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Engineering Geology and Economic Resources of Commonwealth Territory, Jervis Bay

by

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ENGINEERING GEOLOGY AND ECONOMIC RESOURCES
OF COMMONWEALTH TERRITORY, JERVIS BAY

SUMMARY

The Territory of Jervis Bay consists of gently-dipping, well-jointed, Permian sandstone (Jervis Bay Sandstone) overlain in places by unconsolidated Quaternary sand. Dolerite dykes, bosses and sills, weathered in places to pure kaolinitic clay, have intruded the sandstone in several localities.

White, kaolinitic clay, which is being quarried at present (1969), is probably the most important economic deposit; it occurs in substantial quantities and is used as a filler in mortar, and for furnace lining and sealing. Small deposits of glass sands, refractory sands, cement sands, and low-grade road-dressing gravels occur in the Territory. Dolerite is present in very small quantities and is probably of little economic importance. A quartzitic bed or lens of the Jervis Bay Sandstone has been quarried and used for rip-rap; it would probably provide material suitable for aggregate, after crushing.

The Jervis Bay Sandstone is difficult to excavate but it should provide exceedingly strong foundations. The Quaternary sand is easy to excavate, but it provides unsound foundations for anything other than the lightest of structures.

Lakes Windermere and McKenzie provide adequate water for the Territory's present needs. However, valuable water supplies are lost through seepage that takes place when the lake levels are high. Substantial groundwater supplies will probably be found in the Quaternary sands, but the quantity and quality of water in the sands varies from place to place, and an evaluation of available supplies will require extensive further studies.

INTRODUCTION

Locality

The Territory of Jervis Bay is situated on the south-east Australian coast about 125 miles south of Sydney. The Territory has an area of approximately 25 square miles and it is bounded on all but the northern side by water.

Accessibility to the settlement of Jervis Bay is good. A sealed road runs north from the settlement to join the Princes Highway, 8 miles south of Nowra. Accessibility within the Territory is, however, limited. A sealed road runs to the settlement at Wreck Bay and several unsealed roads run to various beaches in the Territory; other than these, vehicular accessibility is difficult.

Aim of Survey

In response to a request from the Department of the Interior, Canberra, for information on the economic resources of the Commonwealth Territory of Jervis Bay, a geological survey of the Territory was carried out during the period 18th November to 13th December, 1968. The investigation was in the form of a combined engineering geology-economic resources survey, so that the results would be useful in planning the future development of the Territory.

A photogeological study was followed by a detailed examination of the area. A piezometer network is being established in the south-west of the Territory to assist in a study of the water resources, and two stratigraphic bore holes were drilled in April, 1969, to provide further information.

Physiography

The average height of the land is approximately 200 feet above sea level (A.S.L.); the highest point in the area is Bherwerre Trig. station at 544 feet.

A large part of the Territory consists of either gently undulating sandstone country or old, fixed, sand dunes. A thick scrub cover, with occasional stunted teees, is common on the sandstone area; while a dense cover of tall eucalyptids is prevalent on the fixed dunes. Most of the vegetation is natural, but large areas in the north-east and south-west have been cleared and used for coniferous afforestation.

The east-facing coasts are formed by precipitous cliffs up to 450 feet high. In contrast, the south and north-facing coasts are of low wave-cut headlands separated by sandy beaches.

The geology is well exposed along the cliffs, where continuous vertical successions are present. Inland, the sandstone occurs as near-horizontal pavements that are commonly covered by thin sandy soils.

Small inherent streams form an irregular drainage pattern on the undulating sandstone country. In places the courses of the streams have been modified by the Quaternary sands. Lakes Windermere and McKenzie were formed when westward flowing streams were dammed by Quaternary dune sands. An absence of streams on the Quaternary sands is noticeable, but the presence of many former marshes and water-holes indicates much higher groundwater levels in the past.

Mapping Techniques

Vertical aerial photographs of the whole area, at a scale of 3 inches to 1 mile, were loaned by the Division of National Mapping, Department of National Development, Canberra. Observation and sample points were marked on transparent overlays, the relevant information being recorded in field note books. The information plotted onto the photographic overlays was later transferred to a 1:12,000 (approx. 5 inches to 1 mile) topographic map of the Territory.

Time restrictions led to the omission of a section of the coast from St George Head, north-eastwards to Steamers Beach. Air photographic interpretation was used to complete this part of the map.

Entry restrictions also prevented the detailed mapping of the R.A.N. airfield. Information from B.M.R. Record 1948/21 (Smith et al, 1948) together with airphotographic interpretation, was used to tie this area into the surrounding areas.

GEOLOGY

The information in this section is largely supplementary to that contained in B.M.R. Record 1952/88 (Perry &Dickins, 1952). Unnecessary duplication has been avoided where possible. The condensed geological logs of two holes, drilled in April 1969, have been included in this report (Appendix 2). Detailed logs of these holes are in preparation.

Jervis Bay Sandstone.

The Jervis Bay Sandstone is a medium to coarse grained, light-grey sandstone of Permian age. Bedding is commonly massive, but finer bedded silty layers and conglomeratic horizons occur at many levels throughout the succession. The dominant constituents in the conglomerates are (in order of abundance) - milky quartz, jasper, chert, blue/grey siltstone and shale, sandstone, and black shale. Rare metamorphic pebbles and coal fragments were also observed. Sorting is good in the sandstone horizons, but poor in the conglomerates. Grading was seldom observed. Sedimentary structures commonly found include cross-bedding, cut and fill channels, and shelly horizons. Annelid burrows and probable plant fragments are common in the Mary Bay area. No determinable fossils were seen, but poorly preserved casts of brachiopods, lamellibranchs and sparse gastropods were found at a number of distinct horizons.

Observations suggest a shallow water (neritic to littoral) environment of deposition, possibly deltaic in places, with a dominant current direction from the south.

Jointing is generally well developed; approximately 80% of the joints are close to vertical. In most outcrops two or more joint directions are present. Faulting, which is well exposed along the cliffed coasts, is predominantly low-angled, with small throws. Few faults were seen inland; this, however, is probably a reflection of the discontinuous nature of the exposures. Folding is noticeably absent except along some of the major faults where contorted and crumpled beds are present.

Bedding dips throughout the Territory are low (generally less than 10°), but steepened dips are present near faults and at St George Head.

Weathering of the Jervis Bay Sandstone is variable and depends largely upon bedding and texture characteristics. The conglomerate horizons, where weathered, tend to form cavernous surfaces which are especially evident on wave-cut platforms. The massive bedded units form smooth unbroken surfaces, and where, as commonly occurs, they are interbedded with thinly bedded units, a characteristic differential weathering pattern is developed.

Cliff undercutting along less resistant layers leads to vertival cliff recession, but deep coastal incision along joints, dykes, and major fualts is superimposed on this simple pattern.

Quaternary Sands.

Quaternary sands of variable thickness occur in over half the area, as semi-consolidated or unconsolidated dune and beach sands. Mapping of these sands was based largely on an examination of the top ten feet of the deposit throughout the area. The divisions erected are, therefore, of near-surface deposits only. No indication of their continuity at depths greater than 10 feet can be given, except where exposures permitted. Distinction of mappable units was based largely on colour and composition and three major divisions were erected -

Grey and white sands,	(Qsw)*
Yellow sands, .	(Qsy)
Orange sands,	(Qso)

These units are distinct and widespread in some areas, but in others (e.g. areas G and F on Plate 2) they are found closely associated in thin vertical sequences. For ease of description the Quaternary sands have been divided into several areas (Plate 2).

Area 'A'

This area is predominatly covered by grey and greyish-white quartz sands, occurring as fixed dunes with a dense eucalyptid cover. The dunes are up to 200 feet high and have a dominant north-easterly trend.

Eight auger holes were sunk to a maximum depth of 10 feet and all encountered grey or greyish-white sand. Orange and yellow sands were observed capping the dunes in the area west of Lake Windermere. These orange and yellow sands are of recent age and are actively migrating, especially in areas where the forest cover has been removed. Tracks only a few years old are obliterated by drifts of this sand up to 10 feet thick.

No sandstone was found at the surface, but it is inferred that it is present at various depths throughout the area. I believe that the thickness of sand is largely controlled by platforms in the underlying sandstone (Plate 6), and that the sand ranges in thickness from a few tens of feet to 150 feet. (Plate 5).

Area 'B'

This area is predominantly covered by yellowish-grey sands, apparently later than, and lying on top of a southerly continuation of the grey sands of ~~Area~~ A. As in Area 'A' the dominent trend of the dunes is north-east. Five auger holes were sunk to a maximum depth of 7 feet. Four water observation holes were also sunk in the east of the area to a maximum depth of 23 feet. Yellowish sands were observed in all these holes.

(*Symbols used on Plate 1)

A stratigraphic hole drilled in this area (Appendix 2, Ulladulla 2) passed through 150 feet of sand before reaching sandstone bedrock. The hole was sited in a depression (25 feet. A.S.L.), consequently sand up to 200 feet thick can be expected in parts of the area.

South of Area 'B' is a wide expanse of orange dune sands up to 80 feet high. The dunes are actively migrating northwards over the fixed dunes of Area 'B' at a rate of a few feet per year. It is suggested that the sands of Area 'B' may have migrated northwards over Area 'A' in a similar fashion.

Areas 'C' and 'D'.

These two areas are of greyish-white sands, similar to those in area 'A'. The sands appears to be generally less than 50 feet thick, especially in the areas north of northing 660. Sandstone boulders and probable outcrops were observed in stream beds south-west of Scottish Rocks, at co-ordinates 37486624, an irregular surface of sandstone therefore probably occurs at shallow depths.

Area 'E'.

This area is of bright orange sands. They are younger than the grey sands of Area 'D' on which they lie. The thickness of sand in the area is probably 200 feet, therefore sandstone would be expected at about 150-200 feet A.S.L.

Area 'F' and 'G'.

These areas contrast markedly with those described above. Pure white, grey, greyish-yellow, and orange sands occur in close proximity and in thin vertical successions. The following section was measured in a 20-foot-deep trench in area G. (grid ref. 36916635)*

Thickness	Character of Sand
0 - 6 inches	Dirty grey sand containing many rootlets.
2 - 3 feet	Clean orange and yellow coloured sands. Sparse rootlets in upper part.
1 foot	Disconformity. Irregular, disturbed junction, with inclusions of underlying white sand in overlying orange/yellow sand.

1 - 8 feet	Pure, clean, white quartz sand.
1 foot	Disconformity. Irregular boundary with marked development of ferruginous nodules and iron staining.
6 feet+	Yellow coloured sands.

