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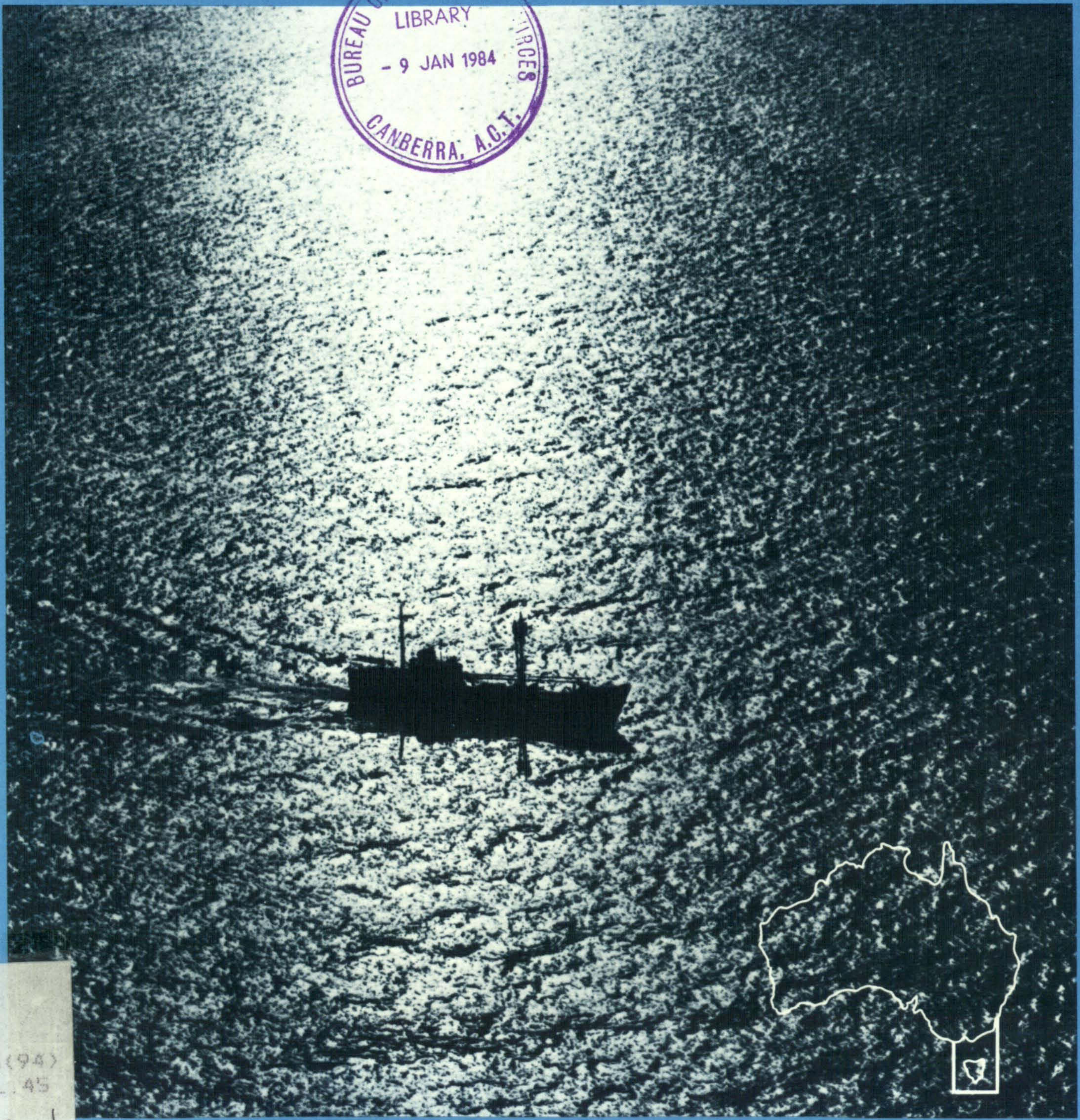
H. A. Jones & P. J. Davies



DEPARTMENT OF RESOURCES AND ENERGY
BUREAU OF MINERAL RESOURCES, GEOLOGY AND GEOPHYSICS

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H. A. JONES & PETER J. DAVIES

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ABSTRACT

Three hundred and sixty-five surface and near-surface seabed samples provide the basis for an assessment of regional lithofacies variations on the Tasmanian shelf and in eastern and western Bass Strait. Quartz-rich sands with variable amounts of shell debris occur on the innermost shelf and on the rises flanking the central Bass Strait basin. They are essentially modern deposits derived in the main from Pleistocene nearshore sand bodies reworked and transported landwards during the Holocene marine transgression. Muddy sediments of the middle shelf off eastern Tasmania and in central Bass Strait are sites of present-day sedimentation, but they are likely to form only a thin veneer, and include coarse material probably reworked from the Pleistocene and early Holocene substrate. Extensive areas of the middle and outer shelf, particularly off southern and western Tasmania, are floored by dominantly relict bryozoan sands and gravels. Fine-grained and shelly, slightly quartzose sands in areas of the middle shelf consist of relict sediment, and sediment from the late Holocene transgressive marine sand sheet, in about equal proportions.

Four main suites of heavy minerals are present in the surface sediments. Provenance relationships with sources in the adjacent hinterland suggest that little offshore sediment transport parallel to the coastline has taken place. Rare grains of cassiterite were identified in marine sediments lying off the tin-producing areas of northeastern Tasmania, but 10 ppm Sn was the maximum value recorded in the geochemical analyses.

Some phosphatisation of relict limestone gravels on the middle and outer shelf off northwestern Tasmania has taken place, but the highest recorded whole-rock analysis was 3.6 percent P_2O_5. Density of sample stations in this part of the shelf is low.

INTRODUCTION

Most of the data on which this account of the superficial sediments of the Tasmanian shelf and Bass Strait is based were collected in 1973, during a marine geological survey by BMR aboard the converted ocean-going tug MV *Sprightly*. Additional data have come from 65 samples that BMR collected aboard the oil-rig supply vessel MV *San Pedro Strait* in Bass Strait during the previous year. A large area in central Bass Strait was not sampled during these two surveys, and there are significant gaps in the coverage in western Bass Strait and to the north and south of King Island (Plate 1). Interpretation and reporting of the results were initially delayed pending follow-up work to fill these gaps. However, further field surveys have not been possible, and eventually it was decided to publish this description based on the data that were available.

Of the total of 365 bottom samples obtained during the 1972 and 1973 cruises (Fig. 1), all but five were recovered with a pipe dredge or a dredge of the chain-bag type with provision for retaining the fine fraction. At five stations a 2-m piston corer was used. Summary accounts of the cruises have been given by Davies & Marshall (1972, 1973), and Jones & Holdgate (1980) have described the shallow structure and geological history of the western half of the area from the seismic data collected during the *Sprightly* cruise. Interpretations of the geochemical data over the whole area, and of the shallow seismic profiles from the eastern shelf, have yet to be completed.

The subsurface geology of the offshore Gippsland Basin is now well known in outline as a result of petroleum search by industry, and geophysical surveys and some drilling have been carried out in the area under review in the western part of Bass Strait. However, little has hitherto been recorded on the nature of the superficial sediments of the continental shelf, apart from studies of restricted areas such as those by Slater (1969) and Taylor (1975). During the BMR surveys, samples were generally collected on an 18 km (10 nautical miles) grid, although stations were more closely spaced in some areas of the east Tasmanian shelf. Station data and summary descriptions of the samples are listed in Appendix 1.

H. A. Jones, P. J. Davies, and J. F. Marshall, all of BMR, took part in both cruises and each acted as cruise leader at various times during the four months spent at sea. Other scientists who helped with the work at sea for short periods included G. Holdgate of the Geological Survey of Victoria, P. Coleman of the Australian Museum, and A. Drummond of Flinders University. B. G. West (BMR) was mainly responsible for grainsize analyses in the laboratory. The heavy-mineral fraction of the sediments was investigated by J. B. Colwell (BMR), and his work forms the basis of the section on heavy minerals in this account. Molluscs recovered in dredge hauls on the east Tasmanian shelf were identified on board by P. Coleman. The results of pollen analyses carried out by M. K. Macphail of Esso Australia Ltd are presented as Appendix 4. T. J. Kimber of the BMR Cartographic Section drew the figures.

TEXTURES

In the laboratory, representative samples from each station were treated with hydrogen peroxide to remove organic matter, washed in fresh water, and air-dried at 50°C. Initial grainsize separation was carried out by wet-sieving into gravel (>2 mm), sand (2.0–0.062 mm), and mud (<0.062 mm) fractions, and the percentages by weight of each were determined. Gravel finer than −5.25 phi (38 mm) was further sieved into eight fractions (1 phi intervals between −5.25 phi and −2.25 phi, and quarter-phi intervals between −2.25 phi and −1.0 phi). The sand fraction was processed in a settling tube, and grainsize distribution at quarter-phi intervals was determined. The mud fraction was analysed by the standard pipette method to give eight readings at half-phi intervals. Finally, the total grainsize data were programmed through a CTC 3600 computer, which provided cumulative and frequency curves, and the standard grainsize statistical parameters were calculated by the method of moments. These data are summarised in Appendix 2.

The interpretation of grainsize data obtained by a combination of different analytical techniques is subject to error; thus the apparent lack of material of about −1 phi size in many of the samples—that is, material on the boundary between very coarse sand and gravel—may be partly due to the gravel being measured by sieving and the sand by settling velocity. However, numerous writers over the years have suggested, from other lines of evidence, that clastic grains in the granule range are not abundant in nature (for example, Udden, 1914; Pettijohn, 1949), and we believe that the relative paucity of material of this size indicated by the mechanical analyses of these sediments is not wholly a product of the measurement techniques.

Two other factors need to be taken into account in assessing the significance of the grainsize data. The first is that part of the sediment, particularly the coarser fraction in shelf areas distant from land, commonly consists of relict gravel, recent shells from the local benthic community, and concretionary or nodular material with authigenic components. None of these are necessarily related to the present-day regime of sediment transport and deposition.

The second factor relates to the sampling technique. Most samples were obtained by dredging, and the material recovered in a single dredge haul may include sediments collected from sites tens of metres apart. In areas of rapidly changing seafloor relief, what appears to be a poorly sorted sediment may therefore represent a composite sample consisting of separate components, each of which may be well sorted and in hydrodynamic equilibrium with its own small-scale environment. In addition, the dredge recovered material from the top few centimetres of sediment, and the resulting mixed sample may be derived from more than one thin bed, or from several laminae; here again, apparent poor sorting may reflect the composite nature of the sample recovered, and in this respect simulate naturally occurring bioturbation effects of burrowing organisms.

The grainsize distribution (Plate 1), based on the 10-compartment three-endmember classification of Shepard (1954), indicates that sand and gravel cover the entire shelf except for areas of silty sand in central Bass Strait and to the east of St Helens, southeast of Bicheno, and off Maria Island. Quite small proportions of silt and clay can impart a very muddy appearance to sediments plotting in the silty sand or even the

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Fig. 1. Sample station.

sand compartments of the Shepard triangular diagram, and this is reflected in the summary descriptions of the sediments given in Appendix 1.

In order to gain a better indication of grainsize differences the sand fraction was subdivided: the mean grainsize at each station was plotted and the values were contoured at 1 phi intervals (Fig. 2); where the distribution was bimodal, the coarser fraction was ignored when it consisted of shell debris from the existing benthic community. This device introduces a

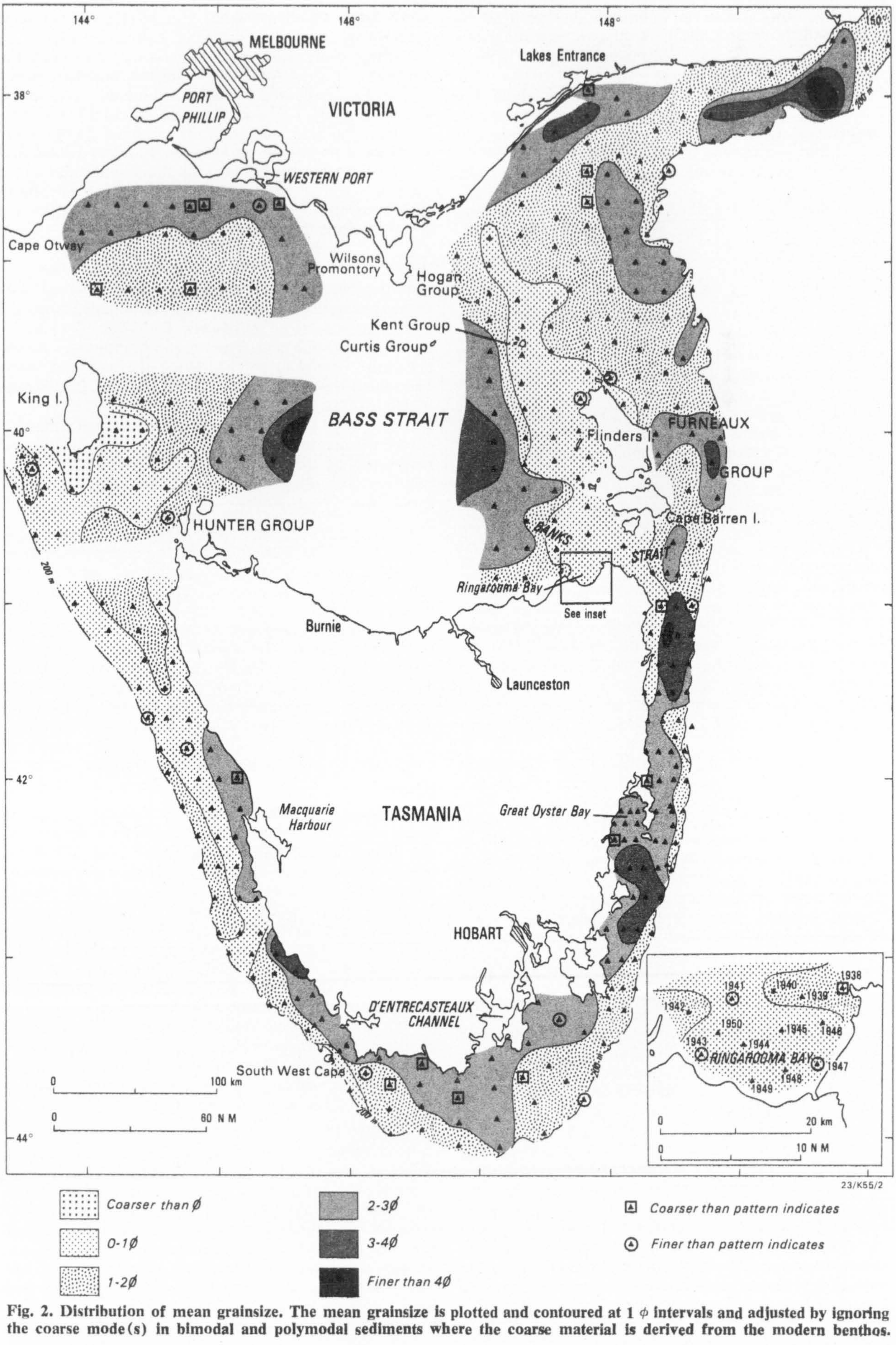


Fig. 2. Distribution of mean grainsize. The mean grainsize is plotted and contoured at 1 ϕ intervals and adjusted by ignoring the coarse mode(s) in bimodal and polymodal sediments where the coarse material is derived from the modern benthos.

subjective element into the interpretation, but it allows more realistic conclusions to be drawn regarding past and present depositional environments. Figure 2 shows that reverse grading (coarsening seaward) is the regional pattern. Fine sand predominate along the inner shelf off Victoria and off much of Tasmania, and grades seawards into medium-grained sand, and locally into coarse sand at the edge of the shelf. Major disruptions of this regional pattern are caused by the areas of very fine sand and mud of central Bass Strait, the southeast Victorian shelf, and off eastern Tasmania, by the belt of coarse sand extending north-northwestwards from Flinders Island, and by the coarse sand covering much of the northwest Tasmanian shelf.

Sorting of the sediments (Appendix 2) reinforces the impression gained from the grainsize data that much of the shelf is floored by relict sediments. Well sorted and moderately well sorted sands (standard deviation less than 1.0 phi) are generally confined to the nearshore zone and to areas between Flinders Island and the Mornington Peninsula, and the middle and outer shelf is covered with poorly sorted and very poorly sorted material. Implications of the textural data are discussed more fully in a later section.

COMPOSITION

Carbonate

Calcium carbonate is the dominant component of the superficial sediments: 81 percent of the samples analysed contain over 50 percent $CaCO_3$, and 62 percent contain over 75 percent $CaCO_3$ (Appendix 1, Plate 1). Apart from restricted occurrences of concretionary limestone and beachrock on the middle and outer shelf, mainly off northwestern Tasmania and southeastern Victoria, and of abundant micritic material in the muddy sediments, mainly on the eastern shelf and towards central Bass Strait, the carbonate consists of recognisable skeletal debris mainly contributed by molluscs, bryozoans, and foraminifera.

