1981/45. Groundwater potential at Cadbury-Schweppes, Claremont, and the prospects for deep drilling

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Abstract

Cadbury-Schweppes are trying to reduce the cost of water use at their Claremont plant by considering the possible use of groundwater from holes drilled to depths of 150-200 metres. The factory land is underlain by basalt. Geophysical evidence and the close proximity of Tertiary sediments indicate that the basalt at this location is underlain by a Tertiary river valley filled with sediments. Three models are suggested for this valley, all of which will affect yields and groundwater quality.

Water from the basalt and Tertiary sediments is likely to be saline, and with the peninsula area so small and narrow, prolonged pumping will make salt water intrusion inevitable. Therefore for any suitable water to be found in the underlying rock, a sealing horizon or impermeable barrier must be provided by the Recent river bottom silts or within the underlying rocks themselves. The first model, with a deep valley cut in dolerite, would give little to no water. The second model, with a very shallow valley on a basement of Permian sediments, would give good quality water but its yield would be low. The third model, with a medium depth of valley and a sequence of quartzose sandstone dipping to the west, would possibly trap good quantities of groundwater, but the quality is likely to be poor. Because of the high risks, drilling could not be recommended.

INTRODUCTION

At the request of Cadbury Schweppes Pty Ltd a groundwater investigation was undertaken of the peninsula on which the Cadbury confectionery factory is situated [EN220620]. The factory uses a large amount of water (446 050 k*l*/year), and with ever increasing costs for water from Hobart's Metropolitan Water Board, the cost of water is becoming more critical in the factory operating costs. To supply this amount from groundwater would require a bore producing continuously 850 *l*/min of water. To produce such a quantity of water from groundwater sources is inconceivable, given the location of the peninsula, the rock types, and the peninsula's lack of area for recharge.

As well as these supply restraints, an even bigger problem at this location is likely to be the poor quality of the groundwater. The sediments underlying the peninsula are likely to produce saline water. With the peninsula surrounded on two sides by the salt water of the River Derwent, intrusion by this water is very likely and almost inevitable in the upper sediments if heavy continuous pumping is undertaken.

Any quantity of reasonable water, even if only to water gardens *etc.*, would be considered if the risk warrants the cost of drilling. The engineer in charge of this project indicated that this investigation should place particular emphasis on the possibility of a deep bore, rather than the shallow bore that had been previously drilled in the area. Depths of 150-200 m could be drilled if there was any possibility of obtaining groundwater supplies. It was accepted as a general principle that the greater the depth, the higher the risk of the project.

