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Geomorphic Perspective on Shallow Groundwater Potential, Coastal North-eastern Tasmania

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GEOMORPHIC PERSPECTIVE ON SHALLOW GROUNDWATER POTENTIAL, COASTAL NORTH-EASTERN TASMANIA

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Introduction

Many coastal areas of Australia are fringed by plains of unconsolidated sand. These sand bodies should contain abundant groundwater because precipitation is able to drain freely through the sand into the groundwater store. Accumulation of this water will create unconfined aquifer conditions provided that excessive quantities of water do not escape from the margins or base of the sand body. Unless traversed by exogenous streams, these areas are often characterised by a lack of permanent surface water. Therefore water is often a scarce resource.

Although Tasmania is generally more humid than the continent of Australia much of eastern Tasmania is subject to summer drought and severe soil water deficits. Thus groundwater may be utilized to enable higher production and crop diversification. At Greens Beach, near the mouth of the Tamar River, the Tasmanian Department of Mines is currently assessing the potential of Holocene marine sands as a source of town water supply. Many holiday home owners in coastal areas of Tasmania require water in small quantities for domestic purposes and use of water from water table aquifers is on the increase.

Hydrologic testing of some unconsolidated coastal sand deposits in Tasmania has been carried out by the Tasmanian Department of Mines on an *ad hoc* basis (Stevenson, 1969, 1970, 1973; Moore, 1968, 1975; Leaman, 1970a, 1970b, 1971; Matthews, 1966, 1971, 1972, 1975; Matthews and Cromer, 1973; Cromer, 1972, 1974a, 1974b and Cromer and Sloane, 1976), but since the overall relationships of the various deposits were not well known, the results could only be applied to the immediate areas from which they were gained. No assessment of the aquifers as systems was attempted.

The initial aim of this project (AWRC Research Project 75/84) was to study hydrological processes in coastal areas of eastern Tasmania and to classify coastal sediment bodies as potential aquifers on the basis of their form, stratigraphy, sedimentary and physical characteristics insofar as these properties can be related to the storage, transfer and yield of groundwater. It was also hoped that the findings could be applied to other areas of similar environment. Initial field work showed that most landform types which occur in eastern Tasmania also occur on the north-east coast. The study area was therefore reduced to include only coastal north-eastern Tasmania.

The reduced study area extends eastward from Bridport to Eddystone Point (Fig. 1) and covers the north-eastern coastal plain of Tasmania. It includes marine plains, terrestrial and coastal dunes, lake floors and alluvial terraces. Thus the surface of the area consists largely of low lying, unconsolidated sands and associated sediments of Late Quaternary age.

The mapping and description of landforms and deposits provided the basis for a systematic study of aquifer characteristics since each of the sediment bodies was identified as a separate unit. This was followed by intensive examination of the hydraulic properties of the sedimentary body which was expected to have the highest potential as a groundwater reservoir.