Twenty-four genera of bivalve molluscs were identified on the east Tasmanian shelf (Fig. 3). Thirteen genera were represented by dead forms only; ten were represented by both living and dead specimens; and a single genus (*Modiolus*) was represented by living specimens only. In most cases the depth range of the dead forms exceeds that of the living, commonly by a large margin, which suggests a relict origin. The same is true to a lesser extent of the gastropods, of which 19 genera were recorded, and the scaphopods (two genera).

Bryozoans contribute the largest single component of the skeletal debris over wide areas of the middle and outer shelf and are completely dominant over much of the west Tasmanian shelf. Much of the gravel-size material represented in Plate 1 and recorded in Appendix 1, consists of bryozoan colonies. Wass & others (1970) noted that reteporiform bryozoan zoarial types predominate in samples from the east Tasmanian shelf, but form only a minor constitutent of samples from the Great Australian Bight and the west Tasmanian shelf.

Calcareous benthic foraminifera make up a significant proportion of the shelf sediments, particularly off eastern Tasmania and in eastern Bass Strait, where they commonly approach bryozoans and molluscs in abundance. Arenaceous benthic forms are less common, and planktonic foraminifera, although present in almost every sample examined, usually do not form a major component of the total shell fraction. The distribution of benthic foraminifera in eastern Bass Strait has been described by Taylor & Mee (1970) who stressed that the physico-chemical properties of the bottom water—rather than water depth—are the critical factors governing species distribution. Among the genera recorded by Taylor & Mee, *Spiroloculina, Amplicornia, Glandulina, Brizalina, Eponides,* and *Lenticulina* are prominent in the BMR samples from the east Tasmanian shelf. These forms also occur in shallower water (40–60 m) in Bass Strait, and on the outer shelf off eastern and southern Tasmania, where their generally unbroken condition contrasts with the comminuted, crushed, and worn appearance of the mid-shelf assemblage comprised largely of species of *Discorbis*, *Guttulina*, *Quinqueloculina*, and *Gaudryina*. This worn comminuted assemblage also occurs in patches along the east and south Tasmanian shelf, and in the central parts of Bass Strait, at depths greater than 60 m.

Along the south Victorian and east Tasmanian coasts, the area of comminuted foraminifera is replaced shorewards by the quartz-rich sediments in which foraminifera are altogether sparser, but dominated by *Elphidium*.

Terrigenous clastics

The terrigenous component of the coarse fraction of the shelf sediments consists mainly of quartz, with subordinate rock fragments, feldspar, and ferromagnesian minerals. Silt and clay of terrigenous origin form major components of the sediments only in restricted areas of the middle shelf off eastern Tasmania. Overall abundance of land-derived clastics decreases rapidly away from the coast and is inversely proportional to the carbonate content (Plate 1). Only east of Flinders Island and off the east Victorian coast do the sediments of the outer shelf consist of more than 20 percent terrigenous material.

Quartz

No attempt has been made to classify the quartz population in terms of optical properties (extinction characteristics and types of inclusions), or grain-shape and grain-surface differences; such data can contribute to provenance studies, but in this instance not enough is known about the characteristics of quartz from possible source areas to allow reliable conclusions to be drawn. However, the abundance of plutonic quartz with straight or slightly undulose extinction in the sediments off Flinders Island and off northeastern Tasmania points clearly to derivation from the Devonian granites of that region. Well rounded grains are not at all common, but are prominent in a number of samples from northwestern Bass Strait and east of Flinders Island. These perhaps represent reworked material from Pleistocene aeolian coastal dunes.

Rock fragments

Rock fragments form less than 10 percent of the sediment, except off southern Tasmania, where they dominate the sediment at some close inshore localities. This coarse material is not far-travelled and the provenance is commonly not in doubt. To the east of Flinders Island, granitic rock fragments predominate, whereas vein quartz, metamorphic quartzite, schist, and metagranite related to the onshore Precambrian and lower Palaeozoic sequences occur off southern and western Tasmania. Pebbles derived from the Tertiary

Fig. 3. Molluscan genera and their depth ranges identified in dredge hauls on the east Tasmanian shelf.

basalt of western and northwestern Tasmania appear in some of the inshore samples in these areas.

Heavy minerals

Sixty-one samples with a large terrigenous component were selected from throughout the area for heavy-mineral separation. Separations were carried out in the −1.2 mm +0.053 mm fraction, and 300 to 400 grains were counted in most samples. The abundance of each of the heavy minerals was determined by grain counts under the microscope. Where necessary, X-ray diffraction was used to confirm mineral identifications. Detailed results are given in Appendix 3.

The mineral assemblages fall into four main suites. The distinctions between these are by no means clear-cut, but, as for the rock fragments, sources in the neighbouring onshore hinterland can commonly be identified, suggesting that transport parallel to the coast is not an important process. The average heavy-mineral content of the sand fraction of the 61 samples analysed was 0.73 percent. Relatively high values

(>2.0 percent) are evident only among the pyroxene and ilmenite-rich samples of suite 1.

Suite 1 is dominated by pyroxenes, and extends along the eastern, southern, and much of the west Tasmanian shelf, and is also found off the Victorian coast in western Bass Strait. Off eastern and southern Tasmania the assemblage consists of 10 to 20 percent opaques (ilmenite, magnetite, hematite, limonite, and minor leucoxene), 50 to 70 percent pyroxene, 5 to 10 percent tourmaline, 2 to 10 percent garnet, 2 to 5 percent apatite, minor quantities of hornblende and rutile, and traces of topaz, zoisite, and metamorphic minerals. The main source of this assemblage is likely to be the extensive areas of Jurassic dolerites of eastern Tasmania. Off western Tasmania the assemblage contains rather more opaque minerals and metamorphic species (chiefly garnet), and less pyroxene. Inshore samples from the Victorian shelf between Cape Otway and Wilsons Promontory contain about 50 percent opaques, 20 to 30 percent pyroxene, and 5 to 10 percent of each of amphibole (hornblende), zircon, and tourmaline. Small quantities of olivine in samples from that area reflect the proximity of the basic volcanics of western Victoria.

Suite 2 occurs east and northeast of Flinders Island and in Ringarooma Bay (Banks Strait) and is distinguished by the abundance of topaz, which averages 42 percent of the heavy fraction, and tourmaline, which averages 21 percent. Derivation from the topaz-bearing Devonian granites of northeastern Tasmania and the Furneaux Group is clearly indicated. Other components of suite 2 are ilmenite and iron oxides (17 percent), garnet (7 percent), zircon (5 percent), and minor to trace amounts of amphibole (hornblende), epidote, rutile, cassiterite, and andalusite.

Suite 3 occurs off northwestern Tasmania to the southeast of King Island, and is characterised by the presence of an unusually high proportion of olivine, derived from the Tertiary basalts which crop out in coastal regions in the northwest of the state.

Suite 4 is a mixed assemblage occurring off the southeast Victorian coast from Ninety Mile Beach to Cape Howe. It consists of between 25 and 46 percent opaques (magnetite and ilmenite with minor leucoxene), 5 to 17 percent zircon, 15 to 25 percent tourmaline, 1 to 2 percent rutile, 5 to 20 percent hornblende, 5 to 10 percent epidote, 1 to 10 percent garnet, 1 to 5 percent andalusite, 1 to 2 percent staurolite, and traces of apatite, topaz, pyroxene, and sillimanite. Many of the stable and ultrastable components are moderately to well rounded and are probably multicyclic. Sources for the suite are likely to lie in the extensive and rugged granitic and sedimentary terrain of eastern Victoria.

A few samples are anomalous and do not readily fit into one of the four suites described above. Thus a single sample from an inshore station off the east coast of King Island (number 2168, included in suite 1) consists mainly of garnet and augite, presumably derived from the contact-metamorphosed pyroxene-garnet-rich scheelite-bearing sediments associated with the intrusive granite of southeastern King Island. The heavy fraction of the sediment from this station was searched for scheelite; none was identified by optical properties, but rare grains were picked out by scanning under ultraviolet light.

Cassiterite is present in trace amounts in suites 1 and 2 from east of Flinders Island and eastern Tasmania. The highest value recorded was 1.7 percent at station 1943 in Ringarooma Bay, but XRF analysis of this sample for tin recorded only 2 ppm Sn. Of 107 samples from the east Tasmanian shelf and eastern Bass Strait analysed for tin, 15 equalled or exceeded the 2 ppm detection limit. The maximum value recorded was 10 ppm Sn in a sample from station number 1940, also in Ringarooma Bay. These low values have no economic significance in themselves, although higher values may be present in the subsurface.

Phosphate

An offshore mineral exploration program to search for phosphate on the Tasmanian shelf was undertaken by a consortium of mining companies in 1966. About 180 dredge samples, mostly from the west Tasmanian shelf, were collected, and nodular phosphatic material was recovered at six of these in water depths of 60 to 150 m. The operating company (Ocean Mining A.G., Washington) reported a maximum P_2O_5 value of 26 percent; however, the overall results of the venture were not sufficiently encouraging to stimulate more detailed evaluation, and no further work was carried out.

Traces of phosphate were found in material from several dredge hauls on the west Tasmanian shelf during the BMR survey, but the highest P_2O_5 value recorded in whole-rock analyses was only 3.6 percent. This does not cast doubt on the results of the earlier mining company work; nodular phosphatic material is highly variable in composition, and, furthermore, few samples were collected by BMR off northwestern Tasmania and southwest of King Island, where it appears that most of the mining company dredging was carried out.

The highest phosphate values in the BMR samples were recorded on material from stations 2121 and 2126, both on the middle and outer northwestern shelf. In both samples the phosphate occurs as collophane associated with goethite, which are present as minor components in the carbonate cement of small brownish limestone nodules. The bulk of the rocks consist of bryozoan fragments in a micritic matrix (2121) and planktonic foraminifera with glauconite pellets in a micritic matrix (2126).

No deposition is taking place on the shelf in this area, and, apart from elements of the modern benthos, most of the material recovered in the dredge hauls consists of brown-stained and bored limestone lag gravel. Seismic data confirm the absence of a Holocene sequence and indicate that Tertiary limestone (probably the Miocene Port Campbell Limestone equivalent) crops out on the sea floor (Jones & Holdgate, 1980). Phosphatisation of relict sediments on continental shelves is not uncommon, although it is usually recorded in water depths somewhat greater than in the Tasmanian occurrences. Phosphorus and iron-rich sediments on the east Australian continental margin have been examined in detail by Marshall & Cook (1980). Their data show that complex multistage diagenetic and physical processes are involved, and suggest that precipitation of apatite occurs during both early and very late phases of the development of the material.

SURFACE SEDIMENT DISTRIBUTION AND DISPERSAL

Most data on mid-latitude temperate shelves come from the northern hemisphere, where the influence of glacially derived sediments is commonly overriding. The composition and textures of the Tasmanian shelf sediments are closely related to Quaternary sea-level changes, but the shelf was never glaciated and Pleistocene glacial deposits are absent. Skeletal carbonate is the dominant component of the sediments; part of this carbonate consists of transported shell debris in equilibrium with the hydrodynamic conditions of the present-day environment, but part, and often the major part, consists of living or recently dead elements of the modern benthos, or of stained and abraded relict shallow-water shell material and altered nodular calcareous material unrelated to the modern regime of sediment transport and deposition.

Relict and modern sediments

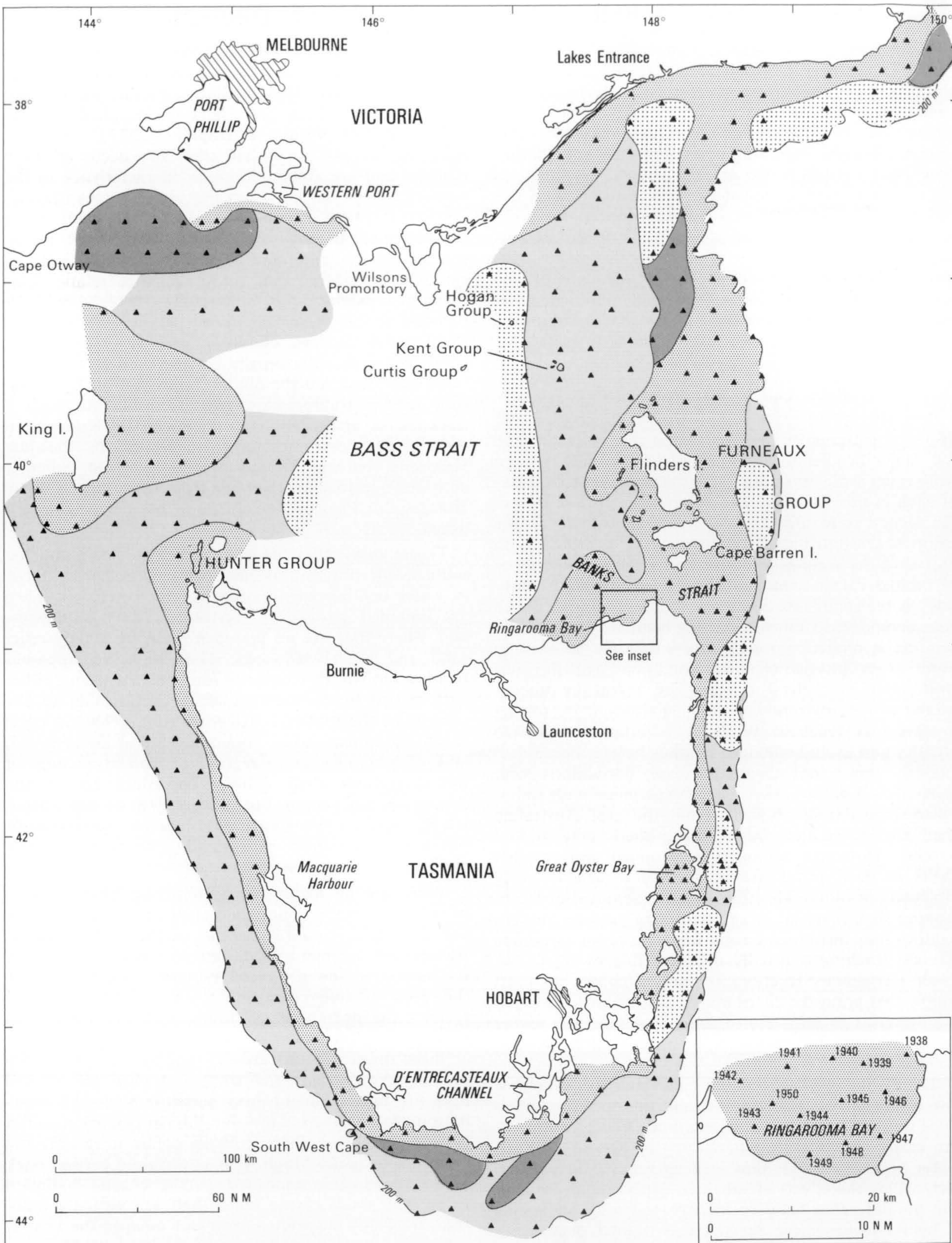
Any attempt to explain the existing distribution and dispersal patterns of the shelf sediments is faced with two major problems. The first is to distinguish modern from relict sediments and assess the relative proportions of each in the extensive areas where the two are mixed; the second is to identify and make allowance for the component contributed by the existing benthos. With regard to the second, grainsize and sorting data will be of limited value as indicators of environmental conditions if the sediments contain a much coarser or much finer component from the existing benthos. The modern benthos is related more or less intimately to existing water depth, physico-chemical conditions, and the substrate, but its skeletal remains are texturally unconnected to the environment until equilibrium by sorting processes is reached. While it is often possible to identify and exclude modern benthos before mechanical analysis, this is not always the case, particularly with broken shell debris. Also recent experience with radiocarbon age dating of shells from the east Australian shelf has shown that fresh-looking shells may in fact be early Holocene, although iron-stained and abraded shells in deep water are apparently invariably early Holocene or older. Thus the selective removal of fresh-looking shell material in an attempt to exclude modern benthos may introduce errors. Removal of all carbonate by acid leaching is usually impracticable owing to the small terrigenous fraction in many samples. It must follow that grainsize distributions as a measure of existing dispersal patterns are to some extent suspect owing to the unavoidable inclusion of some modern benthic skeletal material.