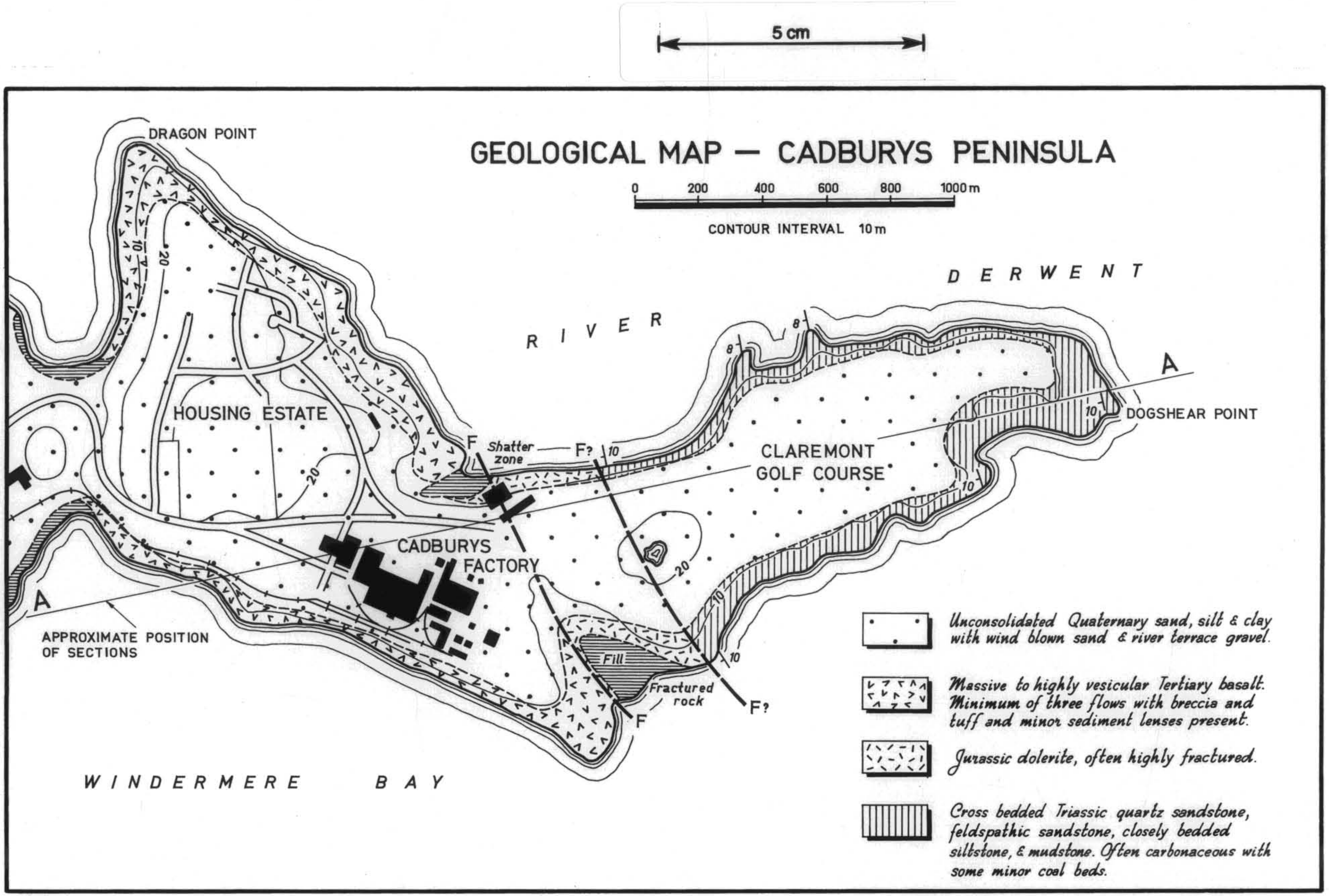

Figure 1

45-2

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One day of field work was undertaken examining the rocks of the peninsula, and a resistivity probe took a further three hours. A further day was required for literature search prior to this report being compiled.

GEOLOGY

The Cadbury peninsula is an isolated remnant of a 27 m high terrace which has little relief. A series of low cliffs border the river with good exposures, so that the peninsula's structure above water level offers no difficulty of interpretation. Covering the peninsula's surface is a thin layer of Quaternary age sediments. The most widespread of these sediments is a thin layer of river gravel, with minor areas of windblown sand and clay.

The rocks underlying these superficial deposits are basalt of Tertiary age, dolerite of Jurassic age, and sandstone, siltstone, and mudstone of Triassic age. Each of these rock types cover approximately one-third of the peninsula (fig. 1).

The basalt forms the western section of the peninsula, where 15 m high cliffs of this rock border the shoreline north of the factory and housing estate around Dragon Point. South of the factory, basalt forms the northern shore of Windermere Bay. The dolerite is the most poorly exposed of the three rock types, forming isolated outcrops of a dyke through the centre of the peninsula. Westerly dipping quartz sandstone, feldspathic sandstone, siltstone, and sandstone with some minor coal beds are exposed on the eastern section of the peninsula to Dogshear Point. The sediments are frequently baked, indicating that dolerite intrudes these sediments at no great depth below sea level. Geologically, the Triassic sediments and dolerite are associated with rocks on the eastern shore of the Derwent at Mount Direction and Old Beach, whereas the basalt is associated with the Tertiary and Permian sediments at Berriedale and Claremont on the western shore. This association is shown on the geological map of the River Derwent (Leaman, 1976), and by the field relation between basalt and Tertiary sediments (fig. 2). These sediments, though not exposed at Cadburys, are exposed on Knights Point on the southern shore of Windermere Bay and are extremely important for the groundwater prospects at Cadburys. The sediments underlie the basalt below sea level at Cadburys and were deposited in an old Tertiary river valley down which the basalt flowed from the north.

GEOPHYSICS

In a gravity survey, Leaman (1972) found strong negative anomalies in the Glenorchy area (fig. 3). Where the Tertiary sediments are exposed at Knights Point and at Cadburys, a negative gradient but no marked anomaly exists. In his first structural interpretation of the gravity of this area, Leaman (1972, grid line 625, fig. 8) shows no Tertiary valley beneath the peninsula. A modified interpretation, with a very shallow Tertiary valley underlain by Permian sediments intruded with dolerite at depth is given in Section A (fig. 4). The dolerite dyke exposed on the peninsula is considered as the westward termination of the lower Mount Direction dolerite sheet, and a possible feeder for this sheet. This sheet dips west from the eastern shore beneath the River Derwent and Triassic sediments of the peninsula at a shallow depth. The dolerite below the Tertiary valley in Section A is not related to the Mount Direction dolerite, but to the deeper dolerite discovered by drilling at Chapel Street, Glenorchy (Leaman, 1976).

