spaces and cavities to be found adjacent to the pebbles where, subsequent to consolidation, there has been some movement and gaps have resulted. These pores are not interconnected. Three bores have been placed in this formation, all successful. It is therefore concluded that all recoverable water must occur in joints and fractures, although these are limited in number (Pl. 6). Differential slippage along the bedding planes between pebbly or non-pebbly, hard or soft mudstone has also resulted in production of aquiferous zones. Bore CG2 taps such a supply. Spacing between individual joints varies from a few inches to many feet, with horizontal or low angle joints being more abundant than near vertical joints (Pl. 6). The effect of weathering or circulating water on this rock is firstly to produce crumbly or friable zones and finally clay. In the early stages of this process the openings produced may be of much hydrological value. Part of such a friable zone can be seen in Plate 6. The yield of bores in this formation is 250-450 g.p.h.

QUAMBY MUDSTONE

The water in this formation is contained in joints, fractures and friable weathered zones. Bore CG1 probably ends in this formation and possibly collects some of its water from it.

BUNDELLA MUDSTONE

Many zones within this formation form excellent porosity aquifers. These are the coarse, sandy beds which are often very fossiliferous and poorly cemented and occur toward the base of the formation. Most of the formation is, however, fine grained, massive and impermeable with the result that it is only aquiferous if fractured. In those parts where fossils are present and layered, the porosity is greatly increased by removal of the actual fossil after consolidation leaving the space it occupied. The porosity of such zones may exceed 40%. Permeability in these zones may also be very high. Water in these 'fossil beds' is essentially confined due to the relatively low permeability between aquiferous bands as compared with that along the bed. Two bores (CG1 and WG2) have been drilled in this formation. It is doubtful whether any water enters CG1 from this formation; more probably it enters at the interface of this mudstone with the Quamby Mudstone and also from the latter.

FAULKNER GROUP

Again, the rocks of this group depend mainly on fractures to transfer water from place to place, although porous zones certainly exist if fossils have been present, as at Tobys Hill, or if well sorted friable sandstone is present, as at Balfes Hill, where removal of cement from the lower beds has increased the porosity. The mudstone members of this group are to be avoided in siting wells since they lack features such as joints or bedding partings. The sandy and silty members, which are petrologically similar to the Ferntree Formation, are more highly fractured. These sandy members, as distinct from the well sorted sandstone mentioned above, often contain many pebbles and much silty material. One bore has been drilled in this formation (C6) with a yield of 250 g.p.h.

GRANGE MUDSTONE

This formation is an excellent aquifer. It is very permeable due to moderate fracturing and the presence of marked porous bands, the fossil zones and distinct bedding partings. The rock between solid beds is often very fissile, one inch to six inches thick and rich in interstices. As a result of these fissile bands and fossil spaces this formation has excellent storage possibilities—better than any other Permian formation. Plate 9 shows some fossil bands, a poorly developed fissile band, some horizontal joints and two near vertical joints. Vertical features such as these are of vital importance to a rock dominated by its horizontal permeability. They feed water from the surface to the water-bearing bands and also enable transfer of water between bands, a very important property with respect to long term pumping. Upon weathering, this formation normally reduces to clay, and should not be drilled in this state.

Eight bores have been completed in this formation; all were successful, with yields of 250-350 g.p.h. Two other bores were begun in this formation, but drilling ceased upon striking dolerite.

Due to high horizontal transmissibility of this rock best results are to be expected where the dip of the rock and slope of the land surface are such that water does not readily escape. For example, south of Lymington the holes are deep due to water level being low because steep slopes and dip permit ready drainage toward Port Cygnet. It should be noted also that the quality of this formation's water is rarely good.

MALBINA FORMATION

Except for Member A, the water-bearing properties of this formation are essentially similar to those of the Ferntree Formation. The basal sandstone may be porous if no redeposition on the grains has occurred. It should not be drilled especially, unless it is below the water table and water can be supplied and retained. This formation has not yet been drilled.

FERNTREE FORMATION

This formation is the best aquifer. All water is contained in fractures or bedding planes; the latter are most marked and aquiferous with the more competent fractured bands being less permeable. Water may be confined in these fissile bedding zones if the more massive beds are poorly fractured. The two distinct types of bed are clearly shown in Plate 11. The conglomerate bands tend to be more massive than either the silty or sandy material of which the bulk of the formation is composed. Due to its competence this formation is normally well endowed with fractures, both horizontal and vertical.

The yield of wells is normally in the range 200-500 g.p.h. averaging 350 g.p.h. The highest yielding wells in the district are in this formation. The yield is not directly influenced by the depth of wells, but rather by the condition of the rock, which may be indicated by the resistivity value. Most resistivity work has been undertaken on this mudstone, in the Cradoc Region, and some conclusions are possible.

In a probe at the site of C2, which failed, the resistivity of the mudstone is very high, 5,000 ohm-m (fig. 3 [iv]). Other probes in the area, taken in the vicinity of successful bores and elsewhere, have curves of the form of (ii) and (iii) in fig. 3. The resistivity in these cases is 100 ohm-m. The low resistivity reflects the presence of water and considerable fracturing.

Thirteen bores have been drilled in this formation, of which three were failures. The quality of the water is fair to excellent.

CYGNET COAL MEASURES

The carbonaceous siltstone is not of sufficient thickness within this district to be of significance. However, if suitably fractured it could be water-bearing.

TRIASSIC SYSTEM

Water may be contained in primary pore spaces, or in secondary openings such as bedding partings, joints, fractures or secondary pore spaces, i.e., where the cement has been removed. The secondary openings, such as bedding partings, are the more important.

It has been noted that water often issues from bedding planes or fractures and it is not unusual to find the rock between dry due to complete cementation or crystal regrowth. The factor of cementation is exceedingly variable. Fractures are scarce, at least 4-5 feet apart.

Due to the thickness of the beds and general paucity of fracturing in all sandstone within the district, it is recommended that any future bores be placed in areas of low resistivity in order to ensure the greatest possible chance of success. Low resistivity implies less cement and/or regrowth and high water content. The massive character of the normal sandstone is contrasted with the feldspathic sandstone at the base where the beds are thinner, often less than 6 inches apart (Pl. 10).

Where water has been allowed to pass freely through the sandstone, particularly that containing some feldspar, soapy compounds from the decomposition of the rock may completely block all passages. No water can be obtained from rock in this state.

No bores have been drilled in the Triassic rocks of this district.

JURASSIC SYSTEM

Most of the dolerite within the area occurs in a fractured state with a very thin weathering and soil cover. In the low-lying areas, for example Glaziers Bay, Wattle Grove and Gardners Bay, the dolerite may be extensively weathered to depths of up to 50 feet. Since the porosity of unweathered dolerite is less than 1%, all water is contained in the fractures and joints. Weathering increases the pore space and permeability. This is only true if the product is a sandy or gravelly material maintaining the original doleritic texture. If the weathering has been extreme, clay results. Layers of clay may have two effects. Firstly they prevent water reaching the underlying rock, thereby affecting its storage, and secondly they do not permit transfer or yield of water.

A comparison of Plates 12 and 13 will demonstrate the increased porosity after partial weathering.

Following weathering many of the fractures may be filled with chloritic or calcareous material. Only if the filling is calcite will the fissures be sealed.

Dolerite in a fractured state has been observed to be an extremely permeable rock. In bores at Glaziers Bay where up to 60 feet of Grange Mudstone was passed through before striking dolerite, no water was found, nor was water found in the dolerite contact zone, of which 5-6 feet was drilled. Such contact zones, particularly those with Grange Mudstone, are highly fractured and commonly aquiferous. That both the Grange Mudstone and the contact zone are dry at depth implies that the dolerite is conducting all water fed to it directly to the Huon River, and that as a result of high permeability the water table is quite flat. These bores were therefore not drilled deep enough to strike water. In the Woodstock Region the dolerite can be demonstrated to be more permeable than Triassic sandstone. Permeability is increased upon weathering.

When drilling difficulties can be overcome it will be found that the dolerite is as reliable an aquifer as the Ferntree Formation. Fractures exist in all directions and are never more than 3 feet apart.

CRETACEOUS SYSTEM

Dyke rocks will not be considered in detail, save to mention their effect as dams. Normally these rocks lack fractures and are of insufficient size to act as aquifers, even upon weathering.

All water contained in the banatite (syenite porphyry) is held in fractures. Although the rock is subject to deep weathering effects, no thick weathering deposits or soils have resulted, due to steep slopes. The change from soil to rock, even though weathered, is very abrupt. There is thus no possibility of storage in basins of decomposition. It has been noted, however, that in the few localities where the rock is closely jointed weathering is advanced and has resulted in a silty material composed principally of clay without hydrated iron compounds. Plate 4 shows the nature of both jointed and completely weathered banatite. Partially weathered rock only suffers surface effects and is no more permeable than the fresh fractured rock.

Jointing is generally irregular, but no blocks larger than 10 x 5 x 5 feet occur. The joints also lack continuity (compare Pl. 4, syenite, with Pl. 12 dolerite). At the surface some joints have half inch openings, but the size of the opening decreases rapidly with depth, often being capillary to sub-capillary at less than five feet below the soil horizon. Near the surface, sheet joints are common (Pl. 3).

This rock offers fewer prospects for successful wells than the dolerite, unless in a suitable topographic location; however, most outcrops occur on spurs or steep slopes and consequently would be drained of any water.

TERTIARY PERIOD

The Tertiary conglomerate is hard and of limited extent and in each locality is drained of water due to its position relative to Port Cygnet.

QUATERNARY PERIOD

PLEISTOCENE GRAVELS

The gravels are generally extremely porous and very permeable. However, as a result of the location of the deposits on hillsides, except at Cradoc and Randalls Bay, they are drained rapidly. Water when present is unconfined, and good supplies could be anticipated in the low-lying deposits if they are of sufficient thickness to store water below the water table.

The clay bands, where present, may result in confined conditions and, if near the surface, may also prevent water reaching the main body of material. This is the case at the northern end of the Beaupre Point deposit.

RECENT ALLUVIAL DEPOSITS

The deposits of alluvium normally lie above the water table but if thick enough in an area of high water table could contain much water by virtue of their high porosity.

Underlying the alluvium in most cases are river gravels. Drilling in these deposits affords the greatest possible chance of success with very high yields within the area.

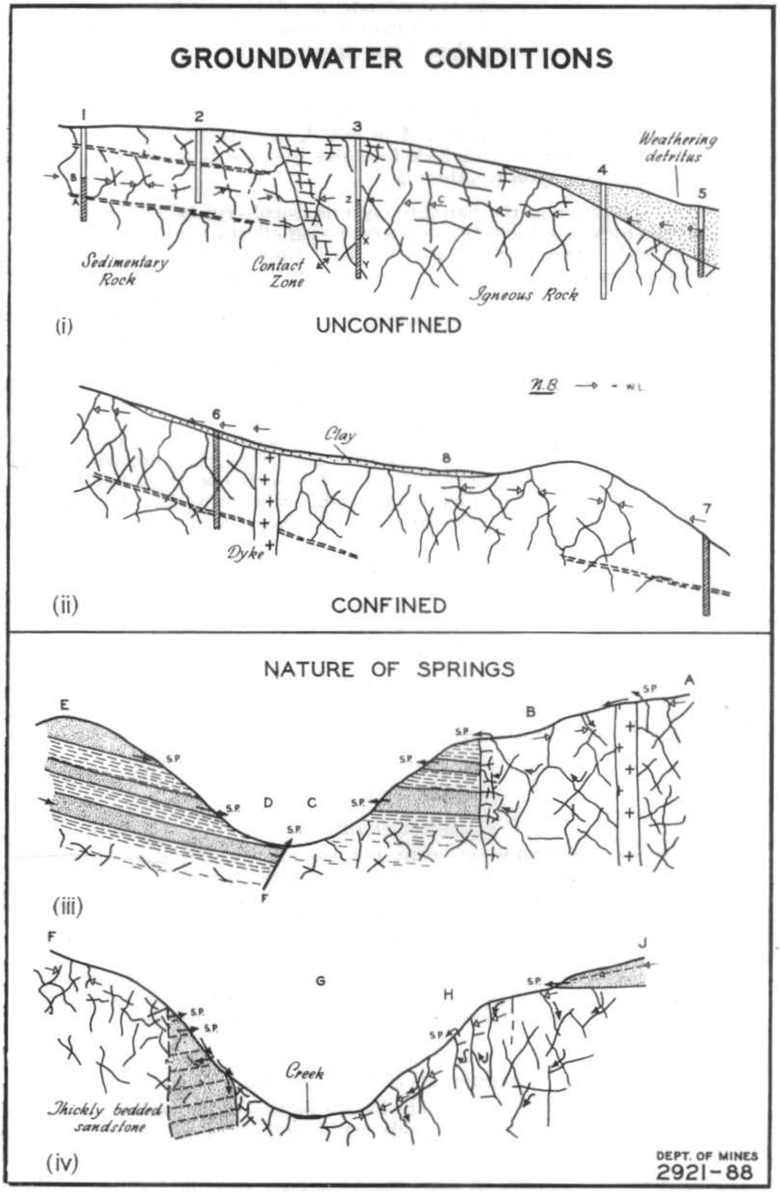

GROUNDWATER CONDITIONS
1
2
3
4
5
B
A
Z
X
Y
C
Weathering detritus
Sedimentary Rock
Contact Zone
Igneous Rock
(i)
UNCONFINED
N.B. → - W.L.
6
Clay
8
7
Dyke
(ii)
CONFINED
NATURE OF SPRINGS
E
B
A
S.P.
D
C
F
(iii)
F
G
H
J
Creek
Thickly bedded sandstone
(iv)
DEPT. OF MINES
2921-88

FIGURE 5.

5 cm

WATER LEVEL AND WATER TABLE CONDITIONS

General Considerations

The definition of a water table as "the surface within a groundwater body at which the hydrostatic pressure is equal to atmospheric pressure" (Jones, 1965) applies to fracture aquifers as well as to porous soils or rocks.

According to this definition a water table exists in all rocks within the area. However, for most rocks it is confined to the secondary openings and is interrupted by the fresh rock between them (fig. 5 [i]). Where the rocks are deeply weathered, or very minutely fractured, an uninterrupted water table may be present, as in porosity aquifers. In such cases the water table lies in the mantle of decomposed material and is interrupted only by solid rock in places where weathering has not proceeded to a depth below the water table (fig. 5 [i]).

The water table in relation to water levels observed in bores

All bores drilled within the district have been placed in the consolidated rocks. In most cases the results suggest that the holes tapped confined water. This is indicated by the fact that holes remain dry until at some depth a water-bearing fissure or zone is intersected. Water then enters the hole and rises within the hole. In some cases this has resulted in a flowing bore. The mechanism is clearly shown in fig. 5 (i), bores 1 and 3. Bore 1 strikes an aquiferous fracture at A, but since A is some distance below the water table the water contained in the fracture at A is under a pressure equal to the head AB of water. The water therefore rises in the bore until its upper surface approximates the level of water in the fractures, i.e., the water table. Friction losses may prevent a full rise. Similarly bore 3 strikes water at X and Y, which rises to the level of Z, the position the water table would have occupied in fractures at that point, had they been present.

The water levels observed in most bores are thus really piezometric surfaces and not a true water table. However, in the majority of cases the water level in bores coincides with the general 'water table' in the secondary openings. Further, as a result of a high degree of interconnection, most areas do not have individual water tables in each joint or joint system and there is an apparent continuity of the water table over large areas.

Since the total volume of openings is small, the total volume of water stored in an individual joint system would also be small. Consequently, if there were no hydraulic connection with other systems over a large area then bores would not be able to yield up to 250 g.p.h. for several months. This does not apply to every bore in the district since some do not have performance of this type.

The confined water conditions observed are the result of the heterogeneous permeabilities of the strata and thus reflect the impervious nature of the enclosing beds.

Flowing bores are not common and are dependent upon build up of pressure. This is not normally the case since infiltrating water is usually dissipated laterally in the aquifer and vertically into the confining beds. Where vertical dissipation is not possible, artesian pressures may be built up (fig. 5 [ii]). The term 'confining beds', as used above, refers to rock which is slightly permeable due to the presence of small joints and fissures, some of which are interconnected. A true confining bed, or aquifuge, does not contain these features.