The distinction between relict and modern sediments also is not always easily made, and this too may introduce uncertainties in interpretation. Relict sediments are easily recognisable where they consist of shallow-water organic remains now in deep water, and particularly where the effects of subaerial exposure are evident. But the difference between modern and relict sediments is by no means clear for the fine-grained deposits in central Bass Strait, off southeastern Victoria, and along much of the middle and outer shelf of eastern Tasmania (Fig. 4). Belts of muddy sediments occur on the middle shelf at a number of places elsewhere on the east Australian continental margin, and the question of whether or not they represent modern deposition has not been resolved. Mid-shelf muds off New England on the United States Atlantic margin have been shown to be relict early Holocene deposits (Milliman & others, 1972; Meade, 1972). On the other hand, fine-grained sediments in over 50 m of water on the south Washington shelf on the United States Pacific margin are considered to be modern deposits supplied by the Columbia River (Smith & Hopkins, 1972). The mud zones on the east Australian shelf also occur off river mouths, and are similar in some characteristics to the modern muds of estuaries on the adjacent coast. Davies (1979) favoured a relict origin for the shelf muds because their textures are similar to those of mixed coastal barrier sands and back-barrier muds, and because he considered that the provenance relationships that they exhibit with hinterland sources would be unlikely to be preserved during dispersal across the shelf under modern conditions. However, vibrocore holes drilled recently on the eastern shelf have shown, locally at least, that the muddy sands rest on the Holocene marine transgression unconformity and reach a thickness of at least 3.5 m off Newcastle (Kudrass, in press). They were therefore deposited in the late Holocene, but the source of the sediment, whether entirely from modern rivers or from reworking of early Holocene or Pliestocene substrates, has not been established.

The muddy sediments of central Bass Strait and the southeast Victorian and east Tasmanian shelves occur in water depths ranging from 44 m to 212 m. They are bounded by mainly terrigenous sand landwards, and, where they are on the open shelf, by mainly relict sand and gravel seawards. They have no apparent relationship to the onshore drainage pattern, either with regard to the location of the deposits or to the sources of the material. They are almost always polymodal; dominant modes commonly fall at about 2, 3.5, and 4.5 phi. The sand-size fraction consists mainly of non-terrigenous shell debris. The thickness of the deposits is not known, but exceeds 1 m at one station (2167) where a piston core was obtained. No significant lithological variation with depth was noted in this core.

There are no major rivers supplying large volumes of sediment to the continental shelf in the survey area, and there is no doubt that most of the relatively little-transported sediment load that is carried to the sea is trapped in the protected estuaries and lagoons of this drowned and embayed coastline. Some, however, reaches the open shelf in times of heavy run-off, as evidenced by the turbid surface-water observed offshore at these times. Coastal erosion, and winnowing of the sea-floor by currents and wave and swell action, will also lift fine sediment into suspension in the near-bottom water layers. How far this suspended material is transported and where it finally comes to rest are the questions at issue. Much of it is certainly carried back landwards and is deposited in the coastal sediment traps. The sands of the inner shelf are virtually mud-free, so if any suspended sediment escapes the coastal sediment traps it must bypass the inner shelf. The presence of modern pollen in the mid-shelf muds suggests that suspended terrigenous sediment that reached the overlying water column in the middle shelf must be deposited there along with the pollen.

The pollen analyses (Appendix 4) were carried out by Dr M. K. Macphail. His results show that pollen from plants introduced since European colonisation, for example *Pinus radiata* and agricultural weeds, are



Mainly quartz sands with variable amounts of modern shell debris

Muddy quartzose and calcareous sediments, mainly in areas of modern deposition

Fine-grained shelly sands, slightly quartzose, with modern and relict components

Bryozoan sands and gravels, mainly relict in origin

Fig. 4. Generalised lithofacies of the surface sediments.

present in the three samples analysed, although only in one sample are the numbers statistically significant. These results prove that modern pollen are being deposited on the middle shelf today, and it follows that hydraulically equivalent or coarser terrigenous material transported to the area must come to rest there also.

No quantitative estimate of the relative proportions of modern terrigenous sediment, relict sediment, and material reworked from the substrate that are present in the mid-shelf muddy sands is possible, but contributions from all three sources are likely. The factors which control deposition are suspension-load concentration, bottom currents, and wave and swell-induced water movement. Data on none of these are available in the survey area, but it must be assumed that the limiting conditions of mud deposition occur at about 45 m water depth off eastern Tasmania. This figure can be compared with 30 m for the mud depositional limit in the North Sea and 73 m in the English Channel (McCave, 1971), and about 50 m on the Washington and Oregon shelves off the western United States (Smith & Hopkins, 1972). The contrast with the west Tasmanian shelf, which is mud-free, is marked. Some mud, and certainly pollen, must be in suspension in the shelf waters, but it is not deposited there, presumably because of the higher incidence of long-period swells on this coastline exposed to the prevailing westerlies of the Southern Ocean.

Origin of the shelf sediments

Some general conclusions on the origin of the surface sediments are summarised in Figure 4. The quartzose sands of the innermost shelf and the rises flanking the central Bass Strait basin are modern and more or less in equilibrium with present conditions. They are dominantly unimodal, suggesting a single transporting mechanism, and the carbonate component consists of fresh comminuted shell debris. They represent the sand sheet laid down during and after the postglacial marine transgression, and were probably derived in the main from outer-shelf Pleistocene beach and nearshore quartzose barrier sands reworked during the early Holocene rise of sea level and transported landwards with the advancing shoreline.

The muddy sediments of the eastern shelf and central Bass Strait are also considered to be mainly modern deposits. The presence of modern pollen in the muds is proof that deposition of fine-grained material is occurring today, but there are no quantitative data on the amount of terrigenous mud that escapes the coastal sediment traps and reaches open shelf waters. Much of the sand-size material (mostly 2–4 phi) consists of fresh shell debris, including planktonic foraminifera, and also appears to be of recent origin. However, sand-size quartz and coarse, mainly bryozoan organic fragments are also present in some samples and it is difficult to conceive of a mechanism which could transport this material to the middle and outer shelf under present conditions. This coarse component is therefore likely to have been deposited when sea level was significantly lower than it is today, and is preserved in the surface sediment layers as a result of bioturbation. The lateral and vertical mixing of sediment during sampling, referred to in an earlier section, may be a contributing factor also. High-resolution seismic profiling, supported by a coring program, is needed to establish the thickness of the shelf muds, and the nature of the substrate, before firm conclusions can be drawn on the relative importance of modern and ancient depositional processes in the genesis of these sediments.

The bryozoan sands and gravels which occupy extensive areas of the middle and outer shelf are mainly relict, although a significant component is contributed by the modern benthos. Planktonic foraminifera are abundant in this facies off eastern and southern Tasmania, but rare or absent in Bass Strait. They are usually poorly or very poorly sorted and polymodal; their main constituents are texturally and compositionally unrelated to the present environments. The relict origin of much of the coarse shell material is evidenced by surface stains of limonitic material, which also fills the extensive algal borings that riddle the skeletal fabric. Glauconite, as cavity infillings in foraminifera tests and as discrete grains, is a common but minor component of these sediments, and collophane occurs in association with ferruginous material in some samples from the west Tasmanian shelf.

The final group of sediments consists of slightly quartzose fine shelly sands in which relict and modern components are present in about equal proportions. They flank the quartzose sands of the inner shelf and the rises in Bass Strait. They vary greatly both in textural characteristics and in composition, but always contain some quartz and are nearly always polymodal with a mixed faunal assemblage which includes both fresh and relict components. These sediments commonly contain a minor amount of terrigenous material in the mud grade, which is likely to be partly or wholly modern in origin. The degree of sorting is variable, and ranges from a standard deviation of about 0.9 for the sands off the southern tip of Tasmania to over 2.0 phi in Bass Strait and off southeastern Victoria. The evidence suggests that these sediments are transitional in nature, the better sorted samples approaching equilibrium with the present-day environment. The coarse fraction, both terrigenous and biogenic, includes modern material, material in process of being reworked from the early Holocene substrate, and material reworked and deposited during the late Holocene transgression.

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APPENDIX 1

Station data, carbonate content, colour, and summary descriptions of samples

Station no.	*Latitude °S*	*Longitude °E*	*Depth m*	*$CaCO_3$ %*	*Colour*	*Summary description*
1784	37°50.0′	149°25.2′	102	29	5 Y 5/6	Quartz sand, medium, shelly
1785	37°50.6′	149°37.5′	119	40	5 Y 5/2	Quartz sand, fine, shelly
1786	37°49.9′	149°49.0′	124	53	5 Y 5/2	Shell sand, fine, quartzose, muddy
1787	37°50.0′	149°59.5′	137	58	5 Y 6/4	Shell sand, medium, quartzose, muddy
1788	37°42.2′	150°10.6′	208	ND	5 Y 5/2	Shell sand, medium, quartzose, muddy
1789	37°43.0′	149°57.4′	95	73	5 Y 5/6	Shell sand, medium, quartzose
1790	37°40.2′	149°47.4′	73	22	5 Y 5/6	Quartz sand, fine, shelly
1791	37°40.4′	149°41.9′	22	ND	ND	No recovery
1792	37°57.9′	149°33.4′	124	56	10 Y 6/2	Shell sand, fine, quartzose, very muddy
1793	38°04.6′	149°40.5′	146	85	10 Y 6/2	Shell sand, fine, very muddy
1794	38°13.2′	149°12.5′	168	86	5 Y 5/2	Shell sand, fine, muddy
1795	38°02.6′	149°13.8′	119	80	10 Y 6/2	Shell sand, fine, muddy
1796	37°52.5′	149°13.0′	88	32	10 YR6/6	Quartz sand, medium, shelly
1797	38°17.8′	148°34.4′	196	58	10 YR5/4	Shell sand, coarse, quartzose gravelly
1798	38°07.3′	148°34.8′	77	39	10 YR5/4	Quartz sand, medium, shelly
1799	37°58.4′	148°36.0′	51	25	10 YR5/4	Quartz sand, coarse, shelly
1800	37°49.4′	148°36.1′	26	03	10 YR6/2	Quartz sand, medium
1801	37°48.2′	148°47.9′	24	21	10 YR6/2	Quartz gravel, sandy, shelly
1802	37°59.0′	148°47.6′	73	26	5 YR6/4	Quartz sand, medium, shelly
1803	38°07.0′	148°47.2′	119	77	10 Y 6/2	Shell sand, fine, quartzose, muddy
1804	38°17.4′	148°47.4′	208	86	5 Y 5/2	Shell sand, fine, muddy
1805	38°20.0′	148°33.2′	185	67	10 Y 6/2	Shell sand, medium, quartzose, slightly muddy
1806	38°13.5′	148°21.2′	70	63	10 YR5/4	Shell sand, medium, quartzose
1807	38°06.0′	148°09.1′	59	81	5 Y 7/2	Shell sand, fine, slightly quartzose, muddy
1808	38°01.5′	148°0.28′	53	71	10 YR5/4	Shell sand, fine, quartzose, muddy
1809	38°27.8′	148°26.5′	187	79	5 Y 6/1	Shell sand, medium, quartzose, gravelly
1810	38°24.3′	148°13.5′	69	62	10 YR5/4	Shell sand, coarse, quartzose, gravelly
1811	38°22.2′	148°03.2′	66	88	5 Y 7/2	Shell sand, medium, quartzose, muddy, gravelly
1812	38°29.2′	147°59.8′	68	88	5 Y 7/2	Shell sand, medium, slightly quartzose, slightly muddy
1813	38°30.0′	148°11.5′	77	67	5 Y 7/2	Shell sand, medium, quartzose
1814	38°29.8′	148°24.9′	128	79	5 Y 7/2	Shell sand, medium, quartzose, slightly muddy
1815	38°39.3′	148°22.2′	190	82	10 YR4/2	Shell gravel, sandy, slightly quartzose
1816	38°38.5′	148°11.4′	81	90	10 YR5/4	Shell sand, medium, slightly muddy
1817	38°38.0′	147°58.6′	75	88	5 Y 7/2	Shell sand, fine, slightly quartzose, muddy
1818	38°50.3′	148°17.2′	179	60	5 Y 6/1	Shell sand, medium, quartzose
1819	38°49.3′	148°07.4′	80	90	10 YR6/2	Shell sand, fine, slightly muddy
1820	38°50.1′	148°00.0′	80	92	5 Y 8/1	Shell sand, medium, slightly muddy
1821	39°00.0′	148°00.0′	70	80	5 Y 8/1	Shell sand, coarse, slightly quartzose, gravelly
1822	39°00.0′	148°11.7′	70	86	5 Y 7/2	Shell sand, medium, gravelly
1823	39°00.0′	148°24.1′	75	71	5 Y 7/2	Shell sand, fine, quartzose
1824	39°00.0′	148°34.6′	187	74	5 Y 6/2	Shell sand, fine, quartzose, muddy
1825	39°09.7′	148°38.2′	179	100	5 Y 7/2	Shell sand, coarse, gravelly
1826	39°10.0′	148°25.0′	59	67	5 Y 7/1	Shell sand, fine, quartzose
1827	39°10.0′	148°11.6′	59	84	10 YR7/2	Shell sand, medium, slightly quartzose
1828	39°10.0′	148°00.0′	59	92	10 YR7/4	Shell sand, coarse, gravelly
1829	39°39.9′	148°00.2′	31	59	5 Y 5/2	Shell sand, coarse, quartzose, gravelly
1830	39°40.0′	148°13.5′	32	31	10 YR6/2	Quartz sand, medium, shelly
1831	39°31.5′	148°45.0′	38	38	10 YR6/4	Quartz sand, medium, shelly
1832	39°41.7′	148°44.2′	130	91	10 YR6/4	Shell sand, medium
1833	39°31.5′	148°45.0′	152	86	10 YR5/2	Shell sand, medium, slightly quartzose, gravelly
1834	39°33.3′	148°33.5′	53	37	10 YR6/4	Quartz sand, fine, shelly
1835	39°31.0′	148°25.7′	35	36	10 YR6/2	Quartz sand, medium, shelly
1836	39°30.6′	148°13.4′	44	73	10 YR6/4	Shell sand, medium, quartzose
1837	39°28.5′	148°01.0′	46	91	10 YR6/2	Shell sand, coarse, slightly quartzose, gravelly
1838	39°50.0′	148°06.6′	13	09	10 YR6/2	Quartz sand, coarse, slightly shelly
1839	39°50.6′	148°18.0′	29	23	10 YR6/4	Quartz sand, medium, shelly