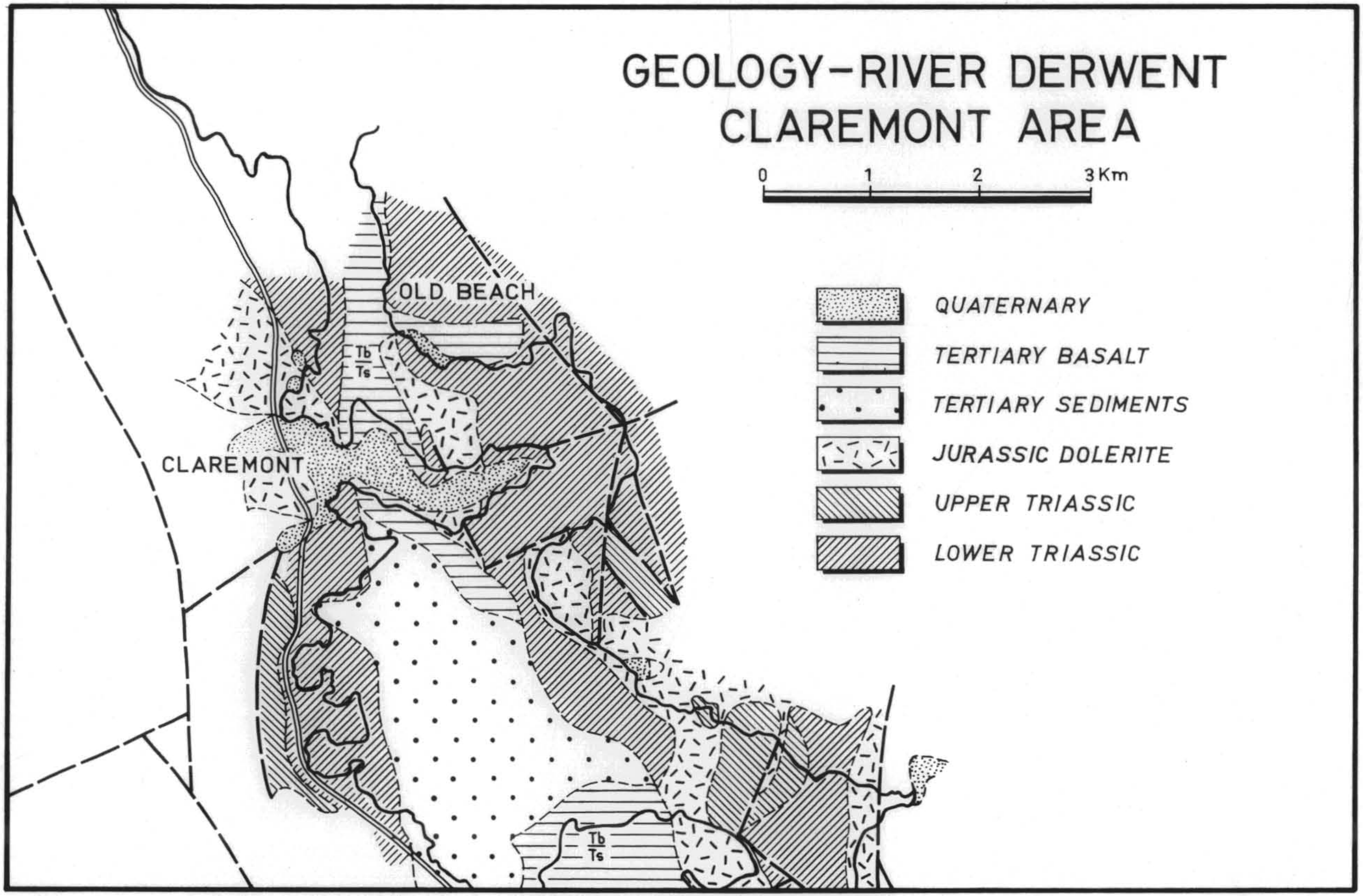

Figure 2 *(after Leaman, 1976)*

5 cm

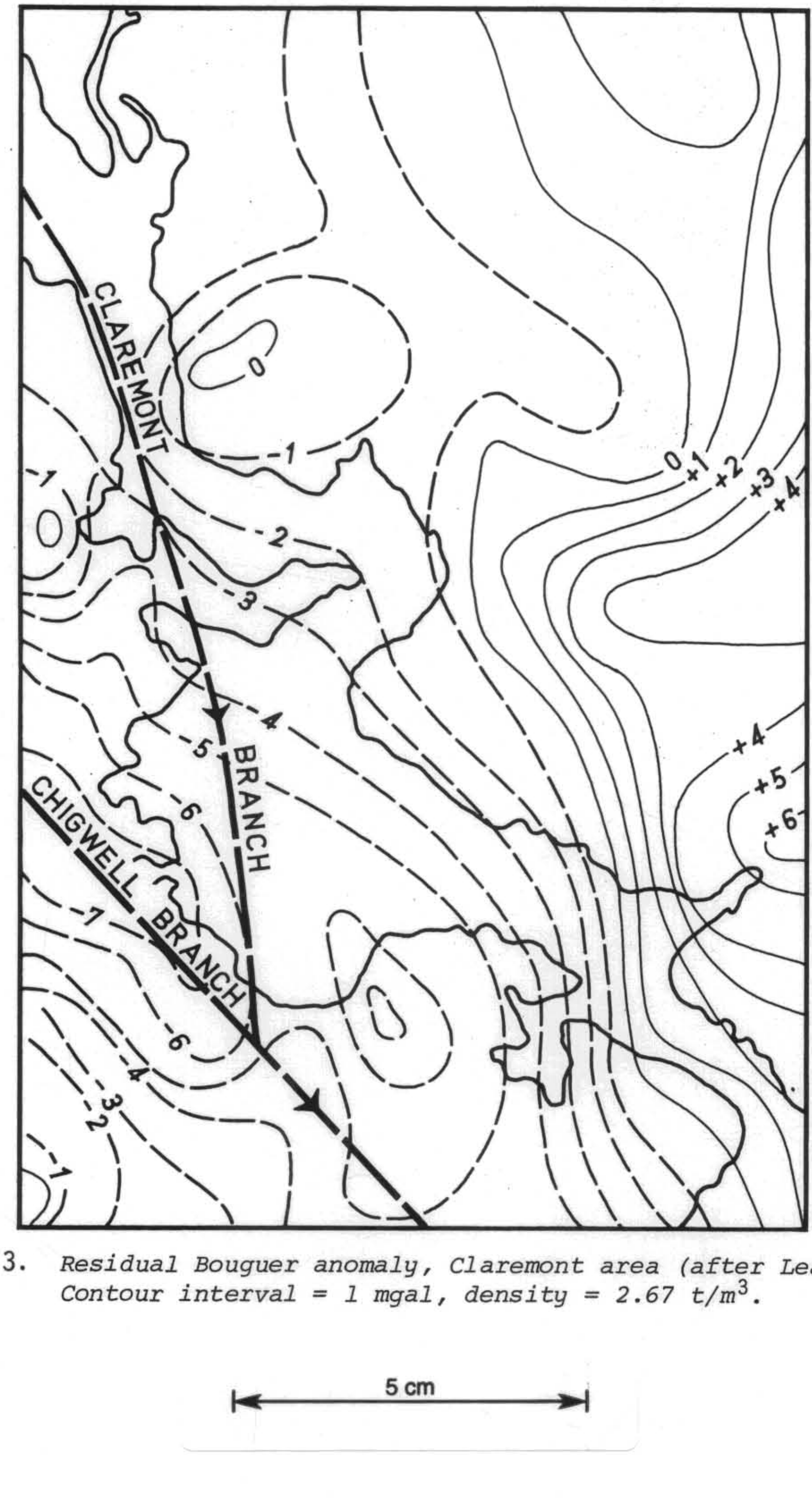

Figure 3. *Residual Bouguer anomaly, Claremont area (after Leaman, 1972). Contour interval = 1 mgal, density = 2.67 t/m*^{3}.

After further work in the Kingston and Lower Derwent areas on Tertiary valleys beneath basalts (Moore, 1979), plus the drilling of the deep bore at Chapel Street, Glenorchy, in which a 300 m thick dolerite sill was encountered, Leaman (1976) re-interpreted his gravity survey and concluded that a Tertiary valley existed beneath the basalt at Cadburys (Leaman, 1976, fig. 10). A magnetic survey of the River Derwent allowed Leaman (1977) to define the boundaries of this valley with more precision and to draw a cross-section of the peninsula. This magnetic survey and his re-interpretation of the gravity led Leaman to believe that the main Tertiary valley passed beneath Cadburys. The results of this magnetic survey are reproduced in Figure 5, and form the basis for Section B (fig. 4).

Both the gravity and magnetic methods rely on small measured differences, for which structural geological models are constructed to meet the field measurements. The restraints on these methods are broad, and alternative geological models are generally possible. The important gravity restraint at Cadburys is that if the basalt is thicker than anticipated, then a greater thickness of Tertiary sediment must exist. Because of the complementary density ranges of basalt and dolerite, the thickness of these two rocks, or the presence of the dolerite below the basalt, becomes a matter of speculation. Both basalt and dolerite are strongly magnetic and it is very difficult to determine if an anomaly is the result of either basalt or dolerite, or if both are present. This is shown at Cadburys, where no major anomaly exists, but a strong negative magnetic anomaly exists at Elwick Bay to the south (fig. 5). Basalt frequently shows magnetic reversals and can cancel out an anomaly produced by dolerite. This cancelling of anomaly is used by Leaman (1977, p. 129) to explain the difference of magnetic anomaly at Elwick Bay and at Windermere Bay and Cadburys.