If the 'confining beds' are relatively permeable, all excess water will be forced into them and thus the head in the aquifer will be lowered gradually until it stands at the same level as the water table in the confining beds. This is the normal condition within the area.

The configuration of the water table is generally a subdued replica of the surface topography.

The level in bores is near surface close to springs, streams or marshes. Such water table features dry up in the summer when the level in the bores also falls.

Resistivity probes in various parts of the district, using bore control, have shown these observations to be true. The water level in bores will thus be regarded as the water table unless otherwise stated.

CONDITIONS IN SEDIMENTARY ROCKS

Conditions in these rocks are usually complicated due to a combination of confined and water table characters. The depth to water table varies throughout the area, being 5-10 feet in the flatter areas and more than 50 feet in some of the hilly regions. There may be local irregularities in level induced by faults, dykes and increased infiltration.

CONDITIONS IN IGNEOUS ROCKS

Water table conditions in these rocks are essentially similar to those in sedimentary rocks, and there is no detectable difference between levels in sedimentary and igneous rocks in the same topographical situation. The water table in weathering detritus in the west of the area is more normal and less interrupted.

Fluctuations of water level

There are no quantitive measurements available to show the fluctuations in water level. However, changes occur due to recharge, pumping, tides and atmospheric pressure. Fluctuations are much more pronounced in consolidated rocks since these are of lower permeability and storage capacity.

Recharge causes a rise in level over a large area. The change may be immediate or delayed, depending on the efficiency of the hydraulic system within the rocks.

Changes due to pumping are usually the most significant. During pumping, the water level in the hole is normally lowered. If the pumping rate exceeds the rate of replenishment for a long period the groundwater supply may be depleted. The time for depletion may be short depending upon the extent of the fracture system and its capacity for transferring water. In coastal regions, where fresh water rests on salt water, the effects of pumping may be very serious. Removal of the fresher water causes the level of the more saline water to rise. If care is not taken salt water will be pumped.

Tidal changes may exaggerate the situation described above by periodically raising and lowering the salt water interface.

Fluctuations due to atmospheric pressure changes are normally slight and most noticeable in bores tapping true artesian aquifers.

Drying-up of Bores

Overpumping, or lack of replenishment during a dry season may cause considerable lowering of the water table. The effects of transpiration cannot be neglected in this context. If a bore has not been drilled deep enough to maintain a free water surface within it during such a period, then the bore will dry up. Bores should thus be drilled 10-20 feet below the water level at the time of drilling, in order to have a reasonable safety factor. As a further protection, no one area should be laden with so many bores that the water level is continually falling. No part of the Cygnet District is in this condition at the present time.

Causes of Variations in Yield of Bores

The yield of bores is a function of the following factors:

(i) Nature of rock type,
(ii) Condition of rock and nature of weathering,
(iii) Nature of catchment,
(iv) Effects of faults and dykes,
(v) Rainfall,
(vi) Nature of vegetation,
(vii) Nature of soil.

Rock type is a factor of little consequence in this district since all bores are placed in fractured consolidated rocks. All yields are thus of the same order, but the more competent the rock, and the more fractures it contains, the better the aquifer, e.g., Ferntree Formation. Alternatively, if it contains many more interconnected openings of other types it will again have excellent yield characteristics, e.g., Grange Mudstone which is also affected considerably by factors (ii) and (vii). Unconsolidated rocks offer the best yield possibilities.

Rock in a fractured state may be a reasonable aquifer, but the same rock in the early stages of weathering may be a much better aquifer (vanWyk, 1963). In this district water is obtained from rocks which are in a relatively unaffected state. If the weathering is degenerate and clay is produced in quantity no drilling should be undertaken. Layers of clay in the weathering profile may hinder infiltration, and thus indirectly affect yield from the rock.

The nature of the catchment will determine the amount of water stored in the rock, and thus place a limit on the yielding capacity of the rock. For example, bore C6, which is situated near what could be expected to be a well fractured and clean fault zone yields only 250 g.p.h. The low yield, compared to other wells in the same area, is probably due to limited catchment since the site is high on Balfes Hill.

The effects of faults and dykes may be twofold. Such features may act as dams, in which case bores placed upflow will have better yields than those on the 'dry' side. Alternatively, the zone of these features may conduct large quantities of water, and to drill them might well lead to exceptional yields. Similar comments apply to other igneous contacts.

Rainfall, nature of vegetation and nature of soil are commonly related. Vegetation and soil character affect run-off, infiltration and evaporation, and thus indirectly the capacity of the rock to yield water. Rainfall is considered to be important only with respect to the changes induced in the rock (van Wyk, 1963, p. 67).

In conclusion, it may be said that yield from a well depends upon that well passing through secondary water-bearing features. The more there are, and the larger they are, the higher the yield. If then the catchment is good or the infiltration high, more of the rock will be aquiferous because the water level will be higher. Thus in a bore of given length, the yield will be greater. Of course, if the bore strikes no aquiferous fissures it must fail (fig. 5 [i]).

GROUNDWATER TEMPERATURES

Temperature measurements, all within the range 50°-55°F which approximates the mean annual air temperature, were made of water from several bores. All measurements were made after the bore had been pumped for a short time. No warm or hot waters have been reported from this district. These facts would imply that all water here is meteoric in origin and that there is no circulation of the water to any great depth.

CHEMICAL QUALITY OF THE GROUNDWATER

The suitability of groundwater for its various uses depends to a large extent on its chemical quality. As part of the investigation, representative samples have been collected and analysed. Analyses are presented in Table 4.

Expression of Data

The concentrations of dissolved constituents in the water are given as parts per million by weight (p.p.m.), and equivalents per million (e.p.m.). One e.p.m. of a cation will react with one e.p.m. of an anion. Since the charges are balanced in solution, the total of the equivalents per million of the predominant cations (calcium, magnesium and sodium) is approximately equal to the total of the equivalents per million of the predominant anions (bicarbonate, chloride and sulphate).

Parts per million may be converted to equivalents per million by multiplication with the appropriate factor (Table 3).

TABLE 3: Conversion Factors, p.p.m.-e.p.m.

Ion	*Factor*	*Ion*	*Factor*
Calcium ..	.. 0.0499	Bicarbonate ..	.. 0.0164
Magnesium ..	.. 0.0822	Sulphate ..	.. 0.0208
Sodium ..	.. 0.0435	Chloride ..	.. 0.0282

The results have also been expressed as an assumed composition, and percentage salt content (Table 5).

Source of Chemical Constituents

The principal solutes in natural water are calcium, magnesium, sodium, chloride, sulphate, and bicarbonate. Silica, iron, aluminium, potassium, fluoride, nitrate and boron are normally present in small amounts. The last four have not been determined by analysis. The amount and type of chemical constituent present depend on the past history of the water.

There is reason to believe that the source of water, in all but one case, is meteoric and that there has been no contamination from other sources. This is suggested from the very low SO_4/Cl ratio in each case, the relatively low total salt content and the normal thermal state. Low sulphate content and low temperature imply no contamination by juvenile waters and low sulphate and total content imply no admixture of connate or present day sea water. In only one bore (L3), analysis 6, has sea water contamination occurred. In all other cases the chemical content of the water has been derived from the rocks in which it has been stored, or through which it has passed.

The greater the extent of contact of the water with the rock, either as a function of exposed surface area, or duration of contact, the more mineralized the water becomes. For example, it is not unusual for water from shale or mudstone to be more saline than that from sandstone or gravel of similar composition simply because the finer grained rocks expose a greater area for reaction with the water. The duration of contact is normally determined by the gradient on the water table in the area.

All groundwater in this district has been derived from rain and snow. Such water initially contains little dissolved matter, mainly carbon dioxide.

Water in this state is, however, a potent weathering agent, being able to effect decomposition of most minerals contained in rocks. The processes of weathering may be listed as carbonation, solution, oxidation, reduction, hydrolysis and ion exchange. Carbonation and solution are of negligible importance here. Oxidation has been active on the iron sulphides associated with some of the dyke rocks, resulting in iron sulphate. The most important processes, with respect to the highly siliceous sedimentary rocks, are hydrolysis and ion exchange. Ion exchange will be discussed more adequately in a later section.

Chemical Characteristics of the Water

The chemical characteristics of the water can be described only in a general way because only a small number of samples were obtained for analysis. The chemical characteristics of water from aquifers in the district may best be seen in Table 5, which shows the assumed composition of the water. Unfortunately, not all formations have been drilled and most of the analytical information shown is derived from the tillite and the Grange Mudstone. Tests on water from the Ferntree Formation have been restricted mainly to those on conductivity. Commonly the water is of sodium chloride type, with subsidiary bicarbonate, but the sodium bicarbonate type is represented.

TABLE 4: Analyses of Selected Bore Waters

Analyses in parts per million (p.p.m.)

Analysis	1	2	3	4	5	6	7
Bore No.	CG4	CG2	CG1	L2	L1	L3	C1
Total dissolved solids	685.8	1,656.0	589	1,892.0	868.8	3,626.0	498.8
$Fe_2O_3+Al_2O_3$	7.0	10.8	0.8	1.0	20.2	55.2	1.4
SiO_2	26.2	26.8	26.2	18.1	19.2	40.0	31.4
Ca	25.1	17.8	10.7	2.7	4.7	42.9	27.8
Mg	19.3	62.4	0.5	41.0	18.0	142.8	9.3
Na	198.1	508.8	187.8	631.0	288.8	950.0	137.6
K	nd	nd	nd	nd	nd	nd	nd
Cl	230.0	714.0	110.0	773.0	387.8	1,596.0	159.5
SO_4	4.8	9.6	10.1	30.5	7.0	535.0	24.0
HCO_3	294.0	487.1	326.6	522.8	210.1	nil	191.7
CO_3	nil	nil	nil	nil	nil	nil	nil
Hardness as $CaCO_3$ (p.p.m.)							
Ca, Mg	141.9	301.2	28.6	175.2	85.8	nd	107.9
pH	7.2	6.4	6.9	6.6	6.3	3.4	7.0
Total ions calculated	773.9	1,799.3	695.5	1,978.9	904.5	nd	545.0
Percent Na	75.0	78.4	93.6	91.7	87.8	74.7	73.8
Na absorption ratio	7.2	12.7	48.0	20.6	13.4	49.6	5.7
Total e.p.m.	11.5	28.2	9.3	30.9	14.2	55.3	8.1

Analyses CG4, CG2, CG1, L1, L2 and C1 by D. Leaman.

Analysis L3, Analyst, Department of Mines Laboratory.

TABLE 5: Assumed Composition of Selected Bore Waters

Concentration in parts per million (p.p.m.)

Analysis ..	1	2	3	4	5	6	7
Bore No. ..	CG4	CG2	CG1	L2	L1	L3	C1
$NaCl$ ..	379.7	1,175.0	181.1	1,257.0	622.5	2,336.0	263.0
Na_2SO_4 ..	7.1	14.2	14.9	45.4	10.6	..	30.5
$NaHCO_3$ ..	169.5	158.6	455.5	416.2	142.6	..	82.1
$Ca(HCO_3)_2$ ..	100.1	72.1	43.7	11.3	19.4	..	112.5
$Mg(HCO_3)_2$	117.5	379.4	0.3	249.0	109.4	..	56.9
$FeSO_4$ ..	..	..	..	..	108.9	..	..
$MgCl_2$ ..	..	..	..	..	..	198.9	..
$MgSO_4$ ..	..	..	..	..	..	455.3	..
$CaSO_4$ ..	..	..	..	..	..	145.7	..
			Percentage of assumed salts				
$NaCl$ ..	49.2	65.3	26.1	63.6	69.2	64.7	48.2
Na_2SO_4 ..	0.9	0.8	2.1	2.9	1.2	..	5.6
$NaHCO_3$ ..	21.9	8.8	65.5	21.1	15.7	..	15.1
$Ca(HCO_3)_2$ ..	13.0	4.0	6.3	0.6	2.1	..	20.6
$Mg(HCO_3)_2$	15.2	21.9	0.0	12.5	12.1	..	10.4
$FeSO_4$ ..	..	..	..	..	..	3.01	..

Analysts as for Table 4.

TILLITE

Two analyses (Table 4, nos. 1, 2) have been made of water from this formation. Although the bores from which the samples were taken are less than a quarter of a mile apart there is a considerable difference in quality. Analysis 1 from bore CG4 contains less than one half the salts of Analysis 2 from bore CG2. There are also marked differences in the proportions of the constituents (Table 5). However, both waters are of the sodium chloride type, with that of Analysis 1 being a sodium chloride bicarbonate type specifically.

The variation in the quality of these waters is undoubtedly a function of the mode of occurrence (p. 63) since they are so close together spatially. The water in Analysis 1 is unconfined whereas that of Analysis 2 is artesian. The confinement and possible complexity of the outlet passages, and also duration of storage, would certainly influence salt content when compared to water which passes rapidly from near surface fractures, with ready replenishment and dilution, to the bore, as in Analysis 1. Further, water from bore CG5, which is also unconfined, has a total salt content of 840 p.p.m.

It will be noted in each case that iron and silica are moderately high, while sulphate is very low. These features are due to the presence of small rock fragments containing unaltered silicates instead of clay in the matrix, and lack of sulphide material. The water is hard to very hard.

QUAMBY MUDSTONE AND BUNDELLA MUDSTONE

Analysis 3, from bore CG1, is probably typical of water from the lowermost part of the Bundella Mudstone, although some water may have been recovered from the Quamby Mudstone.

The water has a very distinctive character, as is clearly shown in Table 5, being a sodium bicarbonate type with subsidiary chloride. Iron, calcium, magnesium and sulphate are low. Silica is moderately high, due probably to solution of a siliceous cement, since the formation is lacking in silicate material suitable for decomposition. The water is very soft.

GRANGE MUDSTONE

Analyses 4, 5 and 6 are of water from this formation in the Lymington Region. There is considerable variation in quality (868-3,626 p.p.m. of dissolved solids).

Analysis 4 is probably the normal water from the mudstone in this Region. Bores PB1, L4 and L5 yield water with approximately 1,500-2,000 p.p.m. by conductivity measurements. Comparison of Analyses 4 and 5 with the others shows that silica is lower in the water from this formation. This is to be expected since the rock is composed to a greater extent of the more stable clay materials.

Calcium and sulphate are also relatively low, although Analysis 4 does show 30.5 p.p.m. sulphate. This sulphate has probably been derived from the sulphide minerals that accompany many of the dyke rocks in the western part of the Lymington Region. The pH of the water is also low.

Table 5 shows that the proportions of compounds in the water are very similar; certainly there is better agreement between Analyses 4 and 5 than 1 and 2. The water is of the sodium chloride bicarbonate type and is moderately hard to hard.

At Glaziers Bay, bore GB1 has recovered water from this formation with very low total dissolved solids. The structure in the Glaziers Bay Region permits rapid water movement and consequently minimal time for interaction with the rock. This is in contrast to the Lymington Region where many dykes hinder freedom of movement.

However, at Wattle Grove (WG1) the water has a distinctly salty taste and it appears that dykes may have hindered free movement here.

FERNTREE FORMATION

One analysis (No. 7) and several conductivity tests have been made on water from this formation. The water is of the sodium chloride bicarbonate type, is moderately hard and generally has a salt content less than 1,000 p.p.m.

The water analysed has a number of interesting features. Silica is high at 31 p.p.m. as is sulphate at 24 p.p.m. Magnesium is fairly low. The silica is presumably derived from solution of the cement in this very siliceous formation. The sulphate is derived from pyrite commonly found in this formation.

OTHER FORMATIONS

There are no analyses of water from the other formations which in most cases have not yet been drilled. One bore has been drilled in the Faulkner Group; the water is of good quality (420 p.p.m. by conductivity test) and is likely to be of similar character to that from the Ferntree Formation.

Suitability of the Water

CHEMICAL CONSTITUENTS IN RELATION TO USE

The chemical character of groundwater, as determined by the actual constituents and their quantity, governs its suitability for different uses.

TOTAL DISSOLVED SOLIDS

The total dissolved solids are the residue on evaporation of the water sample. They consist of all mineral constituents detailed in Table 4, some organic material and a little water of hydration. It should be noted that bicarbonates may be partially or totally reduced to carbonates during the evaporation.

Generally water with less than 500 p.p.m. is suitable for drinking purposes and domestic uses, but water with 500-1,000 p.p.m. may be unsuitable as a result of taste or too much of a given constituent. Only water of analyses 3 and 7 is suitable for drinking and some domestic purposes but all water within the district is suitable for some agricultural use.