Minor Occurrences.

Small pockets of Quaternary sand occur as isolated dunes on the Jervis Bay Sandstone, especially in the area immediately west and north-west of the R.A.N. airfield. These are of predominantly clean white sand, with an average thickness of about 15 feet. (see under Economic Deposits).

Igneous Intrusions.

A number of grey, porphyritic intrusions were seen in the Territory. They generally occur as near-vertical dykes, but a sill or boss-like mass is present on the coast one mile north-west of St George Head. The intrusives are less resistant to weathering than the sandstone, and the presence of dykes is betrayed along the coast by narrow, vertical gorges in the cliffs.

A petrographic description of a typical specimen is given in Appendix 3.

As is evident from Plate 1, the dykes show two trends: a major trend north-west, and a minor trend north-east. The dykes are not exposed inland (except by artificial uncovering), but air-photo interpretation suggests the presence of perhaps three dykes, running south-east, from the area around Huskisson Trig. to south-east of the airfield, where they are covered by thick deposits of Quaternary sand.

The white clay deposit south-west of the airfield was derived by weathering of an intrusion with a similar porphyritic texture (see Economic Deposits)

(*all grid references given in this report are in yards)

Geological Structure

The dip of the bedding in the sandstone is generally low (less than 10°) throughout the area. This, together with a lack of consistent marker horizons, makes structural interpretation difficult. Perry & Dickins (1952) suggest shallow basins and domes as the major structural elements of the area.

An examination of 200 joint and fault readings was made in an attempt to further elucidate the structure. A contoured stereogram and rosettes were plotted to enable an analysis of the results to be made (Plate 3).

The major features that emmerged were -

1. a dominance of near-vertical joints with prominent trends of 330° and 090° (mag.)
2. the presence of low-angled faults with an approximate north-east trend.

From the results obtained it is not possible to formulate a direct relationship between the fractures and the folding. The concentration of major faults along the east coast, together with a steepening of bedding at Governor Head and St George Head, is considered as evidence for the presence of the north-east trending Point Perpendicular Fault, shown along the east coast of the Territory on the 1:250,000 Ulladulla Geological map (SI56-13), and on Plate 1.

ECONOMIC DEPOSITS

A number of economic deposits occur in the Territory. White kaolinitic clay, which is being quarried at the present, is the most important deposit and it occurs in substantial quantities. Small deposits of glass sands, refractory sands, cement sands, and low-grade road dressing gravels are also present. Some of the Quaternary sand could be used for fine aggregate after suitable treatment.

White Clay Deposits

Decomposition of Tertiary sills and dykes has produced pure white, kaolinitic clays in several areas. A deposit which lies south-west of the R.A.N. airfield was described by Smith, et al. (1948). That report includes a description and outline of the probable extent of the deposit, based on an auger hole investigation. In the course of the present investigation the quarry workings were examined, and the following basic conclusion is reached: the clay is the result of decomposition of an igneous sill of average thickness 10 feet. Jervis Bay Sandstone is present stratigraphically above and below the deposit (the lower boundary showing contact alteration), and a porphyritic texture is ubiquitous in the clay. No evidence to support a sedimentary origin (as proposed by Smith et al., 1948) was seen.

Smith et al. also recorded white clay at the eastern end of the 095° runway of the airfield. Although this was not examined it is suspected that this is a similar type of deposit.

The clay contains high proportions of alumina and water and, therefore, is not suitable for direct firebrick production. The powdered clay is used mainly as a filler in mortar, and for furnace lining and sealing.

A white clay dyke, 15 feet thick, has been recognised running south-eastwards from near Huskisson Trig. towards the R.A.N. airfield (Gardner, 1969). Photogeological interpretation suggests that the dyke runs into the sea north-east of Steamers Beach, probably in the southerly gorge incised into the coast in this area (the gorge is not accessible by foot). As noted in the section on Igneous Intrusions, photogeological interpretation also suggests the presence of other clay (or dolerite) dykes in the area immediately east and south-east of the airfield. If further development of white clay deposits is sought, it is suggested that initial photo-geological studies be followed up by systematic augering in selected areas. The presence of a covering of Quaternary sand, and variation in continuity of the dykes, could present problems.

A few small patches of a white, friable, slightly-sandy clay were observed in the ferruginous gravel quarries along the track to Christians Minde (which is on Sussex Inlet at the western boundary of the Commonwealth Territory). The material is plastic when wet, and shows considerable shrinkage on drying. The sandy clay is secondary in origin (Quaternary to Recent in age) and represents reworked clay material probably originatir from decomposed igneous intrusions; it should not be confused with the pure, white, kaolinite dykes.

Ferruginous Gravels

Deposits of ferruginous gravel are present in the north-west of the Territory on either side of the track to Christians Minde. The gravels are concentrated in pockets, generally less than 10 feet thick, that lie on an irregular surface of the Jervis Bay Sandstone.

The gravels range from a limonitic orange sand with scattered ferruginous nodules to a hard, compact, nodular-conglomerate that is strongly bonded by a light-brown limonitic cement. The nodules are of sub-angular to rounded pebbles and cobbles of sandstone, but broken and fractured pebbles of milky quartz are also present. The limonite cement appears to be dominantly syn-diagenetic or early post-diagenetic in age. I consider that the gravels are sedimentary in origin and were formed by reworking of Jervis Bay Sandstone on a ?Quaternary erosion platform, approximately 250 feet above present sea level. The presence of an erosion platform (with ferruginous staining) at about 250 feet A.S.L. is evident in other parts of the Territory.

The ferruginous gravel has been used as a dressing for unsealed roads and forestry tracks. Unfortunately, it forms a poor surface, is dusty in dry conditions, and has little cohesion due to a lack of bonding clays. It is suitable only for unsealed roads and should not be used as a base on tarmacadam roads. About a half of the initially available resources have already been used.

Quartz Gravels

Deposits of quartz gravel occur in the north-east of the Territory and due south of the airfield (Plate 1). They are composed of rounded, broken pebbles of quartz with a average diameter of 1 inch, set in a grey quartz sand. The percentage of pebbles to sand varies considerably from place to place.

The deposits have been formed by weathering and decomposition of conglomerate horizons in the Jervis Bay Sandstone, and are consequently of limited extent and thickness (maximum about 10 feet). The quartz gravel has been used as a road dressing material but, like the ferruginous gravels, they form an irregular surface, are dusty and incoherent. Poor sorting, variable amount of sand, and limited quantity, probably preclude any other economic uses.

Jervis Bay Sandstone

A massively bedded, quartzitic horizon in the sandstone has been quarried (grid reference 37086612) and used for rip-rap in the construction of the breakwater for the settlement of Jervis Bay. This horizon of the sandstone is most suitable for rip-rap use as it is chemically stable, resistant to weathering and can be extracted in large sizes. It is, however, difficult to work and usually requires blasting. This quartzitic sandstone, after crushing, should be suitable for use as a general-purpose coarse aggregate. The fragments would be clean, hard, durable and chemically inert. Although the extent and thickness of this deposit is not known, the rocks exposed in the 20-foot high quarry walls showed very little variation in texture or composition.

Dolerite

Four dykes and a boss-like mass of dolerite were seen in the Territory (Plate 1). All are exposed along the coast; the dykes in steep vertical gorges eroded out by the sea, the boss as a wave-cut platform. Although dolerite usually forms a good road aggregate material, these deposits are small and inaccessible and therefore probably of little economic importance.

Sand Deposits

A considerable volume of Quaternary and recent quartz sand is present in the Territory. Small quantities of this sand appears to be suitable for direct use; much larger quantities should be suitable after treatment (washing and/or sizing) or after blending with other sand. Henderson (1966) records the presence, one mile west of the R.A.N. College of white sand that would be suitable for use as a foundry sand. Local builders use sand from a small pit, ½ mile south of the College, as a fine aggregate in mortar.

To aid evaluation of the sand resources of the Territory, some systematic sand sampling was carried out. Petrographic analyses, conducted by the Australian Mineral Development Laboratories, were used to determine whether any of the samples collected were suitable for industrial use. The results are included as Appendix 4. Extensive further sampling and testing would be needed to assess fully the extent and usefulness of the various deposits of sand.

Glass Sands

Pure quartz sand is present in dunes west of the R.A.N. College (symbol Sg on Plate 1), and along the beaches bounding Jervis Bay, both in the A.C.T., and N.S.W. The sands west of the R.A.N. College occur as Quaternary dunes resting upon an irregular surface of sandstone. Henderson (1966) estimates a volume of at least 300,000 cubic yards of sand in the two dunes he examined. As several dunes are present in the area, quantities of sand (suitable for foundry purposes) in excess of 1 million cubic yards may be present. Some of this potential glass sand has been used for bedding down pipes in trenches. As less desirable sands are easily obtainable, it is recommended that the white sands be preserved in case future demands require their exploitation.

Large quantities of clean, fine-grained recent quartz sand are present along the beaches bounding Jervis Bay. After washing, these would be suitable for use as foundry or glass sand.

Clean white quartz sand was observed in a 20-foot-deep trench (grid reference 36916635) north-west of the R.A.N. College (see page 6). Several random grab-samples from the walls of the trench were combined intuitively and submitted for analysis. The analysis of this sand (Appendix 4, specimen 68360108) showed it to consist of 95% - 100% quartz with only traces of other minerals. The sand would probably be suitable for foundry purposes, but its variability in thickness and presence in a sequence of coloured feldspathic sands, would make development difficult.

Building Sands

Pale, yellow-brown, fine-grained, feldspathic sand, from a pit ½ mile south of the R.A.N. College (grid reference 37106622), is used locally as a building sand. An analysis of a representative sample is given in Appendix 4, specimen 68360109. The grading and sorting of the sample, is outside the value specified for a masonary mortar. The deposit, which is small, is of little economic importance.

Other Sands

Other than the deposits described above, the sands throughout the Territory are not suitable for direct industrial use. Throughout Areas A to D (Plate 2) the Quaternary sands are similar in composition and texture. An average sample would have the following characteristics

Composition	Quartz	70-75%
	Feldspar	20-25% (in all stages of alteration)
	Other minerals	less than 5%

Grain size	0.3 millemetres (mm)
Roundness	0.2 - 0.5 (sub-angular to rounded)

In composition and texture the sand appears to be suitable for use as a general purpose fine aggregate. However, it is not suitable for fine aggregate use in concrete, masonary mortar or bituminous paving mixtures, as the values of grading and sorting are outside standard specifications (A.S.T.M. 1965) for these materials. After suitable testing and treatment, it could possibly be combined with a coarser, less well sorted sand, to produce a mixture suitable for the uses outlined above. However, the weathered state of most of the feldspar may make it unacceptable. Coarser grained sands occur in the Territory along Bherwherre, Caves, and Steamers Beaches. These recent beach and dune sands are slightly coarser grained and less well sorted than the Quaternary sands, but they contain numerous small calcareous shell fragments, and the beach deposits probably contain soluble salts.