With new outcrops of Tertiary sediment having been exposed on the recently constructed Northern Outlet road in the Chigwell area, it appears likely that two Tertiary valleys are present north of Elwick Bay. One, the NW-SE trending Chigwell branch, is probably the larger branch and a Claremont-Cadbury branch is possibly a minor branch running in an approximate N-S direction. These two branches join in the area of greatest negative gravity anomaly (fig. 3).

The possibility of two valleys allows for a third model or interpretation of the geophysical data, with a thin surface layer of basalt (15-25 m thick), Tertiary sediments (30-50 m thick), Lower Triassic (60-150 m thick), and an Upper Permian sequence (100-200 m thick) (Section C, fig. 4), depending on the throw of the fault to the west of the peninsula. No magnetic anomaly exists because the basalts are thin, weathered, and have magnetic reversals within the flows, or a thin dolerite sill compensates this anomaly out. This sill would probably occur near the bottom of the Triassic sequence, as it does in the Claremont area to the north of the peninsula.

Resistivity survey

Whichever of the three geological models is correct will affect the groundwater quantity, but more importantly, the groundwater quality. The surface area of the peninsula is small and is surrounded on both sides by the River Derwent, making the possibility of saline water intrusion, particularly in the basalt and the underlying Tertiary sediments, most likely. In order to see if this saline water could be detected geophysically, a 180 m long resistivity probe using a Wenner configuration was undertaken. The values declined from the surface layer of 36 Ωm to 21 Ωm and climbed gradually back to 37 Ωm at 180 m length for the probe.