Station no.	Latitude °S	Longitude °E	Depth m	$CaCO_3$ %	Colour	Summary description
1840	39°50.3′	148°32.0′	53	25	10 YR5/4	Quartz sand, medium, shelly
1841	39°50.5′	148°48.0′	223	92	5 Y 6/1	Shell sand, coarse, gravelly
1842	40′02.0°	148°51.5′	209	91	5 Y 7/2	Shell sand, fine, muddy
1843	40°00.5′	148°38.0′	80	50	5 Y 5/2	Quartz sand, fine, shelly, muddy
1844	40′00.5°	148°21.5′	26	26	5 Y 6/1	Quartz sand, fine, slightly glauconitic
1845	39°20.5′	147°59.5′	53	93	10 YR6/4	Shell sand, coarse, gravelly
1846	39°20.0′	148°12.4′	53	81	10 YR6/4	Shell sand, medium, slightly quartzose
1847	39°20.0′	148°26.2′	53	62	10 YR6/4	Shell sand, medium, quartzose
1848	39°20.0′	148°41.8′	179	70	5 Y 5/2	Shell sand, fine, quartzose, muddy
1900	37°57′	147°50′	22	07	10 YR5/4	Quartz sand, coarse, slightly shelly
1901	38°07′	147°50′	48	76	10 Y 6/2	Shell sand, very fine, quartzose, slightly muddy
1902	38°17′	147°50′	52	89	10 Y 6/2	Shell sand, coarse, gravelly, slightly muddy
1903	38°27′	147°50′	60	90	5 Y 7/2	Shell gravel and coarse shell sand
1904	38°38.6′	147°50′	64	91	5 Y 7/2	Shell gravel and coarse shell sand
1905	38°47′	147°50′	72	91	5 Y 7/2	Shell, sand, medium, gravelly
1906	38°59′	147°45′	62	94	10 YR7/4	Shell, sand, medium, gravelly
1907	39°10′	147°42′	56	94	10 YR7/4	Shell sand, coarse, gravelly
1908	39°14′	147°35′	60	94	10 YR7/4	Shell sand, coarse, gravelly
1909	39°04′	147°35′	58	93	10 YR7/4	Shell sand, coarse, gravelly
1910	38°54′	147°35′	61	94	10 YR7/4	Shell sand, medium
1911	38°44′	147°35.8′	54	90	10 YR7/4	Shell sand, medium, gravelly
1912	38°33′	147°36.4′	49	88	10 YR7/4	Shell sand, medium, gravelly
1913	38°28.5′	147°35′	45	53	5 Y 7/2	Shell sand, medium, quartzose, gravelly
1914	38°13′	147°35′	35	28	10 YR4/2	Quartz sand, very fine, shelly
1915	38°18.6′	147°20.1′	16	22	10 YR5/4	Quartz sand, fine, shelly, gravelly
1916	38°28.6′	147°20.3′	32	29	10 YR5/4	Quartz sand, fine shelly
1917	38°39′	147°19.5′	45	83	10 YR7/4	Shell sand, medium, slightly quartzose, gravelly
1918	38°50′	147°19′	57	90	10 YR7/4	Shell sand, coarse, gravelly
1919	39°04′	147°18.5′	57	92	10 YR7/4	Shell sand, coarse, gravelly
1920	39°14′	147°18′	58	94	10 YR7/4	Shell sand, coarse, gravelly
1921	39°20′	147°50′	53	94	10 YR7/4	Shell sand, coarse, gravelly
1922	39°30′	147°50′	42	92	10 YR7/4	Shell sand, coarse, gravelly
1924	39°48.5′	147°46.5′	38	32	5 Y 6/1	Quartz sand, fine, shelly
1925	39°59.5′	147°46′	40	63	5 Y 6/1	Shell sand, coarse, quartzose gravelly
1926	40°08.5′	147°51′	34	89	10 YR7/4	Shell sand, coarse, slightly quartzose, gravelly
1927	40°16′	147°45.5′	42	85	10 YR7/4	Shell gravel and coarse shell sand
1928	40°25.5′	147°50′	36	94	10 YR7/4	Shell sand, coarse, gravelly
1929	40°35.5′	147°50.5′	32	89	10 YR7/4	Shell sand, coarse, slightly quartzose
1930	40°39.5′	148°07′	38	ND	ND	Basaltic rock fragments
1931	40°38.5′	148°30.5′	39	59	5 Y 6/1	Shell sand, fine, quartzose
1932	40°39′	148°43′	56	57	10 YR7/4	Shell sand, coarse, quartzose, gravelly
1933	40°07′	148°23′	17	23	10 YR5/4	Quartz sand, medium, shelly
1934	40°10′	148°55′	46	52	5 GY6/1	Shell sand, coarse, quartzose, slightly muddy
1935	40°10′	148°48′	118	78	10 Y 6/2	Shell sand, fine, quartzose, muddy
1936	40°23′	148°50′	97	79	10 Y 6/2	Shell sand, fine, quartzose, muddy, gravelly
1937	40°20′	148°37′	20	41	10 YR5/4	Quartz sand, coarse, shelly, slightly muddy
1938	40°44.7′	147°55.5′	25	ND	10 YR6/2	Quartz gravel, muddy, shelly
1939	40°45.4′	147°51.6′	28	ND	10 YR6/2	Quartz sand and gravel, shelly
1940	40°45.0′	147°49.0′	24	ND	5 Y 6/1	Quartz sand, medium, shelly, gravelly
1941	40°45.8′	147°45.1′	32	ND	5 Y 6/1	Quartz sand, fine, shelly, gravelly
1942	40°46.6′	147°41.0′	30	ND	5 Y 6/1	Quartz sand and gravel, shelly
1943	40°49.5′	147°42.2′	15	ND	5 Y 6/1	Quartz sand, fine, shelly
1944	40°48.7′	147°46.0′	25	ND	5 Y 6/1	Quartz sand and gravel, shelly
1945	40°47.9′	147°49.8′	27	ND	10 YR5/4	Quartz sand, coarse, shelly
1946	40°47.2′	147°53.8′	24	ND	10 YR5/4	Quartz sand, coarse, shelly
1947	40°50.3′	147°53.4′	11	ND	5 Y 6/1	Quartz sand, fine, shelly
1948	40°50.9′	147°50.4′	13	ND	ND	Pebbles and cobbles of algae-coated rock
1949	40°51.5′	147°47.0′	15	ND	5 Y 6/1	Quartz sand, coarse, shelly
1950	40°48.0′	147°43.8′	29	ND	5 GY6/1	Quartz sand, shelly, muddy and rock fragments
1951	40°10.6′	147°35′	46	83	5 Y 6/1	Shell gravel and coarse shell sand, quartzose
1952	40°02′	147°34.8′	50	75	10 YR5/4	Shell sand, coarse, quartzose, gravelly
1953	39°51.5′	147°34.5′	48	93	10 YR7/4	Shell sand, coarse, gravelly
1954	39°51.9′	147°21.5′	58	94	10 YR7/4	Shell sand, coarse, gravelly
1955	40°02′	147°21.5′	63	93	10 YR7/4	Shell sand, coarse
1956	40°11.5′	147°21.5′	64	93	10 YR7/4	Shell sand, coarse
1957	39°31.6′	147°33′	52	94	10 YR7/4	Shell sand, coarse, gravelly
1958	39°22.5′	147°33′	52	94	10 YR7/4	Shell sand, coarse, gravelly
1959	39°23′	147°20.3′	56	84	10 YR7/4	Shell sand, coarse, slightly quartzose, gravelly

Station no.	*Latitude °S*	*Longitude °E*	*Depth m*	*$CaCO_3$ %*	*Colour*	*Summary description*
1960	**39°33′**	**147°20′**	55	ND	10 YR7/4	Shell gravel and coarse shell sand
1961	39°43′	147°20′	59	94	10 YR7/4	Shell sand, coarse, gravelly
1962	39°53′	147°07.5′	70	94	10 Y 6/2	Shell sand, medium, muddy
1963	40°03′	147°07′	71	93	10 Y 6/2	Shell sand, medium, muddy
1964	40°13′	147°07′	72	93	10 Y 6/2	Shell sand, medium, muddy
1965	40°40.7′	147°35.5′	43	61	10 YR7/4	Shell sand, coarse, quartzose, and shell gravel
1966	40°31′	147°35′	46	58	10 YR6/4	Shell sand, coarse, quartzose, gravelly
1967	40°21′	147°35′	46	82	10 YR6/2	Shell sand, fine, quartzose
1968	40°31′	147°21′	55	93	10 YR6/2	Shell sand, fine
1969	40°31′	147°22′	52	88	10 YR6/4	Shell sand, coarse, slightly quartzose, gravelly
1970	40°40.6′	147°21′	50	40	10 YR5/2	Quartz sand, fine, shelly
1971	40°50.5′	147°21.4′	40	62	10 YR5/2	Shell sand, medium, quartzose, gravelly
1972	40°50.6′	147°08.4′	52	90	10 YR5/2	Shell sand, medium, slightly quartzose
1973	40°40.7′	147°08.4′	66	65	10 YR6/2	Shell sand, fine, quartzose, muddy
1974	40°26′	147°08′	70	91	10 Y 6/2	Shell sand, medium, muddy
1975	39°42′	147°05′	71	93	10 Y 6/2	Shell sand, medium, muddy
1976	39°31.7′	147°05′	63	92	5 Y 7/2	Shell sand, medium, muddy, gravelly
1977	39°21′	147°05′	62	92	5 Y 7/2	Shell sand, coarse, gravelly, slightly muddy
1978	39°11′	147°05′	54	92	5 Y 7/2	Shell sand, medium, gravelly
1979	39°01′	147°05′	55	90	10 YR7/2	Shell gravel and coarse shell sand
1980	38°51′	147°05′	52	89	10 YR7/2	Shell gravel and coarse shell sand
1981	38°58′	146°50′	52	89	10 YR7/2	Shell sand, medium, gravelly
1982	43°17.2′	148°00.5′	130	86	10 YR5/4	Shell sand, coarse, and shell gravel
1983	43°17.4′	148°07.2′	39	90	10 YR7/4	Shell sand, medium, gravelly
1984	43°10′	148°12′	172	89	10 YR5/4	Shell sand, medium, gravelly
1985	43°10′	148°06.7′	113	67	10 YR5/4	Shell sand, medium, quartzose, gravelly
1986	43°10′	148°01.4′	95	66	10 YR5/4	Shell sand, coarse, quartzose
1987	43°00.6′	148°00′	80	64	5 YR5/2	Shell sand, fine, slightly quartzose, muddy
1988	43°00′	148°06.8′	97	78	5 Y 5/6	Shell sand, fine, quartzose, muddy
1989	43°00′	148°13.6′	122	89	10 YR7/4	Shell sand, medium, gravelly
1990	42°51′	148°20.4′	157	90	10 YR6/6	Shell gravel and coarse shell sand
1991	42°50′	148°14′	99	84	5 Y 5/6	Shell sand, fine, very muddy
1992	42°50′	148°07.3′	84	62	5 Y 5/2	Shell sand, fine, quartzose, very muddy
1993	42°50′	147°59.8′	58	26	5 Y 4/4	Quartz sand, fine, shelly, slightly muddy
1994	42°39.7′	148°11.6′	84	77	10 YR4/2	Shell sand, medium, slightly quartzose
1995	42°39.6′	148°17.2′	106	82	10 Y 6/2	Shell sand, fine, very muddy
1996	42°39.5′	148°24′	130	83	5 Y 5/2	Mud, calcareous, and shell sand and gravel
1997	42°30.5′	148°03.8′	44	22	5 Y 5/2	Quartz sand, fine, shelly, slightly muddy
1998	42°30′	148°10.4′	66	59	5 Y 5/2	Shell sand, fine, quartzose, muddy
1999	42°29.8′	148°16.6′	88	70	5 Y 5/2	Shell sand, fine, quartzose, very muddy
2000	42°29.8′	148°23.2′	106	86	5 Y 5/2	Shell sand, coarse, muddy
2001	42°30.2′	148°29.3′	184	88	10 YR6/2	Shell gravel and coarse shell sand
2002	42°21.2′	148°31′	115	ND	10 YR6/2	Shell sand, coarse, gravelly, muddy
2003	42°20′	148°13′	45	12	10 YR5/4	Quartz sand, medium, slightly shelly
2004	42°20′	148°07.7′	42	15	5 Y 5/4	Quartz sand, medium, slightly shelly
2005	42°20′	148°03′	33	13	5 YR5/6	Quartz sand, coarse, slightly shelly
2006	42°14.8′	148°02.8′	18	09	5 Y 5/2	Quartz sand, fine, slightly shelly
2007	42°14.5′	148°08.1′	24	21	5 Y 6/4	Quartz sand, fine, shelly, gravelly
2008	42°14.6′	148°13.6′	16	02	5 Y 5/4	Quartz sand, fine, slightly silty
2009	42°10.2′	148°14.2′	15	02	5 Y 5/2	Quartz sand, fine
2010	42°10.2′	148°10.4′	16	02	5 Y 5/2	Quartz sand, fine
2011	42°10.2′	148°06.2′	14	07	5 Y 5/2	Quartz sand, fine, slightly shelly
2012	42°00′	148°35.5′	148	82	10 YR6/4	Shell sand, coarse, gravelly
2013	41°59.5′	148°29.5′	88	91	10 Y 5/2	Shell sand, coarse, very muddy
2014	42°00′	148°23.0′	70	58	5 Y 5/6	Shell sand, fine, quartzose
2015	42°00′	148°18′	28	77	10 YR6/2	Shell sand, coarse, slightly quartzose
2016	42°10.3′	148°21.7′	64	66	10 YR6/4	Shell sand, medium, quartzose
2017	42°10′	148°34.7′	205	89	5 Y 6/1	Shell sand, coarse, gravelly, muddy
2018	42°10.2′	148°29.2′	104	85	5 Y 5/2	Shell sand, coarse, slightly quartzose, muddy
2019	42°08.2′	148°28.6′	95	80	5 Y 5/2	Mud, calcareous, and shell sand and gravel
2020	42°20′	148°26.3′	100	86	5 Y 5/6	Shell sand, medium, slightly muddy
2021	42°20′	148°21.4′	73	57	10 YR6/2	Shell sand, medium, quartzose, gravelly
2022	42°15.1′	148°30′	113	ND	5 Y 5/2	Mud, calcareous, and shell sand and gravel
2023	42°28.5′	148°27.5′	119	ND	5 Y 5/2	Mud, calcareous, and shell sand and gravel
2024	43°14.5′	147°27.8′	53	26	5 YR5/2	Quartz sand, fine, shelly
2025	41°50′	148°17.3′	33	14	5 Y 6/1	Quartz sand, fine, slightly shelly
2026	41°50′	148°23.3′	60	36	10 YR5/4	Quartz sand, fine, shelly
2027	41°50′	148°28.9′	84	88	10 Y 6/2	Shell sand, coarse, muddy
2028	41°49.9′	148°35.3′	128	91	5 Y 7/2	Shell sand, coarse, gravelly
2029	41°41.6′	148°39′	823	ND	ND	No recovery
2030	41°39.8′	148°32.1′	113	85	5 Y 7/2	Shell sand, medium

Station no.	Latitude °S	Longitude °E	Depth m	$CaCO_3$ %	Colour	Summary description
2031	41°40′	148°25.1′	69	81	10 YR7/4	Shell sand, medium, quartzose
2032	41°40′	148°18.4′	27	14	10 YR7/4	Quartz sand, fine, slightly shelly
2033	41°30′	148°17.5′	31	16	10 YR6/6	Quartz sand, coarse, shelly, gravelly
2034	41°30.2′	148°23.6′	71	70	5 Y 6/4	Shell sand, fine, quartzose
2035	41°30′	148°30′	113	78	10 Y 6/2	Shell sand, fine, slightly quartzose, very muddy
2036	41°29.8′	148°36.3′	314	ND	5 Y 6/1	Shell sand, fine, slightly quartzose, slightly muddy
2037	41°20.1′	148°23.4′	73	70	5 Y 6/2	Shell sand, fine, quartzose, very muddy, gravelly
2038	41°20.6′	148°30′	110	79	5 Y 6/2	Shell sand, medium, very muddy
2039	41°20′	148°37′	121	90	5 Y 7/2	Shell sand, medium, muddy
2040	41°10′	148°38.6′	161	87	10 Y 6/2	Shell sand, medium, very muddy, gravelly
2041	41°10′	148°32.2′	110	86	5 Y 6/2	Shell sand, medium, very muddy
2042	41°10.1′	148°25.7′	95	73	5 Y 6/2	Shell sand, fine, slightly quartzose, very muddy
2043	41°09.8′	148°19.2′	60	12	10 YR4/2	Quartz sand, coarse, slightly shelly
2044	41°00′	148°24.3′	60	10	10 YR5/4	Quartz gravel and coarse sand, slightly shelly
2045	41°02′	148°31.5′	97	74	10 Y 6/2	Shell sand, fine, quartzose, very muddy
2046	41°00′	148°38.3′	119	86	5 Y 7/2	Shell sand, fine, muddy
2047	40°48.7′	148°20.1′	33	15	10 YR7/4	Quartz sand, medium, shelly
2048	40°48.7′	148°27′	51	34	5 Y 6/4	Quartz sand, fine, shelly
2049	40°49.5′	148°32.1′	62	60	10 YR7/6	Shell sand, coarse, quartzose
2050	40°49.6′	148°39.9′	82	75	5 Y 7/2	Shell sand, medium, quartzose
2051	40°50.6′	148°46.5′	399	85	5 Y 6/1	Shell sand, coarse, and shell gravel
2052	41°45.5′	148°31.0′	113	87	5 Y 6/1	Shell sand, coarse, gravelly, slightly muddy
2053	41°55.8′	148°31.5′	106	ND	5 Y 5/2	Mud, calcareous, with shell sand
2054	43°28.8′	147°58.0′	161	93	10 YR7/4	Shell sand, medium, gravelly
2055	43°28.6′	147°22.6′	62	36	10 YR6/4	Quartz sand, fine, shelly
2056	43°35.5′	147°32.3′	121	89	10 YR7/4	Shell sand, medium, slightly quartzose
2057	43°40.5′	147°40.3′	146	91	10 YR7/4	Shell sand, medium
2058	43°47.0′	147°48.5′	212	ND	5 Y 7/2	Shell sand, medium, and shell gravel, slightly muddy
2059	43°58′	147°30′	175	93	5 Y 7/2	Shell sand, medium, slightly muddy
2060	43°33.6′	147°06′	84	18	10 YR5/4	Quartz sand, medium, shelly
2061	43°43.5′	147°07.1′	128	81	5Y 7/2	Shell sand, medium, slightly quartzose
2062	43°53.2′	147°08.3′	148	86	10 YR6/4	Shell sand, fine
2063	44°02.9′	147°10′	168	94	5 Y 7/2	Shell sand, fine, muddy
2064	43°47.9′	147°25.6′	154	90	10 YR8/6	Shell sand, medium
2065	43°39.5′	147°20.5′	95	92	5 Y 6/4	Shell gravel and coarse shell sand
2066	43°40.4′	146°50.4′	104	39	10 YR5/4	Quartz sand, fine, shelly
2067	43°46.5′	146°50.5′	124	88	10 YR7/4	Shell sand, coarse, phosphatic
2068	43°55.0′	146°51′	168	83	5 Y 5/2	Shell sand, fine, slightly quartzose, muddy
2069	44°02.2′	146°50.5′	176	92	5 Y 7/2	Shell sand, coarse, gravelly, muddy
2070	43°35.5′	146°33.5′	58	08	10 YR7/2	Quartz gravel and coarse quartz sand
2071	43°42′	146°33′	115	75	10 YR6/4	Shell sand, fine, quartzose
2072	43°49.5′	146°33.5′	159	71	5 Y 6/4	Shell sand, fine, quartzose, slightly muddy
2073	43°57′	146°33.7′	159	85	10 YR7/4	Shell sand, coarse, slightly quartzose
2074	43°58.5′	146°19.1′	168	93	5 Y 7/2	Shell sand, coarse, gravelly
2075	43°50.6′	146°18.5′	165	78	5 Y 6/4	Shell sand, medium, slightly quartzose
2076	43°42.2′	146°18.6′	108	91	10 YR7/4	Shell sand, coarse, gravelly
2077	43°20.3′	147°37.7′	97	63	5 Y 6/4	Shell sand, fine, quartzose, muddy
2078	43°24.6′	147°48.8′	133	87	10 YR7/4	Shell sand, fine, slightly muddy
2079	43°33.5′	146°14.2′	53	32	10 YR7/4	Quartz sand, fine, shelly
2080	43°38.5′	146°07.8′	119	64	5 Y 4/4	Shell sand, very fine, quartzose, muddy
2081	43°44.0′	146°00.5′	159	86	10 YR6/4	Shell sand, coarse, slightly quartzose, gravelly
2082	43°33.5′	145°52.1′	161	ND	10 YR7/4	Shell gravel with shell sand
2083	43°31.5′	145°55.8′	104	56	10 YR6/6	Shell sand, fine, quartzose
2084	43°29.0′	145°59.1′	44	ND	10 YR2/2	Schistose rock fragment, highly weathered
2085	43°20.3′	145°48.2′	82	47	10 YR7/4	Quartz sand, fine, shelly
2086	43°22.5′	145°44.5′	144	68	10 YR7/4	Shell sand, medium, quartzose
2087	43°24.2′	145°41.2′	159	91	10 YR7/4	Shell sand, coarse, gravelly
2088	43°12.2′	145°43.3′	62	ND	10 YR6/6	Quartz-muscovite schist and shell sand
2089	43°13.8′	145°36.9′	132	54	10 YR6/4	Shell sand, fine, quartzose
2090	43°15.0′	145°30.6′	155	93	10 YR7/4	Shell sand, fine
2091	43°16.2′	145°23.7′	190	94	5 Y 7/2	Shell sand, coarse
2092	43°06.4′	145°16.1′	154	94	10 YR7/4	Shell sand, coarse, gravelly
2093	43°05′	145°26′	135	90	10 YR7/4	Shell sand, medium, slightly quartzose
2094	43°04.1′	145°35.7′	73	44	10 YR5/4	Quartz sand, very fine, shelly
2095	42°58.2′	145°26.6′	84	26	10 YR5/4	Quartz sand, very fine, shelly
2096	42°58.1′	145°15.5′	132	92	10 YR7/4	Shell sand, coarse, gravelly