It should be noted that any conclusions reached in this section of the report as to the suitability of the sand, for the purposes mentioned, are based on small, widespread samples only. Before exploitation is considered further sampling should be undertaken and representative bulk samples should be submitted for practical testing.

WATER RESOURCES

Introduction

At several times in the past the water resources of the Commomwealth Territory of Jervis Bay have been in a critical state of balance. The aim of this survey was to discover the main features controlling the water balance, and to recommend methods of improving the Territory's water supply.

The surface geology is simple. Two rock types are present - a hard, coarse to medium grained sandstone of Permian age (280 mill. years old), and an unconsolidated medium to fine grained quartz sand of Quaternary age (less than 1 million years old). The sandstone is impermeable and, through jointed, contains only small quantities of water. The Quaternary sands are of variable thickness and occur on an irregular, platformed surface of sandstone. They are porous, and being underlain by an impermeable layer, have the potential of holding large quantities of water. At present (1969) adequate water supplies are obtained from two standing bodies of water - Lakes Windermere and McKenzie. If future demands require larger quantities than the lakes can supply, it should be possible to obtain supplies from the Quaternary sands, stretching from Lake Windermere south-westwards to Sussex Inlet (Plate 1).

Geological History

A short description of the geological history of the Territory is essential, for it allows us to see what factors influence the distribution of surface and groundwater in the Territory.

Permian

Deposition and compaction of the sandstone in a shallow water, marine environment.

Permian to Quaternary

Uplift of the sandstone to form a land mass, followed by the formation and development of a consequent drainage pattern. No Mesozoic sediments have been found in the area, so it is presumed to have remained a land mass during this long period of time.

Quaternary

Fluctuation of the sea level was a marked feature of the Quaternary Period. Coastal erosion, with the sea at different levels, led to the formation of platforms in the sandstone. Platforms probably exist at about 30, 60, 150 and 280 feet above present sea level. The south-west side of the sandstone land mass (probably a south-easterly trending peninsula) would have been subjected to strong winds and coastal erosion. The platforms developed on the south-west side of the Territory will be more sharply defined than those on the north east-side. The subsequent build up of sand will have been largely controlled by the height and extent of these platforms, and the prevailing winds (assumed to have been dominantly south-westerly during the Quaternary*). Plate 6, a theoretical cross-section of the area, illustrates the contrast between the sand thicknesses on the north-east and south-west sides of the peninsula.

The deposition and migration of the sand lead to the formation of the peninsula of sand in the south-west of the Territory, and so to the enclosure of St Georges Basin.

The deposition of the sand also profoundly altered the drainage pattern that had been initiated on the sandstone. Many of the pre-existing stream valleys were either buried or blocked. Lakes Windermere and McKenzie were formed when south-westerly flowing streams were dammed by Quaternary sand.

B.M.R. Bore hole Ulladulla 2 (Appendix 2) shows that a marshy/lagoonal area - called the old Bherwerre Lagoon in this report - was present in the area south-west of Lake Windermere (Plate 4). Finally, the sea retreated to its present position, leaving the Territory essentially as we find it today.

This picture, although incomplete, allows us to predict the possible distribution and movement of water in the Territory. The presence of a buried sandstone topography, with its platforms and stream courses; the variation in thickness of the sand; and the presence of the old Bherwerre Lagoon; all have had a marked influence upon the quality and quantity of water in the Territory.

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*Migration of the sands of Area B over those of Area A (page 6) would tend to substantiate this assumption.

Lake Windermere Water Supply

The water supplies for the R.A.N. College, the township at Jervis Bay and the Settlement at Wreck Bay are obtained from Lake Windermere.

Lake Windermere -

total capacity (at flood level)	800 million gallons
capacity (April, 1969, lake level 51 feet)	500 " "
estimated consumption (April, 1969)	40 million gallons/year

These figures may suggest that ample reserves are present. It is important, however, that as much as possible of the water collecting in Lake Windermere is retained for use, so that periods of prolonged drought, and future demands, can be met. A comparison between records of lake level and rainfall indicates that at times of high water levels seepage takes place through the Quaternary sands forming the south-west shore of the lake. Little seepage occurs at present (lake level 51 feet) as a layer of clay alluvium forms a seal to the lake (Plate 5, cross section 3). At times of high lake levels, water probably seeps through the porous, wave-scoured, south-west shore and flows towards Bherwerre Beach along pre-Quaternary drainage valleys (Plates 4 & 5). A network of piezometers[1] has been installed in this area (Plate 4) to measure water-table[2] fluctuations and to assist in determining the quantity of water involved in the seepage. It is recommended that geophysical traverses be carried out along selected lines to determine the exact positions and levels of the seepage paths. With this geophysical information it should be possible to recommend methods that will restrict this water loss.

Groundwater Resources

The following information on groundwater is based only on surface observation, piezometeric readings, and one stratigraphic hole drilled through the sands.

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[1] Piezometer - small-diameter cased hole that is used for observing flucations in the level of the water table.

[2] water table - the term given to the upper surface of the zone of water saturation in the upper layer of the earth's crust.

The quantity of water available depends upon the thickness of sand and the position of the groundwater table, in the area under consideration. The quality of the water depends upon the composition of the sand, the composition of other horizons in the Quaternary succession, and on the amount of wetting by salt spray that takes place.

Bore Ulladulla 2 passed through 150 feet of sand before reaching sandstone bedrock. The watertable at the time of drilling was 10 feet below the surface; therefore a column of water-saturated sand 140 feet thick is present in the area. A pump-out test was done and a return of 2,000 gallons/hour was obtained. This preliminary test would appear to indicate that large, easily obtainable supplies of water should be expected from the sands. The three black clay bands encountered in the hole could cause the water to be too acidic for domestic use. Subject to confirmation by analyses of water from Bore Ulladulla 2, it would appear that the area shown as the old Bherwerre Lagoon on Plate 4 should be avoided when searching for groundwater supplies as the water is likely to be found to be acidic. Assuming that the black clay horizons are not widespread, suitable water supplies should be obtainable from other areas. The area of sand between piezometers 1 and 3 (Plate 4) will probably hold reasonable supplies of water. The water should be of good quality as this area is recharged by water seeping from Lake Windermere; depth to bedrock determines the quantity of water present. The large expanse of sand west of easting 364 on Plate 4 probably holds suitable supplies of water but little is known about this area. Smaller supplies of water are expected to occur in the sands ¼ mile due west of Lake Windermere, and in the sands near the Fire Tower, south of Lake McKenzie. The sand in these areas is thought to be too thin to hold large volumes of water, but further information is required before any recommendations can be made.

In conclusion, it should be noted that the opinions expressed above are based on much inference and conjecture. The utilization of groundwater from the sands in this area will only be possible after a more detailed examination. Geophysical traverses, test boring, and sample analyses, should be carried out before installation of any production wells or bores.

EXCAVATION AND FOUNDATION CONDITIONS

The sandstone can be excavated only by heavy drilling and blasting, but it should provide exceedingly strong foundations. Shaping of foundations or footings by excavation will be costly. The sandstone is well jointed, but the joints are thin and show very little development of clay. A large number of major faults was seen near the east coast of the territory. Investigation of major fissures should be made (to determine possible lines of weakness) if heavy construction, close to the coast, is considered.

The Quaternary and Recent sand can be excavated easily by bulldozer or hand. The sand is unconsolidated so that walls in steep excavations or deep trenches will probably be unstable. Flat lying areas of sand will be suitable for light loadings. The sand ranges in thickness from place to place so geophysical investigations will be required to predict the exact position of a firm basement for any heavy loadings. The upper surface of the sandstone, where covered by water-saturated sand, will have undergone weathering. The top 15 to 20 feet of sandstone in B.M.R. Ulladulla 2 was highly weathered, but fresh sandstone probably occurs a few feet deeper. Seismic investigation and test boring should be carried out, to determine depth to bedrock, if heavy structures are to be sited on the Quaternary sands.

No mines or underground excavations are known to occur in the area.

ACKNOWLEDGEMENTS

The project was supervised jointly by E.K. Carter and G.M. Burton, who made several helpful suggestions.

The assistance given by officers of Department of the Interior, Jervis Bay, and the personnel of the Royal Australian Navy College, H.M.A.S. Creswell, is gratefully acknowledged.

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APPENDIX 1

DEFINITIONS OF SEMI - QUANTITIVE DESCRIPTIVE TERMS

Particle Size

Pebble	4 to 64mm
Very-coarse-grained sand	2 to 4mm
Coarse-grained sand	1 to 2mm
Medium-grained sand	¼ to 1mm
Fine-grained sand	1/16 to ¼mm

Degrees of Weathering

Fresh	Rock shows no discolouration, loss of strength, or any other effect of weathering.
Slightly weathered	Rock is slightly discoloured, but not noticeably lower in strength than the fresh rock.
Moderately weathered	Rock is discoloured and noticeably weakened, but a 2-inch diameter drill core cannot usually be broken up by hand across the rock fabric.
Highly weathered	Rock is usually discoloured and weakened to such an extent that 2-inch diameter cores can be broken up readily by hand, across the rock fabric.
Completely weathered	Rock is discoloured and entirely changed to a soil, but original fabric of the rock is preserved.

Hardness

Hard to very hard	Rock impossible to scratch with knife blade.
Moderatley hard	Shallow scratches with knife blade.
Soft	Deep scratches with knife blade.

Percussive Strength of Rock

Strongly to very strong	Not broken by repeated blows with a 2 lb. geological hammer.
Moderatley strong	Rock broken by 3 or 4 heavy blows with a 2 lb. geological hammer.
Weak	Rock broken by one blow or with hand pressure.

