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RECORD NO. 1972/94

A CHENIER SEQUENCE

AT BROAD SOUND QUEENSLAND

AND EVIDENCE AGAINST A

HOLOCENE HIGH SEA LEVEL

by

P.J. Cook, Bureau of Mineral Resources, Canberra

and

H.A. Polach, Australian National University, Canberra

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ABSTRACT

A prograding chenier plain on the west side of Broad Sound is up to 5 km wide and individual beach ridges (cheniers) are up to 5 km long. The cheniers are believed to have formed during periods of low sediment supply, leading to the erosion of mangrove deposits and the attendant development of a beach ridge. Radiocarbon dating of two sequences, revealed that cheniers formed at about 5000, 4500, 3550, 2500, 1600 and 700 years BP. There is no significant change in the elevation of the cheniers during this 5000 year interval and it would seem from the Broad Sound evidence that sea level stabilized at about the present level approximately 5000 years BP. Since that time mean sea-level has varied by no more than ± 1 metre.

INTRODUCTION

A comprehensive study of modern sedimentation and the Quaternary history of Broad Sound on the central Queensland coast has been undertaken by the Bureau of Mineral Resources as part of the Estuary Study Project. This investigation began in 1970 and involved both offshore and onshore work; the latter included field mapping, sampling, and drilling of unconsolidated Quaternary sediments. The purpose of this paper is to discuss that portion of the study dealing with the beach ridges (cheniers).

The geology of the Broad Sound area has been the subject of several regional surveys, in particular those of Malone, et al. (1969) who mapped the west side of Broad Sound, and Kirkegaard, et al. (1970) who mapped the east side. Both surveys were primarily concerned with the bedrock geology, and the Quaternary sediments were only cursorily investigated. General observations on the Quaternary sediments have been made by a number of authors, in particular Jardine (1928), who believed that there has been a Recent regression in the Torilla Plains area and suggested that a relative lowering of sea level of up to 6 m has occurred over the past 4500 years. Maxwell (1968) briefly discusses the Cenozoic history of Broad Sound and mentions the presence of old beach ridges in the area. However, the present investigation (Cook and Mayo, 1972, in prep.) was the first to undertake a comprehensive study of the Quaternary coastal features of the Broad Sound area. As part of these investigations W.A. Burgis and W. Mayo (Burgis, 1972) undertook a drilling program in the Torilla Plains area. P.J. Cook carried out auger drilling and sampling of beach ridges in the Charon Point area and near the confluence of Waverley Creek and The Hoogly (Fig. 1).

THE CHENIER PLAINS

Extensive coastal plains are present throughout the Broad Sound area. The most landward portion (generally rising to 1 - 2 m above high spring tide) is grass-covered; it is flanked on the seaward side by high tidal mudflats which are only inundated during spring tides or storm tides. Lucia (1972) uses the term "supratidal" for this zone. The mudflats are bordered by mangrove, and then in turn by extensive intertidal muds and sands subject to semi-diurnal marine inundation. The coastal plains are particularly well developed on the east side of Broad Sound, where the Torilla Plains (Fig. 1) are up to 20 km wide and are underlain by as much as 40 m of unconsolidated sediments in places (Burgis, 1972). Beach ridges are either absent or poorly developed in this area.

On the west side of Broad Sound (Fig. 1) the plains are rather less extensive, and are underlain by no more than 10 m of unconsolidated sediments. The plains of this area are notable for the presence of well developed beach ridges or cheniers. Howe et al. (1935, p. 3) describe the cheniers of southwest Louisiana as follows "Rising slightly above the surrounding marshes, several long, narrow, sandy ridges run roughly parallel to the coast of southwestern Louisiana and form the most conspicuous topographic features of the region. Sharply localized, well drained and fertile, they support naturally luxuriant vegetation cover ...... the ridges have been called cheniers by their Creole inhabitants."
The cheniers at Broad Sound are particularly well developed near the mouth of estuaries, where the coastal plains are up to 5 km wide (Fig. 2A, B). Price (1955) has used the term "chenier plain" for this type of coastal geomorphic feature in Louisiana which he described (p. 75) as "shallow-based, perched, sandy ridges resting on clay .... along a marshy or swampy seaward facing, tidal shore, with other beach ridges stranded in the marsh behind, form a belted marsh-and-ridge here called the chenier plain ....". Although this picture has been modified by later work (Gould and McFarlan, 1959; Coleman, 1966) the chenier plains of Broad Sound are geomorphically comparable with, although somewhat narrower than, the chenier plains of Louisiana.