HARDNESS

The hardness of water is a characteristic of groundwater commonly noted by the amount of soap required to form a lather.

Hardness may be produced by two types of compounds. The bicarbonates of calcium and magnesium produce what is termed "temporary hardness" which can be removed by boiling. "Permanent hardness" is caused by the sulphates and chlorides of calcium and magnesium and cannot be removed by boiling. Total hardness is the sum of both types. Most of the hardness in the samples analysed was of the carbonate type which causes deposits to be formed in cooking utensils and boilers. The scale of hardness given below, while arbitrary, is in standard use in North America. It does, however, give an indication of the usefulness of the water.

0- 60 p.p.m. $CaCO_3$	Soft
61-120 p.p.m. $CaCO_3$	Moderately hard
121-180 p.p.m. $CaCO_3$	Hard
180 p.p.m. $CaCO_3$	Very hard

On this scale only water from bore CG1 (analysis 3) is soft. Water from bores CG2 and L3 (analyses 2 and 6) needs softening.

IRON

Iron is expressed as $Fe_2O_3 + Al_2O_3$ in the analyses. If present in excess of 0.3 p.p.m. staining occurs; if the iron content is large, growth of iron bacteria may result in blockage of pipes. All water in this district contains iron in excess of 0.3 p.p.m. Removal of iron may be accomplished by any of the following methods:

(*a*) Aeration by spraying and then filtering.

(*b*) Neutralization of the water with milk of lime. This is necessary where the iron is held in solution by carbonic acid. Aeration and filtering will then remove the iron.

(*c*) Precipitation by addition of alum.

(*d*) Precipitation by the Permutit process.

CALCIUM AND MAGNESIUM

Compounds of these elements produce hardness in the water. Domestic and industrial uses may be limited if magnesium sulphate is present in any quantity.

SODIUM

Sodium does not affect domestic water unless it is present in very large amounts but it is of considerable importance if the water is to be used for irrigation, due to its causing soil destruction by ion exchange. The applicability of water for irrigation is evaluated in terms of percent sodium and sodium adsorption ratio:

$$\text{Percent sodium} = \frac{100\ Na}{Ca + Mg + Na}$$

$$\text{Sodium adsorption ratio} = \frac{Na}{\sqrt{\frac{Ca + Mg}{2}}}$$

All concentrations are given in equivalents per million.

BICARBONATE

No carbonate is present in water from this district, since the pH must be greater than 8.2 for it to be present. The only water lacking bicarbonate is that of analysis 6, where the pH is too low. Bicarbonates only occur above pH = 4.5 (Williamson, 1965). The importance of this constituent has been shown under Hardness.

SULPHATE

This ion is derived from sulphides and fertilizers. If in the form of sodium or calcium sulphate, it imparts a bitter taste to the water.

CHLORIDE

Chlorides are derived from rocks, sea spray and sewage. Chloride is not noticeable below about 200 p.p.m. and a limit of 250 p.p.m. is taken for drinking water. Three bores have less than this amount.

pH

The hydrogen ion concentration of water, expressed as pH, is a measure of the acidity and alkalinity of the water and hence its corrosiveness. A pH less than 7 means that the water is acid, greater than 7 alkaline, equal to 7 neutral. Water should have a pH between 5.5 and 8.6 in order to prevent corrosion of metalware. This problem does not arise in this district.

UTILIZATION OF GROUNDWATER

DOMESTIC SUPPLIES

None of the water analysed is really suitable for usage under the standards laid down by the U.S. Public Health Service (Durfor and Becker, 1964). Table 6 shows the suggested limits on the composition for domestic supplies.

TABLE 6: Composition Limits for Domestic Supplies

	p.p.m.		p.p.m.
Fe	0.3	Cl	250
Mg	125	F	1.5
SO_4	250	T.D.S.	*500

*1,000 p.p.m. permitted if no other water is available.

The factor which makes many of the waters from this area unsuitable is the iron content. The water of analysis 3, which is soft and has only 0.8 p.p.m. Fe, is the water most suitable for domestic use. The water of analysis 7 may also be used but iron staining will be more marked.

AGRICULTURAL USES

Stock

The following table shows the upper limits of salinity for stock usage, as adopted by the New South Wales Department of Agriculture.

TABLE 7: Salinity Limits for Stock Usage

	p.p.m.
Sheep	14,000
Cattle	10,000
Horses	7,000
Pigs and Poultry	4,000

There is no lower limit for salinity, and generally the lowest salinity water available is considered the most desirable. It should be noted that dairy cattle require sodium chloride in their diet and consequently will often prefer bore water to fresher water. Further, if water near the upper limit is being used, lush herbage is necessary to offset any harmful effects which may arise from drinking too hard or too mineralized a water.

With respect to pigs and poultry, chickens prefer fresh water and pigs on a high protein diet will require good quality water.

Sulphates are the most injurious common constituents of groundwater and water of analysis 6 should not be used for stock watering. All other water within the district is suitable for stock, with water of analyses 1, 3, 5 and 7 being suitable for all types of stock in any condition. Reservations on the use of water in analyses 2 and 4 for pigs and poultry should be noted (see above).

Irrigation

The suitability of a groundwater for irrigation is dependent upon the effects of the constituents on both the plant and the soil.

Table 8 presents the desirable upper limits for usage of water for crops growing within the district (after Chatfield, 1965).

TABLE 8: Crop Tolerance Limits

Crop	*Limit of Tolerance* *p.p.m.*
Beet, asparagus, spinach	1,850
Potato, pea, onion, carrot, cucumber, tomato, cabbage, cauliflower, lettuce	1,600
Pear, apple, plum, apricot, peach, strawberry, celery, green beans, radish, clover and most flowers	600
Blackberry, gooseberry	400

It can thus be seen that water of analyses 2 and 4 should be diluted before any use whatsoever. A normal method of doing this is by allowing the water to pass to a dam which also collects rain and streamwater.

Table 8 applies only if calcium and magnesium chlorides or sodium and magnesium sulphates are not present in large amounts. Only water of analysis 6 is affected by this qualification.

The character of the soil may be affected adversely by water containing sodium in concentrations considerably higher than those of calcium and magnesium. This results in the replacement by sodium of calcium and magnesium ions adsorbed on the soil colloids, thus leading to the destruction of the soil. The sodium adsorption ratio and percent sodium are valuable criteria for determination of suitability as an irrigation supply.

Table 9 shows the classification of water for irrigation with respect to these criteria (after Todd, 1959, pp. 191-192).

TABLE 9: Classification of Water for Irrigation

Water Class	*Percent Sodium*	*Sodium Adsorption Ratio (S.A.R.)*
Excellent	20	10
Good	20–40	10–18
Permissible (fair)	40–60	18–26
Doubtful	60–80	..
Unsuitable	80	26

The sodium adsorption ratio is considered to be the most useful criterion. Todd (1959) regarded the percent sodium as of little use unless correlated with the total concentration in e.p.m. Whitcomb and Morris (1964) considered the sodium adsorption ratio to be more valuable if correlated with the total concentration. Table 10 indicates the usefulness of the water in each analysis with respect to these criteria.

TABLE 10: Usefulness of the Analysed Waters

Analysis	*S.A.R.*	*S.A.R.-e.p.m.*	*%Na-e.p.m.*
1	excellent	dangerous in fine textured soils.. ..	fair
2	good	needs good drainage, high leaching, organic additions	fair
3	very poor	not recommended in any conditions ..	poor
4	fair	not recommended	poor
5	good	needs good drainage, high leaching, organic additions	fair/poor
6	very poor	not recommended	poor
7	excellent	can be used on all soils with little danger	fair

Table 10 shows that water samples 1, 2, 5 and 7 are suitable in their present state for irrigation if soils are well drained; drainage is necessary to prevent salinity hazard; dilution may be necessary depending on the crop tolerance. Water from sample 4 may be usable if the soil is light and well drained and there is sufficient rainfall to dilute any salt concentrations. It should be noted that dilutions of three to four times are necessary if the water is to be improved sufficiently for irrigation usage.

Local Hydrology

The Cygnet District has been divided into eight principal drainage units, clearly shown in fig. 10.

WOODSTOCK REGION

This Region lies at the north of the surveyed area, and has an area of approximately 12 square miles. The geology is shown in fig. 10. The major sedimentary outcrop within the region appears to be a 'raft' in the dolerite. The dolerite in this Region has the form of large dyke-like bodies which connect two sheets. All drainage is toward Sandfly Rivulet which runs E-W toward the Huon River.

Form of the Water Table and Depth to Water

The character of the water table depends on the rock types present, any heterogeneities within the rocks, and the topography.

In the alluvial deposits, through which the Sandfly Rivulet flows for the last three miles of its course, the water table is virtually planar and slopes gently upstream with the rivulet. The stream actually flows in gravels and thus water can be recovered from the gravels. It is unconfined and less than five feet below the surface.

Away from the alluvial plain the water table rises with the land surface.

On the northern side of Sandfly Rivulet, the rise is very sharp, as is the rise in the land surface. There are a number of springs in Triassic sandstone extending the length of the dolerite-sandstone contact. These are largest in the east. The general nature of these springs is indicated in FG, fig. 5 (iv). Water passes from the dolerite, which caps all the high country in the north of this Region, into the sandstone which lacks sufficient vertical permeability to transfer the water downward; the horizontal permeability, along bedding partings, is such that the water is fed along them up dip, due to the head of water above, to the surface. These springs only occur near the top of the sandstone, never in the dolerite nor lower in the sandstone. The water from these springs generally runs off, although some may be re-absorbed by the sandstone. In the far NE of the Region, where dolerite occurs in the bed of Sandfly Rivulet (fig. 5 [iv]), the water table is again present as a shallowly dipping uniform body. The relatively high permeability of the dolerite here is due to its intensive fracturing. The water table in the dolerite in the east of the Region rises gently under the hills. Drilling in such material should always be undertaken near the creeks, otherwise deep holes will be necessary. All drilling, whether in sandstone or dolerite, on the north side of Sandfly Rivulet should be done as near to the Rivulet as possible, or where the slopes are gentler, in order to avoid deep holes.

On the southern side of the rivulet conditions are more variable. In sandstone of Upper Permian and Triassic age the water table lies up to 30 feet below the surface but, since the land in which these sandstones outcrop is relatively flat, the water table is nearly planar, rising shallowly to the south away from the rivulet. There are no springs in the sandstone in this part of the Region.

In the massive dolerite bodies to the SE and SW of Woodstock the water table is of low slope even though the surface may be very rugged. This feature of the water table in the dolerite is due to its high vertical permeability and accounts for the ephemeral and influent nature of most streams flowing across the dolerite. The water table rises toward the divides on the east and west of this Region.

There are occasional springs in the dolerite in various places on the slopes of Grey Mountain. These are not permanent and are due to zones in which the system of fracturing is local and not interconnected through the entire dolerite mass. Since these are of limited storage, they often dry up (GH in fig. 5 [iv]). This diagram also indicates the nature of the water source which supplies the few permanent streams flowing across the dolerite in this Region. Water is passed from the dolerite which forms the top of the mountain into sandstone (J, fig. 5 (iv)). Due to blockages in the conducting zones of the sandstone, caused by the presence of soapy compounds, and limited vertical permeability, there are large perennial springs in the sandstone (compare with FG, same figure).

The detailed character of the water table in this Region is conjectural due to the rugged topography.

Springs of the type ED (fig. 5 [iii]) occur in the Malbina Formation and Grange Mudstone in the NW of the Region, where the dip of these sediments is toward the river. Again the water is supplied from the dolerite higher on the hill and passes down bedding zones in the sediments.

Water Movement

Essentially all water moves, under the influence of gravity, from the enclosing divides toward Sandfly Rivulet. Recharge is from rainfall (35 inches) and snow. The proportion of the rainfall infiltrating to the water table is difficult to gauge due to the variation in rock and soil types. Discharge occurs by run-off, evapotranspiration and seepage into streams and springs. Such discharge is irregular and few springs or streams are perennial. Run-off is a variable factor, being high in the south, east and north of the region in the dolerite country and considerably less in the sandstone country about Woodstock. Groundwater movement is also much more rapid toward the divides, particularly in the dolerite, than in the sandstone area south of the rivulet.

General Comments

The quality of water recovered is likely to be good, as indicated by conductivity tests made on springs in both dolerite and sandstone.

Drilling the sandstone within the Region should not be difficult, but drilling the dolerite is not recommended. There are three reasons for this. Firstly, the dolerite is jointed, fresh and outcropping, weathering being very limited. Percussion drilling would thus be very difficult. Secondly, in most parts of the region the depth to the water table is such that the costs would be great; and thirdly, the success rate must be lower when drilling to the depths envisaged since the joint spacing increases and the chance of striking an aquiferous joint decreases.

The best sites in the area, in both dolerite and sandstone, are in the valleys and flatter areas adjacent to the streams where water should be struck within 20-30 feet. Hillsides should be avoided in either rock type.

CRADOC REGION

This Region, five square miles in area, is enclosed by the Cradoc Hill and Balfes Hill divide, and the Huon River. Much of the surface is fairly level but it rises sharply toward the Cradoc Hill divide. Plate 14 shows Cradoc township with the Huon River in the middle distance. The geology is shown in fig. 10. All sedimentary formations dip northward at 5°-10°.

Form of the Water Table and Depth to Water

The level of water in bores and fractures and the water table are considered equivalent. This was deduced from depth probes taken near bores and water