Station no.	Latitude °S	Longitude °E	Depth m	$CaCO_3$ %	Colour	Summary description
2097	42°58.2′	145°05′	188	88	10 YR7/4	Shell sand, coarse, gravelly
2098	42°51.1′	145°19.5′	91	90	10 YR5/4	Shell sand, coarse, gravelly
2099	42°51.1′	145°09.9′	124	93	10 YR7/4	Shell sand, medium
2100	42°51.2′	145°00.6′	146	95	10 YR7/4	Shell sand, medium, gravelly
2101	42°39.8′	144°58.6′	142	ND		No recovery
2102	42°39.5′	145°09.6′	90	93	10 YR7/4	Shell sand, medium, gravelly
2103	42°39.8′	145°17.6′	51	ND		Quartz gravel
2104	42°30′	145°09.1′	88	89	10 YR6/6	Shell sand, coarse, gravelly
2105	42°30′	145°01.0′	104	93	10 YR6/6	Shell sand, medium, gravelly
2106	42°30.2′	144°52.5′	154	94	10 YR7/4	Shell sand, medium, gravelly
2107	40°30.5′	144°37.5′	44	55	10 YR7/4	Shell sand, fine, quartzose
2108	40°30′	144°23.4′	50	81		Shell gravel with basalt pebbles
2109	40°29.8′	144°09.7′	71	95	10 YR7/4	Shell sand, medium
2110	40°20′	144°10′	58	88	10 YR7/4	Shell sand, coarse, slightly quartzose, gravelly
2111	40°20′	144°22.9′	55	ND	10 YR7/4	Shell gravel with shell sand
2112	40°20′	144°36.4′	55	79	10 YR7/4	Shell sand, coarse, muddy, gravelly
2113	40°19.8′	144°49.5′	49	84	10 YR6/6	Shell sand, coarse, quartzose, gravelly
2114	40°20.2′	145°02.5′	49	75	10 YR6/6	Shell sand, medium, quartzose
2115	40°10.2′	145°00.7′	53	89	5 Y 7/2	Shell sand, fine, slightly quartzose
2116	41°00′	144°33.7′	55	88	10 YR5/4	Shell gravel with slightly quartzose coarse shell sand
2117	41°01.2′	144°21.5′	80	94	10 YR6/4	Shell sand, medium, gravelly
2118	41°00′	144°07.5′	104	90	10 YR7/4	Shell sand, coarse
2119	41°00′	143°55′	170	93	10 YR7/4	Shell sand, coarse, gravelly
2120	41°09.4′	144°10.6′	132	93	10 YR7/4	Shell sand, coarse, with shell gravel
2121	41°09.2′	144°24.2′	88	94	10 YR7/4	Shell sand, medium, gravelly
2122	41°29.5′	144°24.4′	119	96	10 YR7/4	Shell sand, coarse, gravelly
2123	41°29.5′	144°36.2′	91	94	10 YR6/4	Shell sand, coarse, gravelly
2124	41°30.3′	144°45.8′	49	89	10 YR5/4	Shell sand, coarse, quartzose, gravelly
2125	41°39.8′	144°47.3′	60	94	10 YR5/4	Shell sand, coarse, with shell gravel
2126	41°39.5′	144°37.1′	130	88	10 YR7/4	Shell sand, coarse, quartzose, with shell gravel
2127	41°39.6′	144°28.7′	186	93	5 Y 7/2	Shell sand, medium, gravelly
2128	41°50′	144°34.6′	170	94	5 Y 7/2	Shell sand, coarse, gravelly
2129	41°49.5′	144°46′	86	92	5 Y 7/2	Shell sand, medium, gravelly
2130	41°50′	144°57.1′	69	12	10 YR5/2	Quartz sand, fine, slightly shelly
2131	41°58.3′	144°37.3′	155	92	10 YR7/4	Shell sand, medium
2132	42°00.2′	144°51.8′	132	90	10 YR7/4	Shell sand, coarse, gravelly
2133	42°00.5′	145°00.6′	88	16	10 YR5/4	Quartz sand, fine, slightly shelly
2134	41°59.8′	145°09.0′	48	16		Quartz gravel with medium quartz sand
2135	42°10.2′	145°10.4′	37	07	10 YR6/2	Quartz sand, fine
2136	44°10.2′	144°57.2′	128	90	10 YR7/4	Shell sand, coarse, gravelly
2137	44°09.6′	144°43.8′	161	89	10 YR8/2	Shell sand, fine, gravelly
2138	44°19.8′	144°51.0′	170	93	10 YR8/2	Shell sand, medium, gravelly
2139	44°20.2′	145°00.3′	122	91	10 YR7/4	Shell sand, coarse, gravelly
2140	42°20′	145°08.3′	90	19	10 YR5/4	Quartz sand, fine, shelly
2141	41°11.2′	144°35.6′	80	84	10 YR6/2	Shell sand, coarse, quartzose
2142	41°20.3′	144°39.8′	30	ND	ND	Rock fragments, possibly weathered basalt
2143	41°19.6′	144°26.6′	128	ND	ND	Limestone gravel and coarse shell sand
2144	40°10.2′	144°06.5′	49	50	10 YR7/4	Quartz sand, coarse, shelly
2145	40°10.5′	144°18.6′	51	ND	10 YR8/2	Shell gravel with coarse shell sand
2146	40°10′	144°32.6′	59	88	10 YR8/2	Shell sand, medium, slightly quartzose
2147	40°10′	144°45.8′	59	90	10 YR7/4	Shell sand, coarse, slightly quartzose, gravelly
2148	40°09.2′	145°11.6′	51	88	10 YR7/4	Shell sand, fine, slightly quartzose
2149	40°09.5′	145°25.5′	64	83	10 Y 6/2	Shell sand, very fine, muddy
2150	40°22.5′	143°39′	128	95	10 YR6/6	Shell sand, coarse
2151	40°09.4′	143°37.5′	81	ND	ND	No recovery
2152	40°09.5′	143°30.6′	104	94	10 YR7/4	Shell sand, fine
2153	40°20′	143°27.5′	106	95	10 YR7/4	Shell sand, coarse
2154	40°20.5′	143°41′	86	51	10 YR5/4	Shell sand, coarse, quartzose
2155	40°21.2′	143°53.6′	59	27	10 YR7/2	Quartz sand, very coarse, shelly, gravelly
2156	40°14.5′	143°46.4′	68	ND	ND	Shell gravel
2157	40°13.8′	143°35.7′	95	91	5 Y 7/2	Shell sand, medium, gravelly
2158	40°24.8′	143°34.3′	110	93	10 YR7/4	Shell sand, medium
2159	40°36.5′	143°37′	108	94	10 YR7/4	Shell sand, medium, gravelly
2160	40°36.4′	143°47′	90	95	10 YR7/4	Shell sand, coarse, gravelly
2161	40°00.1′	144°13.7′	33	28	10 YR7/4	Quartz sand, coarse, shelly, gravelly
2162	40°00′	144°26.5′	46	33	10 YR7/7	Quartz sand, very coarse, shelly, gravelly
2163	40°00′	144°38.5′	46	59	10 YR7/4	Shell sand, medium, quartzose, gravelly
2164	40°00′	144°52.6′	53	78	10 YR7/2	Shell sand, medium, quartzose
2165	40°00′	145°06.0′	55	89	10 YR7/2	Shell sand, medium

Station no.	Latitude °S	Longitude °E	Depth m	$CaCO_3$ %	Colour	Summary description
2166	40°00′	145°19.0′	64	84	10 YR6/2	Shell sand, fine, slightly quartzose
2167	40°00′	145°32.5′	73	84	10 YR6/2	Shell sand, fine, very muddy
2168	39°49.6′	144°11.9′	27	48	5 Y 5/2	Quartz sand, medium, shelly, gravelly
2169	39°49.9′	144°25.3′	37	52	10 YR7/4	Shell sand, medium, quartzose
2170	39°50′	144°38.7′	46	52	10 YR7/4	Shell sand, medium, quartzose
2171	39°50′	144°51.3′	49	69	10 YR7/2	Shell sand, medium, quartzose
2172	39°50′	145°04.6′	51	76	10 YR7/2	Shell sand, medium, quartzose, and shell gravel
2173	39°50′	145°18.0′	59	83	10 YR7/4	Shell sand, fine, quartzose
2174	39°50′	145°31.0′	68	86	5 Y 6/1	Shell gravel with slightly quartzose fine shell sand
2175	38°40′	144°01.1′	71	84	10 YR6/6	Shell sand, fine, slightly quartzose
2176	38°40′	144°14.0′	73	86	10 YR5/4	Shell sand, fine, slightly quartzose
2177	38°40′	144°27.0′	77	86	5 Y 5/4	Shell sand, fine, slightly quartzose
2178	38°40.5′	144°39.4′	77	87	10 YR5/4	Shell sand, fine, slightly quartzose
2179	38°40.5′	144°47.4′	75	42	10 YR6/6	Quartz sand, very coarse, shelly, gravelly
2180	38°40′	144°53.8′	73	67	10 YR5/4	Shell sand, medium, quartzose
2181	38°40′	145°06.7′	73	81	10 YR5/4	Shell sand, fine, slightly quartzose
2182	38°40′	145°19.2′	73	62	5 Y 5/2	Shell sand, very fine, quartzose, muddy
2183	38°40.3′	145°30.2′	44	26	5 YR4/4	Quartz sand, coarse, shelly
2184	38°50′	143°58.5′	77	85	10 YR6/2	Shell sand, fine, slightly quartzose
2185	38°49.6′	144°11.2′	75	84	10 YR6/2	Shell sand, fine, slightly quartzose, gravelly
2186	38°50′	144°24′	79	87	5 Y 7/2	Shell sand, fine, slightly quartzose
2187	38°50′	144°36.6′	73	90	10 YR5/4	Shell sand, medium, slightly quartzose
2188	38°50′	144°49.3′	73	90	5 Y 6/1	Shell sand, fine, slightly quartzose
2189	38°49.2′	145°02.4′	72	ND	5 Y 6/1	Shell gravel and coarse shell sand
2190	38°49.6′	145°14.0′	73	90	10 YR6/2	Shell sand, medium, gravelly
2191	38°52.5′	145°30′	71	87	5 Y 5/2	Shell sand, fine, slightly quartzose
2192	39°10.0′	144°05.3′	84	66	10 YR6/6	Shell sand, coarse, quartzose, gravelly
2193	39°09.5′	144°19.0′	75	92	10 YR7/4	Shell sand, medium
2194	39°09.5′	144°33.6′	66	94	10 YR7/4	Shell sand, medium
2195	39°09.0′	144°47.6′	62	92	10 YR6/4	Shell sand, coarse, gravelly
2196	39°09.0′	145°02.2′	68	92	10 YR7/4	Shell sand, fine
2197	39°08.5′	145°15.9′	71	91	10 YR7/4	Shell sand, medium, gravelly
2198	39°08′	145°31.0′	73	93	10 YR7/4	Shell sand, fine
2199	39°08′	145°39.5′	71	92	10 YR6/4	Shell sand, medium

Notes: BMR registered numbers of the samples consist of the 4 digits of the station number preceded by 7263 (station nos. 1784–1848) and by 7363 (station nos. 1900–2199). Colour notations are those of the Rock-Color Chart, Geological Society of America, and were determined on the fresh samples. In the summary description, the Wentworth Scale is used for grainsize descriptions, which refer to the dominant modes; the term *gravel* is used for all material larger than 2 mm grainsize. *Quartzzose (shelly)* indicates 15 to 49% of quartz (shells). *Slightly quartzose (shelly)* indicates 5 to 15% quartz (shells). *Very muddy* indicates more than 30% mud, *muddy* indicates 10 to 30% mud, and *slightly muddy* indicates 3 to 10% mud. *Gravel with sand,* or *sand and gravel* indicate approximately equal amounts (over 40%) of both components; *gravelly* indicates 10 to 40% gravel. ND = not determined.