No salt water layer was detected and the apparent resistivity curve is interpreted as a two layer case of surface soil or clay layer with a second layer of weathered basalt. The depth penetration was not considered adequate to have reached the water table level. The power intake was not sufficient to allow the spread to be increased in length.

GROUNDWATER PROSPECTS OF ROCK TYPES

Basalt

The basalt flows exposed on the cliff sections of the peninsula are vesicular and highly jointed with small sedimentary lenses and breccia zones present. Given that there was an adequate thickness of this rock (30-50 m), reasonable bore yields of 75-230 *l*/min could be anticipated. Because of the peninsula's location, the water is likely to be saline, especially if the basalt is extensive enough to be continuous beneath the River Derwent to the Old Beach basalt as suggested by Leaman (1976, fig. 4).

Tertiary sediments

These sediments are variable in composition, with very fine sand, silt, and clay. The sediments exposed at Knights Point - Windermere Bay are poorly sorted, and the sands are muddy and appear to be a poor aquifer. The exposures of Tertiary sediment are so few that they may not be representative if any great thickness of these sediments is present beneath the peninsula. The quality of the groundwater from the Tertiary sediments in south-east Tasmania is generally very poor in Tertiary valleys (Moore, 1979). With downward infiltration from the overlying basalt or directly from the River Derwent, the Tertiary sediments cannot be considered favourably as an aquifer at this site.

Dolerite

Though some successful bores in this rock type have been reported *e.g.* Old Beach (Leaman, 1976, p. 88), very little definite evidence is available. The cost of drilling this rock is a deterrent. Where close jointing or fracture zones exist it is conceivable that some supplies of groundwater can be obtained from this rock. The water quality from dolerite rocks is often poor in quality and hard. Drilling this rock for groundwater is not recommended.

The dolerite, if present as a thin continuous sill (30 m or less thick) could serve as an impermeable barrier to the downward migration of the overlying saline water from the Tertiary sediments and River Derwent into the underlying sediments. However if dolerite is encountered in the drilling of the bore, it will be difficult predicting the thickness of the rock.

Lower Triassic sediments

Two-hundred and fifty metres of Lower Triassic sediments are exposed along the cliff section of the peninsula covered by the golf course. Exposed in this section are quartz sandstone, closely bedded muddy sandstone, slate, and mudstone with minor coal seams.

This area is part of Leaman's (1976) Lower Triassic age sequence in which the massive, coarsely bedded quartz sandstone dominates. This sandstone is not well represented in the peninsula outcrops but is well exposed on the Old Beach cliffs on the eastern side of the River Derwent.

It is this massive quartz sandstone that has the potential as a groundwater source rock or aquifer to give the yields that warrant deep drilling.

It is possible that these sandstones are down-faulted and may not appear in the Triassic sequence below Cadburys; even if this faulting has not occurred the lateral variation of facies may mean that these rocks do not appear. These cliffed sandstones lense out rapidly in the Hobart area and certainly do not form regional marker horizons that continue for any great distance. This fact is well illustrated by the range of Leaman's estimate of their thickness (15 m to 120 m).

To form a consolidated sedimentary aquifer of any use, these sediments must have a structural dip to the west, with dolerite or Permian rocks faulted against them to form a structural trap for the groundwater. They will also require an overlying impermeable barrier. The mudstone, shale, and coal sequence exposed on the south side of the peninsula would be very suitable for such a barrier.

The massive Triassic sandstone would be classified as a consolidated sediment type of aquifer and its known yields to date have not been spectacular. Yields of 75-200 *l*/min have been reported, but little is known of the bore structure, the type of pump test run (if any), and even the location is often in doubt; such yield claims must be treated with scepticism. Unfortunately there is not enough reliable water bore information to make a reliable statistical assessment of the yield from these sediments. In north-east Tasmania, where sandstone of similar type and age has been drilled, their yields were disappointingly low at less than 15 *l*/min.

Leaman (1976) estimates the quality of water from this rock type as rarely better than 1500-2000 mg/*l* total dissolved solids. The quality of the water from similar rock types in north-eastern Tasmania is in a similar range. The problem at Cadburys, as elsewhere, is that the sandstone at surface outcrop could be free draining, allowing water to escape, and thus is not strictly comparable with water which is structurally trapped at depth.

Permian sediments

If the upper members of the Permian System are encountered, their yields can be anticipated to be low. These rocks form rock fracture aquifers, and their storage and permeability must be low, even though they are reliable low yielding aquifers. They will provide some water, but hardly enough to warrant being considered as a target for any deep drilling. Yields of 7-15 *l*/min could be anticipated, with the exceptional fracture zone giving yields up to 75 *l*/min. The water quality is generally good to excellent, with total dissolved solids content varying from 200-1050 mg/*l* in the Cygnet area, the only area where a systematic groundwater survey of these sediments has been undertaken (Leaman, 1967). Because of the sulphide minerals in the veins of these rocks, the iron content often makes the groundwater unsuitable for household use.