The Broad Sound cheniers are low ridges up to 5 km long and 50 m wide. They rise to a maximum of 2 m above the surrounding flats although their apparent height is accentuated by a thick vegetation cover, with trees reaching a height of 10 m (Fig. 2C). This is in marked contrast to the surrounding flats which are totally devoid of trees and support only grass, or in the more seaward areas , are either bare or support a sparse discontinuous halophytic cover only a few centimetres high. The thick vegetation cover on the cheniers is due to the firm substratum and their ability to hold large quantities of comparatively fresh water, in contrast to the surrounding hypersaline mudflats. The cheniers are made up of sand and gravel. The sand is composed predominantly of quartz grains and finely comminuted carbonate fragments. The gravel is in some places composed of well rounded pebbles and cobbles, up to 10 cm in diameter, of Paleozoic igneous and sedimentary rocks, or more rarely of mud-balls derived from intertidal sediments. However, the gravel fraction is generally composed of whole and fragmentary bivalve shells with minor coral, gastropod, echinoderm, sponge and bryozoan fragments. All the ridges examined are thinly bedded, with a shallow seaward depositional dip. The bedding is generally obscured by a thin soil (up to 40 cm thick) developed on the ridges, particularly on the more landward ones.

Auger drilling revealed that the cheniers extend for a depth of 0.5 m to 1 m below the level of the plain. Many rest on soft green high tidal muds with a low organic matter content, but some extend down to a firmer substrata of dark grey muds and sandy muds, rich in mangrove fragments (Fig. 3). The chenier sediments also interfinger to some extent with the supratidal muds on their flanks. Many of the cheniers consist of a single ridge, but some show a branching form, with branches characteristically curving into the estuary mouth; these are particularly abundant on Rosewood Island (Fig. 1). The cheniers commonly trend parallel to the present shoreline and to each other, such as in the Charon Point area. In the area between The Hoogly and Waverley Creek cheniers commonly converge. The cheniers almost invariably slope more steeply on their seaward side. In places, e.g. along the west bank of The Hoogly, the young cheniers are being eroded at the present time.

The elevation of the cheniers was difficult to establish because of the large tidal range in Broad Sound (about 10 m), the lack of detailed local tidal variation data, and the absence of bench marks. However, the high tidal mudflats flanking the most seaward chenier stand within a few centimetres of mean high water springs and consequently this level was used as datum for all subsequent levelling. In Figure 4 the relative elevations of the crest and base of each chenier are shown. The crests are somewhat irregular and may be somewhat eroded. The true base of the chenier lies as much as 1 m below the apparent (exposed) base. The significance of the elevation data will be discussed in more detail later.

AGE OF THE CHENIERS

Woody material is sparse in the Broad Sound cheniers, consequently all dating was undertaken on shell material. The samples were obtained from the crest of the ridge, below the zone of soil development and obvious staining. This generally involved obtaining a grab sample from the bottom of a hole 50 - 100 cm deep, from which the least-weathered shells were hand picked. It was decided to use oyster shells for dating purposes as these are obviously of marine origin and in addition are ubiquitous in the cheniers. Oyster shells also have the additional advantage that the primary shell material is calcitic and not aragonitic, thus minimizing any recrystallization effects. The oyster shells were leached with hydrochloric acid to remove the outer one third of the shell. CO_2 was then evolved from the inner portion of the shell for use in the age determination. This procedure was adopted to remove any surface material which might possibly be contaminated (Olson and Blake, 1961): post-depositional weathering can render the otherwise tight calcite structure somewhat permeable in the outer layers. In a moist environment this could lead to exchange between carbonate of the shell and bicarbonate in solution in equilibrium with atmospheric CO_2, which has a C^{14} content foreign to that of the sample. Consequently, dating the whole of the shell could possibly lead to erroneous results. To check for such contamination in the environment studied, the outer, middle and inner thirds of one shell sample were dated (sample ANU-903, Table 1). Although the outer portion of the shell appears to give the oldest date, in fact all three dates are in statistical agreement to within two sigma, suggesting that post-deposition modification of the age is minimal. In addition, X-ray diffraction analysis of the shell material indicated that there had been no recrystallization. Counting was carried out in the Radiocarbon Laboratory of the Australian National University using the benzene liquid scintillation techniques developed for this purpose (Polach & Stipp, 1967; Polach, 1969) and a counting time of approximately 1000 minutes. The ages are reported with respect to the 0.95 C^{14} activities of N.B.S. oxalic acid, the international radiocarbon dating standard, using a C^{14} half life of 5570 ± 30 years. The results were normalized to allow for C^{13}/C^{12} isotopic fractionation, assuming a delta C^{13}, value of $0 \pm 2^{0}/_{00}$ for marine carbonate (Craig, 1954; Brocker and Olson, 1959; Polack, 1969). This normalization procedure allows the measured C^{14} concentration to be expressed relative to 19th century wood with a delta C^{13} of $-25^{0}/_{00}$.