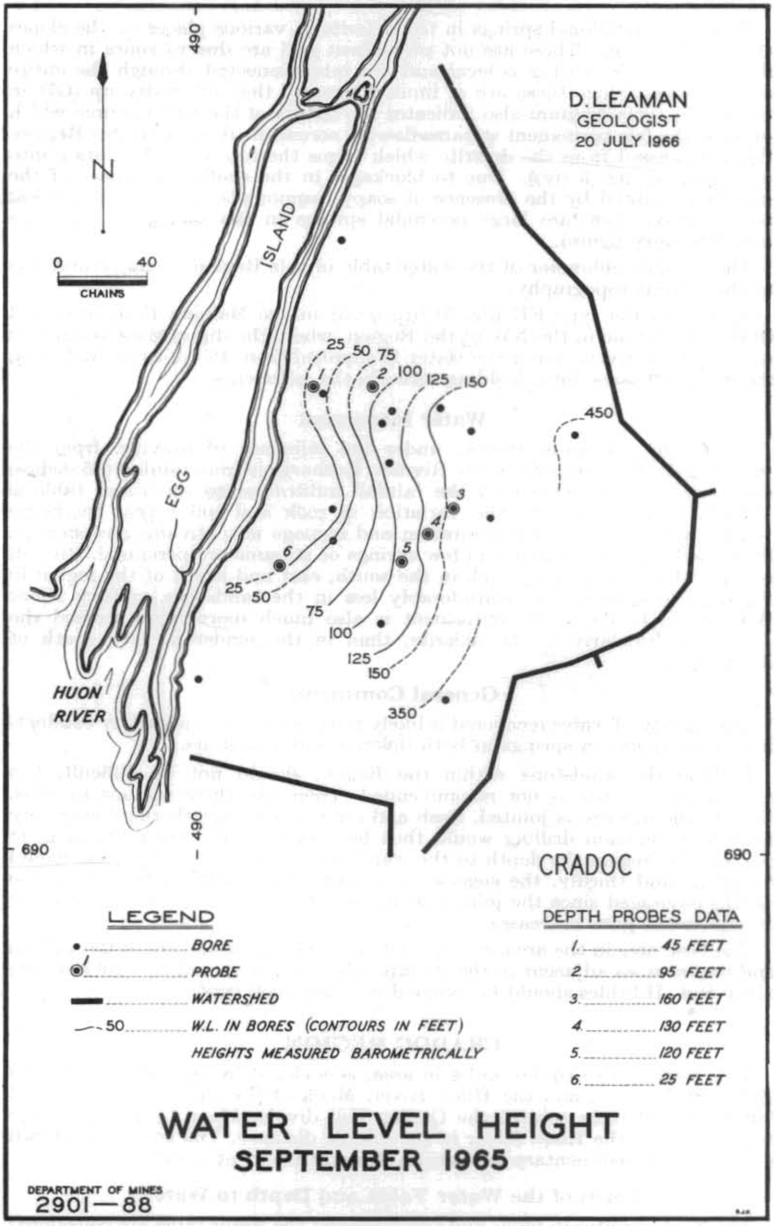
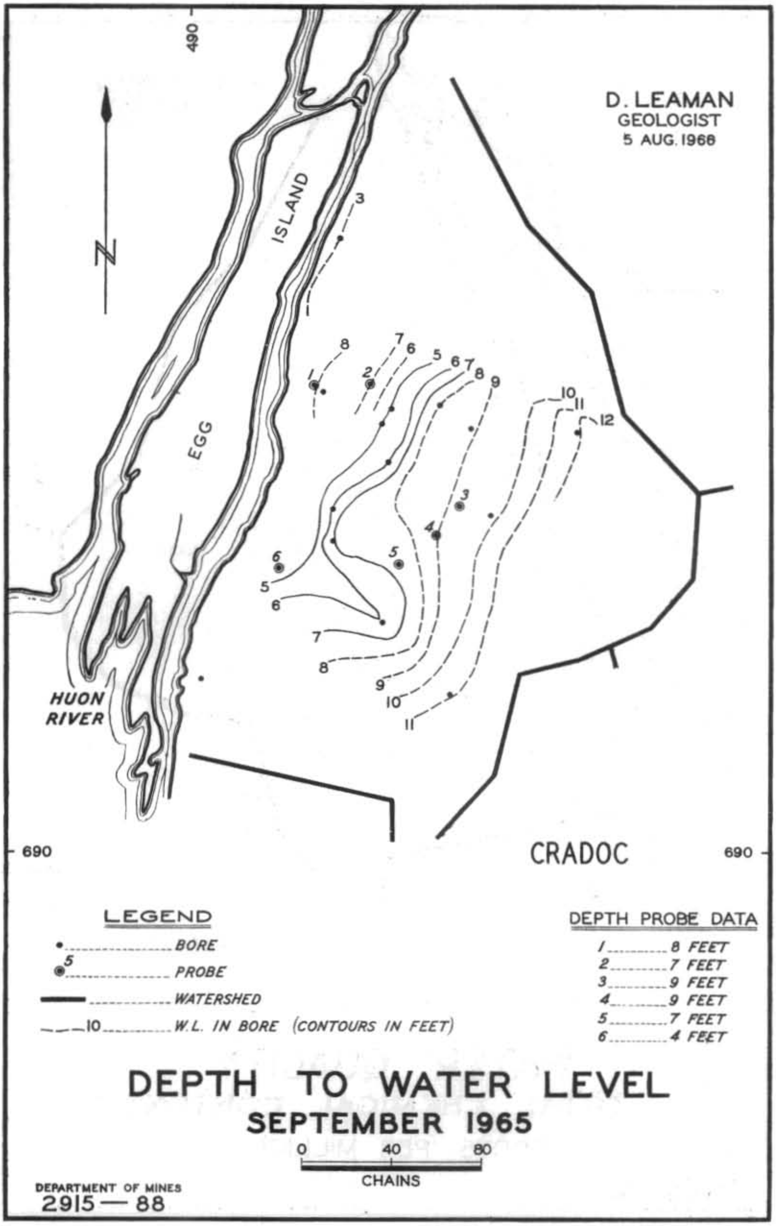

D. LEAMAN
GEOLOGIST
20 JULY 1966
N
0 40
CHAINS
ISLAND
EGG
HUON
RIVER
490
690
CRADOC
450
350
LEGEND
BORE
PROBE
WATERSHED
50 W.L. IN BORES (CONTOURS IN FEET)
HEIGHTS MEASURED BAROMETRICALLY
DEPTH PROBES DATA
1. 45 FEET
2. 95 FEET
3. 160 FEET
4. 130 FEET
5. 120 FEET
6. 25 FEET
WATER LEVEL HEIGHT
SEPTEMBER 1965
DEPARTMENT OF MINES
2901—88

FIGURE 6.

5 cm



490
D. LEAMAN
GEOLOGIST
5 AUG. 1966
ISLAND
EGG
N
HUON RIVER
690
CRADOC
690
LEGEND
BORE
PROBE
WATERSHED
10 W.L. IN BORE (CONTOURS IN FEET)
DEPTH PROBE DATA
1 8 FEET
2 7 FEET
3 9 FEET
4 9 FEET
5 7 FEET
6 4 FEET
DEPTH TO WATER LEVEL
SEPTEMBER 1965
0 40 80
CHAINS
DEPARTMENT OF MINES
2915 — 88

FIGURE 7.

5 cm

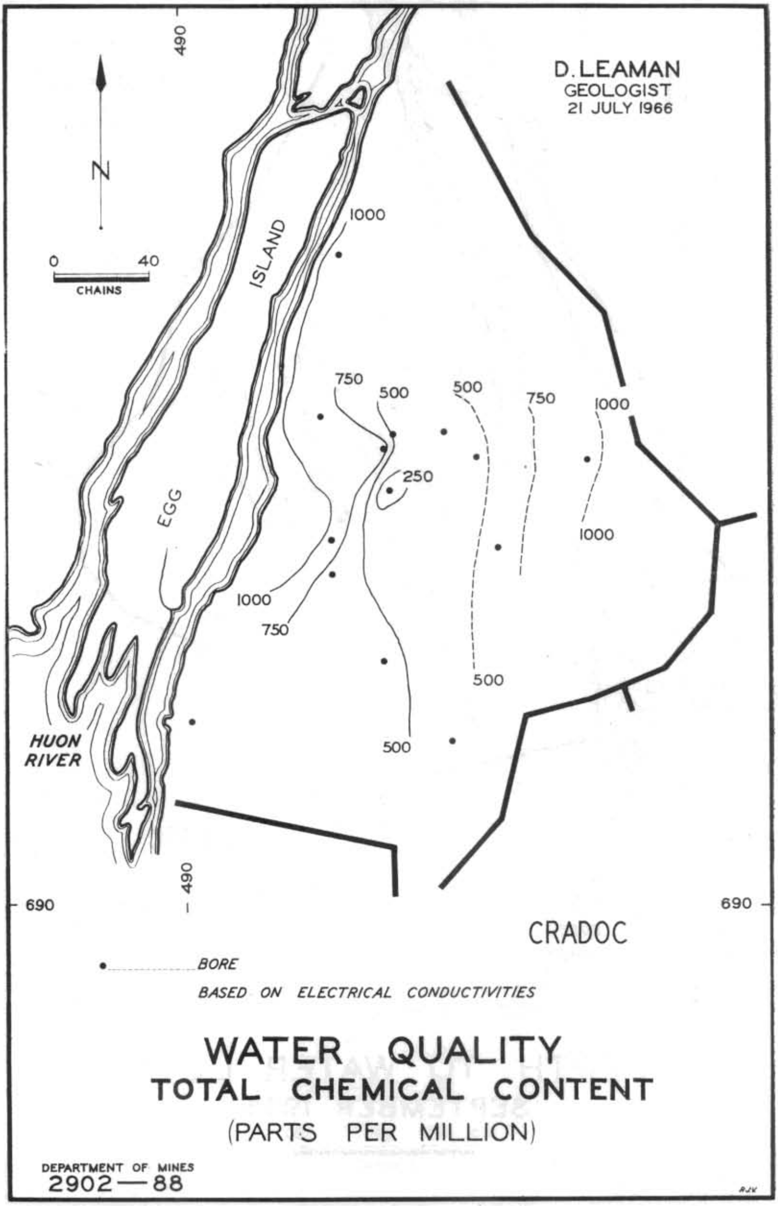

D. LEAMAN
GEOLOGIST
21 JULY 1966
N
0 40
CHAINS
490
ISLAND
EGG
HUON
RIVER
1000
750
500
250
690
CRADOC
BORE
BASED ON ELECTRICAL CONDUCTIVITIES
WATER QUALITY
TOTAL CHEMICAL CONTENT
(PARTS PER MILLION)
DEPARTMENT OF MINES
2902—88

FIGURE 8.

5 cm

table features such as streams. Fig. 6 gives contours on the height of the air-water interface as at 1st September, 1965. Six depth probes placed in areas where no bores have been drilled have enabled the form of the surface to be more completely defined. Probe 1 is given in fig. 3 (iv), and the remaining probes have the same form as (ii) and (iii) (same figure).

The water table is a subdued replica of the surface topography and is thus a gently sloping surface over much of the Region. There is considerable steepening toward Cradoc Hill.

The depth to water level is not more than 10 feet over the greater part of the Region. Contours on the depth to water are given in fig. 7 which shows that the depth to water is minimal in the centre of the area. This may result from the effect of four factors. To the east, with steepening slopes the depth to water is naturally greater; to the west in the gravel deposit which increases in thickness toward the Huon River, the depth to water is increased as a result of higher permeability; the land surface is flatter in the centre of the region, where the water table is shallowest; infiltration is probably greater in the centre both as a result of the level character of the land and the presence of many dams.

Water Movement

All water movement is from the enclosing ridge toward the Huon River. In the south of the Region all movement is in a NW direction away from Balfes Hill. Further north the movement is westerly away from Cradoc Hill. In the south some movement is directly toward the creek which distorts the water table contours in this part of the area. It is noteworthy that the major fault within the Region also passes through this zone of distortion and indeed the higher permeability induced in the rocks by this feature is undoubtedly the cause of distortion.

There is a limited discharge as springs or streams, consequently most of the streams in the Region are small and intermittent. Intake occurs across the entire area due to the northerly dip of the formations. Infiltration is greatest in the level area about Cradoc itself, and least in the hills of the southern divide where run-off is more pronounced. Water percolates through the soil, clay and weathered rock and then passes to the water table down bedding partings or joints. Since bedding partings are dominant in the Ferntree Formation (Pl. 11), the principal formation, the movement is down dip.

Water Quality

The quality of the water is generally good, the range of total dissolved solids being 240-1,040 p.p.m. (fig. 8). The arrangement of the contours is not unlike that of the depth of water, and this implies that increased infiltration of fresher water does occur near the centre of the region. The increased infiltration may be due to the thin cover of porous sands and gravel which occurs near bores C1, C4, C5 and C13.

The quality of the water deteriorates toward both the river and the Cradoc Hill-Balfes Hill ridge. In the former case the deterioration is due to contamination from river water, e.g. bores C9 and C12, and in the latter case due to decreased infiltration and subsequent dilution, e.g., bore C14.

The quality of the water is such that it may be used for most purposes although water from a few bores is not suitable for domestic use unless the iron content is reduced.

General Comments

Excellent bore sites exist across most of the Region. Drilling should however be avoided on the steep slopes of the enclosing divides and the dolerite in the north due to drainage problems.

Drilling conditions in the Ferntree Formation are reasonable although some parts of the formation are hard to drill. Up to 20 feet of casing is needed for each bore to prevent collapse of sand, gravel, soil or clay.

Three principal faults cross the Region and bores placed near them have a better chance of success. Bores C6, C7, C8 and C11 were placed near faults but bore C11 was too far away and failed. Failures have been relatively few, but in each such case the mudstone drilled was hard and massive. Resistivity probes show the mudstone in this condition to have a resistivity greater than 5,000 ohm-m, e.g., near C2, a failure (fig. 3 [iv]). All future sites in this mudstone should be checked with a depth probe. If the form of the probe is as fig. 3 (ii) or (iii), the site should be drilled.

At the present time all water is unconfined but this was not always the case. Early bores drilled in the region (C1, C4 and C6) were artesian upon completion. Presumably the rock between the clay and soil surface capping and the aquiferous zone was dry. However, once the bores were filled with water which then had access to the dry joints and partings in the upper levels of the rock, unconfined equilibrium conditions were soon reached. Drilling may also have induced fracturing which permitted pressure release. Certainly later bores drilled nearby are not artesian and recover their water from a much shallower depth. The siting and depth of these bores is such that no artesian head is possible. It should be noted that bore C1 struck water at more than twice the depth of many later bores and the confined zone cannot be bedding partings since no higher land exists to the south of the bore, up dip, from which the head might be applied. It is therefore suggested that the water initially recovered was contained in an isolated fracture set with an intake point on the slopes of Cradoc Hill. The bore thus provided connection to more numerous higher fractures with greater interconnection, and consequent pressure release.

This confined system still applies in the case of bore C4 where water may be supplied from high on the southern slopes of Cradoc Hill, by northerly dipping bedding zones. No other bores are in juxtaposition. In the case of bore C6, water was presumably confined in the northerly dipping bedding planes on the slopes of Balfes Hill. Bores C4 and C6 only overflow at present when the system is filled, as in winter.

Bores should not be sited on the hillside flanking the Huon River north of Glaziers Bay. In this area there is rapid drainage to the river caused by (1) the steep dip of the rocks toward the river and (2) underlying dolerite. Bore C10 struck dolerite at 64 feet and failed because the water table was low, due to drainage through the dolerite, and the hole not deep enough.

Yields of bores in this Region range between 250 and 500 g.p.h. The highest yields are obtained in the centre of the area. It should be mentioned that although bore C13 was tested at 500 g.p.h., this is the highest rate that can be determined with the method used.

AGNES RIVULET REGION

This Region covers the entire drainage basin of Agnes Rivulet. The topography is of moderate relief and the only level area is the flood plain of the rivulet. Only the western portions are occupied. The drainage basin can be clearly seen in the Frontispiece (view looking NE toward Grey Mountain) and Plate 1.

The geology is shown in fig. 10. Generally, the dolerite appears as a large sheet passing below Grey Mountain with a dyke margin on its western side. The small outcrops of Malbina Formation in the bed of the rivulet in the centre of the Region occur as inclusions in the dolerite. The top of a plug is present on the divide west of the rivulet.

The area of the Region is about 12 square miles and the annual rainfall is 35-40 inches. All drainage is toward Agnes Rivulet and most streams are perennial, even those on the dolerite in the east of the Region.

Form of the Water Table and Depth to Water

No detailed information is available on the water table in this Region.

Agnes Rivulet flows in gravels throughout the length of its flood plain. The water table in these alluvial deposits is planar and rises upstream. The depth to water is, to a large extent, dependent on the thickness of gravels and alluvium above the level of the rivulet. It is commonly less than 10 feet to water in this zone. Probe vi, fig. 3, is an example of a resistivity probe in these alluvial deposits.

West of the rivulet, in the hilly country composed of Upper Permian sedimentary rocks, little can be said about the condition of the water table. The depth to the water table is likely to be up to 50 feet due to drainage from the upper parts of the rocks.

The character of the water table in the dolerite country in the east of the Region is similar to that in the Woodstock Region. However, the regional slopes here are less and the volume of supply to streams greater. As a result, the water table is higher and there are fewer streams of an influent nature. Generally the water table rises shallowly to the east and north across the basin north of Mt Morrison. Due to the hilly nature of the terrain, the depth to water is variable.

A large volume of water is supplied to the streams forming the headwater of Agnes Rivulet from the sedimentary block on the southern slopes of Grey Mountain. Due to the presence of impermeable bands in the Triassic sandstone and Ferntree Formation, water is emitted as springs and the water table in the Grey Mountain area is rather step-like.