PREVIOUS DRILLING

The manager of the Claremont Golf Course (Mr Brown) reported that two bores were drilled on the course and that water from both was salty. No record of these two bores can be found, nor of the bore reported by Mr Cohen (engineer, Cadbury-Schweppes Pty Ltd) to have been drilled in the Glenorchy area by a drilling contractor and to be producing 150 *l*/min of water. It would be advisable that the location of this bore be checked by Cadbury-Schweppes staff and, if possible, to check its pumping rate and method of testing its yield. It is difficult to envisage a bore in this locality producing this amount of water, and claims of high yields frequently made by commercial drilling operators are based on blowing air in a bore for short intermittent periods. Such a method is not a reliable guide to a bore's yield, and the yield is generally highly exaggerated.

The only boresnear this area for which records are available are those at Old Beach which were drilled at the old hotel site. Their yields were low (3-15 *l*/min), with no water quality recorded (Leaman, 1976, p. 97). The three bores were all drilled in sediments of Triassic age.

FURTHER EXPLORATION

Of the available geophysical methods, a detailed gravity survey is the only one which would add any further information. Extended resistivity penetration would be blanketed out by a salt water intrusion and the depths involved are too shallow for a reflection seismic survey. A gravity survey would require at least three surveyed and levelled lines across the peninsula starting from some known base station, such as the Claremont railway station. Such a survey would, without doubt, allow for a better structural interpretation of the area than now available, but would tell nothing about the groundwater potential and water quality.

Such a detailed gravity survey, including precise levelling and computer time interpretation, would probably be a costly exercise.

CONCLUSIONS

(1) To replace the water used at the Cadbury-Schweppes factory by groundwater resources is not hydrogeologically conceivable, given the size of the peninsula and its location in the saline waters of the River Derwent.

(2) Given less ambitious aims, the possibility of obtaining any suitable quantities of groundwater from shallow bores in the surface basal rocks appears very unlikely. Any water in the basalt is likely to be saline from infiltration of river water.

(3) The geological and geophysical evidence indicate that a Tertiary river valley filled with unconsolidated sand, silt, and clay is present below the basalt. The thickness and lithological composition of these sediments is unknown. From surface outcrops, it is likely that the groundwater from these sediments will be of poor quality, even if they are sealed off from the river water by river bottom silt and clay. If they are not sealed, as appears to be likely at this location in the river, downward infiltration of surface river water will make the groundwater in these unconsolidated sediments saline.

(4) The only possibility for any supplies of groundwater appears to be a deep bore into the rocks below the Tertiary sediments.

(5) Three geological models are proposed to fit the geological and geophysical evidence:
(a) the first, with basalt and little to no Tertiary sediments overlying a Permian sequence, would give low yields, with possibly the best quality of water if no surface water contamination occurred. The gravity survey results require that a dolerite sill intrudes these sediments at some level.
(b) the second model, with a very deep Tertiary valley filled with

sediment and the valley cut into dolerite, is likely to yield little to no water from the dolerite.
(c) the third model requires a shallow tributary Tertiary valley with thin overlying basalt and sediment. The valley would have to be cut in Triassic sediments as exposed opposite the Cadbury peninsula at Old Beach on the eastern shore. A sealing layer of mudstone and slate would be required to overlie a thick sequence of massive quartzose sandstone with a dip to the west, forming a structural trap to allow groundwater to accumulate in the sandstone aquifers. The likelihood of obtaining all these necessary geological combinations make this model the least likely, and with the highest risk. The yields from such an aquifer could be adequate to warrant the cost of drilling a deep bore, but the water quality from these sediments is likely to be only fair to poor.

(6) With all of these geological models the possibility of encountering dolerite is high and it would not be possible to estimate the thickness of the dolerite when drilling.

(7) Pumping will probably cause downward infiltration and salt water intrusion from the upper basalt and Tertiary sediment section of the bore. This section would have to be cased and cemented to stop such downward leakage. This would be a difficult drilling operation for local drilling contractors.

RECOMMENDATIONS

(1) No shallow drilling (15-30 m) be undertaken or contemplated. If such a bore was in basalt and fresh water was encountered, such water is likely to have a very limited depth. This fresh water is likely to be underlain by more dense saline water infiltrated from the river. With pumping, such a lens of fresh water would be rapidly exhausted, and with such a limited surface area of basalt on the peninsula, no adequate recharge is likely to occur.

(2) The only possible groundwater supplies are from a bore up to 150-200 m deep. Geologically it would be a most attractive and interesting exercise to drill such a deep bore on the factory site. The possibilities of obtaining groundwater supplies in adequate quantities are low, and even more problematical is finding a suitable quality of water. To the writer the high risk and the considerable cost of drilling such a bore appears not warranted.

Therefore no drilling can be recommended for this site.

If the management of Cadbury-Schweppes do decide to go ahead with this project and a deep bore is drilled, it should ensure that the drilling contractor employed is competent, and has the equipment and knowledge to drill from hard rock to unconsolidated sediments and back to hard rocks. He should also be able to seal by casing and cement any contamination of the lower aquifers by poor quality water from the overlying rocks.