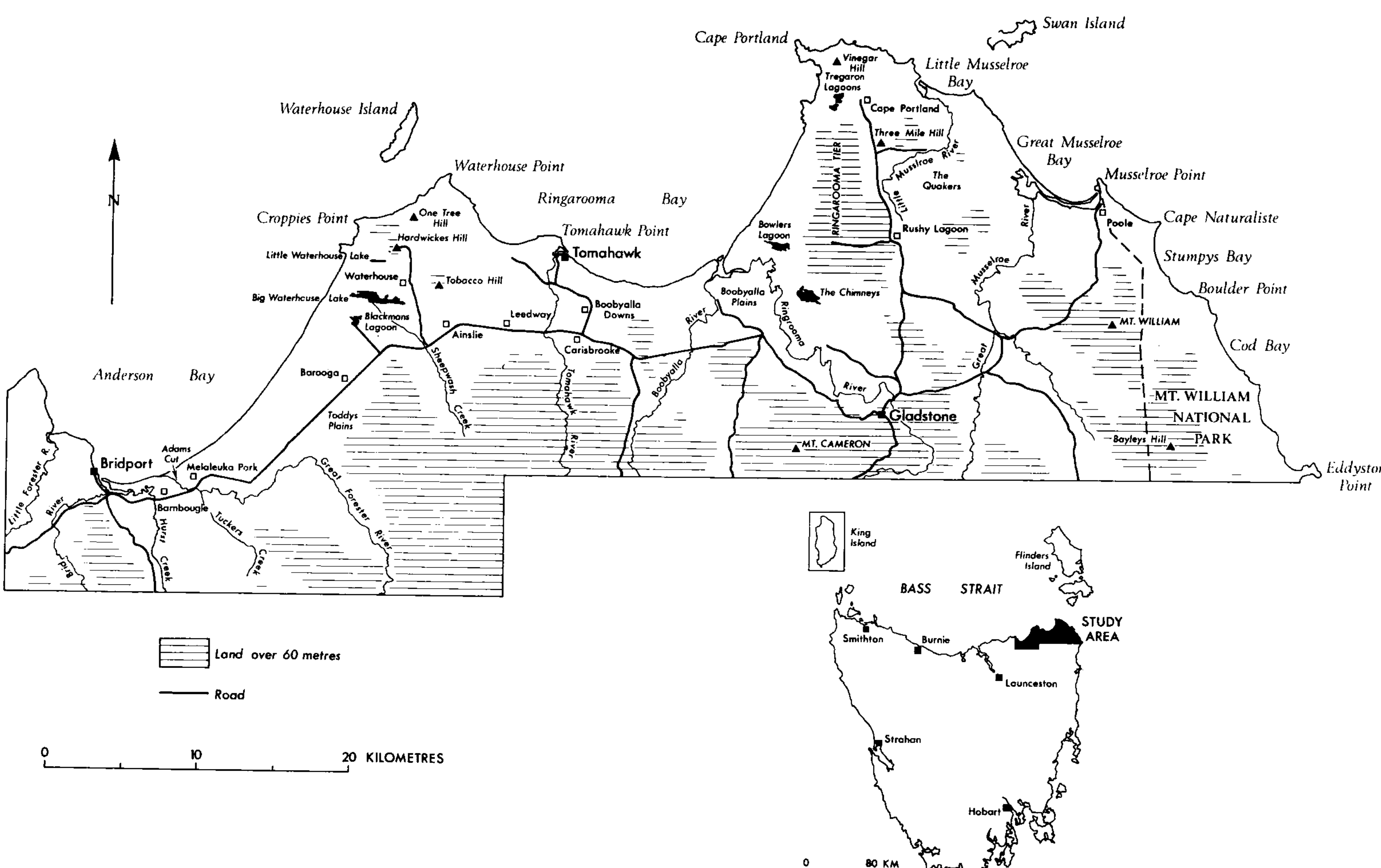


FIGURE 1

Locality Map

SUMMARY OF RESULTS

The approach adopted for this study, which has been to define the potential aquifers as discrete units and then to examine their hydraulic properties, has been very useful for the systematic evaluation of their shallow groundwater potential. Detailed field mapping, drilling, and continuous monitoring of groundwater levels carried out within a case study area enabled the dynamics of a selected aquifer system to be determined.

Large embayments of marine sands were deposited up to 32 m above present sea level, probably during the Last Interglacial Stage. During the Last Glacial Stage, when the sea level was between 100 to 125 m below the present level (Flint, 1965; Jennings, 1971), the plains of marine sand provided the source material for a large system of longitudinal sand dunes. The decreased temperature and precipitation which prevailed during this climatic stage caused a reduction in vegetation cover which allowed aeolian mobilization of the sand plains. During the period of longitudinal dune formation freeze-thaw action and associated processes were responsible for slope instability on steep, poorly vegetated, hillsides. This general slope instability was probably responsible for increased sediment load in the major river catchments of the area, and resulted in the deposition of alluvial terraces above the present floodplains. At this time, or slightly later, deflation hollows were excavated in the plains of marine sand. Where the deflation hollows were excavated to the water table lakes were created and lunettes were formed on their leeward margins. Lunette formation probably terminated at the close of the Last Glacial Stage when the vegetation stabilized the surfaces from which the sands were derived.