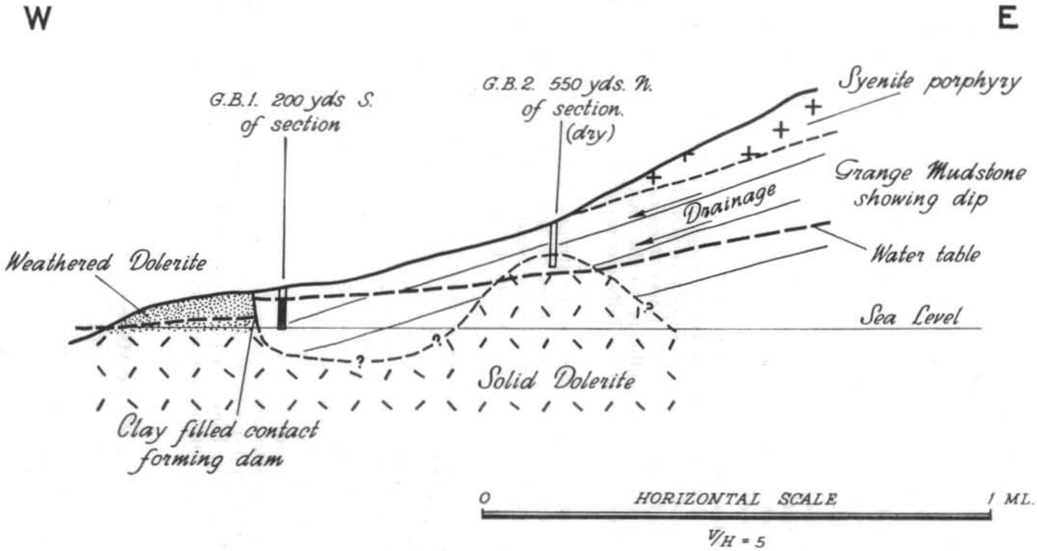
In the sedimentary rocks south and east of Agnes Rivulet, on the slopes of Mt Morrison and Tobys Hill, water table conditions are more straightforward and drilling prospects are excellent. The structure of this part of the Region is shown generally in BC, fig. 5 (iii), where B is east and C, west. The dip of the sediments is eastward toward the steep dolerite contact. The slope of the land surface steepens toward the contact and no drilling should be contemplated more than 600 yards east of the rivulet. In the region of Mt Morrison the dolerite has formed a small sill and this conceals part of the steep intrusive contact that extends from Cradoc to Gardners Bay. The land near the rivulet is undulating with gentle slopes before rising steeply to the eastern divide. The water table appears fairly uniform and shallow, never more than 20 feet and commonly less than 5 feet below the surface. There is a large number of small streams supported by springs of the type shown in BC, fig. 5 (iii).

Water Movement

Most recharge is by rainfall, and all movement is toward Agnes Rivulet. Discharge is effected either by direct underflow to the rivulet or indirectly by streams supplied by springs on hillsides. West of Agnes Rivulet and the dolerite contact all discharge is of the former type. However, in the eastern portions of the area discharge is of both types, the latter type being dominant in the Grey Mountain, Mt Morrison and Tobys Hill zones.

In the Grey Mountain area water is stored in the large sandstone block and emitted as springs in zones where the permeability is reduced.

In the Mt Morrison-Tobys Hill zone water from the dolerite massif is fed westward downslope to the contact, then, depending on the permeability of



WATER TABLE – GLAZIERS BAY REGION
(SECTION ALONG 689·5 N)

FIGURE 9.

the sediments, it is transmitted to the rivulet. The diagram indicates the transfer of water up dip, as a result of the head of water, in the formations with marked horizontal permeability. The formations referred to are the Grange and Bundella Mudstones. The Faulkner Group and the non-fossiliferous silty zones of the Bundella Mudstone act as less permeable zones and do not pass the water as readily. Thus while all the rocks are permeable to some extent, and there is a continuous water table, the depth to water is variable. Most of these springs are small but perennial.

General Comments

Drilling should be avoided in the hilly areas, either dolerite or sedimentary, since the water table will be at considerable depth as a result of the dip of the sediments and slope of the hills. These factors cause the draining of the water from the upper part of the rocks particularly in the hills flanking the Cradoc Hill divide in the west of the Region. The best general sites for drilling, in order, are: the flood plain of Agnes Rivulet; the lowland flanking the plain in the SW corner of the Region, particularly that east of the rivulet on the lower slopes of the Tobys Hill-Mt Morrison divide; valleys flanking streams. The best sites in the Region occur in the Grange Mudstone. Other drill site possibilities are near the dolerite contact zone.

There are also a number of faults in the western half of this Region which may play an important part in water movement. Most faults have resulted in planes of decomposition that act as dams to groundwater movement. Flow is downslope to such a feature and then along it, again downslope, to the nearest stream. There is thus considerable distortion of flow line behind such a feature and considerable flows are to be expected in some places near the outlets.

GLAZIERS BAY-WATTLE GROVE REGION

This Region is enclosed by the Huon River in the west and the mid-peninsula ridge in the east and lacks level ground since it essentially covers the western slopes of the ridge. It has an area of approximately 10 square miles and an average rainfall of 35 inches. The gradient of the surface averages 1,000 feet in two miles. Plate 15 shows the nature of the surface near Glaziers Bay.

The geology is shown in fig. 10. The sedimentary rocks dip westward at an angle approximately that of the hillslope. The dolerite contact near the Huon River appears to be vertical although outcrop behaviour near Wattle Grove is suggestive of an eastward dip. The syenite porphyry outcrops on two spurs, one on Silver Hill and the other near Wattle Grove, and forms part of the denuded laccolith (p. 23).

Form of the Water Table and Depth to Water

The water table rises inland from the Huon River in a planar fashion with a marked step near the dolerite contact. The dissection of the ridge becomes more pronounced inland and since some streams are permanent for most of their length it can be seen that the depth to the water table also increases inland. This results particularly from the ability of the water to drain from the rocks due to their attitude with respect to the hills. There is considerable drainage from the dolerite also.

The water table in the dolerite is virtually a true water table, due to the decomposed and porous state of this rock within the Region (e.g. Pl. 13). As a result of the relatively high permeability of this rock the water table is not a great height above river level. Hence, even though the dolerite is never more than 100-150 feet above the river, the depth to water may be considerable, commonly more than 70 feet.

Little information is available on the water table east of the dolerite contact. At Glaziers Bay two bores have been drilled in the Grange Mudstone. GB1, drilled on the side of a spur above a creek, struck water at 28 feet with water level approximately at 100 feet. The mudstone in this locality is deeply weathered. In view of the differences in level between the mudstone and dolerite, it would seem that deep weathering has occurred in the highly fractured contact zone and formed a clay dam. The postulated form of the water table in this part of the Region is shown in fig. 9.

GB2, drilled on top of a spur, failed to strike water in 56 feet of mudstone and 8 feet of dolerite. This is due to the great depth to water in the higher levels of this Region caused by the underlying dolerite of moderately high vertical permeability and the draining of the near surface sediment. This latter factor is not to be neglected since stream levels may be more than 100 feet lower than bore sites on spurs in this region. The suggested form of the water table below GB2 is shown in fig. 9.

At Wattle Grove conditions appear to be similar. Water was obtained within 20 feet in bores WG1 and WG2, and rose to near the surface. This is to be expected here in view of the dip of the rocks and the tendency for water to be confined in bedding planes. Both bores are sited near the dolerite contact where presumably flow restriction has occurred.

It is likely that the dam in the contact zone will be absent in the south of the Region, since the lower Permian formations do not form clay as readily as the Grange Mudstone, and therefore the step in the water table will also be absent and the depth to water a little greater behind the contact there than at Glaziers Bay.

Water Movement

All water movement is directly down slope toward the Huon River, mostly at right angles to the river. It is thought that there is little subsidiary movement from spurs to streams due to the dominating influence of conductive sedimentary bedding zones which dip downslope.

The intake areas for water are toward the top of the ridge where the average rainfall is approximately 35 inches. The water is then fed down fossil or bedding zones, many of which are drained on the lower slopes due to outcrop. Small, ephemeral springs of the type ED, fig. 5 (iii) result. Due to some vertical permeability of the Grange Mudstone, lower levels not outcropping in the intake area are also saturated with water.

The syenite porphyry, which occurs as a thin skin on spurs, is devoid of water as a result of drainage vertically into the mudstone below, or laterally into the adjacent streams. Probe vii, fig. 3, shows the thin coating of syenite, the highly decomposed conducting and draining zone in the mudstone below the syenite, and the more massive mudstone below. The Grange Mudstone commonly has alterations of high and low resistivity (fig. 3 [v]) due to the presence of zones of decomposition resulting from water transfer.

Near the Huon River, the water impounded at the dolerite contact either passes slowly through the dam or proceeds laterally to streams, where conditions permit, and thus across the contact. Once in the dolerite it is passed vertically to the water table. In either case, there may be a fall of 50-70 feet.

General Comments

The quality of water recovered should be excellent due to the high rate of movement, for example GB1.

Drilling should be undertaken only in valleys if water is to be recovered from a reasonable depth. Other good sites lie within a few hundred feet of the dolerite contact on the up-hill side at Glaziers Bay. At Wattle Grove bores should be further from the contact because of the shallower dip of the dolerite.

PETCHEY BAY REGION

Extending from Beaupre Point to Brabazon Point, and enclosed by the southern extensions of the mid-peninsula ridge and the Huon River, this Region has an area of five square miles with an annual average rainfall of 32 inches. It covers the southern slopes of the ridge and is of moderate relief with all drainage toward the Huon River. The land surface is relatively flat only in the vicinity of Petchey Bay and the coastal strip from Petchey Bay to Beaupre Point.

The geology is shown in fig. 10. All formations, including the lower surface of the syenite porphyry (banatite) which caps the Mt Windsor-Direens Spur section of the ridge, dip south. There is a maximum thickness of 400 feet of the porphyry on Mt Windsor. Two smaller masses of porphyry occur on the banks of the Huon River. These are small sills.

Form of the Water Table and Depth to Water

Little can be said of the form of the water table, save that it rises inland and is very broken as a result of many faults and dykes being present. Much of the Region consists of tillite and Quamby Mudstone, and thus, since bedding and fossil zones are usually absent, all water transfer is by joints, as in the banatite. Springs of the type AB, fig. 5 (iii), are common in the western half of the Region in both the banatite and the sedimentary rocks.

Except for the small area about the village of Petchey Bay and the coastal strip toward Beaupre Point, the water table is unpredictable on the present information. Although the general tendency is to slope steeply southward, it may be very high on the upslope side of a dyke, as in AB, fig. 5 (ii), and very low on the downslope side due to lateral drainage into the quite deep valleys which are cut in the northern part of the Region.

In the lower coastal areas, particularly where the rock type is tillite or Quamby Mudstone, the water table is shallow and uniform.

In the eastern part of the Region, where the outcropping formations are the Grange Mudstone and the Malbina Formation, there is much drainage down dip to the river. This results in many springs of the type DE, fig. 5 (iii), and a planar water table which rises shallowly inland at an angle normally less than the dip of the rocks. This angle can not be permanently greater than the angle of dip, unless some heterogeneity exists, since the water table will be most stable at the lowest possible angle. In considering the state of the water table in Grange Mudstone, for example, it must be remembered that the lateral permeability is greater than the vertical permeability and thus all water in beds above the datum level (sea level in this Region) can drain readily, resulting in intermittent springs. There must exist a bed, the critical bed, from which such drainage cannot occur. After drainage from the upper levels has occurred, the water in the critical bed and those below it, which have been resupplied by the same rainfall that induced the springs to flow, passes slowly and vertically, thereby 'consolidating' the water into one connected body and fully saturating the rock. The angle of dip of the water table is less than the angle of dip of the rocks due to head requirements and the tendency of the whole system to reach maximum stability; i.e., a horizontal water table. Since the outlet point is fixed by the sea, river or stream, all rises or falls in the water table under the hill are hinged about this point. Thus, as the water is pushed laterally in the water system by the applied hydrostatic head, both the head and height of the water table fall at every other point. Thus in the usual condition the angle of dip of the water table is between 0° and angle of dip of the formation. This situation may be confused if the drainage flow is not down the true dip.

It should be noted that the water table angle may be greater than dip for a short time after replenishment and before drainage is completed, or if some disturbing influence such as a dyke, bedding heterogeneity, cliff or deep cutting is present, in which case the state may be permanent.

This condition of dip of rocks downslope is very common on the Cygnet Peninsula and the foregoing discussion is a suggested explanation of the observed form of the water table in many such instances.

Due to the low angle of the water table the depth to water may be considerable on the hillslopes away from the coast; in similar conditions it is at least 70 feet in the Lymington Region.

One bore, PB1, has been drilled on the coastal flats. The bore is not far from the Huon River and the water level in the bore is approximately river level, as predicted by the theory.

The water table does not exist within gravels at any locality within the Region, usually because they are of limited surficial extent or are located in positions where rapid drainage occurs.

Water Movement

All water movement is directly toward the river in the east of the Region due to the bedding control, but may be indirectly toward the river in the west due to the conditions being more nearly true water table with the water surface following closely the undulations of the surface.

General Comments

Drilling should be considered only in the Petchey Bay low area and the coastal strip. Elsewhere conditions are too variable and unpredictable, although occasional good sites do exist. Fault zones should generally be avoided since the rocks of this region readily decompose on crushing and subsequent exposure to circulating water. It should also be noted that the quality of water from bores sited near the coast may not be good (e.g. PB1, 2,000 p.p.m.). Away from the coast an improvement in quality may be expected but a deeper bore will be needed for the recovery of the water.

LYMINGTON REGION

The Lymington Region, with an area of eight square miles, occupies the SE slopes of the mid-peninsula ridge and has all drainage toward Port Cygnet. The major drainage system is that of Forsters Rivulet, although there is subsidiary direct drainage from the Regatta Point-Mt Mary area. The Region, as a whole, is of moderate relief but the relief is relatively low surrounding the village of Lymington, the surface rising gently westward. Part of the Forsters Rivulet drainage system and Lymington can be seen in Plate 2.

The geology of the Region can be seen in fig. 10. The principal geological characteristics are the faulting, the eastward dip of the sediments and the large number of dykes intruded into all parts of it.

Form of the Water Table and Depth to Water

The basic form of the water table is again a subdued replica of the land surface with complexities superimposed on this simple form by the dykes (p. 23; fig. 4). The water table is relatively shallow between A and B and west of C but is non-existent between B and C due to lack of catchment.

The water table throughout the region is generally about 50 feet in depth although, as will be shown, it is commonly deeper. This is a direct result of the easterly dip across the area and rock drainage toward Forsters Rivulet or Port Cygnet, all bores to the present time having been drilled west of these features.

In the centre of the Region, about Lymington where the land surface slopes gently west, the water table also slopes westward but is stepped due to the effects of dykes. Due to regular and evenly distributed rainfall and irregular orientation of the dykes there is not usually a great variation in depth to the water table across these features. The water table about Lymington is scoop shaped, and although the curvature is slight about Lymington it steepens markedly toward the hills west and south of Lymington. Contours on the water table in East Lymington have an E-W trend whereas those in West Lymington have a N-S trend. The whole 'scoop' slopes toward Forsters Rivulet.

The depth to the water table is minimal in East Lymington. For example, at bore L1 the depth to water is approximately 20 feet, whereas further west at L2 the depth is 40 feet. As the surface rises to the west and the rocks dip east, so the depth to water increases.

The water table in the syenite porphyry (banatite) masses is unpredictable due to the damming effect of dykes. Many such dykes are detected by the occurrence of springs of type AB, fig. 5 (iii). Generally, however, it may be expected that much of these igneous masses will be devoid of water due to lateral drainage to streams in the deeply cut valleys which cross them.

In the SE of the Region, between Lymington and Beaupre Point, the conditions are comparable with those in parts of the Glaziers Bay and Petchey Bay Regions. The dip of the rocks is toward Port Cygnet, as are the hillslopes. Consequently much of the rock (Grange Mudstone) is drained. Bores L4 and L5 drilled in this zone have depths to water of 57 and 70 feet respectively. The water table is planar and has a dip of about 2° toward Port Cygnet; this is less than half the dip of the rocks (see discussion, p. 59). Springs of the type DE, fig. 5 (iii), occur in various parts of this zone, the largest being 200 yards north of bore L5.

Although the gravel deposits near Beaupre Point are thick, they are easily drained and only small perched water tables are likely to be present above suitable clay bands.

The water table in the dolerite, which extends from Shag Point to Beaupre Point, is also likely to be at considerable depth due to the highly weathered and porous state of the rock.

Water Movement

Water movement within this Region falls into two main categories; either direct flow to Port Cygnet or indirect flow via Forsters Rivulet.

All movement in the east of the Region, from the hillslopes which face Port Cygnet, is direct, essentially down bedding zones. There may be minor variations in flow induced by dykes or other igneous contacts (for example, the dolerite near Beaupre Point).

In the vicinity of Lymington itself, all drainage is toward Forsters Rivulet. The movement is northerly in the east of the district but easterly in the west. Again, the movement is somewhat confused by irregularly distributed dykes.

Water movement in the older Permian rocks, in the far west of the Region, is much more uniform since these rely on fractures only for their water-bearing properties. Since the surface where these rocks outcrop is hilly, there is much downslope movement to the tributary streams of Forsters Rivulet.

In the igneous rocks in the north of the Region, there is much vertical movement as a result of deep dissection by streams.

Faults also exert an important control on water movement, most fault zones acting as dams. This is particularly true of the Wheatley Bay Fault.