APPENDIX 2
Grainsize distribution : statistical parameters

Station no.	*Gravel %*	*Sand %*	*Silt %*	*Clay %*	*Mean φ*	*Std dev. φ*	*Skewness*	*Kurtosis*
1784	6.47	93.53	0.00	0.00	1.03	1.49	−2.01	4.84
1785	1.10	98.90	0.00	0.00	2.17	0.86	−3.86	26.95
1786	1.06	86.57	7.86	4.51	2.92	2.13	1.90	7.15
1788	7.16	82.91	7.55	2.38	1.75	2.31	0.95	5.32
1789	7.28	92.72	0.00	0.00	1.18	1.52	−1.97	4.95
1790	1.16	98.84	0.00	0.00	2.42	0.91	−4.24	27.29
1792	0.00	66.57	22.89	10.54	4.41	2.45	1.83	2.69
1793	0.55	58.93	31.44	9.08	4.12	2.72	1.05	1.63
1794	2.05	82.96	11.87	3.12	2.55	2.19	1.21	6.42
1795	0.72	78.22	15.02	6.04	3.57	2.23	1.58	4.57
1796	3.00	97.00	0.00	0.00	1.49	1.10	−2.95	13.61
1797	23.63	76.37	0.00	0.00	0.23	2.15	−1.05	0.12
1798	1.77	98.23	0.00	0.00	1.48	0.96	−3.33	17.62
1799	9.54	90.46	0.00	0.00	0.81	1.48	−2.17	5.11
1800	0.53	99.47	0.00	0.00	1.12	0.58	−0.80	16.20
1801	56.17	43.83	0.00	0.00	−0.81	1.93	−0.01	−1.12
1802	3.40	96.60	0.00	0.00	1.17	1.12	−2.36	10.07
1803	0.11	78.01	15.49	6.39	3.82	2.08	2.20	5.48
1804	2.47	81.33	12.18	4.02	2.69	2.39	1.04	4.29
1805	4.24	89.21	4.86	1.69	1.83	2.00	0.94	6.66
1806	2.67	97.33	0.00	0.00	1.34	1.07	−2.78	13.39
1807	5.37	84.26	7.43	2.94	2.71	2.18	0.49	6.22
1808	4.62	82.75	9.57	3.06	2.41	2.30	0.81	4.91
1809	10.66	89.34	0.00	0.00	1.41	1.86	−1.57	2.34
1810	12.17	87.83	0.00	0.00	0.81	1.69	−1.70	2.77
1811	10.62	79.07	7.53	2.78	1.87	2.65	0.29	3.10
1812	10.30	81.58	5.25	2.87	1.75	2.54	0.50	4.20
1813	3.48	92.98	2.10	1.44	1.69	1.78	1.01	10.89
1814	4.14	90.80	3.37	1.69	1.82	1.95	1.06	7.60
1815	66.04	33.96	0.00	0.00	−1.38	1.46	−0.01	0.03
1816	3.49	92.57	2.22	1.72	2.00	1.89	0.83	9.40
1817	3.24	84.87	6.32	5.57	2.45	2.54	1.43	4.95
1818	4.06	95.94	0.00	0.00	1.47	1.24	−2.04	7.17
1819	7.23	87.93	1.97	2.87	2.13	2.26	0.16	6.13
1820	8.89	85.97	2.06	3.08	1.86	2.49	0.41	5.02
1821	16.58	83.42	0.00	0.00	1.00	2.08	−1.58	1.33
1822	14.42	85.58	0.00	0.00	1.33	2.15	−1.52	1.42
1823	2.45	97.55	0.00	0.00	2.61	1.00	−4.18	22.21
1824	3.57	80.54	11.83	4.06	2.24	2.54	1.10	3.52
1825	10.44	89.56	0.00	0.00	0.82	1.78	−1.81	3.28
1826	1.75	98.24	0.00	0.00	2.24	0.91	−3.40	20.74
1827	5.29	94.71	0.00	0.00	1.75	1.34	−3.01	10.26
1828	16.51	83.49	0.00	0.00	0.48	2.02	−1.52	1.23
1829	29.32	70.68	0.00	0.00	0.30	2.31	−0.75	−0.71
1830	4.02	95.98	0.00	0.00	1.86	0.93	−3.51	17.08
1831	3.82	96.18	0.00	0.00	1.39	1.09	−2.92	12.43
1832	6.08	93.92	0.00	0.00	1.89	1.17	−2.36	6.97
1833	10.64	89.36	0.00	0.00	1.12	1.64	−1.70	3.01
1834	1.29	98.71	0.00	0.00	2.16	0.72	−3.56	24.99
1835	2.89	97.11	0.00	0.00	1.58	1.09	−3.41	15.30
1836	1.81	98.19	0.00	0.00	1.58	0.92	−3.82	22.36
1837	17.23	82.77	0.00	0.00	0.66	1.89	−1.56	1.47
1838	6.70	93.30	0.00	0.00	0.45	1.30	−1.85	5.91
1839	3.71	96.29	0.00	0.00	1.06	1.05	−2.45	10.57
1840	1.43	98.57	0.00	0.00	1.12	0.86	−2.97	18.82
1841	15.73	84.27	0.00	0.00	0.65	1.90	−1.56	1.61
1842	5.92	82.52	6.49	5.07	2.28	2.68	−0.96	4.16
1843	0.41	87.32	8.56	3.71	2.84	2.00	2.12	7.28
1844	1.54	98.46	0.00	0.00	2.70	0.96	−3.53	19.63
1845	37.49	62.51	0.00	0.00	−0.29	2.24	−0.58	−1.06
1846	9.08	90.92	0.00	0.00	1.52	1.64	−2.30	5.06
1847	4.39	95.61	0.00	0.00	1.69	1.31	−2.97	11.11
1848	5.09	79.66	10.98	4.27	3.03	2.35	0.63	4.74
1900	2.29	96.94	0.77	0.00	1.27	0.85	0.70	10.33
1901	8.11	85.52	6.08	0.29	2.61	1.85	−1.69	4.90
1902	21.89	75.07	3.04	0.00	1.23	2.14	−0.56	−0.01

Station no.	*Gravel %*	*Sand %*	*Silt %*	*Clay %*	*Mean* ϕ	*Std dev.* ϕ	*Skewness*	*Kurtosis*
1903	52.51	47.14	0.35	0.00	−0.38	2.11	0.21	−0.98
1904	49.95	48.16	1.89	0.00	−0.41	2.27	0.20	−0.64
1905	20.62	78.18	1.20	0.00	1.03	1.83	0.73	0.41
1906	19.29	79.38	1.33	0.00	0.96	1.53	−0.67	1.26
1907	12.69	86.31	1.00	0.00	1.02	1.23	−0.69	3.55
1908	46.37	53.02	0.38	0.23	−0.26	1.61	0.68	4.14
1909	27.93	71.62	0.45	0.00	0.24	1.99	−0.80	−0.25
1910	6.18	93.24	0.58	0.00	1.55	1.06	−1.38	5.38
1911	14.45	84.91	0.64	0.00	1.35	1.46	−1.30	1.74
1912	18.98	79.63	1.39	0.00	1.08	1.62	−0.47	0.59
1913	10.01	85.10	3.91	0.98	1.98	1.90	−0.11	5.25
1914	1.25	96.81	1.94	0.00	2.94	0.96	−2.61	16.19
1915	19.34	76.98	3.68	0.00	1.68	2.18	−0.81	−0.04
1916	2.84	96.55	0.61	0.00	2.17	1.05	−2.91	16.01
1917	27.32	70.75	1.93	0.00	0.51	2.05	−0.46	0.10
1918	33.17	65.44	1.39	0.00	0.41	1.78	−0.11	−0.12
1919	25.26	73.67	1.07	0.00	0.49	1.43	−0.18	1.34
1920	37.90	60.83	1.27	0.00	0.07	1.65	0.08	0.54
1921	20.96	77.27	1.77	0.00	0.72	1.62	−0.52	1.34
1922	26.92	71.51	1.57	0.00	0.52	1.74	−0.35	0.46
1923	26.99	71.48	1.53	0.00	0.28	1.46	0.19	2.09
1924	0.00	97.94	2.06	0.00	2.39	0.69	1.93	15.59
1925	40.85	57.74	1.41	0.00	0.20	2.26	0.06	−0.95
1926	23.57	74.93	1.50	0.00	0.45	1.42	0.26	1.98
1927	60.81	38.05	1.14	0.00	−0.55	1.59	1.09	1.64
1928	28.11	71.08	0.50	0.31	0.22	1.54	0.43	6.44
1929	4.63	94.64	0.73	0.00	0.96	0.89	1.00	7.60
1931	0.51	97.44	2.05	0.00	2.62	0.71	0.87	14.24
1932	11.03	88.50	0.47	0.00	0.85	1.27	−0.61	2.73
1933	0.00	98.09	1.91	0.00	2.02	0.78	2.27	10.07
1934	21.44	73.70	4.21	0.65	1.25	2.22	0.22	1.47
1935	0.79	77.33	17.08	4.80	3.22	2.30	1.47	2.84
1936	14.97	74.36	8.20	2.47	2.01	2.30	1.80	3.20
1937	5.92	87.66	6.42	0.00	1.30	1.55	0.55	3.02
1938	75.84	2.34	21.82	0.00	−1.66	4.03	1.09	−0.38
1939	58.45	41.04	0.5	0.00	−0.84	1.53	0 80	1.17
1940	11.23	87.06	1.71	0.00	1.20	1.61	−0.63	1.86
1941	12.56	86.53	0.91	0.00	1.74	1.85	−1.61	2.09
1942	65.52	33.91	0.57	0.00	−1.22	1.97	0.67	−0.35
1943	0.28	98.52	1.20	0.00	2.30	0.68	0.84	12.91
1944	69.02	30.03	0.95	0.00	−1.27	1.81	0.80	0.81
1946	14.49	85.20	0.31	0.00	0.34	1.02	0.30	2.56
1947	0.00	98.65	1.35	0.00	3.01	0.63	−0.69	14.44
1949	3.97	95.59	0.27	0.17	0.91	0.91	0.74	28.70
1951	73.94	25.41	0.40	0.25	−1.69	1.97	1.49	3.55
1952	44.61	55.02	0.23	0.14	−0.80	1.47	0 65	5.21
1953	14.12	84.72	0.72	0.44	0.69	1.44	0.76	11.18
1954	22.22	76.87	0.56	0.35	0.45	1.71	0.70	4.31
1955	9.89	88.60	0.93	0.58	1.16	1.42	1.30	11.60
1956	9.84	89.61	0.34	0.21	0.90	1.23	0.60	9.37
1957	19.73	79.51	0.47	0.29	0.61	1.66	−0.36	4.16
1958	31.93	67.06	1.01	0.00	0.19	1.96	−0.51	−0.36
1959	39.30	56.81	0 89	0.00	−0.12	1.75	−0.13	0.25
1961	23.47	75.73	0.80	0.00	0.41	1.27	0.12	2.00
1962	2.08	80.21	12.50	5.21	2.69	2.36	1.71	3.87
1963	1.94	70.12	18.62	9.32	3.37	2.89	1.36	1.53
1964	0.54	74.13	21.86	3.47	3.09	2.27	1.37	2.42
1965	39.79	59.62	0.59	0.00	−0.13	1.63	0.22	−0.29
1966	12.03	87.70	0.17	0.10	0.34	1.11	0.37	8.92
1967	0.62	96.61	2.78	0.00	2.31	0.90	0.94	8.18
1968	0.36	97.32	2.32	0.00	2.34	0.87	0.90	6.79
1969	13.23	85.79	0.98	0.00	0.74	1.29	−0.46	3.12
1970	1.34	97.44	1.22	0.00	2.21	0.92	−0.93	9.36
1971	10.68	87.64	1.68	0.00	1.15	1.38	−0.12	2.16
1972	0.76	97.36	1.8	0.00	1.94	0.88	1.01	7.85
1973	6.79	71.45	13.48	8.28	2.92	3.01	0.97	1.80
1974	0.63	89.14	10.23	0.00	2.02	1.49	0.96	1.32
1975	4.07	73.31	15.99	6.63	2.95	2.71	1.28	2.22
1976	14.94	71.75	9.45	3.86	1.96	2.67	1.03	2.53
1977	25.04	71.05	3.88	0.00	0.74	2.06	−0.28	0.32
1978	22.65	75.71	1.64	0.00	0.85	1.65	−0.15	0.49
1979	56.73	41.59	1.68	0.00	−0.81	2.23	0.46	−0.45
1980	50.05	47.70	2.25	0.00	−0.30	1.76	0.83	1.30

Station no.	*Gravel %*	*Sand %*	*Silt %*	*Clay %*	*Mean φ*	*Std dev. φ*	*Skewness*	*Kurtosis*
1981	24.47	73.96	1.57	0.00	1.00	1.91	−0.50	−0.13
1982	44.73	54.33	0.94	0.00	−0.44	2.03	0.00	−0.71
1983	16.19	83.18	0.63	0.00	0.86	1.28	−0.77	1.95
1984	23.80	75.40	0.80	0.00	0.54	1.86	−0.95	0.29
1985	17.01	81.67	1.32	0.00	0.90	1.57	−0.56	1.37
1986	7.58	91.98	0.44	0.00	1.02	0.98	−1.22	6.09
1987	8.87	80.49	9.24	1.40	2.31	2.00	0.21	3.99
1988	1.34	87.65	9.27	1.74	2.78	1.62	1.77	8.05
1989	15.55	82.74	1.71	0.00	1.33	1.53	−0.53	1.04
1990	51.48	46.76	1.76	0.00	−0.34	2.27	0.33	−0.73
1991	4.85	58.31	31.73	5.11	3.46	2.49	0.59	1.75
1992	1.41	64.54	29.92	4.13	3.47	2.12	1.43	3.87
1993	0.39	90.21	8.70	0.70	2.66	1.19	2.05	14.06
1994	6.28	92.55	1.17	0.00	1.50	1.26	−0.51	3.17
1995	2.34	61.00	32.48	4.18	3.56	2.23	0.57	0.84
1996	16.76	32.64	45.73	4.87	3.22	3.16	−0.12	−0.36
1997	0.00	93.27	6.06	0.67	3.06	0.99	3.15	22.19
1998	0.43	73.58	22.74	3.25	3.36	1.75	1.39	4.35
1999	1.35	65.13	30.47	3.05	3.40	2.04	0.85	1.86
2000	8.24	70.70	20.01	1.05	2.33	2.20	0.69	1.98
2001	66.94	32.14	0.57	0.35	−0.96	1.98	1.23	3.38
2002	15.14	73.30	9.50	2.06	1.25	2.19	1.74	4.95
2003	0.00	98.91	0.68	0.41	2.14	0.91	3.48	32.06
2004	0.25	98.49	0.78	0.48	2.30	0.90	3.60	36.90
2005	3.80	95.60	0.37	0.23	0.41	0.88	4.34	45.43
2006	2.58	95.86	0.97	0.59	2.34	1.23	0.54	16.18
2007	18.17	81.25	0.58	0.00	0.95	1.85	−1.15	0.71
2008	0.84	94.97	4.19	0.00	2.74	0.92	−0.64	18.79
2009	0.83	98.42	0.75	0.00	2.35	0.68	−1.03	17.21
2010	0.00	97.17	2.83	0.00	2.38	0.88	1.47	6.00
2011	1.25	95.84	1.80	1.11	2.59	1.21	2.79	22.87
2012	37.91	61.41	0.42	0.26	−0.07	2.03	0.02	0.86
2013	5.90	61.30	27.75	5.05	2.65	2.77	1.05	1.04
2014	1.38	96.45	1.34	0.83	2.39	1.25	1.85	16.36
2015	4.98	94.78	0.15	0.09	1.49	1.15	—0.83	7.83
2016	1.14	98.70	0.10	0.06	2.19	0.68	−0.33	24.49
2017	33.17	47.49	16.12	3.22	1.30	2.98	0.84	0.69
2018	3.86	82.59	11.61	1.94	2.00	1.94	1.61	4.39
2020	5.93	86.01	4.98	3.08	2.10	2.09	1.95	6.90
2021	12.56	87.18	0.26	0.00	1.58	1.40	—1.36	1.52
2024	0.44	99.23	0.33	0.00	2.75	0.72	−0.91	6.08
2025	8.00	91.92	0.08	0.00	1.92	1.60	−2.41	5.46
2026	2.69	97.00	0.31	0.00	2.03	0.87	−2.38	11.51
2027	5.83	77.61	14.72	1.84	2.06	2.09	1.29	3.18
2028	23.79	75.81	0.40	0.00	0.65	1.58	−0.44	−0.07
2030	7.87	89.20	2.93	0.00	1.60	1.42	−0.04	2.24
2031	2.21	97.38	0.41	0.00	1.83	0.98	−0.72	3.87
2032	3.68	95.86	0.46	0.00	2.18	1.10	−3.12	13.39
2033	19.11	78.05	2.84	0.00	−0.11	1.91	−0.26	1.69
2034	9.71	87.94	2.35	0.00	1.70	1.61	−0.94	2.11
2035	0.92	66.20	26.20	6.68	3.60	2.43	1.36	2.37
2036	13.17	80.20	5.07	1.56	2.06	2.21	−0.25	2.01
2037	10.85	56.15	30.70	2.30	3.24	2.99	0.03	−0.24
2038	0.31	65.76	26.18	7.75	3.77	2.52	1.35	1.84
2039	2.03	78.38	13.99	5.60	2.79	2.49	1.65	3.12
2040	10.68	51.51	26.87	10.94	3.41	3.45	0.55	−0.04
2041	0.41	69.21	21.27	9.11	3.48	2.78	1.35	1.30
2042	1.61	54.39	32.61	11.39	4.31	2.92	0.49	1.64
2043	8.08	91.36	0.56	0.00	0.37	1.08	1.40	4.38
2044	37.29	62.42	0.29	0.00	−0.38	1.11	1.15	2.60
2045	0.39	63.09	27.90	8.62	3.61	2.77	1.23	1.09
2046	1.63	85.15	10.79	2.43	2.53	1.90	2.18	7.57
2047	6.08	93.84	0.08	0.00	0.98	1.18	−0.67	0.14
2048	5.51	93.67	0.82	0.00	2.44	1.49	—2.86	9.11
2049	3.86	95.79	0.35	0.00	0.88	0.92	—0.59	5.56
2050	2.30	96.46	1.24	0.00	1.74	1.08	0.29	2.99
2051	40.10	59.64	0.26	0.00	−0.17	1.63	−0.21	−0.64
2052	12.66	77.74	8.09	1.51	1.56	2.12	1.17	4.05
2054	16.12	83.36	0 32	0.20	1.04	1.48	−0.37	3.93
2055	0.11	99.57	0.20	0.12	2.60	0.69	1.77	25.28
2056	3.11	96.40	0.30	0.19	1.59	1.07	—0.25	15.17
2057	6.95	91.89	0.72	0.44	1.41	1.33	0.92	11.27
2058	43.87	52.75	2.09	1.29	0.37	2.76	0.54	0.64