During the post glacial, or Holocene marine transgression, marine sands were deposited on the coast and now form narrow plains to a level of around 3.8 m above present high water mark. Siliceous parabolic dunes derived from the beaches are closely associated with these marine deposits, but are now essentially stabilized by vegetation. Large, mobile, transverse dunes also occur and are derived from the present beaches and through some erosion of older parabolic dunes. Table 1 summarises the Late Quaternary stratigraphy of coastal north-eastern Tasmania.

The classification of the above landforms and deposits has highlighted the groundwater potential of the Tomahawk Formation and Barnbougle Member on the basis of their wide extent, moderate thickness, and composition. Detailed study of the East Tomahawk area revealed that the interglacial marine sands form unconfined aquifer systems which gain water from precipitation and lose water through evapotranspiration. Lateral groundwater flow, although present, is not responsible for significant water table fluctuations. The water table responds quickly to rainfall inputs and evapotranspiration losses, but the nature of the response is controlled by the soil moisture conditions in the zone of aeration. The presence of moisture in this zone reduces the pore space available for rainwater, and when precipitation occurs, causes large water table rises. If the moisture in the zone of aeration is below field capacity, rainfall inputs must raise the soil moisture level to field capacity before excess water is able to percolate to the water table. Thus, during dry periods when this zone is below field capacity, significantly more rainfall is needed to produce an equivalent rise of the water table than is needed during moist periods. The capillary fringe component of the

TABLE 1

Late Quaternary Stratigraphy of Coastal North-Eastern Tasmania

Age	*Formation*	*Member*	*Landform and Origin*
HOLOCENE	Anderson Bay	Bowlers Lagoon	Coastal Transverse Dunes
		Blackmans Lagoon	Coastal Parabolic Dunes
		Barnbougle	Marine Plains
LAST GLACIAL	Waterhouse	Forester	Fluvial Terraces
		Rushy Lagoon	Terrestrial Lunettes
		Ainslie	Terrestrial Longitudinal Dunes
		Croppies	Inland Lake Deposit
LAST INTERGLACIAL	Tomahawk		Marine Plains Beach Ridges

zone of aeration has a profound effect on the short term response of the water table to rainfall inputs. Where the capillary fringe is well developed, the water table rises sharply in response to precipitation, and the capillary fringe is temporarily destroyed by the downward moving water. The water table then declines until the capillary rise from the water table re-establishes the capillary fringe and equilibrium is again attained. The complex nature of these short term reactions to inputs precludes direct correlation between water table response and precipitation.

The above relationships which have been determined for the aquifer formed by the Tomahawk Formation probably also apply to the aquifer formed by the Barnbougle Member, provided that the inputs from river water, where significant, are taken into consideration. The amount of groundwater estimated to be stored in the Tomahawk Formation is approximately 283,000 Ml. The Barnbougle Member is estimated to contain 472,000 Ml. The estimated recoverable reserves for both of these aquifers is approximately 50 per cent of the groundwater in storage, and they therefore show promise as valuable groundwater sources in these areas of scarce surface water supplies. Water budget calculations indicate that the amount of water added to the aquifer system of the interglacial marine sands by precipitation is closely balanced by evapotranspiration losses. If water is pumped from the aquifer at a rate sufficient to lower water table levels over wide areas, then less water will be lost through evapotranspiration since the water table will be further from the surface. Also, as more rainfall is needed to raise the water table to the surface, under these conditions, there is less likelihood of water-logging during winter. For an irrigation application of 200 mm of water, the general level of the water table would need to be lowered by only 1 m.

Measurements of rates of groundwater yield from bores in the Tomahawk Formation indicate that if the aquifer is less than 3 m thick, it will not generally yield a steady flow of water. However, once this minimum aquifer thickness is exceeded, the yield increases at a rate of approximately 5,000 l/day for each additional metre.

The quality of the groundwater stored in the Tomahawk Formation is adequate for most irrigation and livestock purposes. The pH is slightly acid, 6.1 on average. The salinity ranges from 190 to 2,320 mg/l TDS and half of the samples collected contained less than 500 mg/l TDS.