The dates obtained for the cheniers in the Charon Point and the Hoogly-Waverley Creek areas are given in Table 1. The relative location of the samples referred to by ANU number is shown in figures 1, 2 and 5. From the ages obtained it is evident that the oldest chenier has an age of about 5000 years B.P. and that the ridges become progressively younger seawards. The whole of the Broad Sound chenier sequence is therefore of Holocene age. ANU-791 and 907 are not synchronous; the chenier represented by ANU-904 is not present at Charon Point. It appears, however, that some of the cheniers formed at the same time in both the Charon Point and the Hoogly-Waverley Creek areas. ANU-792 from Charon Point may be correlated with ANU-905 from the Hoogly-Waverley Creek area at the 95% confidence level (mean age of 3570±70 years). At the 99% confidence level ANU-793 may be correlated with ANU-906 and -902 (mean age of 2510±50 years). Similarly at the 95% confidence level ANU-903 may be correlated with ANU-901 and 900 (mean age of 1630±50 years). The coincidence of chenier ages at two different sites is important not only for showing that chenier development was synchronous but also because it strongly suggests that reworking of old shell beds was not an important factor. It is highly unlikely if the shells were derived that cheniers at localities 15 km apart would give synchronous dates. This is also supported by the consistent sequences of decreasing age from inner to outer cheniers.

ORIGIN OF THE BROAD SOUND CHENIERS

Brouwer (1953) describes a chenier sequence from the Surinam coast and states that "nearly all of the ridges were gradually developed from east to west by means of beach drift. Nothing indicates that the ridges originated as offshore bars and moved landwards only afterwards". Russell and Howe (1935) suggested that the cheniers of the Louisiana coast represent beaches that have been driven landward over the coastal plains. They regarded the cheniers as the result of beach reworking along a retreating coastline. Byrne, Le Roy and Riley (1959), and Gould and McFarlan (1959) concluded that the ridges are accretionary features, which formed immediately seaward of previously formed mudflats, along an essentially stable shoreline.

Coleman (1966) considers that both accretion and reworking operate simultaneously along different portions of the Gulf shoreline. Todd (1968) suggests that three conditions are necessary for formation of cheniers: (i) stability, or recession of sea level; (ii) a variable supply of sediments from rivers; and (iii) effective longshore currents.

Drilling has revealed that everywhere in the Broad Sound area the coastal plains are underlain by a regressive sequence comprising intertidal muds and sands at the base, followed by mangrove deposits which in turn are overlain by high tidal mudflats, and finally, if the regression has proceeded to completion, by coastal grasslands. Similarly the dates on the cheniers indicate a progressive seaward advance of the plain. There is, however, no indication that any marked relative sealevel change accompanied this seaward movement of the shoreline. It is apparent from Figure 4 that whether the base or the top of the chenier is taken, the change in elevation between the highest and lowest cheniers in either sequence is less than 1 m. The Charon Point sequence shows a fairly regular increase in the height of the chenier with increasing age; however, neither the base elevations at the same locality nor the elevation in The Hoogly-Waverley Creek sequence reflect this variation. Thus over a 5000 year interval there is no evidence from the Broad Sound chenier sequences of any regular trend of changing sealevel. Moreover, any changes which might be deduced from elevational changes cannot have been greater than 1 metre. Therefore the sequence appears to be the result of depositional progradation rather than eustatic change of sealevel. In the course of this progradation there were, however, several periods of chenier development.