Station no.	*Gravel %*	*Sand %*	*Silt %*	*Clay %*	*Mean φ*	*Std dev. φ*	*Skewness*	*Kurtosis*
2059	7.33	89.35	2.05	1.27	1.90	1.66	1.61	8.78
2060	0.29	99.03	0.42	0.26	2.16	0.88	2.45	22.43
2061	0.74	97.91	0.83	0.51	2.36	1.08	2.03	18.23
2062	1.67	95.67	1.65	1.01	2.55	1.32	1.76	14.37
2063	7.49	82.45	7.77	2.29	2.27	2.07	0.87	4.92
2064	2.65	96.19	0.72	0.44	1.96	1.24	0.88	11.89
2065	52.81	46.44	0.75	0.00	−0.44	1.55	0.40	0.43
2066	0.55	98.46	0.99	0.00	2.71	0.73	−1.24	17.29
2067	7.72	92.09	0.19	0.00	1.01	1.10	−0.10	1.58
2068	3.83	79.74	13.35	3.08	2.75	2.03	1.40	5.42
2069	23.51	59.81	13.84	2.84	1.72	2.78	0.73	1.39
2070	50.61	49.05	0.34	0.00	−0.80	1.59	0.51	0.74
2071	1.36	97.40	1.24	0.00	2.39	0.94	−0.43	4.56
2072	2.58	88.53	7.44	1.55	2.71	1.70	1.30	7.03
2073	3.27	95.70	1.03	0.00	1.39	1.11	0.23	3.12
2074	17.70	80.98	1.32	0.00	1.02	1.47	−0.13	0.95
2075	5.62	93.42	0.96	0.00	2.00	1.48	−1.14	2.78
2076	27.59	71.94	0.47	0.00	0.26	1.45	−0.41	0.46
2077	1.03	79.80	16.58	2.59	3.41	1.63	1.63	7.51
2078	2.52	88.63	7.52	1.33	2.58	1.58	1.41	8.06
2079	0.11	99.36	0.53	0.00	2.52	0.65	−0.12	6.65
2080	0.82	88.17	9.72	1.29	3.60	1.23	1.63	17.04
2081	21.77	77.12	1.11	0.00	0.67	1.52	−0.32	1.13
2082	77.56	21.50	0.94	0.00	−1.31	2.13	1.32	0.75
2083	0.41	99.45	0.14	0.00	2.74	0.64	−0.74	7.00
2085	0.14	99.58	0.28	0.00	2.61	0.61	0.18	4.77
2086	4.36	94.94	0.70	0.00	2.09	1.30	−0.95	2.09
2087	13.04	86.21	0.75	0.00	1.04	1.37	−0.54	1.67
2088	88.19	11.26	0.55	0.00	−2.56	1.99	1.70	2.65
2089	1.33	97.61	1.06	0.00	2.93	0.91	−2.15	12.41
2090	4.01	95.49	0.50	0.00	1.95	1.21	−1.00	2.87
2091	9.07	89.66	1.27	0.00	1.41	1.32	−0.24	1.76
2092	13.64	85.96	0.40	0.00	0.95	1.23	−0.34	1.27
2093	6.57	92.88	0.55	0.00	1.56	1.24	−0.51	1.24
2094	0.00	99.46	0.54	0.00	3.44	0.50	−1.42	14.29
2095	0.00	98.90	1.10	0.00	3.21	0.55	0.31	11.04
2096	25.33	74.17	0.50	0.00	0.50	1.49	−0.23	0.32
2097	29.28	69.87	0.85	0.00	0.21	2.08	−0.48	−0.47
2098	38.89	60.87	0.24	0.00	0.09	1.56	−0.11	−0.76
2099	8.74	90.82	0.44	0.00	1.38	1.43	−1.14	2.82
2100	20.57	78.91	0.52	0.00	0.81	1.51	−0.77	0.56
2102	24.70	74.61	0.69	0.00	0.83	1.76	−0.49	−0.47
2104	26.25	73.37	0.38	0.00	0.28	1.38	−0.24	0.80
2105	15.03	84.69	0.28	0.00	1.01	1.40	−1.04	1.51
2106	13.46	86.30	0.24	0.00	1.04	1.40	−0.83	1.10
2107	3.52	96.38	0.10	0.00	1.97	0.96	−2.31	8.47
2108	77.70	22.08	0.22	0.00	−2.06	1.89	0.72	0.26
2109	5.13	94.56	0.31	0.00	1.40	1.11	−2.06	7.93
2110	25.58	74.25	0.17	0.00	−0.03	1.83	−0.86	−0.24
2111	81.45	18.20	0.35	0.00	−1.65	1.48	1.20	2.15
2112	33.34	47.62	10.88	8.16	1.35	3.65	1.31	1.38
2113	24.97	74.56	0.47	0.00	0.42	1.70	−0.38	−0.18
2114	4.98	94.80	0.22	0.00	1.70	1.06	−2.74	10.25
2115	7.69	92.00	0.31	0.00	1.93	1.43	−1.94	4.56
2116	53.21	45.85	0.94	0.00	−0.76	1.63	0.50	0.89
2117	14.27	84.92	0.81	0.00	1.06	1.36	−0.79	1.79
2118	5.14	94.63	0.23	0.00	1.05	1.02	−1.14	4.79
2119	19.76	79.29	0.95	0.00	0.92	1.59	−0.42	0.42
2120	49.25	50.00	0.75	0.00	−0.62	1.59	0.20	0.49
2121	24.44	75.00	0.56	0.00	0.45	1.60	−0.74	0.28
2122	36.44	62.75	0.81	0.00	−0.01	1.70	−0.28	−0.18
2123	28.67	70.63	0.70	0.00	0.62	1.89	−0.50	−0.53
2124	37.54	61.54	0.92	0.00	−0.28	1.88	−0.13	−0.35
2125	43.06	56.58	0.36	0.00	−0.38	1.24	0.15	1.33
2126	42.41	57.14	0.45	0.00	−0.20	1.84	−0.06	−0.64
2127	24.60	74.41	0.99	0.00	0.82	1.79	−0.46	−0.01
2128	18.67	79.73	1.60	0.00	0.90	1.62	−0.27	0.80
2129	19.36	80.06	0.58	0.00	0.82	1.65	−1.02	0.99
2130	0.71	98.69	0.60	0.00	2.69	0.92	−2.40	8.95
2131	4.91	94.11	0.98	0.00	1.87	1.36	−0.74	2.09
2132	24.69	74.62	0.69	0.00	0.26	1.38	0.32	1.69
2133	0.10	99.21	0.69	0.00	2.65	0.56	0.23	15.22
2134	83.19	16.69	0.12	0.00	−1.10	1.26	1.72	2.56

Station no.	Gravel %	Sand %	Silt %	Clay %	Mean φ	Std dev. φ	Skewness	Kurtosis
2135	0.00	99.38	0.62	0.00	2.93	0.53	0.97	6.23
2136	17.52	82.29	0.19	0.00	0.54	1.11	−0.65	1.70
2137	3.04	95.90	1.06	0.00	2.40	1.09	−1.11	3.97
2138	4.05	94.94	1.01	0.00	1.95	1.20	−0.35	1.66
2139	41.33	57.04	1.63	0.00	−0.12	1.77	0.30	0.55
2140	0.10	99.19	0.71	0.00	2.83	0.56	0.64	10.78
2141	2.61	97.18	0.21	0.00	1.50	0.85	−0.26	4.70
2144	2.17	97.58	0.25	0.00	0.97	0.69	−0.12	9.95
2145	60.32	39.41	0.27	0.00	−0.32	1.10	1.24	1.94
2146	5.11	94.47	0.42	0.00	1.68	1.03	−1.88	7.18
2147	25.64	74.21	0.15	0.00	0.34	1.51	−0.92	0.13
2148	3.62	95.96	0.42	0.00	2.30	1.13	−3.48	15.74
2149	1.42	88.47	7.08	3.03	3.48	1.61	1.94	11.40
2150	4.90	94.47	0.63	0.00	1.48	1.36	−0.04	0.55
2152	1.01	98.84	0.15	0.00	2.37	0.65	−1.66	13.09
2153	9.47	90.26	0.27	0.00	1.07	1.44	−1.18	2.75
2154	4.24	95.46	0.30	0.00	0.21	0.66	1.60	20.48
2155	28.12	71.57	0.31	0.00	−0.60	1.04	0.70	4.75
2157	11.75	88.12	0.13	0.00	1.23	1.50	1.18	1.38
2158	2.46	97.31	0.23	0.00	1.84	1.09	−0.49	2.05
2159	20.35	79.25	0.40	0.00	0.76	1.79	−0.83	0.14
2160	10.94	88.76	0.30	0.00	0.97	1.31	−0.46	0.87
2161	45.33	54.33	0.34	0.00	−0.64	1.35	0.20	0.98
2162	23.37	76.12	0.51	0.00	−0.15	1.38	−0.13	1.48
2163	28.42	71.16	0.42	0.00	0.26	1.85	−0.96	0.32
2164	7.75	92.05	0.20	0.00	1.47	1.28	−2.27	6.05
2165	2.16	97.41	0.43	0.00	2.24	0.89	−2.16	11.57
2166	3.12	96.34	0.54	0.00	2.77	1.09	−3.44	15.93
2167	0.96	49.82	37.78	11.44	4.28	2.77	0.97	0.88
2168	12.03	86.01	1.21	0.75	1.38	1.82	0.70	3.85
2169	2.14	97.41	0.28	0.17	1.79	0.92	−0.35	23.09
2170	0.73	98.91	0.22	0.14	1.94	0.70	1.58	0.14
2171	2.54	96.98	0.30	0.18	1.98	0.96	−1.17	24.08
2172	41.16	57.59	1.15	0.10	0.00	2.39	−0.25	−1.14
2173	7.49	91.86	0.40	0.25	2.38	1.57	−1.99	7.49
2174	63.51	35.85	0.40	0.24	−0.88	2.84	0.68	−0.86
2175	2.36	97.33	0.19	0.12	2.13	1.10	−2.34	17.45
2176	2.87	96.17	0.59	0.37	2.72	1.19	−0.98	14.46
2177	1.28	97.02	1.05	0.65	2.81	1.17	1.06	15.18
2178	1.38	97.77	0.53	0.32	2.69	0.92	0.69	24.37
2179	24.86	74.79	0.22	0.13	−0.05	1.26	0.73	7.25
2180	6.43	93.26	0.19	0.12	1.87	1.26	−1.60	7.70
2181	3.39	95.83	0.48	0.30	2.43	1.19	−0.54	10.71
2182	0.30	75.08	15.22	9.40	4.11	2.45	1.49	2.49
2183	8.98	90.61	0.25	0.16	0.41	1.34	0.00	7.26
2184	2.75	96.65	0.37	0.23	2.69	1.21	−1.41	11.36
2185	17.30	81.67	0.64	0.39	1.72	1.94	−0.40	1.18
2186	3.58	95.08	0.83	0.51	2.79	1.52	−0.74	5.57
2187	5.17	94.35	0.30	0.18	1.40	1.23	−1.12	12.25
2188	6.37	92.74	0.55	0.34	2.65	1.57	−1.28	5.18
2190	23.14	76.48	0.24	0.14	0.64	1.60	−0.21	2.01
2191	4.25	89.68	4.91	1.16	2.37	1.63	0.98	7.49
2192	17.26	82.54	0.12	0.08	0.41	1.48	−0.89	2.95
2193	2.98	96.57	0.28	0.17	1.81	1.05	−0.40	14.17
2194	8.26	91.59	0.09	0.06	1.62	1.54	−2.03	5.34
2195	26.29	73.32	0.24	0.15	0.46	1.42	0.14	3.37
2196	5.60	93.95	0.28	0.17	1.98	1.25	−1.19	8.24
2197	10.10	89.28	0.38	0.24	1.77	1.55	−0.85	4.16
2198	5.68	93.88	0.27	0.17	2.26	1.32	−1.55	7.97
2199	7.37	91.93	0.43	0.27	2.06	1.52	−1.12	5.83

APPENDIX 3

Heavy-mineral assemblages in selected surface sediments

Station no.	*Suite*	*Grains counted*	*Total HM*	*Opaques*	*Zircon*	*Tourmaline*	*Pyroxene*	*Amphibole*	*Epidote*	*Garnet*	*Olivine*	*Andalusite*	*Topaz*	*Rutile*	*Cassiterite*	*Apatite*	*Others*
1925	1	256	0.24	13	5	13	47	6	1	6	—	1	3	tr	—	tr	5
1931	1	334	0.28	19	2	5	55	4	3	3	—	2	2	tr	—	2	3
1934	1	326	0.13	22	4	7	47	4	2	4	—	1	5	1	1	1	1
1941	1	356	0.90	13	1	9	50	6	4	5	—	1	1	1	1	5	3
1943	1	241	0.36	13	2	14	42	9	3	4	—	2	2	1	2	1	5
1947	1	333	0.18	10	1	10	57	14	1	1	—	—	1	2	—	1	2
1949	1	386	2.62	13	1	22	42	1	1	2	—	—	10	1	—	5	2
1985	1	320	2.13	17	2	2	60	tr	1	3	tr	1	1	tr	—	11	2
1997	1	506	1.35	14	2	5	60	2	2	10	—	1	tr	1	—	3	—
2003	1	317	1.04	23	2	5	53	1	1	8	—	1	1	1	tr	1	3
2004	1	392	0.55	11	2	6	73	1	—	4	—	1	tr	1	—	1	—
2006	1	338	1.58	10	3	6	70	1	—	8	—	tr	tr	1	—	1	—
2007	1	326	1.05	10	3	4	69	tr	—	9	—	1	—	1	tr	1	2
2008	1	305	0.29	6	2	8	73	1	—	7	—	tr	—	—	1	1	1
2009	1	478	0.34	20	3	18	45	1	—	6	—	1	1	1	1	2	1
2010	1	468	1.00	9	2	10	56	tr	1	14	—	1	—	2	—	5	—
2011	1	455	1.22	12	1	7	71	tr	tr	4	—	1	—	1	—	2	1
2014	1	370	0.57	18	2	5	62	2	tr	6	—	1	tr	1	—	2	1
2024	1	390	1.96	34	1	3	56	1	1	1	—	—	tr	tr	—	1	2
2025	1	397	2.21	16	9	6	47	2	tr	16	—	1	—	1	—	1	1
2032	1	306	1.66	12	3	12	48	4	tr	16	—	1	1	tr	—	2	3
2047	1	310	0.32	27	3	8	51	—	tr	5	—	tr	1	1	—	3	1
2048	1	331	0.65	20	2	3	64	4	tr	2	—	1	—	tr	—	2	2
2055	1	341	1.68	11	1	5	78	1	—	1	—	1	tr	—	—	1	1
2079	1	299	0.37	44	2	28	7	2	2	8	—	3	1	1	—	1	1
2080	1	336	0.64	22	2	7	59	3	1	2	—	1	tr	1	—	1	1
2085	1	329	0.92	39	4	21	9	2	2	13	—	2	1	2	—	1	4
2094	1	330	1.06	29	1	10	47	3	4	2	—	1	tr	tr	—	tr	3
2095	1	253	3.28	34	3	13	27	3	2	3	—	4	5	2	—	1	3
2114	1	302	0.16	21	2	3	59	1	1	2	—	1	2	1	—	1	6
2115	1	214	0.04	21	1	4	67	—	1	1	—	1	1	1	—	1	—
2130	1	357	1.93	20	1	7	61	1	1	4	—	3	2	tr	—	—	—
2133	1	447	0.89	29	2	11	46	1	2	1	—	3	1	1	—	1	3
2135	1	330	5.70	24	2	25	32	2	4	4	—	2	2	tr	—	1	2
2140	1	395	1.17	41	1	8	41	1	2	2	—	1	1	tr	—	1	1
2168	1	459	0.70	5	2	1	48	4	tr	35	tr	—	1	tr	—	1	3
1830	2	408	0.06	15	8	31	—	—	—	5	—	2	38	1	tr	—	—
1831	2	381	0.09	16	8	16	—	1	2	10	—	2	44	1	tr	—	—
1834	2	715	0.13	16	6	29	—	3	1	14	—	2	26	1	tr	—	2
1835	2	332	0.05	10	7	23	—	1	1	7	—	1	49	1	tr	—	—
1836	2	309	0.04	20	11	32	—	—	1	8	—	tr	24	1	1	—	2
1838	2	247	0.26	9	tr	9	—	tr	—	2	—	1	77	—	2	—	—
1839	2	238	0.06	10	3	22	—	1	1	4	—	1	55	tr	tr	—	3
1840	2	402	0.13	8	3	23	—	1	1	3	—	tr	60	1	tr	—	—
1844	2	424	1.34	17	7	22	1	7	5	20	—	2	13	2	1	1	2
1924	2	301	0.08	28	8	28	3	—	2	10	—	2	17	2	—	—	—
1933	2	282	0.19	23	7	26	—	1	2	4	—	3	32	1	—	—	1
1937	2	111	0.06	37	2	4	—	1	3	4	—	1	47	1	tr	—	—
1940	2	363	0.35	14	1	16	1	tr	1	4	—	2	59	1	tr	tr	1
1946	2	333	0.18	19	1	7	—	1	1	1	—	1	69	—	—	—	—
2107	3	229	0.20	31	1	5	47	—	—	1	13	tr	tr	tr	—	—	2
2110	3	290	0.27	29	3	3	6	tr	—	1	56	—	—	2	—	—	—
1790	4	377	0.36	25	5	28	1	16	11	6	—	3	1	1	—	tr	3
1792	4	189	0.13	31	5	20	1	15	9	7	—	2	1	1	—	2	6
1796	4	248	0.06	27	6	24	2	17	9	4	—	3	1	tr	tr	2	5
1798	4	252	0.07	37	3	25	—	12	8	6	—	4	—	2	—	1	2
1799	4	301	0.10	28	3	28	—	9	7	10	—	5	—	1	—	tr	9
1800	4	251	0.31	46	6	15	1	5	12	4	—	5	1	tr	—	—	5
1802	4	319	0.12	31	3	25	tr	20	10	4	—	2	tr	1	—	1	3
1803	4	377	0.08	26	11	27	tr	15	5	5	—	2	1	2	—	1	5
1914	4	444	0.22	40	10	14	tr	21	7	1	—	1	1	2	1	—	2
1915	4	367	0.63	38	17	15	tr	12	7	3	—	1	1	3	—	1	2

Notes: Mineral abundances are percentages based on grain counts of the heavy fraction. Trace (tr) indicates less than 0.5%. Total heavy-mineral (HM) values are percentages by weight of heavy minerals (S. G. >2.96) in the —1.2 mm + 0.053 mm fraction of the whole sediment.