The Barnbougle Member has not been studied in as much detail but is similar to the Tomahawk Formation, and comparisons indicate that the Barnbougle Member is also a potentially good aquifer. The potential of the other landforms and deposits which occur in the study area is severely restricted due to their limited extent, and in most cases their inability to arrest water. The results gained from the detailed study can be applied to similar situations in coastal northern and eastern Tasmania, and may be applicable in other coastal areas of Australia where shallow water tables occur in extensive, unconsolidated, sand deposits.

Deposits and Related Landforms

INTRODUCTION

Assessment of the groundwater potential of landforms and deposits is facilitated by close examination of their extent, composition, origin, and age. Where this approach is adopted in the initial stages of an assessment study it enables some degree of prediction of the groundwater potential of the various deposits and of possible application elsewhere.

TOMAHAWK FORMATION

Extent

Coastal sand plains, which occupy former large coastal embayments, are widely distributed in north-eastern Tasmania (Fig. 2(a)). The main areas are at Stumpys Bay, Boobyalla Plain, Tomahawk, Toddys Plain, and east of Bridport in the Tuckers Creek area (Fig. 1). In most cases the inland boundary of the plain is well defined by a break of slope at an altitude of around 30 m above HWM (High Water Mark). The plains have a relatively even surface, and slope towards the sea with a gradient of around 8 to 10 m/km. These coastal plains, and their associated deposits, show striking similarities, are closely related, and are therefore considered to constitute the Tomahawk Formation.

The Tomahawk Formation at Stumpys Bay (Fig. 1), in Mount William National Park, forms a narrow plain 2 to 3 km wide and 14 km long, wedged between the sea to the east and the prominent rise of Mount William to the west. The western boundary is formed by a fairly well defined break of slope at an altitude of around 3 m above HWM. Drilling indicates that the Formation in this area has a maximum thickness of 8 m (but see also Jennings and McShane, 1971) and is underlain by granite (Fig. 3). The Formation thickens towards the sea and wedges out at the break of slope on its landward margins. Although the plain at Stumpys Bay is largely devoid of natural surface drainage, several streams originate in the Mount William area and traverse the sands of the plain. An important feature of the plain is that some original beach ridges lie sub-parallel to the coast and remain in a good state of preservation. Figure 4 is a schematic east-west cross profile of the Stumpys Bay area.

Boobyalla Plain (Fig. 1) is a coastal sand plain bounded by hills to the south and west and bounded to the north by the sea. The eastern margin of the plain is the Ringarooma River. The Tomahawk Formation of Boobyalla Plain is generally 4 m or less thick, but does not form a continuous cover of consistent thickness. Near the sea, the Boobyalla Plain is underlain by weathered dolerite near the coast, and by Mathinna Beds of Siluro-Devonian age further inland (Fig. 3). There is no natural surface drainage on this plain.

At Tomahawk the plain has an area of approximately 40 km^2 and the Tomahawk Formation varies in thickness from 2 to 12 m, with an average thickness of 6 m. It is underlain by highly weathered Devonian granite, which consists of clay with angular fragments of feldspar, quartz, and some mica. The plain at Tomahawk is bounded to the south by granite outcrops and on the north by the sea. Apart from the Tomahawk River, which flows from south to north and bisects the plain, there are no natural surface drainage channels. The schematic cross profile shown in Figure 5 is fairly typical of the East Tomahawk area.

Toddys Plain (Fig. 1) covers an area of approximately 20 km^2, and is bounded by granite hills to the west, hills composed of Mathinna Beds to the east, the Great Forester River to the south, and by the sea to the north. One bore hole drilled on this plain penetrated 14 m without reaching the base of the Tomahawk Formation.

The area of sand near Tuckers Creek (Fig. 1) is situated between low river terraces of the Great Forester River to the north-east and more elevated sediments of Tertiary age to the south-west. The Tomahawk Formation is up to 12 m thick and is underlain by Tertiary sediments. The alluvium of the river terraces is younger than the Tomahawk Formation. Figure 6 shows the general relationships of the Tomahawk Formation to other deposits in the Barnbougle-Tuckers Creek area.

Internal Composition

The Tomahawk Formation consists predominantly of quartz sand which is moderately rounded and sorted. It is medium to fine grained (1.5-2.5 phi mean grain size) and sediments outside this size range are uncommon.