In addition, the hole should be logged regularly by a geologist as it is being drilled in order to know what rocks the bore is penetrating.

A written contract should be drawn up with the costs of drilling hard rock, soft rock, and casing to be clearly stated. Before drilling is undertaken the cost of a limited gravity survey should be investigated and the project discussed with a geophysicist.

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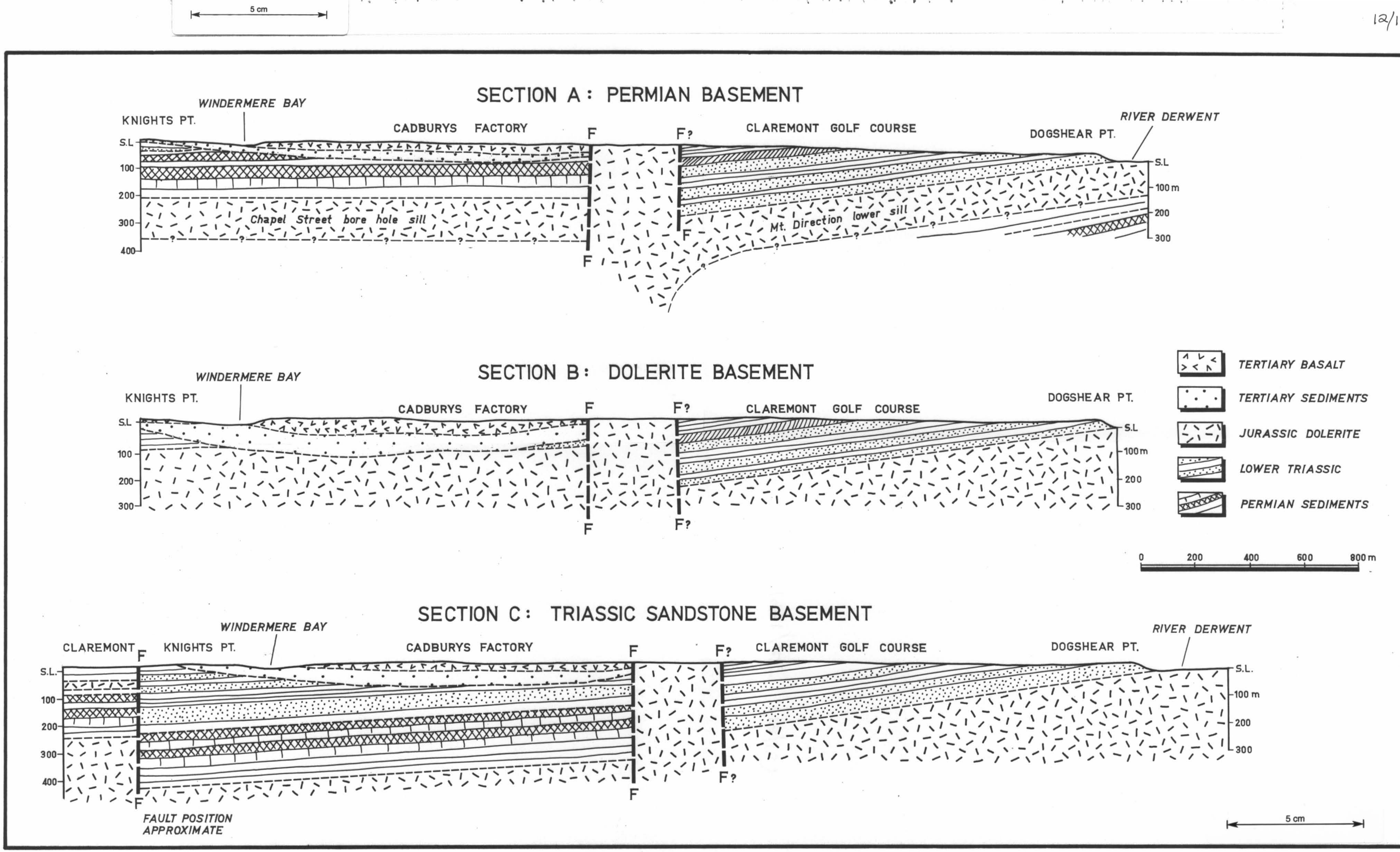
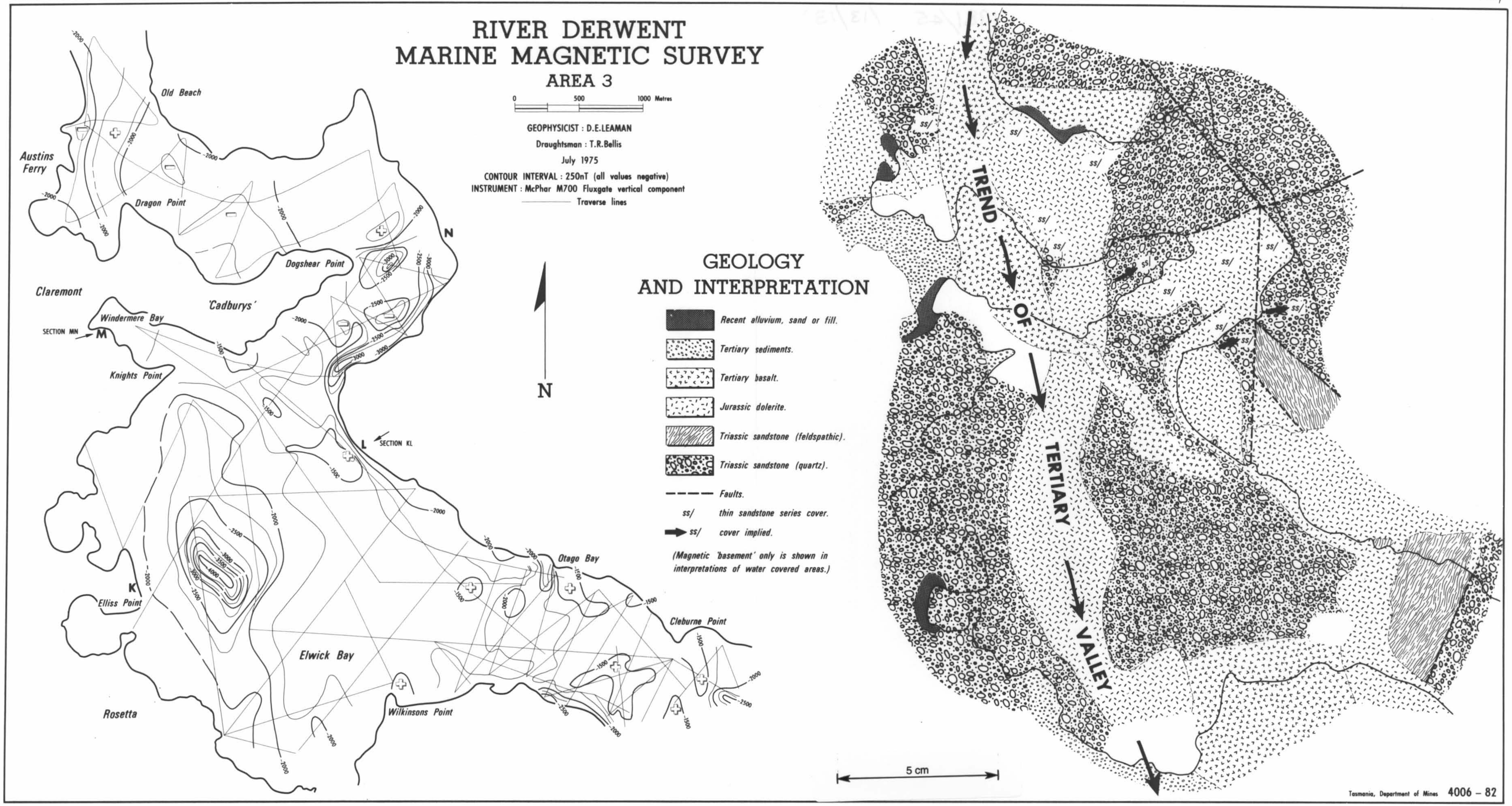
[28 September 1981]