Bedding Thickness (After Ingram 1954)

Very thick-bedded	100 - 1000cm
Thick-bedded	30 - 100cm
Medium-bedded	10 - 30cm
Thin-bedded	3 - 10cm
Very thin-bedded	1 - 3cm
Thickly laminated	0.3 - 1.0cm
Thinly laminated	0.1 - 0.3cm

APPENDIX 2

GEOLOGICAL LOGS OF DIAMOND DRILL HOLES

B.M.R. Ulladulla 1 (condensed and simplified)

B.M.R. Ulladulla 2

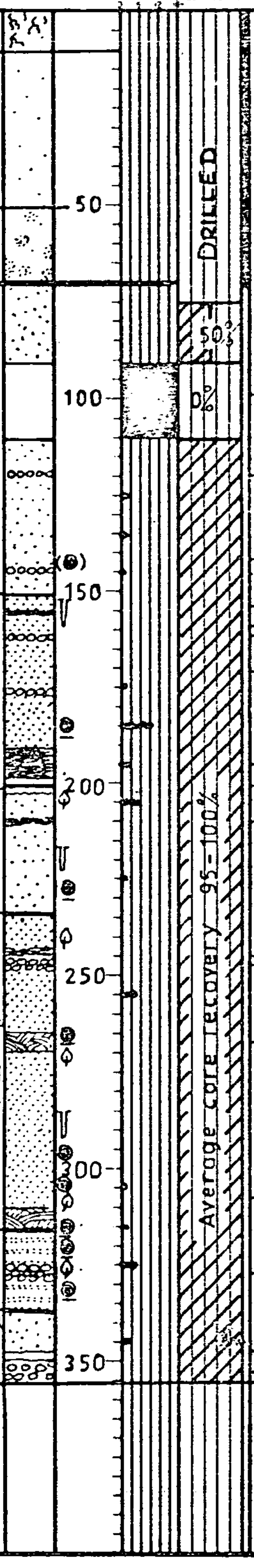
BUREAU OF MINERAL RESOURCES,
GEOLOGY AND GEOPHYSICS

GEOLOGICAL LOG OF DRILL HOLE

PROJECT Statratigraphic Hole.
LOCATION 3800' N. from Bherwerre Trig.
JERVIS BAY, Commonwealth Territory.
ANGLE FROM HORIZONTAL 90°
DIRECTION Vertical
COORDINATES 1119250'E 1980200'N
R.L. 285ft A.S.L.

HOLE NO ULLADULLA 1
SHEET 1 OF 1

ROCK TYPE & DEGREE OF WEATHERING	DESCRIPTION LITHOLOGY, COLOUR, STRENGTH, HARDNESS, ETC
SOIL	Grey sandy soil with rootlets
QUATERNARY SAND	Unconsolidated fine grained grey, yellow, orange and brown sand.
SAND WITH SST. PEBBLES	Fine grained sand with pebbles and cobbles of coarse, highly weathered sandstone.
HIGHLY TO MOD. WEATHERED SANDSTONE	Coarse to medium grained, massively bedded, light grey sandstone.
MODERATELY WEATHERED SANDSTONE	Weak to Moderate strength. Moderately hard. Occassional breaks in sedimentation.
MODERATELY TO SLIGHTLY WEATHERED SANDSTONE	Sandstone showing repeated alternation of two units ① Medium grained, massively bedded dark-grey sandstone ② Medium to fine grained, very thinly bedded light-grey, slightly silty sandstone Grey/black, thin, clay bands present
FRESH JERVIS BAY SANDSTONE (Moderately weathered along joints, faults, and porous shell horizons)	Medium grained, massively bedded grey sandstone Hard to very Hard. Moderately strong. Sandstone showing repeated alternation of units ① and ② of above. Marked conglomeratic horizons and horizons showing small scale cross-stratification present. Hard to very hard Moderately Strong. Medium grained, light-grey very thinly bedded sandstone (unit ②) Abundant fossils. Predominantly massively bedded sandstone. Hard quartzitic horizons and conglomeratic horizons present.
	END OF HOLE



STRUCTURES JOINTS, VEINS, SEAMS, FAULTS, CRUSHED ZONES

FRACTURES IN SANDSTONE ARE USUALLY HORIZONTAL AND OCCUR ALONG PLANES OF PARTING.
SOME HIGH ANGLED JOINTS ARE PRESENT.

20' core loss; rapid penetration. γ-Ray log indicates extremeley high clay values. May represent clay sill?

119'→120' Conglomeratic Sandstone
144'→145' cgl. Sst.
155'→156' Black clay band
159'→160' Black clay band
160'→162' cgl. Sst
176'→177' cgl. Sst
180'→187' blk, mic Cl.
200' 4" crs, hd Qzt
210'→212' blk, mic, pyr Cl.
245' blk, hd cl/Mdst
245'→249' cgl. sst
265'→270' xstratd, tn bdd, Sst
310'→316' xstratd, tn bdd, Sst.
325'→330' cgl Sst
349' 3" crs, hd Qzt
350'→365' crs, cgl Sst.

356' 0"

WATER LEVEL

WATER PRESSURE TEST Loss in gallons per minute per foot

DRILL TYPE MAYHEW 1000
FEED MECHANICAL
CORE BARREL TYPE TRIEFUS
15FT. 2½ DIA.
DRILLER K. REINE
COMMENCED 5·3·1969
COMPLETED 26·3·1969
LOGGED BY M. J. JACKSON
VERTICAL SCALE 1" = 50FT.

NOTES

FRACTURE LOG:- Number of fractures per foot of core. Zones of core loss are blocked in.
BEDDING AND JOINT PLANES:- Angles are measured relative to a plane normal to the core axis.

This log has been condensed from one recorded at a scale of 1" = 5ft.

⊛ Macrofossil horizon
⊛ Abundant Macrofossils
ϕ Fossil Plant Horizon
Ʊ Abundant Annelid Burrows

WATER PRESSURE TESTS
PACKER TYPE
SUPPLY LINE
VERTICAL SCALE
Figures given are gauge pressures
Test sections are indicated graphically by blocked in strips

PHOTOGRAPH REFERENCE SYSTEM
BLACK AND WHITE
COLOUR

M(Pf)99

To accompany Record 1969/88

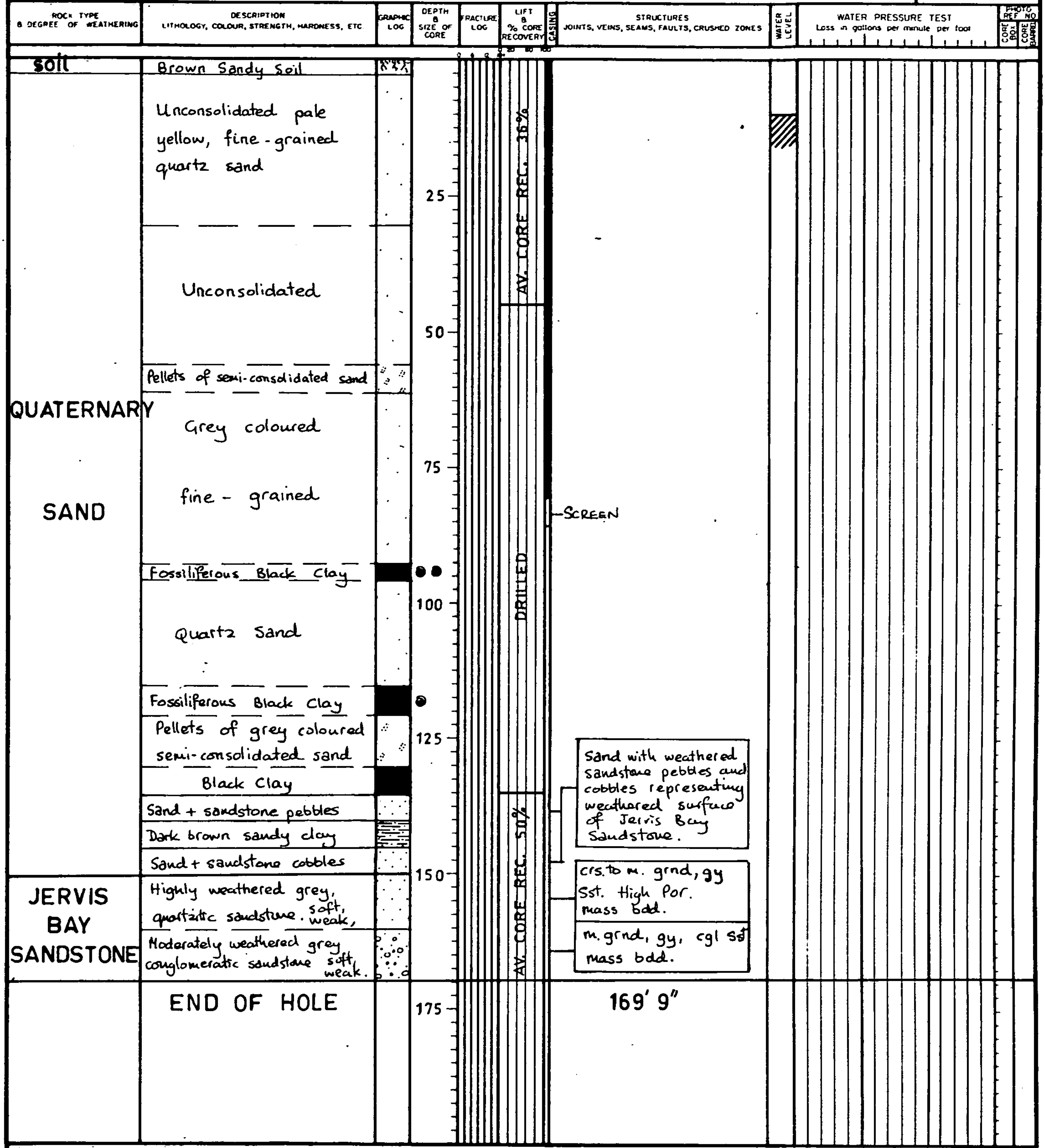
156/A13/14

BUREAU OF MINERAL RESOURCES,
GEOLOGY AND GEOPHYSICS

GEOLOGICAL LOG OF DRILL HOLE

PROJECT Stratigraphic Hole
LOCATION 1 mile S.W. of Lake McKenzie, JERVIS BAY, Commonwealth Territory.
ANGLE FROM HORIZONTAL 90°
DIRECTION Vertical
COORDINATES 1096880ft E 1979380ft N
R.L. 25ft ASL