Water Quality

All water in this region is recovered currently from Grange Mudstone. The quality of the water is generally fair. The better quality of the water from bore L1 may result from increased infiltration or increased subsurface flows in this part of the Region induced by dyke dams.

The general quality of water to be expected throughout the Region, in view of the fact that the major rock types are Grange Mudstone and tillite, is fair but rarely good.

General Comments

Except for most parts of the alkaline igneous rocks and the steep slopes toward Mt Windsor and Direens Spur good sites exist for drilling. The depth to water may be considerable in the eastern parts, but generally less elsewhere.

All five bores drilled to date have been successful, although bore L3 suggests that sites should not be placed close to Port Cygnet. In this case the bore struck water below sea level, and was consequently contaminated.

Care should be taken not to drill dykes, faults or the possibly dry zone between dykes. All future sites in this Region should be tested by resistivity methods to determine whether these features are indeed present. This is most pertinent with respect to the dykes and faults since the outcrop is rarely good enough to locate them precisely. A resistivity survey west of bore L2 revealed large numbers of dykes and to drill haphazardly here may well result in failure.

The yield of bores is 300-400 g.p.h., which appears to be typical of the Grange Mudstone. The highest yield is obtained from bore L1 which suggests that increased flow may exist in this locality.

CYGNET REGION

The Cygnet Region, with an area of nine square miles, occupies the E and NE slopes of the mid-peninsula ridge. All drainage is eastward toward the lower reaches of Agnes Rivulet and the head of Port Cygnet (fig. 10). Most of the streams have large valleys and relatively low gradients for much of their length. An example of this is clearly seen in Plate 17 which shows "Golden Valley". The Frontispiece shows the lower part of this valley and the confluence of the major streams of both the Cygnet and Agnes Rivulet Regions, a little north of Cygnet.

The Region is of moderate relief and many of the hills have steep slopes. There is a large area of low relief extending northward from Cygnet and enclosed laterally by the lower slopes of Tobys Hill, Mt Mary and Silver Hill.

The geology is shown in fig. 10, the dominant formation being the tillite. The dip of all formations is eastward. There are large numbers of dykes intruded into the southern and western portions of the region.

Form of the Water Table and Depth to Water

The rocks within this Region rely principally on fractures for their water-bearing properties although some bedding influences may be present. As a result, the water table is normally unconfined and uniform, disturbed only by the effects of dykes.

The water table in the wide valleys and lowland north of Cygnet is shallow, uniform, roughly planar and rising to the NW. Water level is seldom more than 20 feet below the surface, e.g., bores CG1, CG4, CG5, all three of which are near a stream, and the depth to water is approximately equal to the elevation of the bore-site above stream level. The water table is thus quite level in the floors of valleys such as seen in Plate 17. The depth to water increases away from the floor of the valleys since the slope of the water table in these rocks, which have considerable vertical permeability as a result of their irregular fracturing, tends to be very slight and certainly less than the slope of the surface.

The situation on the hills or hillsides is more complex. In many cases the water table may not be present. This conclusion results from consideration of the following factors. Firstly there are few openings other than joints in the tillite or Quamby Mudstone of which the greater part of the Region is composed. Secondly, such openings cannot exist to great depth. I suspect that only the very largest openings are still open enough to contain water at 100 feet in these not very competent rocks. These properties may be contrasted with those of the Grange Mudstone where water may exist in depth. Thirdly, due to the steep slopes and presence of many near surface joints, all water, after infiltration, will be passed downward until no further movement of this type is possible. The water is then transferred laterally to the side of the hill or to the water table body in the stream valley which flanks the hill. Thus much of the rock under such hills will be dry, and in places the water table may be absent, at least temporarily during dry periods.

Confined conditions, of the true artesian type, have also been noted, e.g., bore CG2 which flows most of the year. Bore No. 6, fig. 5 (ii), illustrates the conditions at bore CG2. There is a clay cover over this part of the area and the water was recovered from a bedding zone at 35 feet, this zone being marked by the abrupt change from soft to hard mudstone. The water rose 36 feet. The dyke is necessary to completely confine the water in order that artesian pressures might be built up. The intake for this system is probably upstream in the bed of the creek, since the yield properties of this bore show that the water is not supplied only from a closed fracture system. The yield falls from 450 to 250 g.p.h. after several months' extended pumping. This implies hydraulic connection with a stream, which also maintains the head of the water. A bore drilled at No. 8, fig. 5 (ii), would show the same condition as CG4, that is, an unconfined water table under a clay cover. It will be noted that the yield of bore CG4 is little more than half that of CG2; the higher yield is undoubtedly due to the hydraulic connection which maintains the level and pressure of water.

Water Movement

This aspect has been partially covered in the preceding section. Essentially all movement is downslope to the streams, all water finally passing toward Port Cygnet. This condition may be disturbed by the effects of dykes or faults.

Water Quality

Analyses have been made of water from bores CG1, CG2 and CG4. Bores CG2 and CG4 are drilled in tillite and the quality of this water is discussed on p. 42. That the quality of the water from bore CG2 is poorer than from CG4 and CG5, also in tillite, suggests that the hydraulic connection between the stream and the bore is tortuous and that considerable rock-water interaction can occur, particularly since the system is under a pressure of at least 36 feet of water. The quality to be expected of water from the tillite is 700-1,000 p.p.m. total dissolved solids where the conditions are normal and the water table is supplied from direct infiltration.

The quality of water from the Bundella Mudstone or Quamby Mudstone cannot be completely discussed due to lack of information.

General Comments

Bores should be drilled only on the lower slopes of the hills and in the valleys. The water table at hill sites is either deep, and the bore very costly, or non-existent, and the bore a failure. All bores drilled in the Region have been in valley sites and all were successful. The yield range is 250-450 g.p.h.

There should be no drilling difficulties in this Region.

NICHOLLS RIVULET-RANDALLS BAY REGION

This Region, which occupies most of the undulating country west of the Mt Cygnet divide and east of Port Cygnet, has an area of 12 square miles. Although there are zones of relatively low relief, as near Deep Bay (Pl. 2) and Randalls Bay (Pl. 18), the Region as a whole is of moderate relief with most drainage being E-W and downslope to Port Cygnet. Most of the streams are perennial but relatively small, although some are large and have flood plains, e.g., Nicholls Rivulet (see Pl. 16) and Gardners Rivulet.

The geology of the Region is shown in fig. 10. All formations dip east toward the hills of the Mt Cygnet divide. Most geological structure has an easterly trend, for example, most of the faults are E-W and the dolerite body crosses the Region in this direction. The northern face of the dolerite intrusion is steep but dips northward and extends to considerable depth. The southern contact of the dolerite may have the form of a shallowly transgressive sill and is the top of the intrusion, at least near Port Cygnet.

Form of the Water Table and Depth to Water

The water table in the alluvial deposits through which Nicholls Rivulet flows is continuous, unconfined and planar, rising eastward with the rivulet. The water table is shallow, being less than 4 feet below the surface in many places and is present within the gravels, as may be clearly seen in Plate 16, where a cut in the alluvial plain reveals water in the gravels. The actual course of the rivulet is several hundred feet away.

The water table in the older Permian rocks, tillite and Quamby Mudstone, in the north of the Region probably rises shallowly under the low hills flanking Nicholls Rivulet. The depth to water in this zone may be more than 40 feet.

The dolerite south of Gardners Bay is extensively weathered, and as a result of this porous state the water table is deep, uniform and rising shallowly eastward with the land surface. Near the coast it is not far from sea level and the depth to water may be up to 50 feet. Further inland where the rock becomes more massive, and is jointed but not extensively weathered, the surface is such that considerable drainage occurs and the water table is very deep.

Further south in the low relief area about Deep Bay, where the rocks are Upper Permian, the water table is less than 20 feet in depth, is uniform and rises concentrically about the bay.

In the far south of the area, at Randalls Bay, the water table is normal and unconfined and occurs in the large gravel deposits. These are not drained of water as at Beaupre Point due to the low nature of the surface (Pl. 18). The depth to water increases away from the beach and swampy zone at Randalls Bay. Generally it is less than 10-15 feet. The water table rises inland toward the hills north of Randalls Bay and south of Deep Bay. In this hilly zone, known as the Devils Royals, the water table may be at considerable depth in the Triassic and Upper Permian sandstones, although no precise details are available.

Water Movement

All water moves toward Port Cygnet, except for the small zone at Randalls Bay where the movement is to the Huon estuary. The movement is generally simple and downslope and has few interruptions. Dykes are absent over much of the Region and most of the faults occur in or near stream valleys.

General Comments

Good sites may be found in all parts of the Region. The best sites are in valleys and not too distant from a stream or rivulet. Drilling should generally be avoided in the hillier areas.

Summary and Conclusions

The Cygnet District has an abundance of groundwater, and the resources have only begun to be developed. Even if 20% of the annual precipitation is added to the groundwater reserve, then the overall recharge is of the order of 5,000 million gallons annually. At the present time less than 0.1% (estimated) is being used.

There is no one principal aquifer within the area, most formations being reasonable aquifers under suitable conditions. That only the Grange Mudstone, tillite and Ferntree Mudstone have been drilled to the present time tends to imply that the other formations are poor aquifers. This is not the case; rather, the above formations commonly occur in the populated areas where demand is greatest.

Except for undesirable concentrations of iron in the water, making it of doubtful use domestically, the water is generally suitable for most purposes. All water for irrigation should be analysed prior to usage.

Bores should not normally be placed on hills or hillsides, particularly where there are steep slopes. In these conditions deep holes or failures can be expected. Success with a deep hole is common only in Grange Mudstone. The best sites, in all formations, are in valley floors or on the low slopes flanking the valley.

Bores should be drilled to an adequate depth. It is not uncommon for drilling to cease if the hole is dry to 60 feet. However, the conditions might be such that the water table could not be expected before 70 feet. Thus a minimum depth must be estimated and drilled following a study of the occurrence. Resistivity methods are recommended for this. Estimates have been given in the text for each Region. Holes should then be continued 20-25 feet below the estimated depth, which should include an error factor, in order to strike aquiferous fractures. The bore should be at least 10 feet deeper than the summer water level to safeguard against exceptionally dry periods.

The groundwater is normally unconfined, i.e., the upper surface of the water body is exposed to the atmosphere although in bores it commonly gives the illusion of being confined (sub-artesian). This is explained by the disrupted nature of the water table in fractured rocks and the tendency of the water to seek its own level. The water level in bores is thus usually that of the water table. True artesian conditions seldom exist.

Appendix

DRILLING RESULTS

Bore	Date	Owner	*Water Level ft.	Total Depth ft.	Output g.p.h.	†T.D.S. p.p.m.	Alt. ft.	Bore Log
**C1	26/7/62	G. Griggs	24	64	400-500	..	110	0-28′ soil, clay, sand 28′-64′ mudstone and sandstone.
C2	29/4/64	E. Rowe	..	115	..	..	75	0-20′ sand and gravel, 20′-70′ clay and mudstone, 70′-115′ hard mudstone
C3	12/5/64	F. Beechy	..	135	..	..	145	0-6′ clay, 6′-9′ boulders, 9′-135′ mudstone
C4	19/5/64	K. Bennett	16	67	300	400	165	0-16′ clay, 16′-40′ gravel, clay and sandstone, 40′-67′ mudstone
C5	21/5/64	Bennett and Fletcher	12	45	200	240	110	0-12′ clay, 12′-45′ hard mudstone
C6	6/6/64	H. Duggan & Sons	15	60	250	420	375	0-25′ clay, shale and mudstone, 25′-50′ grey mudstone, 50′-60′ harder mudstone
C7	8/7/64	T. Beechey	15	50	300	580	110	0-20′ clay, shale, 20′-50′ grey mudstone
C8	15/7/64	G. Harrison	12	60	300	600	60	0-12′ sand, clay and gravel, 12′-60′ mudstone
C9	21/7/64	K. Woolley	12	60	250	1040	30	0-23′ soil, clay and gravel 23′-60′ mudstone
C10	31/7/64	C. Edwards	..	64	..	..	120?	0-25′ sand and clay, 25′-64′ fossiliferous mudstone, 64′ dolerite
C11	20/8/64	V. Brown	..	66	..	..	150	0-18′ clay and gravel, 18′-66′ hard mudstone
C12	18/11/64	L. Duggan	6	42	..	..	5	0-20′ gravel, 20′-42′ sand, 42′ dolerite
C13	30/11/64	G. Griggs	10	40	500	840	110	0-10′ clay, 10′-12′ sand and gravel, 12′-15′ white mudstone, 15′-35′ grey mudstone, 35′-40′ black mudstone
C14	10/12/64	G. Roberts	20	75	250	960	470	0-10′ clay, 10′-20′ soft sandstone, 20′-35′ sandstone and gravel, 35′-75′ grey mudstone
‡C15	1/2/66	C. Piesse & Co.	35	45	400	..	120	0-3′ soil, 3′-12′ clay, 12′-45′ mudstone
‡C16	24/2/66	Dillon Bros.	30	40	400	..	120	0-3′ sand, 3′-12′ clay, 12′-40′ mudstone
**CG1	2/8/62	C. Smith	12	48	350-400	..	205	0-12′ soil and clay, 12′-48′ hard dark mudstone
**CG2	6/8/62	J. Cripps	34	40	400-500	..	110	0-35′ clay and soft mudstone, 35′-40′ hard mudstone
‡CG3	31/1/64	H. Connor	40	50	120	..	..	0-3′ 6″ clay, 3′ 6″-50′ mudstone
**CG4	4/8/64	S. Fitzpatrick	28	70	250	700	80	0-45′ clay, sand and cemented gravel, 45′-70′ mudstone
CG 5	14/8/64	M. Lawler	12	57	300	840	240	0-12′ sand and clay, 12′-57′ mudsone
PB1	28/7/64	R. Duggan	20	78	250	2000	20	0-58′ clay, soft sandstone, 58′-64′ gravel and sand 64′-76′ hard sandstone, 76′-78′ mudstone

*Depth at which water was first struck.

†Total dissolved solids, determined with a conductivity meter.

**Water from bores C1, CG1, CG2, CG4, L1, L2 and L3 has been analysed.

‡Drilled by Tasmanian Drillers, Hobart.

Bore	*Date*	*Owner*	**Water Level ft.*	*Total Depth ft.*	*Output g.p.h.*	*†T.D.S. p.p.m.*	*Alt. ft.*	*Bore Log*
GB1	10/9/62 10/8/64	A. McMullen	28	75	350-400	..	125	0-15′ soil and clay, 15′-69′ sandstone and mudstone, 60′-75′ white sandstone
GB2	13/9/62	L. Norris	..	64	..	..	410	0-20′ soil, clay and gravel 20′-56′ fossiliferous mudstone, 56′-64′ dolerite
‡WG1	4/3/64	Hammond Bros.	20	30	500	..	200	0-7′ clay, 7′-30′ hard mudstone
‡WG2	4/3/64	B. Norris	20	30	500	..	300	0-1′6″ soil, 1′6″-10′ clay, 10′-30′ mudstone
**L1	14/8/62	A. Reardon	25	73	350-400	..	90	0-20′ clay, 20′-43′ soft mudstone, 43′-73′ blue-grey mudstone
**L2	17/8/62	G. Reardon	40	70	300-350	..	250	0-33′ soil, clay and boulders, 33′-48′ grey mudstone, 48′-70′ dark blue-grey mudstone
**L3	23/8/62	A. Reardon	68	96	300	..	55	0-45′ filling and clay, 45′-65′ soft grey mudstone, 65′-96′ dark grey mudstone
L4	29/8/62	W. Neil	57	77	300-350	..	110	0-48′ soil, clay and soft grey mudstone, 48′-77′ mudstone and sandstone
L5	6/9/62	J. Mills	70	106	300	..	150	0-20′ clay and gravel, 20′-60′ sandstone, 60′-106′ grey mudstone
‡L6	18/9/66	R. Griffiths 495450E, 681375N	..	16	..	..	..	0′-8′ clay, 8′-16′ dolerite
‡C17	13/10/66	G. Slater 492300E, 693400N	28	60	1200	..	..	0′-2′ soil, 2′-7′ clay, 7′-9′ coarse sand, 9′-60′ hard mudstone
‡C18	4/1/67	H. Duggan & Sons 491600E, 694950N	60	100	2000	..	..	0′-15′ clay, 15′-25′ soft mudstone, 25′-100′ firm mudstone
‡C15	1/2/67	C. Piesse & Co.	45	63	600	..	..	43′-63′ hard mudstone
Extension to existing bore								
‡C19	9/3/67	K. Bennett	45	60	1500	..	..	0′-1′6″ soil, 1′6″-15′ soft clay, 15′-60′ mudstone

*Depth at which water was first struck.