Deposits of rounded quartz pebbles, derived from Tertiary gravels and from vein quartz within the Mathinna Beds, and possibly the granite, often occur between the base of the Formation and the bedrock. The cobbles are probably lag material derived from weathered bedrock or from surficial deposits that occurred on the land surface prior to the marine transgression.

Discontinuous peat beds, of very restricted area, occur near the margins of the sand embayment in the Tomahawk area, and form beds up to 20 cm thick. At Barooga (Fig. 1) such a bed of peat 80 cm thick is exposed in the base of a drainage ditch. Augering through the peat showed that it overlies the basal, thin sand and cobble bed which rests directly on weathered Mathinna Beds. A bore hole drilled 30 m west of the ditch did not encounter the peat and only penetrated the basal gravel.

Sedimentary structures have been found within the Tomahawk Formation in many field sections. Extensive, thinly cross-bedded structures dip at low angles towards the sea. The seaward inclined beds dip at 10° to 20°, while the shoreward dipping beds mainly lie at angles of less than 5°. Biotic structures have not been found.

Except for one specimen of a ferruginized cheilostome polyzoan, calcareous fossils have not been found in the sands. This is attributed to the acid nature (pH 4.5 to 6.5) of the groundwater. Microscopic examination of the sediments revealed the presence of siliceous sponge spicules in a large proportion of the samples.

Groundwater podzolization is the dominant soil forming trend, which has controlled the nature of the soil profiles in the sands. Podzolized soil profiles have been found in all bore holes and sections. The A_1 horizon consists of 20 to 30 cm of brown organic sand with root material. Below the A_1 horizon a well developed A_2 horizon attains thicknesses of 120 to 140 cm. The A_2 horizon is a highly leached zone and is greyish white in colour. Root fragments do not persist through this zone but some fragments of ferruginized organic material are common in some localities. The A_2 horizon is the freely drained and oxidised zone of the profile. Below the A_2 horizon the $B_{2h,ir}$ horizon is 30 to 150 cm thick and is dark brown in colour. The contact between the two horizons is often diffuse with the change occurring over 3 or 4 cm. The surface of the $B_{2h,ir}$ horizon is often undulatory in section and this horizon may divide into multiple horizons. The above characteristics indicate that