Depositional conditions in the Broad Sound area over the past 5000 years appear to have approached stability, the first of Todd's three conditions. There is no effective unidirectional longshore current in the Broad Sound area, but tidal currents are an equally effective mechanism for redistributing sediments alongshore, as the 10 m tide gives rise to currents of up to four knots. The variability of the sediment supply into Broad Sound is rather more conjectural though undoubtedly possible. The abundance of cheniers on the west and southwest sides of the Sound, where all the major estuaries are located, compared with the paucity of beach ridges on the east side does suggest that supply of sediment from the rivers was a major factor in chenier development. In addition the southwest side is less sheltered than the eastern side, the wave fetch is greatest, and the shore more subject to the erosive action of waves driven by the northerly and northeasterly winds. Consequently any decrease in sediment supply to this region would very rapidly be followed by coastal erosion and regression. Since the cheniers extend to a metre below the surrounding flats (Fig. 4), in some instances down to mangrove deposits (Fig. 3), and exhibit a seaward depositional dip they are unlikely to be beach deposits which have been driven across the mudflats.

Investigation of the modern depositional conditions offshore, using such techniques as dredging, coring, and echosounder and seismic (sparker) traverses, did not reveal any offshore bar features analogous to the cheniers in Broad Sound. A feature comparable with the cheniers feature was however observed at Charon Point, where mangrove is being destroyed at the present time. As the trees die so the mangrove sediment, which consists predominantly of mud with minor sand and shells, is acted on by high energy conditions (Fig. 6A). The mud, and to some extent the sand is carried in suspension completely out of the mangrove environment. The shells and the remainder of the sand are carried landward by wave action through the few remaining mangrove stumps until the swash line is reached, at which point shells and sand are deposited, gradually forming a beach immediately landward of the mangrove (Fig. 6B). If this were the only process then all cheniers would rest on mangrove deposits as shown in figure 3. This is not the case however as some cheniers do not extend below the mudflat deposits. In such cases strong wave action may have driven the shell material beyond the edge of the mangrove zone, onto the high tidal mudflats.

In an uninterrupted progradational sequence, mangrove sediments will ultimately give way to mudflats as the shoreline progrades. Cheniers reflect periodic interruptions to this sequence, forming when the mangrove sediment is exposed to erosion and the shell material winnowed out. This destruction of the mangrove could be the result of a change in sealevel, storm activity or a decrease in sediment supply. It has already been demonstrated that there has been no marked sea level change; in any case such a change would have affected the whole of Broad Sound whereas the cheniers are primarily restricted to the mouths of the major estuaries. Storm activity is also a potential agent for the formation of cheniers, particularly as the region is frequently subjected to severe tropical storms during the summer months. A strong cyclone passed through the Broad Sound area in the summer of 1971; it was of sufficient force to break large trees on land in the Charon Point area, but had no noticeable effect on the mangrove and certainly did not produce any feature analogous to a chenier on the landward side of the mangrove. The third and perhaps the most reasonable explanation for the death of the mangrove and the subsequent development of the chenier is that a decrease in supply of sediment resulted in erosion exceeding the rate of depositional progradation; the mangrove died or became greatly depleted as the result of being subjected to higher energy erosive conditions, particularly in those areas exposed to strong wave action, and the chenier finally developed from the winnowed out shell material.

SIGNIFICANCE OF THE AGE OF THE CHENIERS

Since a decrease in sediment supply was probably responsible for the development of the cheniers, it is reasonable to expect that some of the cheniers would have developed synchronously at the Charon Point and The Hoogly-Waverley Creek sites, as both regions are situated at the mouth of the Styx River (Fig. 1). Thus we indeed find that cheniers were developed (and presumably the sediment supply decreased) at both sites at about 3570, 2510 and 1630 years B.P. There were also periods of chenier development at one or the other site at about 5020, 4520 and 740 years B.P. If these dates are plotted against maximum distance from the shoreline (Fig. 5) it appears that from about 5000 to 1000 years B.P. the rate of progradation at both sites was comparatively constant, averaging about 12 cm per year in the Charon Point area and 11 cm per year in The Hoogly-Waverley Creek area. More recently, the rate of progradation in the Hoogly-Waverley Creek area appears to have increased markedly, though it has decreased slightly in the Charon Point area. This is in accord with the fact that the Charon Point area is being eroded at the present time. Conceivably the material being eroded from this area is contributing to the increased rate of progradation elsewhere.

If the dates of chenier sequences from other parts of the world are considered (Fig. 7) it is apparent that no correlation is possible between these widely separated areas; nor would one expect any such correlation if the cheniers have formed in response to some purely local event such as a decrease in the rate of sediment supply.