HOLE NO. ULLADULLA 2
SHEET 1 OF 1



ROCK TYPE & DEGREE OF WEATHERING	DESCRIPTION LITHOLOGY, COLOUR, STRENGTH, HARDNESS, ETC.	STRUCTURES JOINTS, VEINS, SEAMS, FAULTS, CRUSHED ZONES
soil	Brown Sandy Soil	
QUATERNARY SAND	Unconsolidated pale yellow, fine-grained quartz sand	
	Unconsolidated	
	Pellets of semi-consolidated sand	
	Grey coloured fine-grained	
	Fossiliferous Black Clay	
	Quartz Sand	
	Fossiliferous Black Clay	
	Pellets of grey coloured semi-consolidated sand	
	Black Clay	
	Sand + sandstone pebbles	Sand with weathered sandstone pebbles and cobbles representing weathered surface of Jervis Bay Sandstone.
	Dark brown sandy clay	
	Sand + sandstone cobbles	
JERVIS BAY SANDSTONE	Highly weathered grey, quartzitic sandstone. soft, weak,	crs. to m. grnd, gy Sst. High Por. mass bdd.
	Moderately weathered grey conglomeratic sandstone soft, weak.	m. grnd, gy, cgl Sst mass bdd.
	END OF HOLE	169' 9"

DRILL TYPE Mayhew 1000
FEED Mechanical
CORE BARREL TYPE Triefus
15ft. 2½" Dia.
DRILLER K. Reine.
COMMENCED 28·3·1969
COMPLETED 2·4·1969
LOGGED BY M.J. Jackson.
VERTICAL SCALE 1" = 25'

NOTES

FRACTURE LOG:- Number of fractures per foot of core. Zones of core loss are blocked in.
BEDDING AND JOINT PLANES:- Angles are measured relative to a plane normal to the core axis

This log has been condensed from one recorded at a scale of 1" = 10ft

WATER PRESSURE TESTS
PACKER TYPE
SUPPLY LINE
VERTICAL SCALE
Figures given are gauge pressures
Test sections are indicated graphically by blocked in strips

PHOTOGRAPH REFERENCE SYSTEM
BLACK AND WHITE
COLOUR

M(Pf)99

To accompany Record 1969/88

156/A13/15

APPENDIX 3

Petrographic description of specimen 68360103, a porphyritic dolerite from a dyke at Steamers Beach, Jervis Bay,

(grid ref: 37336577)

The specimen is a grey, medium grained porphyritic rock. It is hard, heavy, and exhibits a very irregular surface that is crowded with elongated lathes and tabular crystals of twinned plagioclase feldspar. Weathering out of these feldspar lathes to leave a pitted surface, together with light brown ferruginous staining, are characteristic features exhibited by this rock in the field, and in hand specimen.

A thin section of the rock was cut and the following minerals were identified under a petrographic microscope -

	Approximate Percentage
Feldspar (plagioclase)	60%
Olivine	12%
Pyroxene (probably augite)	10%
Muscovite	8%
Magnetite	10%

The feldspar is present in two phases. It occurs as large phenocrysts, and as small crystals that form a large proportion of the groundmass. The phenocrysts occur as elongated, euhedral lathes (up to $\frac{3}{4}$ inch in length), generally with well defined crystal boundaries, but occasionally showing reaction phenomena with the groundmass. The feldspar in the groundmass occurs as a confusion of small lathes and crystals that show less well developed crystal outlines. Albite and combined Albite/Carlsbad twinning, indicate that the feldspar is labradoritic in composition. Many of the phenocrysts are fresh, but a few show incipient alteration, especially along the cleavage traces.

The olivines are of various sizes, and occur as euhedral crystals or anhedral crystals with polgonal outlines. The cleavage traces usually show the development of antigorite or secondary magnetite.

Occasional phenocrysts of pyroxene (probably augite) are present, but the bulk of this mineral occurs as small prismattic crystals in the groundmass.

Small tabular flakes of muscovite and large numbers of small rhombic crystals of magnetite make up the rest of the groundmass.

The phenocrysts of augite, olivine, and feldspar were the earliest to crystallize so that they attained their relatively large sizes. These were followed by the rest of the rock so that a uniformally-grained, compact groundmass was formed. Some exosolution between phenocrysts and groundmass is present, but this is often masked by late stage alteration, of some of the minerals, to secondary magnetite and limonite.

APPENDIX 4

PETROGRAPHIC DESCRIPTIONS OF SEVEN SAND SAMPLES FROM COMMONWEALTH TERRITORY, JERVIS BAY.

Sample: 68.36.0107, Field No. 16: TS C4541.

Locality: Dune on northern shore of Lake Windermere (grid ref. 36736633)

Rock Name:

Feldspathic sand.

Hand Specimen:

A medium to coarse grained brown sand, containing mainly quartz, with much less than 1% of darker minerals.

Thin Section:

The following minerals are present:

Quartz (some containing fibrous ?chlorite)	
K-feldspar with biotite or epidote inclusions - slightly altered	
K-feldspar perthite; - no biotite/epidote inclusions - slightly altered	
Microcline	
Chert/Quartzite (with ?graphitic inclusions)	
Plagioclase (Oligoclase)	
Brown tourmaline	1 grain
Zircon	2-4 grains
Opaques (iron oxides/hydroxide)	
Apatite	

	%
Siliceous grains	80-85
Feldspar	15-20
Accessories	Trace
Opaques and limonite	Trace - 1

Silica.

Grains of quartz (single crystals), quartzite, and chert are present. The average grain size is 0.2-0.4 mm. The average roundness is 0.3-0.5 (that is, usually quite low), with rare grains with roundness 0.8. A few grains even show sharp crystal faces. The sphericity typically is 0.3-0.5, but a few grains reach 0.8. Most of the quartz shows strain extinction. A few grains contain small fans of nearly colourless ?chlorite. The quartzite is composed of recrystallized grains ?of metamorphic origin. Chert grains are rare: these are highly rounded and are apparently elliptical.

Feldspar.

Feldspar is typically the same size as quartz or slightly smaller. The sphericity is slightly lower because of fracture along and across the cleavage but the roundness is slightly higher. Both plagioclase (which includes recognisable grains of oligoclase) and K-feldspar are present. The oligoclase grains are fresh, as is microcline, but other plagioclase and K-feldspar micro-perthite are kaolinised and some grains contain fine brown biotite/epidote inclusions. Some of the K-feldspar has a low 2V and appears to be sanidine. Other grains appear to be low temperature K-feldspar.

Opaques.

Three or four grains of opaque minerals appear to be of iron oxide or hydroxide. Limonite forms a thin-film-covering on the quartz and feldspar grains.

Accessory Minerals.

One grain each of brown tourmaline (anhedral), zircon (very irregular), and apatite (enclosed in quartz) were noted.

Origin of Sand.

The prominance of K-feldspar and oligoclase in this rock indicates that the sand is derived from acidic (granitic) or intermediate rocks. The quartzite grains suggest a metamorphic region. The sorting is moderately good. Most of the grains have had their sharp edges partly abraded and this appears to be a well travelled or well rolled sand.

The abundant feldspar might suggest little movement from the region of origin yet Russell[1] (1937) noted only little change in the proportions of feldspar to quartz in 1100 miles of Mississippi sediments. Following the arguement in Pettijohn[2] (p. 556 ff) it is suggested that most of the sand has rolled 50-200 miles at least, and probably more. If sanidine (or anorthoclase) is present it implies a comparatively recent acid-intermediate volcanic contribution.

Sample: 68.36.0108, Field No. 32: TS C4542.

Locality: Garbage trench N.W. of Jervis Bay R.A.N.C. (grid ref. 36916635)

Rock Name:

Quartz sand.

Hand Specimen:

A light buff, fine-grained sand with occasional dark grains of a similar size. A few grains ($\ll 1\%$) reach 1 mm in diameter.

Thin Section:

An optical estimate of the constituents gives the following:

	%
Quartz	95-100
Chert	Trace - 1
Opaques	Trace
Limonite	Trace
Leucoxene	Trace
Altered feldspar	Trace - 2
Rutile (enclosed in quartz)	Trace
Tourmaline	Trace
Apatite (enclosed in quartz)	Trace

---

[1] Russell, R.D., 1937 - Mineral Composition of Mississippi River Sands. Bull. Geol. Soc. Am. Vol. 48. pp. 1307-1348.

[2] Pettijohn, F.J., 1957. Sedimentary Rocks (2nd ed.). Harper, New York, pp. 718.

Silica.

Quartz is the most abundant mineral. It occurs mainly as single grains. Several grains are of two crystals, and a few grains are quartzite. The dominant grain size is 0.1 to 0.3 mm. Grains are angular to subrounded (roundness 0.2-0.4), and the sphericity is 0.6-0.8. One grain showed fibrous chalcedony and there are several grains of chert. Extinction is commonly strained.

Feldspar.

There are several grains of an altered, kaolinised, unrecognisable feldspar. The proportion of feldspar is much less than in 68.36.0107. If very highly altered, the feldspar grains are rounded; if alteration is less intense, they are very angular.

Opaques.

The chief opaque mineral has been ilmenite. Most grains are partly or fully altered to leucoxene. Ilmenite occurs in angular [illegible]; fragments; the leucoxene has more rounded edges.

Accessory Minerals.

One grain each of green-brown tourmaline, apatite and rutile were seen. The tourmaline is discrete and anhedral, the other two are euhedral but enclosed in quartz.

Origin of Sands.

It is not possible to give an origin for this sand. There are traces of feldspar, but not sufficiently clear to indicate the nature. The presence of chert indicates silicification in some of the rocks of origin. The degree of rounding is low but this is normal, even in well rolled quartz sands (Pettijohn, p. 545 ff). The sorting is good, suggesting that this is a winnowed beach sand.

Sample: 68.36.0109, Field No. 40: TS C4543.

Locality: Sand pit ½ mile S. of Jervis Bay Settlement (grid ref. 37106622)

Rock Name:

Feldspathic sand.

Hand Specimen:

A pale yellow-brown, fine grained sand, less than 1% is opaque or dark coloured material.

Thin Section:

An optical estimate of the constituents gives the following:

	%
Quartz	85-95
Quartzite	1
Chert	1
? K-feldspar	2-5
Feldspar with brown alteration product - ?albite	2-5
Pale green amphibole	Trace
Tourmaline	Trace
Opaques	Trace
Altered grains with ?chlorite and opaques	Trace

Size and Texture.

The predominant size of grains present is 0.2-0.3 mm, however there are a number of grains which reach up to 0.5 mm. There is one grain of ?iron oxide which is 1.2 mm in diameter. The sphericity of all grains is high, 0.6-0.9, and the roundness is also quite high, 0.5-0.7. Sorting is quite good.

Silica.

Quartz, as single grains, is the most abundant mineral. It commonly, but by no means always, shows strain extinction. The original shape has been euhedral or subhedral in squat prisms and rounding of the corners has taken place. There are a few grains of compound quartzite and chert. All silica grains have a very thin brown stain round their rims.

Feldspar.