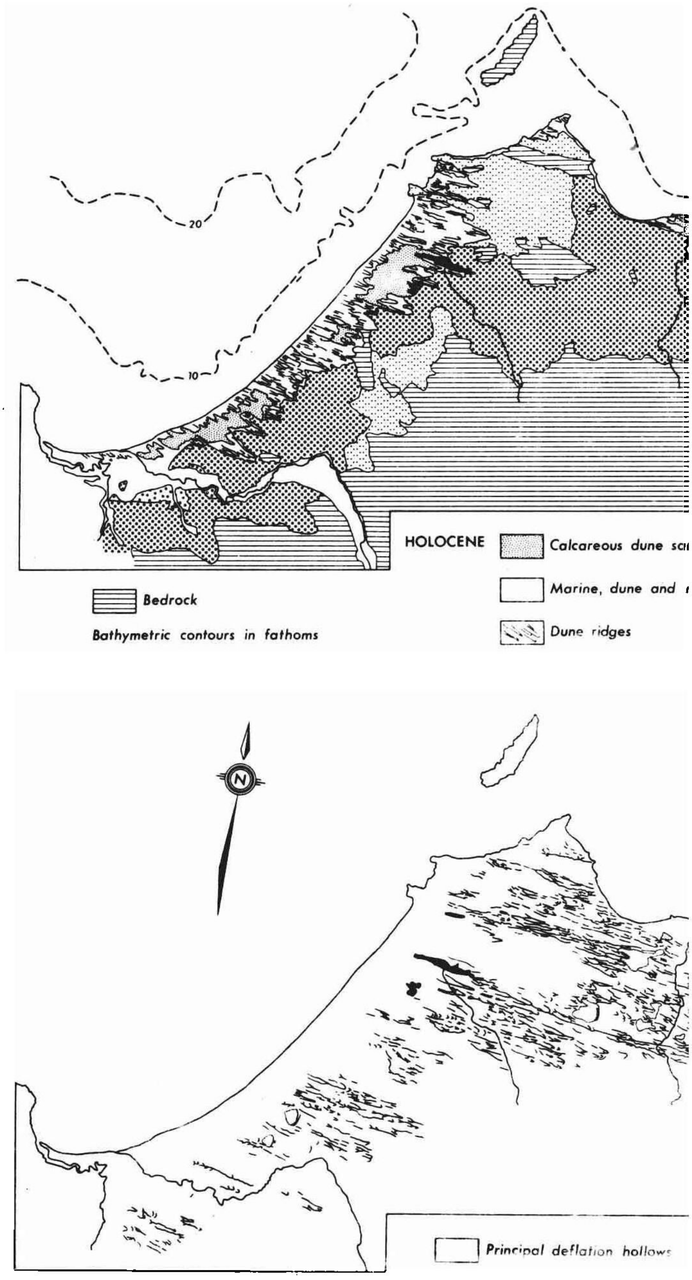
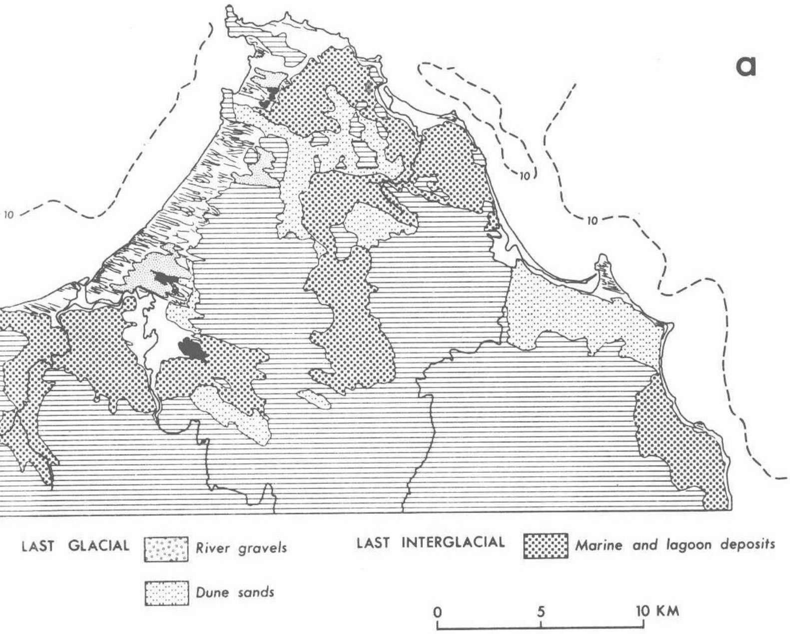
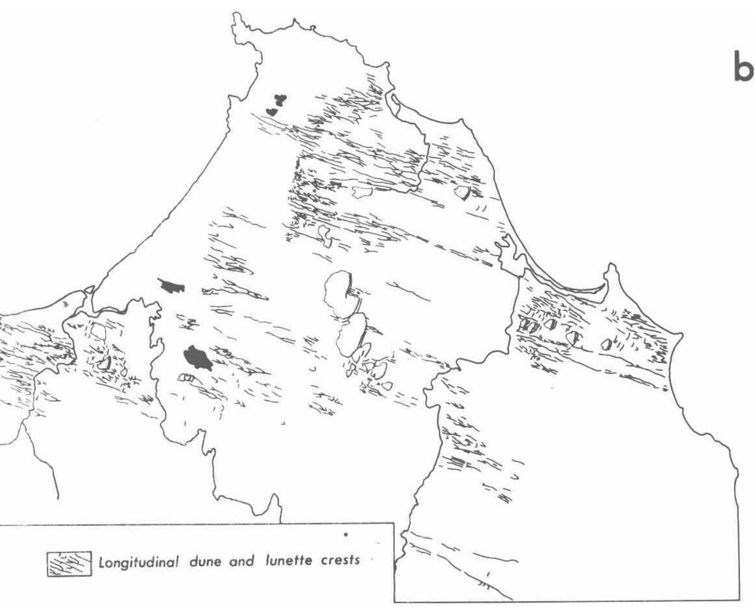