†Total dissolved solids, determined with a conductivity meter.

**Water from bores C1, CG1, CG2, CG4, L1, L2 and L3 has been analysed.

‡Drilled by Tasmanian Drillers, Hobart.

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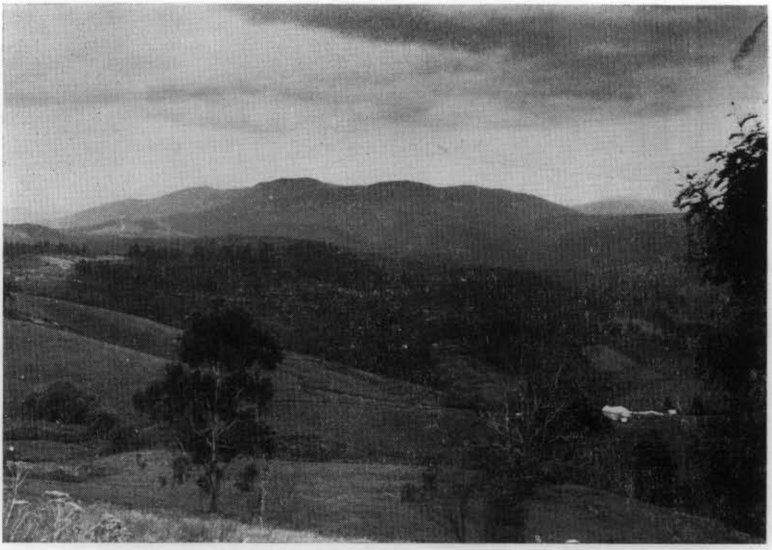


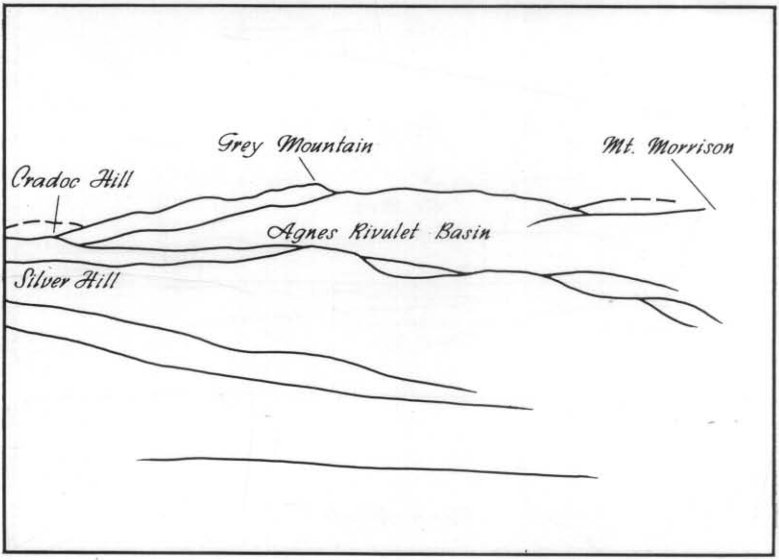
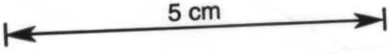


PLATE 1.—View from Coads Hill looking towards Grey Mountain.



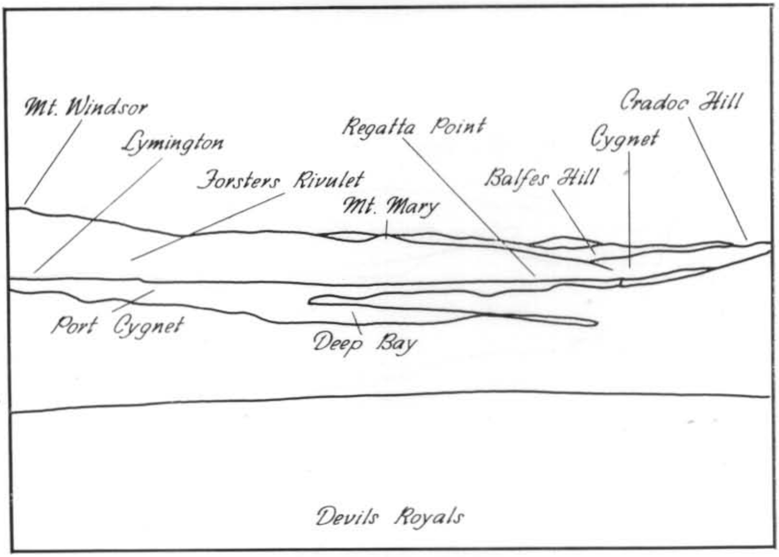


PLATE 2.—View of Port Cygnet.

5 cm

PLATE 3.—Sheet joints in syenite porphyry, Silver Hill.

PLATE 4.—Fractured and weathered syenite porphyry, Silver Hill.

5 cm

PLATE 5.—Gravels at Point Beaupré.

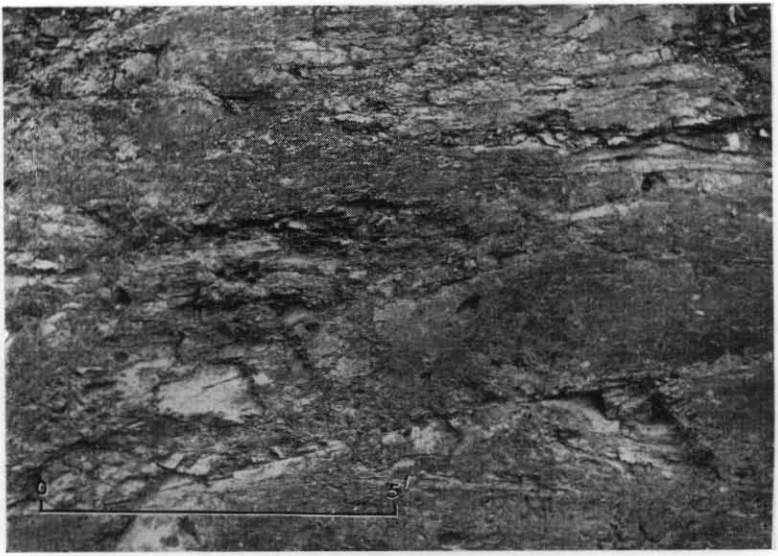


PLATE 6.—Openings in tillite.

5 cm

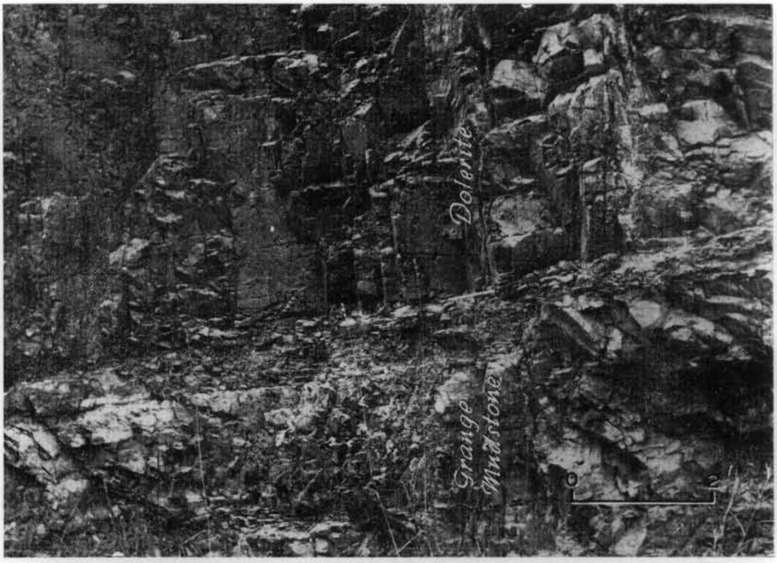


PLATE 7.—Dolerite-Grange Mudstone contact zone, Mt. Morrison.

PLATE 8.—Tinguaite-Grange Mudstone contact zone, Lymington Jetty.

5 cm

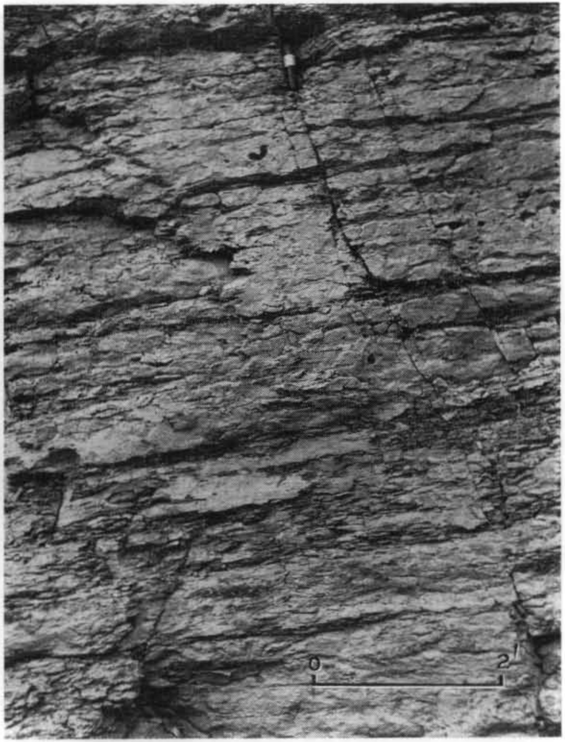


PLATE 9.—Character of the Grange Mudstone.

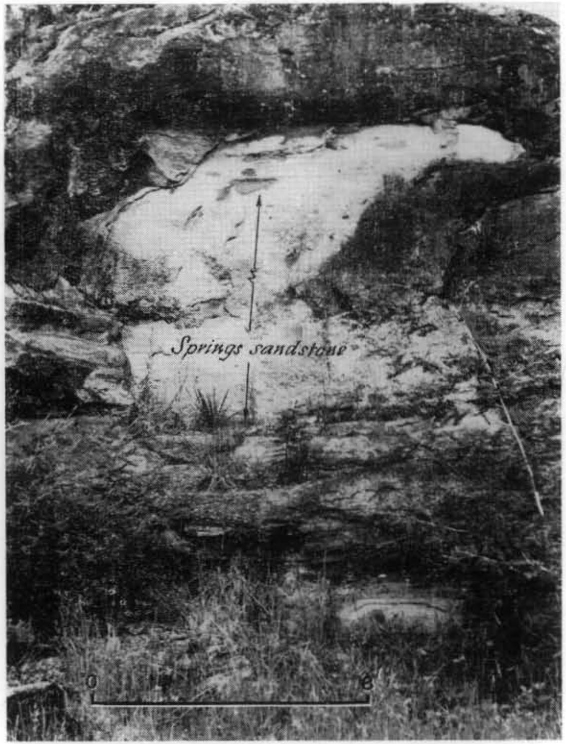


PLATE 10.—Character of the Triassic sandstone.

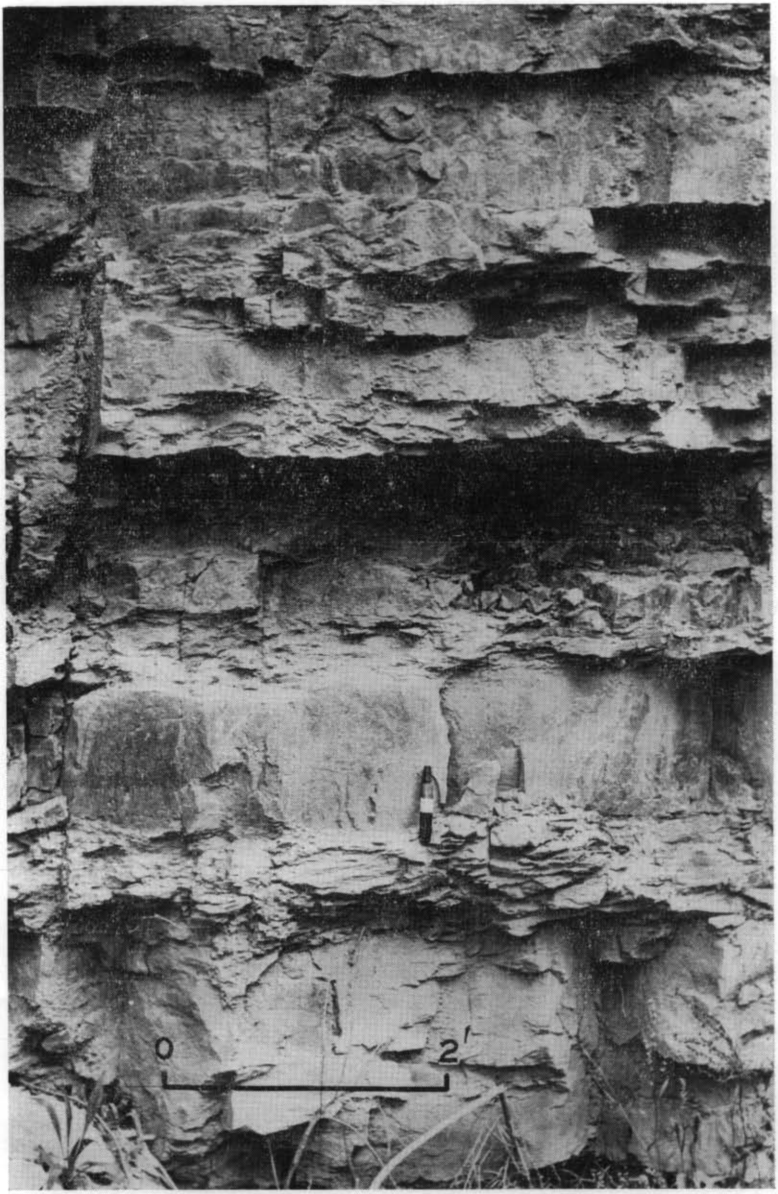


PLATE 11.—Character of the Ferntree Formation Mudstone.

5 cm

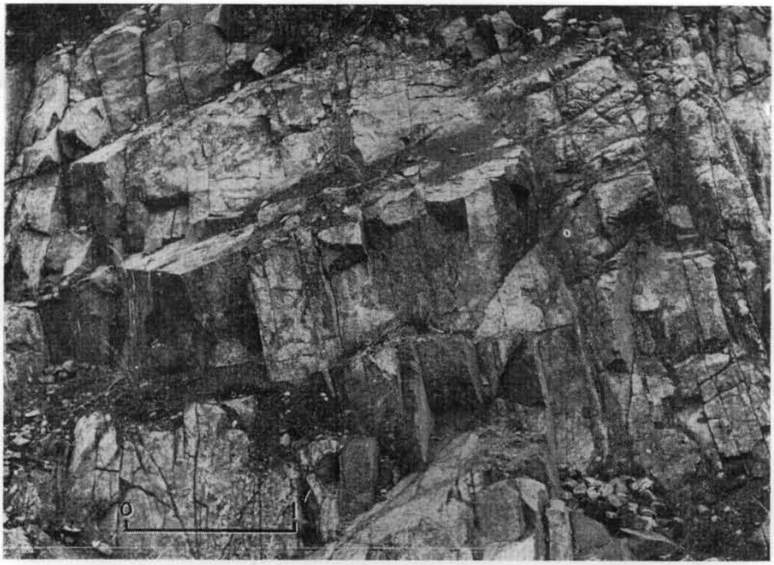


PLATE 12.—Jointed dolerite.

PLATE 13.—Weathered dolerite.