Feldspars, more angular than the quartz, in all stages of alteration to a brown alteration product, are present. This is apparently K-feldspar (?which is/was microperthitic). Several grains of albite are present, and other feldspars are unrecognisable. The fresher feldspar shows the broken edges of cleavage flakes. Some highly altered grains are very rounded and are composed of ?chlorite and opaque material in ?clay.

Opaque minerals.

One large grain of an ?oxide mineral (very irregular) and a few other rounded grains of ?ilmenite are present.

Accessory Minerals.

One elliptical grain of green tourmaline and two angular-subrounded deep green fragments of hornblende are present in the slide.

Origin of Sands.

The sand is well sorted and the degree of rounding and sphericity is quite high. Feldspar is present at different stages of alteration and angular-subrounded amphibole is present. It is possible that the source rocks were acid rocks (with some silicified material) and that the distance of travel, has not been too great (for the feldspar and amphibole at least). The rounding of much of the quartz suggests a very protracted reworking of this sand by the sea.

Sample: 68.36.0110, Field No. 97: TS C4544.

Locality: 500 yards S of white clay pit (grid ref. 26886601)

Rock Name:

Conglomerate sand with some clay.

Hand Specimen:

A dark chocolate coloured, conglomeratic sand. Coarse pebbles up to 5 mm diameter are present in the sand.

Thin Section:

The constituents are the following:

- Quartz
- Quartzite pebbles
- Chert
- Brown mica/clay/chlorite
- Feldspar
- Apatite

Over 90% of this sand is quartz.

The coarse, rounded pebbles are of recrystallised quartzite with the contacts between the quartz grains highly sutured and with some elongation of the grains (? a pressure solution effect?). These pebbles are up to 1 cm in diameter. Adhering to their surface and forming the bulk of the rest of the 'sand' are smaller, single quartz grains (angular or subrounded roundness 0.2-0.4) about 0.1-0.2 mm in diameter. Between these grains is a brown mica whose size becomes sufficiently small to be called clay. This mica is only very slightly pleochroic and is associated with limonite. Brown, partly oxidised chlorite also appears to be present.

Limonite or limonitic clay rims all the free quartz or quartzite grains.

Two grains of chert are present in the slide, and several of the quartzite pebbles contain grains rich in sericite/chlorite. There are traces only of albitic feldspar.

Origin.

The quartzite appears to be a recrystallized quartzose sediment. Included micaceous grains have apparently been deformed by compaction. The coarse pebbles are reasonably well rounded and may have travelled some distance. The smaller quartz grains are angular and have not travelled far.

Sample: 68.36.0111, Field No. 101: TS C4545.

Locality: A combined sample from three localities within Area E on Plate 2.

Rock Name:

Feldspathic sand.

Hand Specimen:

A rich, brownish yellow, moderately coarse sand. Few dark coloured minerals are visible.

Thin Section:

An optical estimate of the constituents gives the following:

	%
Quartz Quartzite, some with chlorite Quartz/amphibole grains Chert with hematite	75-95
K-feldspar with chlorite/sericite K-feldspar microperthite Microcline	5-25
Tourmaline	Trace-1
Limonite	Trace-1
Brown clay	Trace
Monazite	Trace
Opaques	Trace
Epidote	Trace
Zircon	Trace

The sand is composed mainly of grains of quartz and subordinate feldspar, typically 0.1-0.3 mm in diameter but extending up to 0.8 mm in one grain. Sphericity of all minerals is commonly high 0.8-0.9. Rounding is more variable. Some grains are sub angular (roundness 0.3), others are quite rounded, 0.7-0.8. All have a brown-stained rim.

Most of the silica occurs as single grains, but there are a few grains of quartzite (some of which carry chlorite between individual quartz grains) and there is at least one grain of quartz with amphibole. K-feldspar is more variable with fairly fresh microcline (slight brown colour) and more altered forms which may contain chlorite, sericite, or be altered to clay. Some of the K-deldspar is microperthitic. Some ?feldspar is altered beyond recognition. Sanidine was not detected in this sand.

Opaque minerals and accessory minerals are relatively more common than in other rocks described. Tourmaline is highly rounded, monazite as cleavage fragments slightly rounded. Opaques include hematite (in chert) and ?magnetite, as well as limonite.

Origin of Sands.

This arkosic sand has been derived from a region of acid rocks. Sorting is generally good, but rounding is not at a high degree. Transport has probably been moderate and may represent either distance travelled or wave action.

Sample: 68.36.0112, Field No. 102: TS C4546.

Locality: A combined sample from five localities within area A on Plate 2.

Rock Name:

Feldspathic sand.

Hand Specimen:

A light, grey-brown, moderately coarse sand. It appears to be mainly felsic, with a few flakes of muscovite.

Thin Section:

An optical estimate of the constutients gives the following:

	%
Quartz) Chert)	70-80
Feldspar) ?Albite)	20-30

Rutile	Trace
Opaques	Trace-1
Amphibole	Trace
Tourmaline	Trace
Zircon	Trace
Chlorite/sericite	Trace

The typical grain size of this quartz-feldspar sand is between 0.2 and 0.4 mm and sorting is moderately good within this range. Some grains are larger. The sphericity is 0.5-0.7 and the roundness commonly 0.3-0.5. Chert and tourmaline are well rounded however, and the more altered feldspar approaches their roundness.

Most quartz grains are single crystals. Several grains are quartzitic with intergrowths of two or more grains. There is a faint brown stain edging the grains.

The feldspar has varying degrees of freshness. There is a mixture of microcline and untwinned feldspar. As in other sands the feldspar tends to be less spherical and less rounded than the quartz. Much of the feldspar is only slightly altered, but a few grains are wholly altered to a brown alteration product. One or two grains almost wholly converted to chlorite/sericite are present. Most K-feldspar has a high 2V and is orthoclase or ?microcline. A few grains have a low 2V (<30°) and are therefore probably sanidine.

<u>Origin of Sand.</u>

This appears to have formed by the weathering of an acid igneous or metamorphic rock sequence. The material here does not look to have been as transported as far as several of those described earlier. The presence of traces of angular sanidine indicates a volcanic origin and little transport for some of the sand material.

<u>Sample: 68.36.0113, Field No. 103: TS C4547</u>.

<u>Locality</u>: A combined sample from five localities with area B on on Plate 2.

Rock Name:

<u>Feldspathic sand</u>.

Hand Specimen:

A light brown, medium brown, mottled sand (with plant remains). There is little sign of dark coloured material.

Thin Section:

An optical estimate of the constituents gives the following:

	%	
Quartz	70-80	80-90
Quartzite	5	
Chert	3-5	
K-feldspar	10-20	
Albite		
Leucoxene	Trace	
Chlorite	Trace	
Opaques	Trace	
?Pyroxene (?diopside)	Trace	
Amphibole	Trace	

This is relatively poorly sorted sand, and both sphericity and roundness are also variable. The general grain size varies from 0.1 to 0.5 mm, the sphericity from 0.3 to 0.7, and the roundness from 0.2 to 0.5.

The grains are like those of the sands described earlier but are slightly more angular. One or two quartz grains appear to have been partly resorbed, others have an overgrowth of fibrous ?quartz. Feldspar, both K-feldspar and albite (oligocalse) appears in all stages of alteration to full replacement. The most highly altered K-feldspar may have been sanidine.

One grain each of green amphibole and colourless ?pyroxene were noted.

Origin of Sand.

This has apparently formed, like the others, from granitic rocks and possibly including some volcanic rocks. Sorting here is poor and grains tend to be angular suggesting that there has been a relatively short distance of travelling from the source.

GEOLOGICAL MAP COMMONWEALTH TERRITORY JERVIS BAY

Geology by M J Jackson
Compiled and drawn by M J Jackson

REFERENCE

QUATERNARY	Qa	Alluvium – marsh or coastal flat
	Qbd	Beach and dune sands
	Grf	Ferruginous gravels
	Grq	Quartz gravels
	Qso	Orange coloured sands
	Qsy	Yellow/light brown coloured sands
	Qsw	Grey/white coloured sands (incl – glass sand Sg building sand Sb)
	Cw	White clay deposits
TERTIARY	Td	Porphyritic igneous intrusions
PERMIAN	s/Pj	Jervis Bay Sandstone covered by thin sandy soils (<10)
	Pj	Jervis Bay Sandstone outcropping at the surface

- Contact, position accurate
- Contact, position approximate or inferred
- Strike and dip of bedding
- Fault, position accurate, with dip of fault plane
- Fault, position approximate
- Macrofossil locality
- × Speciman locality
- Direction of movement of sediment-bearing currents (determined by cross-stratification)
- Igneous dyke
- Sealed road
- Track
- Fence
- ⌖ Auger hole – abandoned (max. depth 10')
- g.w.⊙ Ground water observation hole