FIGURE 2

Landforms and Deposits: Coastal North-eastern Tasmania
(a) Quaternary deposits (b) Terrestrial dunes


a
10
10
10
LAST GLACIAL
River gravels
Dune sands
LAST INTERGLACIAL
Marine and lagoon deposits
0
5
10 KM


b
Longitudinal dune and lunette crests

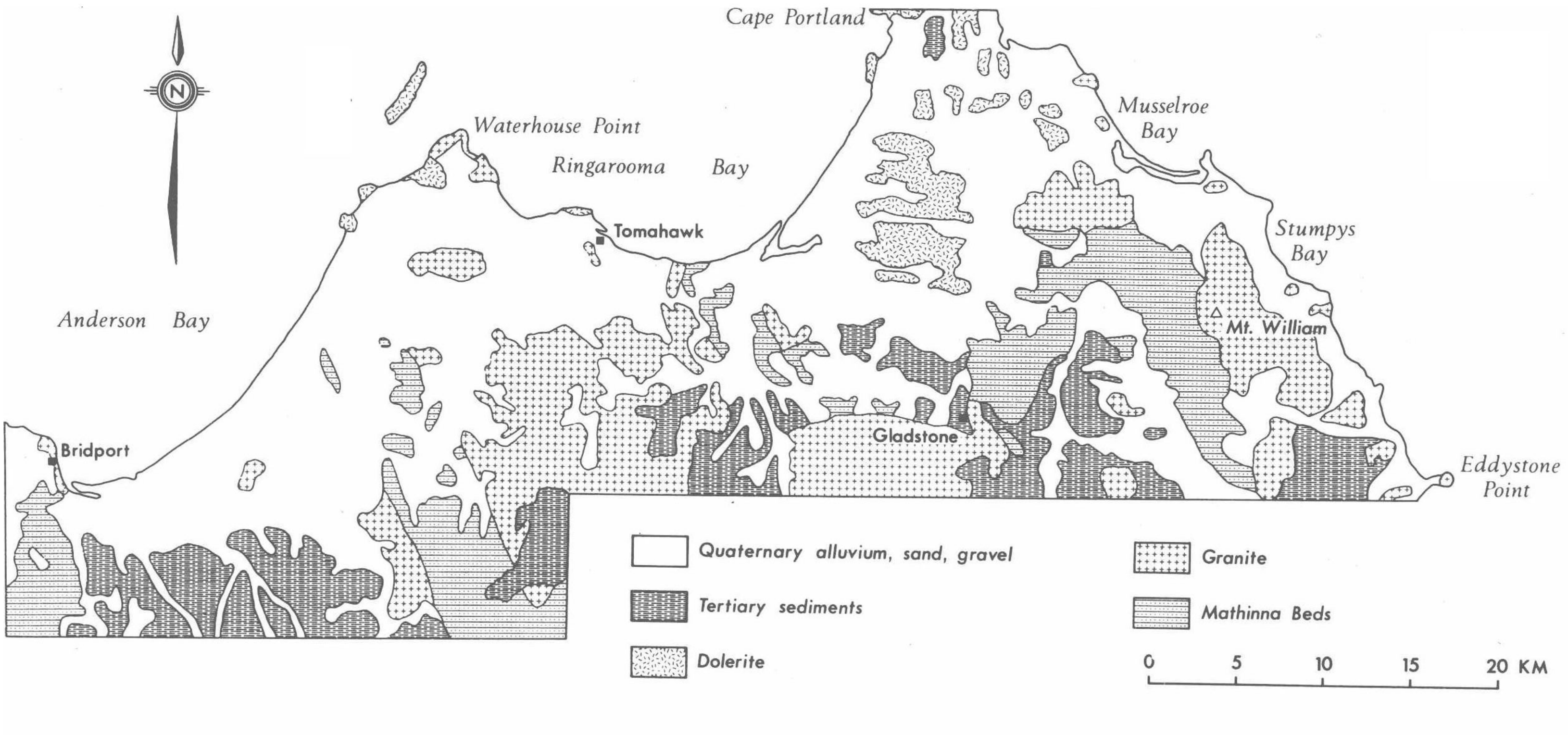


FIGURE 3

Generalized Geology: North-eastern Tasmania