APPENDIX 4
Pollen analyses of sediments from the Bass Strait shelf

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Method and results

Dr H. A. Jones submitted three samples of organic mud from the Bass Strait shelf (Table A1) for pollen analysis. All samples were treated with hydrofluoric acid, followed by hydrolysis and acetolysis according to the method outlined by Faegri & Iversen (1964). Samples 2 and 3 were filtered through 7–μm filtration cloth to improve concentration of the palynofloras. Pollen and spores were counted from a minimum of two slides per sample at magnifications of 300 to 600.

TABLE A1. LOCATIONS OF SAMPLES

No.	*BMR No.*	*Depth*	*Lat.°S*	*Long.°E*	
1	7363 1963	71 m	40°03′	147°07′	ca 85 km NNE of mouth of R. Tamar
2	7363 1997	44 m	42°31′	148°04′	ca 7 km N of Maria Island
3	7363 2042	95 m	41°10′	148°26′	ca 25 km NE of St Helens Point

Results of the pollen analyses are given in Table A2. Only in sample 1 were statistically significant numbers of pollen present; these data are expressed as percentages of the total identifiable spore-pollen count. The data for the two other samples are expressed only as numbers of pollen counted.

All samples contained identifiable pollen and spores, but are dominated by charcoal particles (long axis >10 μm) and marine organisms including dinoflagellates and radiolarians. Most of the palynomorphs were indistinguishable from living taxa and have been identified as such. The species aff. *Pteris* and cf. *Selaginella* (Table A2) may be reworked Mesozoic spores. Spores and pollen referable to Tertiary form species described by Stover & Partridge (1973) were absent.

Pollen and spore preservation varied from mostly good (sample 3) to poor (samples 1 and 2). The same small group of spores and pollen dominate all assemblages: *Dicksonia, Cyathea*, trilete fern spores, *Pinus radiata*, Chenopodiaceae, Compositae, *Eucalyptus*, and Gramineae.

All samples contained exotic pollen, including *Pinus radiata*, and agricultural weed taxa such as *Taraxacum, Rumex*, and *Plantago lanceolata.* Exotic taxa that could not be referred to known families or genera have been included with other unidentified palynomorphs in Table A2.

Discussion

The presence of exotic pollen demonstrates that sedimentation persists at all three sites. Planting of *Pinus radiata* did not become widespread until the 1930s, providing a broad maximum age for that component of the sediment.

Because pine plantations are uncommon in Tasmania, it may be possible to use *P. radiata* pollen as a sediment tracer: for example those in sample 1 may reflect stands within the catchments of the Tamar, Mersey, and Forth Rivers; and, in sample 3, plantations between Scottsdale and St Helens. Occurrences of the same pollen at lower latitudes in Bass Strait would undoubtedly include Victoria-derived grains.

Differential preservation has distorted the composition of the pollen assemblages, resulting in the preferential recovery and identification of robust palynomorphs—e.g., Epacridaceae, *Dicksonia*, and *Cyathea*—and taxa that remain distinctive despite considerable corrosion—e.g., *Pinus radiata*, Compositae, Chenopodiaceae, Gramineae, and Myrtaceae.

Nevertheless the majority of the pollen and spore types present in the samples are known to float well and/or be wind-dispersed over long distances (Hope 1968; Macphail 1975, 1976). For example, pollen-trapping in Tasmania has shown Chenopodiaceae pollen to be transported across Bass Strait in sizable numbers. Other Australian taxa—including *Eucalyptus, Casuarina, Amperea*, and Gyrostemonaceae—have been recovered in New Zealand sediments (Macphail 1979b). This strongly suggests that the palynofloras in the shelf sediments accurately reflect the general or background 'pollen rain' over Bass Strait. Charcoal particles from bushfires on both sides of Bass Strait are a common component of this 'rain'.

The common pollen and spores are also those produced by taxa that are abundant in coastal or riverine environments—e.g., Chenopodiaceae in salt marsh communities, and *Pomaderris apetala, Cyathea*, and *Dicksonia* in moist coastal valleys. *Myoporum* (sample 1) is characteristic of sandy coasts. Accordingly the simplest hypothesis is that all elements in the pollen assemblages are recent, and the different degrees of preservation reflect spatial variation in transportation, bioturbation, and facies.

On this hypothesis, the sampled strata are also recent in age. However, several factors suggest a more complex origin, possibly obscured by the sample retrieval techniques:

(a) the presence of palynomorphs that are rare, even in samples taken from within the source vegetation —e.g., Papilionaceae, *Sprengelia*, and *Pimelea* in sample 2;

(b) the rarity or absence of some robust pollen types that are common components of the modern pollen rain—e.g., *Casuarina* and *Dodonaea*—whilst less common components of the pollen rain are well represented in the samples—e.g., Compositae;

(c) the similarity between a major portion of the palynoflora in sample 1 and Late Pleistocene palynofloras from eastern and northwestern Tasmania and the southeast mainland.

TABLE A2. TAXA IDENTIFIED IN SAMPLES

Taxon	Sample 1 No. counted	%	Sample 2 No. counted	Sample 3 No. counted
(a) trees				
Nothofagus cunninghamii	—	—	?	1
Phyllocladus	2	+	1	1
Pomaderris apetala-type	4	1	—	2
Eucalyptus	32	10	26	21
Casuarina	4	1	2	—
Acacia	1	+	1	—
Cupressaceae/Taxodiaceae	1	+	1	—
(b) shrubs				
Rhamnaceae	5	2	1	3
Bursaria	—	—	—	1
Pimelea	—	—	1	—
Nothofagus gunnii	—	—	—	1
Drimys	1	+	—	—
Melaleuca-type	2	+	1	4
Melaleuca squamea	1	+	1	—
Baeckia-type	1	+	1	—
Leptospermum	2	+	1	—
Indet. Myrtaceae	—	—	2	3
Papilionaceae	1	+	1	—
Epacridaceae	1	+	3	—
Monotoca	—	—	1	1
Sprengelia-type	—	—	1	1
Amperea	—	—	—	1
Myoporum	1	+	—	—
Gyrostemonaceae	2	+	—	—
Chenopodiaceae	40	12	2	7
Compositae	40	12	6	9
(c) herbs				
Gramineae	28	9	4	6
Plantago	1	+	—	—
Cruciferae	4	1	—	—
Liliaceae	—	—	—	1
Cyperaceae	6	2	1	2
(d) ferns & lycopods				
Dicksonia antarctica	49	15	3	24
Cyathea australis-type	21	6	—	3
C. cunninghamii-type	5	2	—	1
Gleichenia	3	+	2	8
aff. *Pteris*	1	+	1	—
Trilete fern spores	13	4	6	12
Histiopteris	1	+	—	1
Phymatodes	1	+	—	—
Monolete fern spores	9	3	—	2
cf. *Selaginella*	—	—	—	1
(e) exotics				
Pinus radiata	38	12	3	3
Betula	—	—	—	1
Taraxacum	7	2	3	—
Plantago lanceolata	1	+	—	—
Rumex	—	—	—	1
(f) unidentifiable	21	6	8	9
(g) marine microorganisms				
Radiolarians	39	12	18	31
Dinoflagellates	244	74	19	13
Crustacean parts				1
Charcoal particles	∞	∞	743	∞

Less than 1% expressed as +

Late Pleistocene palynofloras in Tasmania are typically dominated by two or more of Gramineae, Compositae, and Chenopodiaceae pollen. Tree pollen is rare, suggesting that the vegetation before ca 11 500 BP comprised a mosaic of grasslands and heath (Macphail 1975, 1979a). The Late Pleistocene vegetation in eastern Tasmania may have included a chenopod 'cold steppe'; and eucalypts appear to have been confined to near-coastal locations (Macphail & Jackson 1978). On the basis of similar pollen assemblages in deposits from northwest Tasmania and the southeast mainland, Hope (1978) has proposed that this mosaic of grassland, Compositae-rich shrubland, and *Eucalyptus* savannah extended across the Bassian Plain to the Adelaide region. Because of the bathymetry of the landbridge, Chenopodiaceae saltmarsh communities are likely to have been part of this vegetation, and possibly widespread during early stages of marine transgression.

Accordingly, it is conceivable that the (much corroded) Gramineae, Compositae, Chenopodiaceae, Cyperaceae, and *Eucalyptus* pollen in sample 1 are of Late Pleistocene age and reflect part of the landbridge flora. If so, a portion of the charcoal content may reflect Late Pleistocene firing of the vegetation by Aboriginals. On this hypothesis the stratum represented by sample 1 is terrestrial or possibly lagoonal, of Late Pleistocene age, and overlain by recent sediments.

Because of variations in the amount of detritus left after processing, it is difficult to assess the relative concentration of charcoal particles. Nevertheless, these seem surprisingly abundant and, if able to be metabolised by the benthic fauna, would form a significant source of carbon within the sediments.

Conclusions

(a) Sedimentation persists at the three sites sampled by BMR. It may be possible to use pollen from plants having restricted distributions as tracers for sediment transport.

(b) Sample 1 may contain a Late Pleistocene palynoflora mixed with modern spore-pollen and dinoflaggellates. Analysis of a core preserving the original stratigraphy will resolve this point.

(c) The fact that diverse palynofloras are preserved in Bass Strait shelf sediments will allow direct testing of hypotheses concerning the last glacial palaeoecology and prehistory of the Bassian Plain.

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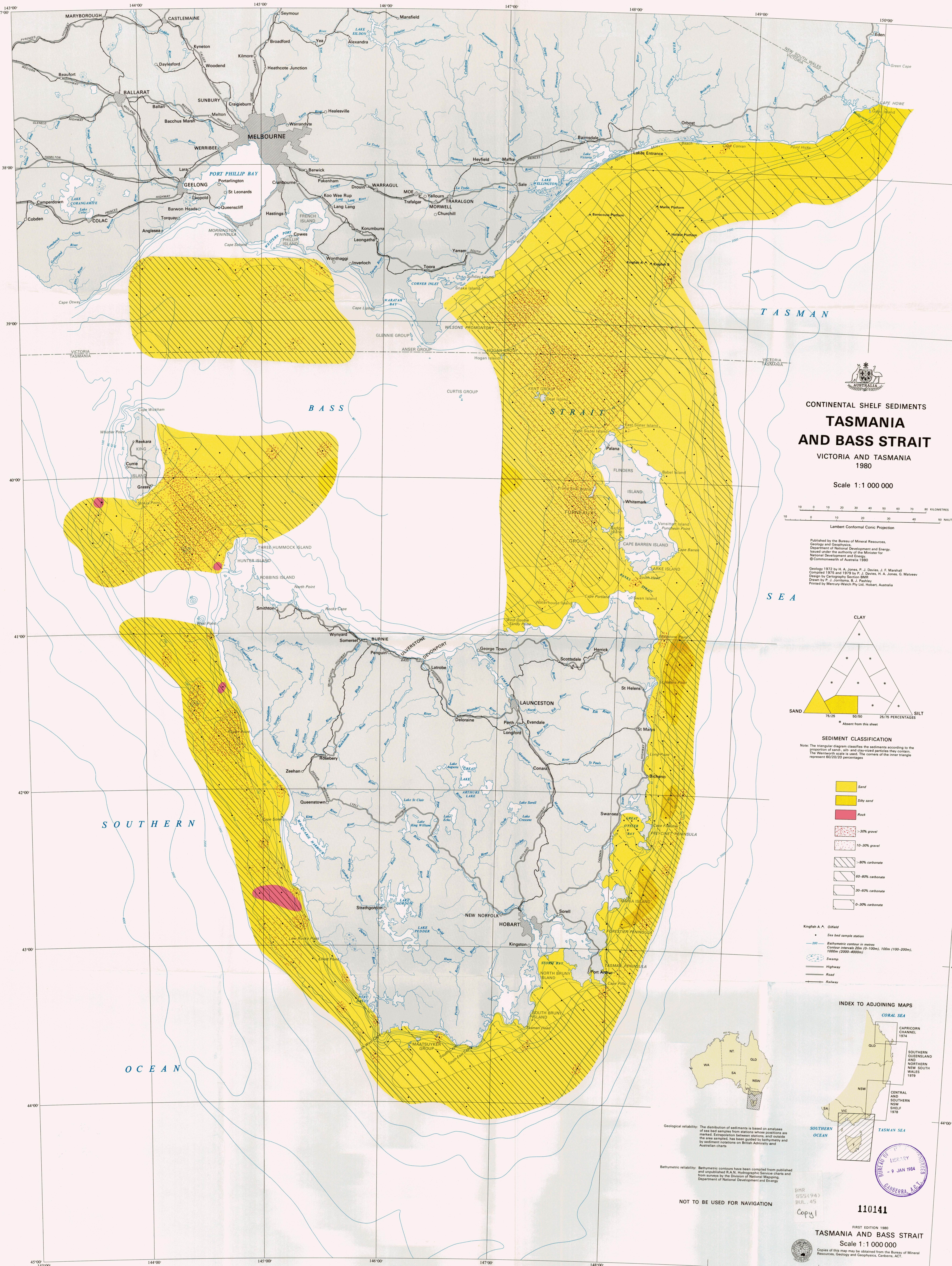
PLATE 1


CONTINENTAL SHELF SEDIMENTS
TASMANIA AND BASS STRAIT
VICTORIA AND TASMANIA
1980
Scale 1:1 000 000
KILOMETRES
NAUTICAL MILES
Lambert Conformal Conic Projection
Published by the Bureau of Mineral Resources, Geology and Geophysics, Department of National Development and Energy. Issued under the authority of the Minister for National Development and Energy. © Commonwealth of Australia 1980
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Design by Cartography Section BMR
Drawn by P. J. Jorritsma, B. J. Pashley
Printed by Mercury-Walch Pty Ltd, Hobart, Australia
CLAY
SAND
SILT
75/25
50/50
25/75 PERCENTAGES
* Absent from this sheet
SEDIMENT CLASSIFICATION
Note: The triangular diagram classifies the sediments according to the proportion of sand-, silt- and clay-sized particles they contain. The Wentworth scale is used. The corners of the inner triangle represent 60/20/20 percentages
Sand
Silty sand
Rock
>30% gravel
10–30% gravel
>80% carbonate
60–80% carbonate
30–60% carbonate
0–30% carbonate
Kingfish A Oilfield
Sea bed sample station
Bathymetric contour in metres Contour intervals 20m (0–100m), 100m (100–200m), 1000m (2000–4000m)
Swamp
Highway
Road
Railway
INDEX TO ADJOINING MAPS
Geological reliability: The distribution of sediments is based on analyses of sea bed samples from stations whose positions are marked. Extrapolation between stations, and outside the area sampled, has been guided by bathymetry and by sediment notations on British Admiralty and Australian charts
Bathymetric reliability: Bathymetric contours have been compiled from published and unpublished R.A.N. Hydrographic Service charts and from surveys by the Division of National Mapping, Department of National Development and Energy
NOT TO BE USED FOR NAVIGATION
FIRST EDITION 1980
TASMANIA AND BASS STRAIT
Scale 1:1 000 000
Copies of this map may be obtained from the Bureau of Mineral Resources, Geology and Geophysics, Canberra, ACT.