5 cm
SECTION A: PERMIAN BASEMENT
KNIGHTS PT.
WINDERMERE BAY
CADBURYS FACTORY
F
F?
CLAREMONT GOLF COURSE
DOGSHEAR PT.
RIVER DERWENT
S.L
100
200
300
400
Chapel Street bore hole sill
Mt. Direction lower sill
100 m
SECTION B: DOLERITE BASEMENT
TERTIARY BASALT
TERTIARY SEDIMENTS
JURASSIC DOLERITE
LOWER TRIASSIC
PERMIAN SEDIMENTS
0
200
400
600
800 m
SECTION C: TRIASSIC SANDSTONE BASEMENT
CLAREMONT
S.L.
FAULT POSITION APPROXIMATE
5 cm

4862

Fig 4



RIVER DERWENT
MARINE MAGNETIC SURVEY
AREA 3
0 500 1000 Metres
GEOPHYSICIST : D.E.LEAMAN
Draughtsman : T.R.Bellis
July 1975
CONTOUR INTERVAL : 250nT (all values negative)
INSTRUMENT : McPhar M700 Fluxgate vertical component
Traverse lines
Old Beach
Austins Ferry
Dragon Point
Dogshear Point
Claremont
'Cadburys'
Windermere Bay
SECTION MN
M
N
Knights Point
L
SECTION KL
K
Elliss Point
Elwick Bay
Rosetta
Wilkinsons Point
Otago Bay
Cleburne Point
N
GEOLOGY
AND INTERPRETATION
Recent alluvium, sand or fill.
Tertiary sediments.
Tertiary basalt.
Jurassic dolerite.
Triassic sandstone (feldspathic).
Triassic sandstone (quartz).
Faults.
ss/ thin sandstone series cover.
ss/ cover implied.
(Magnetic 'basement' only is shown in interpretations of water covered areas.)
TREND
OF
TERTIARY
VALLEY
ss/
5 cm
Tasmania, Department of Mines 4006 – 82

Figure 5