SCALE : 1:24000

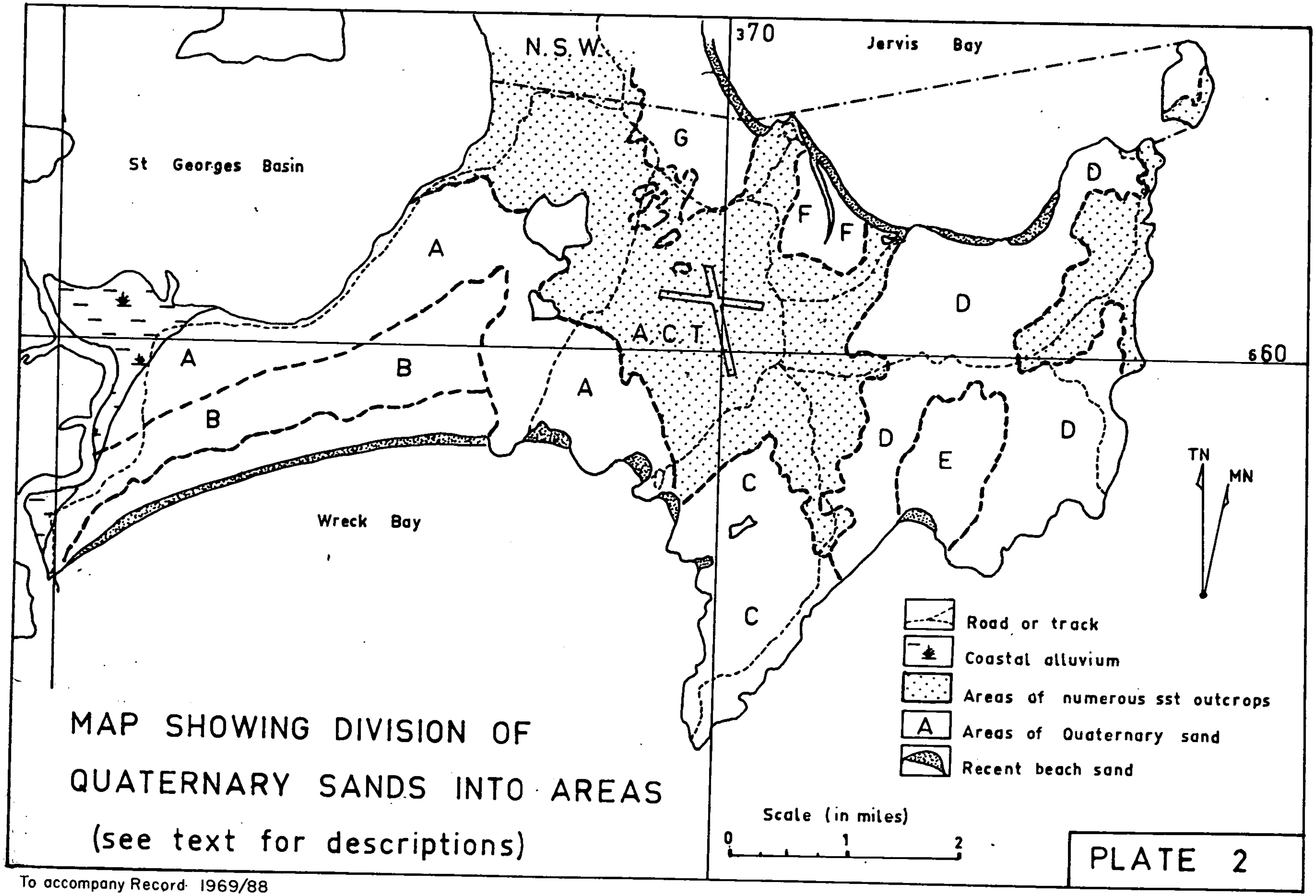
1000 0 1000 2000 3000 4000 5000 Feet
Miles 0 ¼ ½ ¾ 1

TRANSVERSE MERCATOR PROJECTION

PLATE 1

To accompany Record 1969/88

I56/A13/8



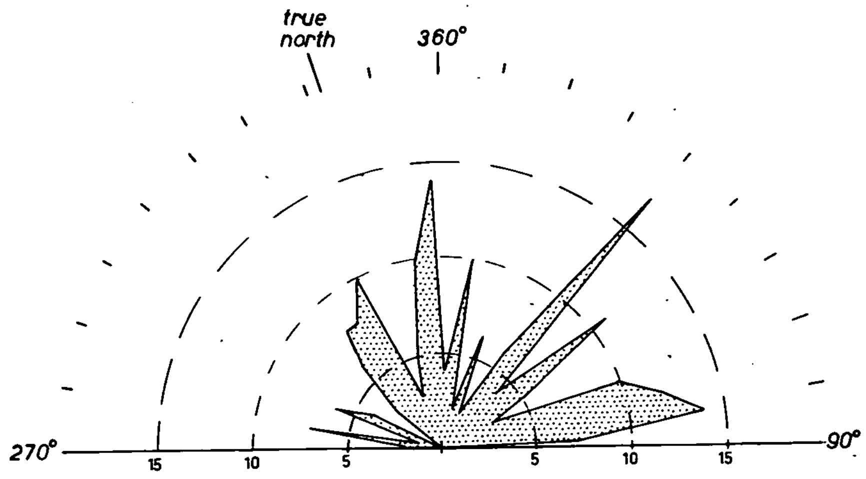
MAP SHOWING DIVISION OF QUATERNARY SANDS INTO AREAS

(see text for descriptions)

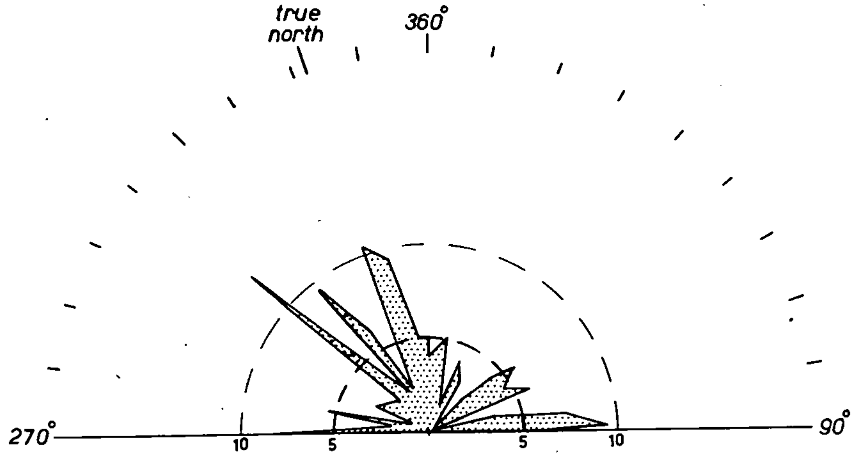
PLATE 2

To accompany Record 1969/88

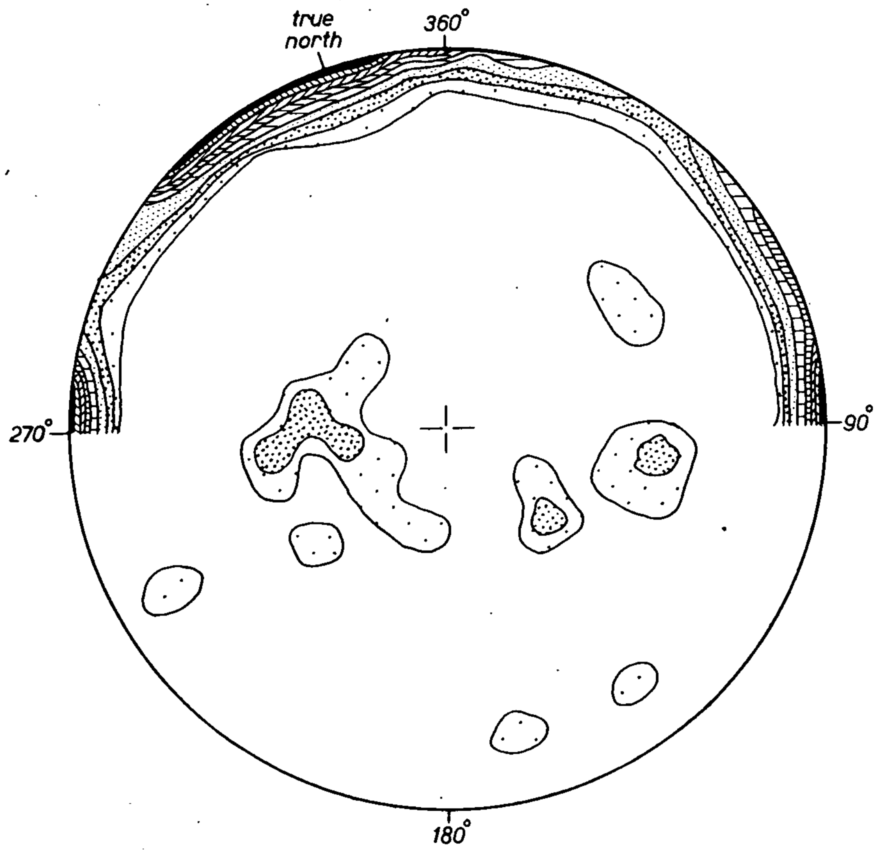
I 56/A13/9



ROSE-DIAGRAM OF FRACTURE ORIENTATIONS.
(200 fault and joint readings)



ROSE-DIAGRAM OF VERTICAL FRACTURES ONLY.
(134 fault and joint readings)



CONTOURED STEREOGRAM OF FRACTURES

POLES OF THE JOINT PLANES WERE PROJECTED INTO THE LOWER HEMISPHERE OF A STEREOGRAPHIC (WULFF) NET.

THE PERCENTAGE DISTRIBUTION OF THE POLES OVER THE NET IS REPRESENTED BY CONTOURS.

COUNTING OF POLES WAS BASED ON A METHOD PROPOSED BY PRONIN & MELLIS.

VERTICAL JOINTS WERE PLOTTED FROM BEARING 270° to 090° (mag).

□	⁚	▩	▒	☰	☰	▨	▧	■
0	1	2	3	4	5	6	7	8

PERCENTAGE DISTRIBUTION

PLATE 3

MAP SHOWING INFERRED POSITION OF A QUATERNARY EROSION PLATFORM AND POSSIBLE GROUNDWATER MOVEMENT S.W. OF LAKE WINDERMERE, JERVIS BAY.