5 cm

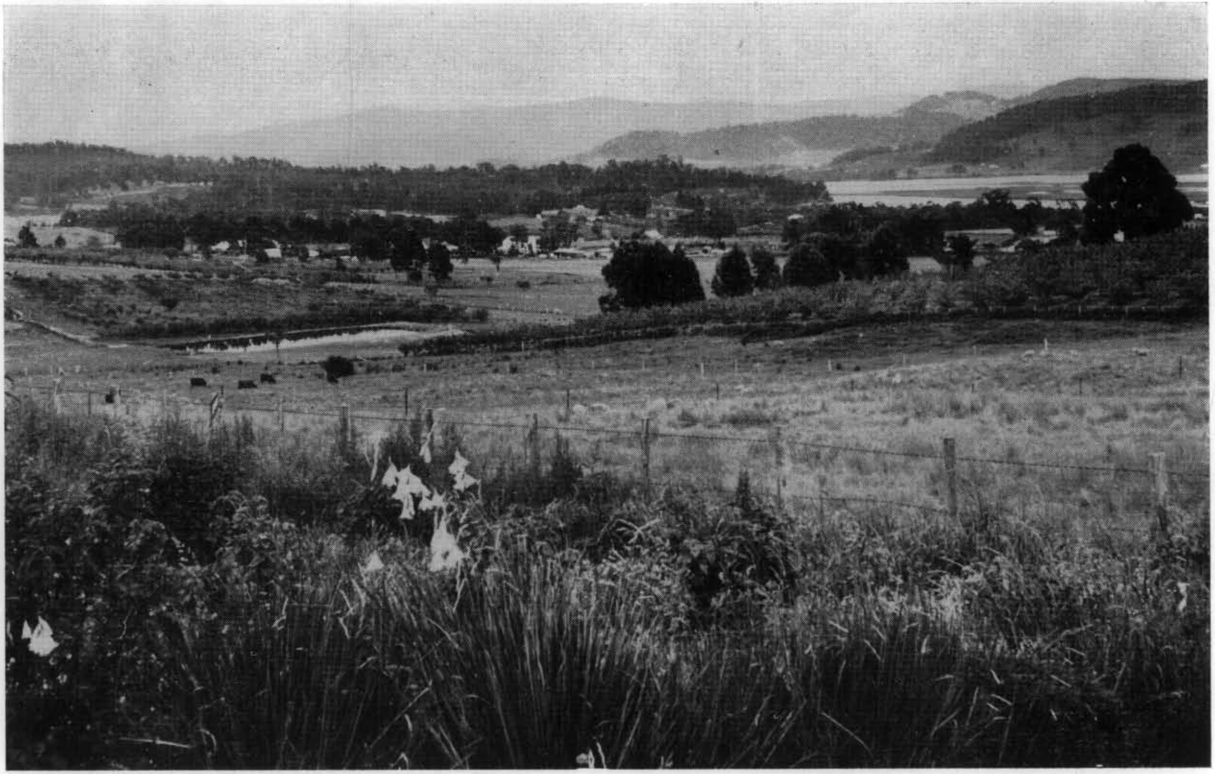
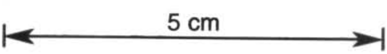


PLATE 14.—Cradoc from Cradoc Hill.

PLATE 15.—Glaziers Bay from Silver Hill.

PLATE 16.—Flood plain, Nicholls Rivulet.



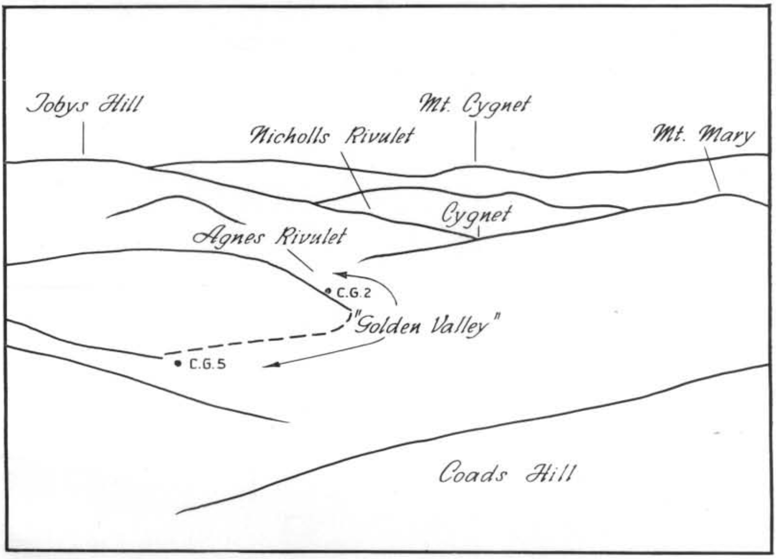


PLATE 17.—View of southern part of Cygnet Region.

5 cm

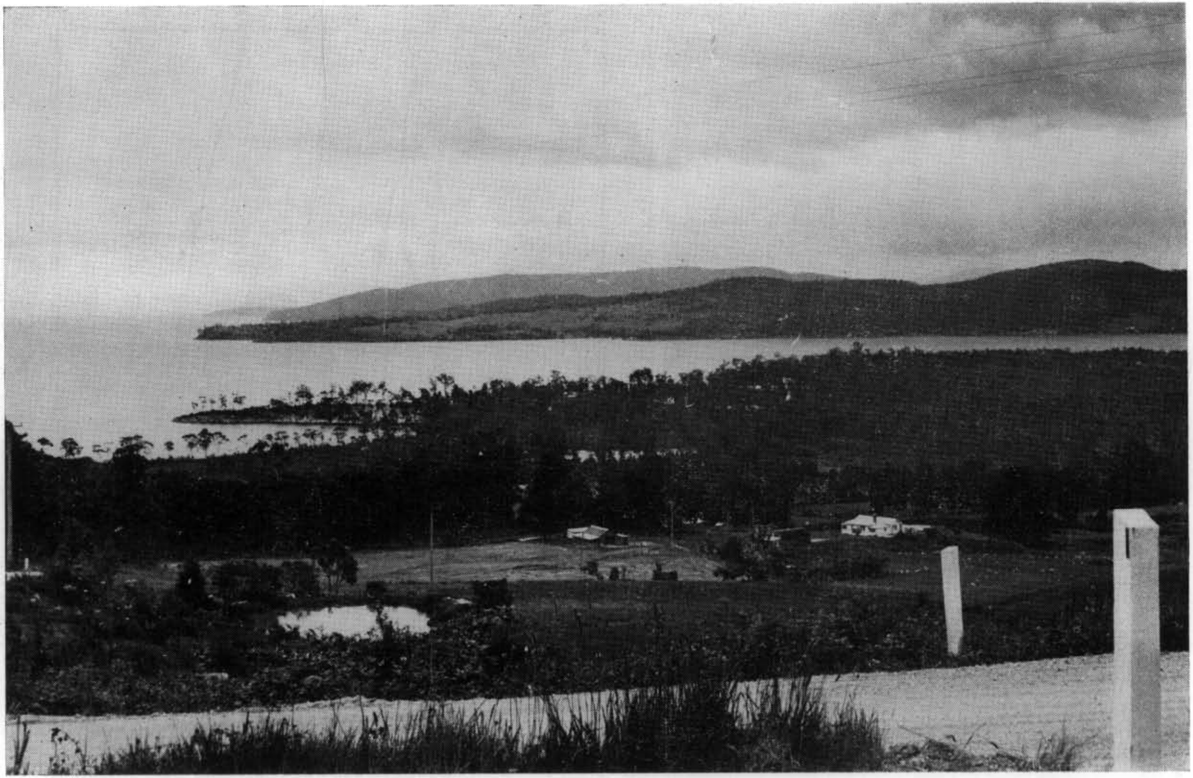
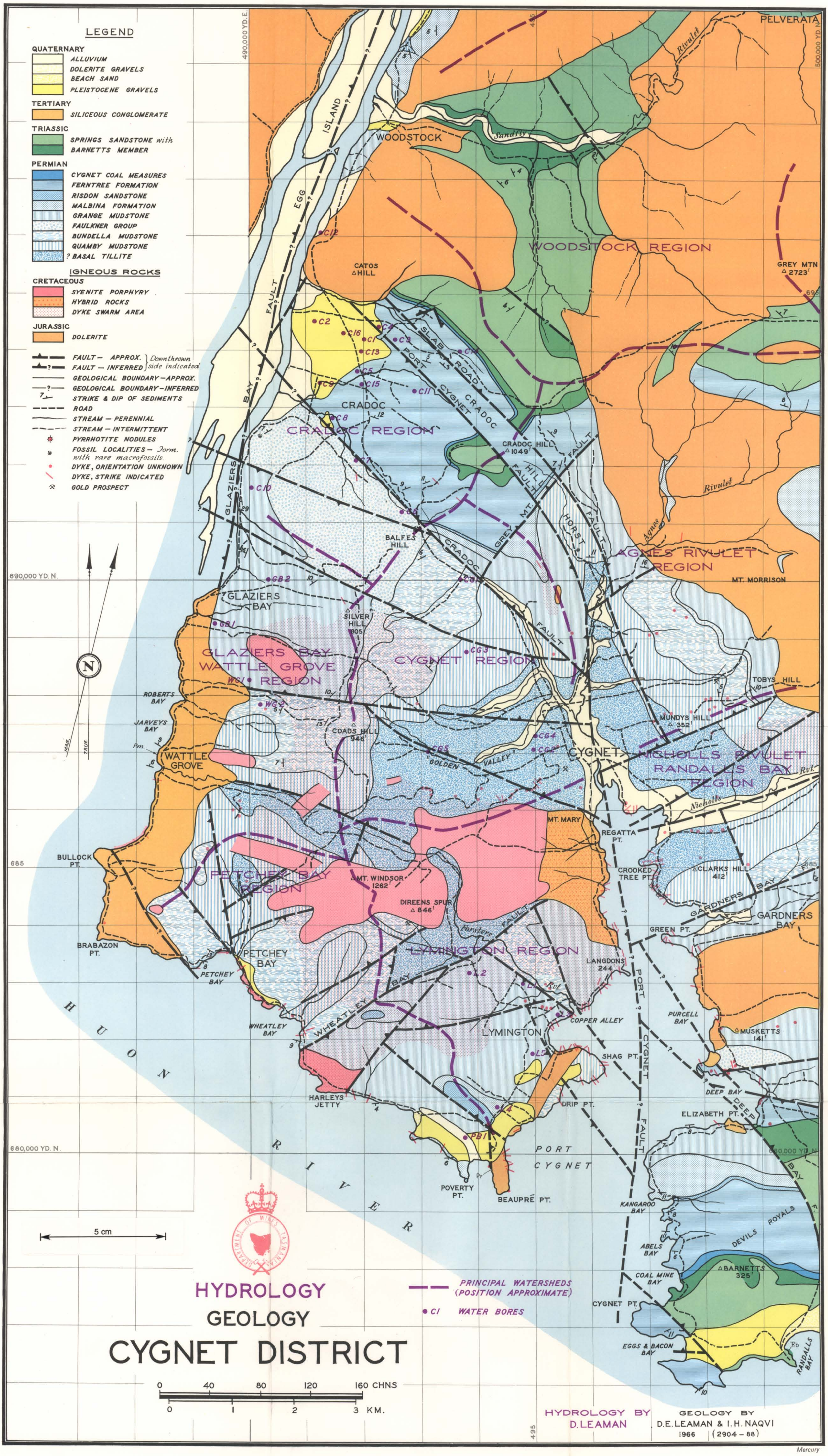


PLATE 18.—View of Randalls Bay.



HYDROLOGY
GEOLOGY
CYGNET DISTRICT

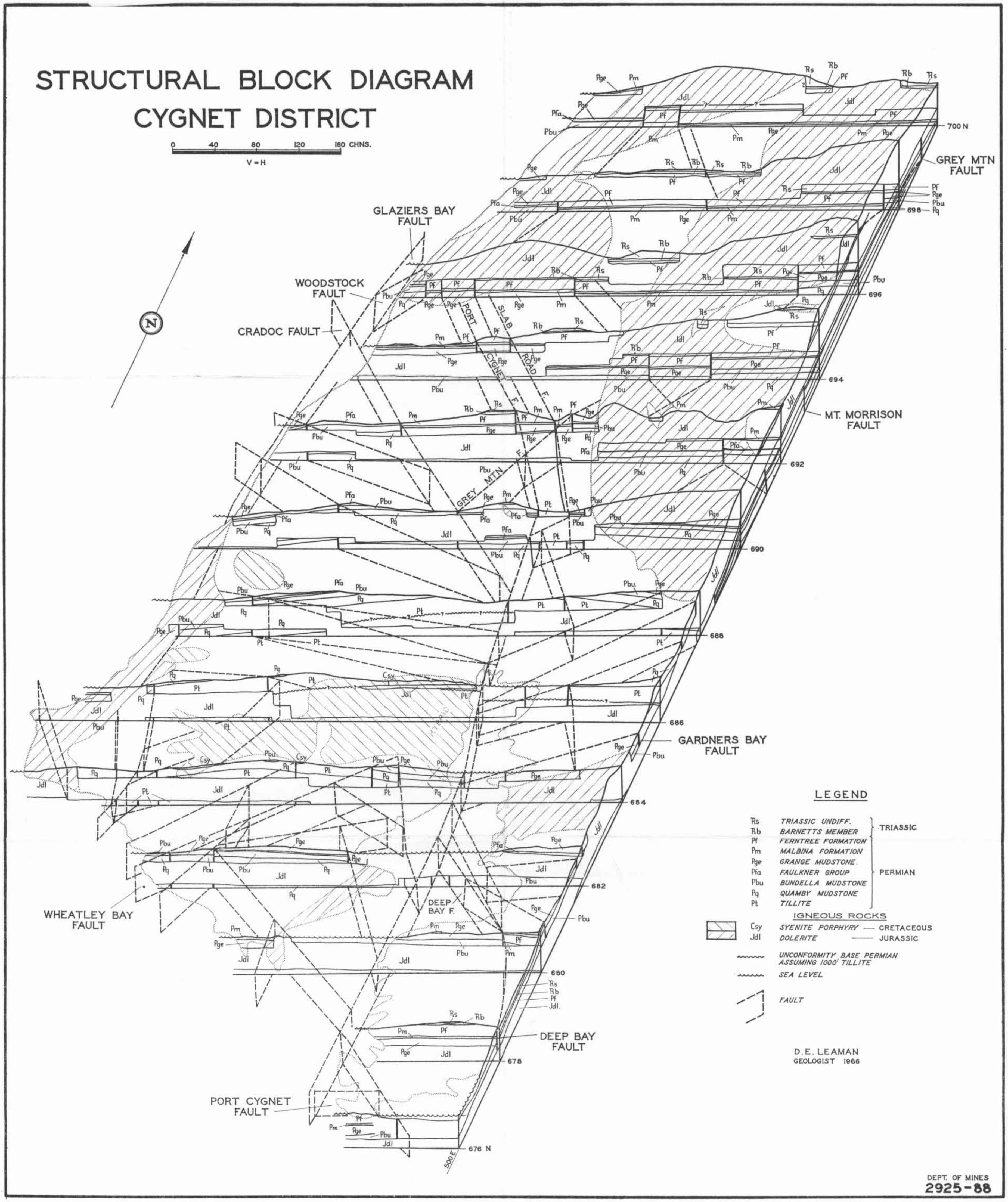
HYDROLOGY BY D. LEAMAN

GEOLOGY BY D.E. LEAMAN & I.H. NAQVI

1966 (2904 – 88)

Mercury

5 cm



STRUCTURAL BLOCK DIAGRAM
CYGNET DISTRICT
0 40 80 120 160 CHNS.
V = H
GLAZIERS BAY FAULT
WOODSTOCK FAULT
CRADOC FAULT
PORT CYGNET SLAB ROAD F.
GREY MTN. F.
GREY MTN FAULT
MT. MORRISON FAULT
GARDNERS BAY FAULT
WHEATLEY BAY FAULT
DEEP BAY F.
DEEP BAY FAULT
PORT CYGNET FAULT
700 N
698
696
694
692
690
688
686
684
682
680
678
676 N
500 E
LEGEND
Ʀs TRIASSIC UNDIFF.
Ʀb BARNETTS MEMBER
Pf FERNTREE FORMATION
Pm MALBINA FORMATION
Pge GRANGE MUDSTONE
Pfa FAULKNER GROUP
Pbu BUNDELLA MUDSTONE
Pq QUAMBY MUDSTONE
Pt TILLITE
TRIASSIC
PERMIAN
IGNEOUS ROCKS
Csy SYENITE PORPHYRY — CRETACEOUS
Jdl DOLERITE — JURASSIC
UNCONFORMITY BASE PERMIAN ASSUMING 1000' TILLITE
SEA LEVEL
FAULT
D.E. LEAMAN
GEOLOGIST 1966
DEPT. OF MINES
2925-88

FIGURE 2.