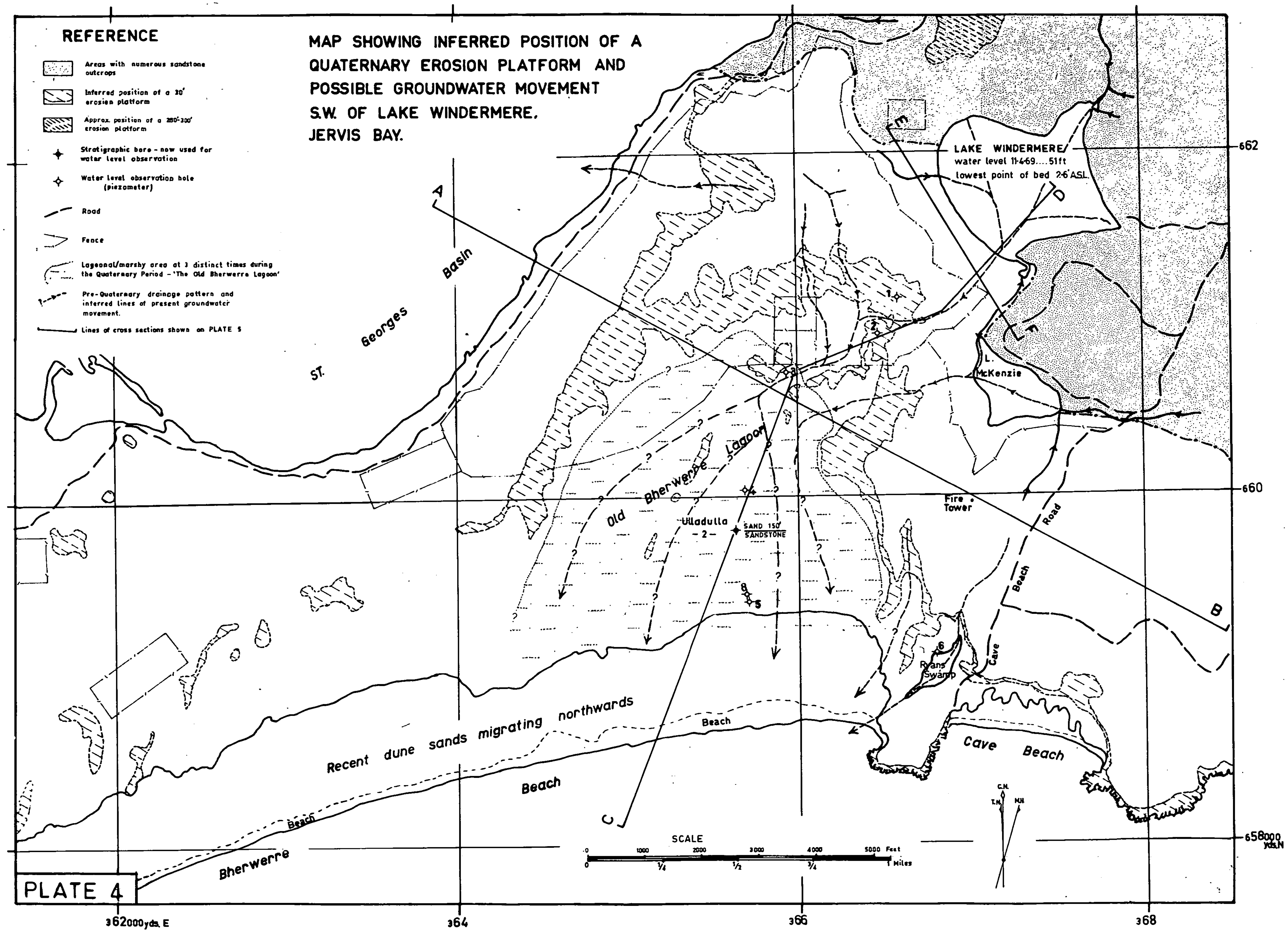
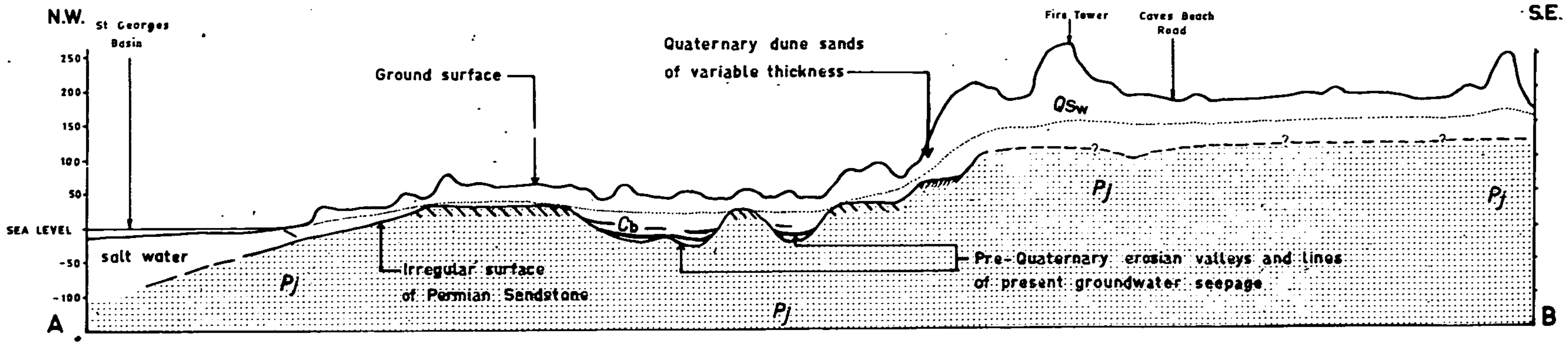


PLATE 4

To accompany Record 1969/88

1 56/A13/11

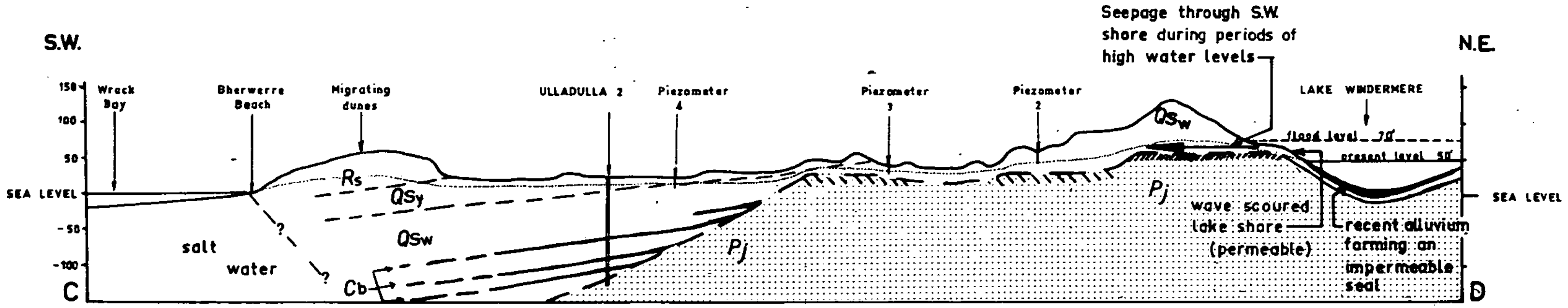


① SECTION ALONG LINE A-B

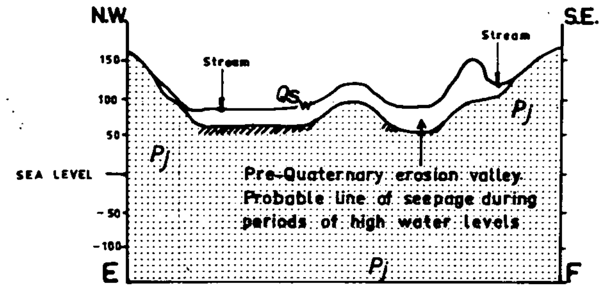
R_s	Recent, orange/yellow dune sands
Qs_y	Quaternary, yellow/grey sands
QS_w	Quaternary, white/grey sands
C_b	Quaternary, black clay
P_j	Permian, Jervis Bay Sandstone
⊓⊓⊓	Erosion platform – 30'A(mean)S.L.
▨	" " – 60' "
——	Approx. position of groundwater table (April 1969)

REFERENCE

Section lines are shown on Plate 4



② SECTION ALONG LINE C-D



③ SECTION ALONG LINE E-F

GEOLOGICAL CROSS SECTIONS ILLUSTRATING THE INFERRED POSITIONS OF QUATERNARY EROSION SURFACES AND THEIR POSSIBLE INFLUENCE UPON PRESENT GROUNDWATER MOVEMENT

HORIZONTAL SCALE
0 1000 2000 3000 4000 Feet

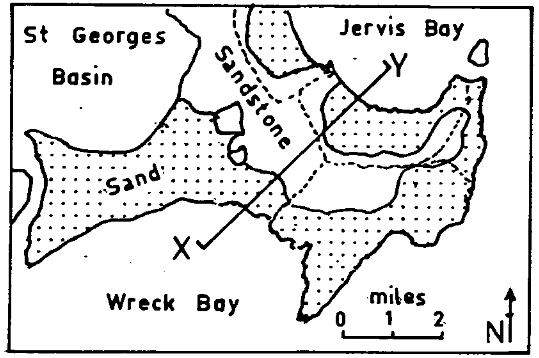
VERTICAL SCALE
0 100 200 300 400 500 Feet

$\frac{V}{H}$ - 8

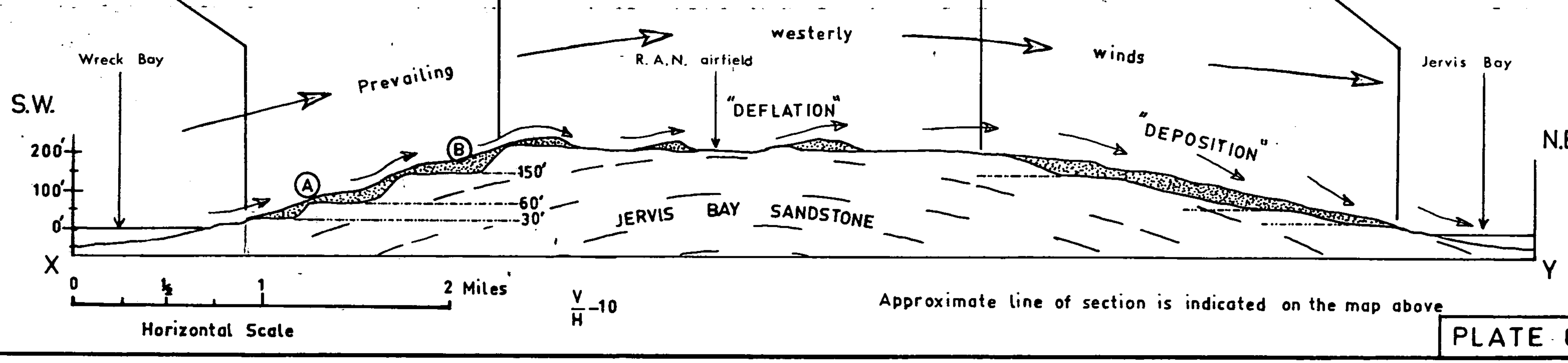
PLATE 5

To accompany Record 1969/88

DIAGRAMMATIC CROSS-SECTION illustrating the SANDSTONE PLATFORMS and their possible influence upon GROUNDWATER RESOURCES and FOUNDATION CONDITIONS in Commonwealth Territory, Jervis Bay.



S. W. SLOPES	UNDULATING UPLAND	N. E. SLOPES	
Well defined		Poorly defined	PLATFORMS
Windward slopes: sand builds up in pockets against platform scarps	Exposed sandstone upland: deflation active. A few small dunes present	Leeward slopes: fairly uniform sand deposition	QUATERNARY SAND
Probably SMALL, perched supplies. Contamination by sea spray?	VERY SMALL. Joints in sandstone probably contain small supplies	Probably GOOD	GROUNDWATER RESOURCES
DIFFICULT Depth to bedrock ranges from a few tens of feet at Ⓐ upto approx. 100 feet at Ⓑ	EXCELLENT Bedrock at surface	FAIR Sandstone bedrock uneven but not sharply platformed	FOUNDATION CONDITIONS



Approximate line of section is indicated on the map above

PLATE 6

To accompany Record 1969/88

156/A13/13