What is evident from all these widely scattered occurrences is that none of the cheniers are older than about 5000 years B.P. Thus, it follows from the point made by Todd (1968) regarding the necessity of sealevel stability for the formation of cheniers, that until about 5000 years B.P. sea-level was rising but since that time has been relatively stable. This second conclusion is reached both from the lack of cheniers older than about 5000 years B.P. and from evidence in the Broad Sound area that there has been no significant change in the elevation of the cheniers with age. The maximum possible difference in altitude between the highest and lowest cheniers (fig. 4) is in the order of only 1 metre. This would seem inconsistent with a sea level of -5.5 m at 5500 years B.P. given by Gould and McFarlan (1959) unless there was a very rapid rise between 5500 and 5000 B.P. Coleman and Smith (1964), considered that sea-level reached the present day level about 3650 years B.P. The Broad Sound evidence undoubtedly conflicts with the views of Fairbridge (1961) and others (see review by Guilcher, 1969), who suggest that sea level has ranged between +3 m and -4 m in the past 5000 years. Morner (1969, 1971) on the other hand considers from various lines of evidence that there has been no Holocene high sea-level of greater than +0.4 m.

Hopley (1968, 1971) believes from evidence on the North Queensland coast that there was a Holocene high sea level stand of 3 to 4 m. Bird (1971) points to the difficulty in establishing the true elevation of coastal features, but has deduced from the age of a beach ridge in the Cairns (North Queensland) region, that "Sea level stood at or slightly above its present day level relative to the land, in the vicinity of Admiralty Island about 5500 years ago". Drawing on evidence from the southern Queensland and New South Wales coasts Thom et al. (1969, 1972) question the validity of a Holocene high sealevel. Subsidence in the Broad South chenier plains does not appear to have been a significant factor over the past 5000 years; there is, for instance, no evidence of downwarping of the substrata below cheniers. In addition the area could not have been affected by post-glacial isostatic rebound and appears to be tectonically stable. It is therefore considered that there is no evidence from the Broad Sound area of any major change in sea level over the past 5000 years.

CONCLUSIONS

1. The chenier plains of the west side of Broad Sound formed as a result of depositional progradation.

2. The cheniers are believed to have developed in response to phases of

decreased sediment supply from adjacent estuaries leading to the erosion of mangrove by wave action, the subsequent winnowing out of shell material and the attendant formation of a chenier landward of the mangrove deposits.

3. The chenier plains have developed over the past 5000 years; during the period 5000 to 1000 years B.P. progradation proceeded at a maximum rate of about 12 cms per year, but was interrupted by several phases of erosion and associated chenier development.

4. The lack of any significant change in the elevation of the chenier with age on the west side of Broad Sound, suggests sea level reached its present level about 5000 years ago and since that time has varied by no more than $\pm$ 1 m.

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TABLE 1. RADIOCARBON DATES ON OYSTER SHELLS FROM CHENIERS IN THE BROAD SOUND AREA, QUEENSLAND.

Lab. Number	Age (Years BP)	Remarks
Charon Point Area		
ANU 791	4520 ± 125	Outer one-third of sample removed by dilute HCl. Only inner portion used for age determination.
ANU 792	3465 ± 110	
ANU 793	2480 ± 100	
ANU 903A	1640 ± 100	Dated on outer one third shell.
ANU 903B	1410 ± 90	Dated on middle third of shell.
ANU 903C	1430 ± 90	Dated on inner one third of shell.
Hoogly-Waverley Creek Area		
ANU 907	5020 ± 90	Outer one third of sample removed by dilute HCl. Only inner portion used for age determination.
ANU 905	3640 ± 80	
ANU 906	2530 ± 70	
ANU 902	2500 ± 70	
ANU 901	1710 ± 70	
ANU 900	1670 ± 70	
ANU 904	740 ± 70	

CAPTIONS TO FIGURES

Figure 1. Location of cheniers in the Broad Sound area.

Figure 2A. The chenier plains of the Hoogly-Waverley Creek area, looking west from an altitude of about 1000 m. Rosewood Island in the foreground. Cheniers dated as follows: V - 740 years B.P., W - 1670 years B.P., X - 2500 years B.P., Y - 3640 years B.P., Z - 5020 year old chenier. White areas are salt-encrusted high tidal mudflats.

Figure 2B. Cheniers at Charon Point from an altitude of about 750 m; dated as follows; K - 1640 years B.P., L - 2480 years B.P., M - 3465 years B.P., N - 4520 years B.P.

Figure 2C. Tree covered chenier (age of 4520 years B.P.) at Charon Point, flanked by tidal mudflats.

Figure 3. Section through the 740 year old chenier at the Hoogly-Waverley Creek locality.

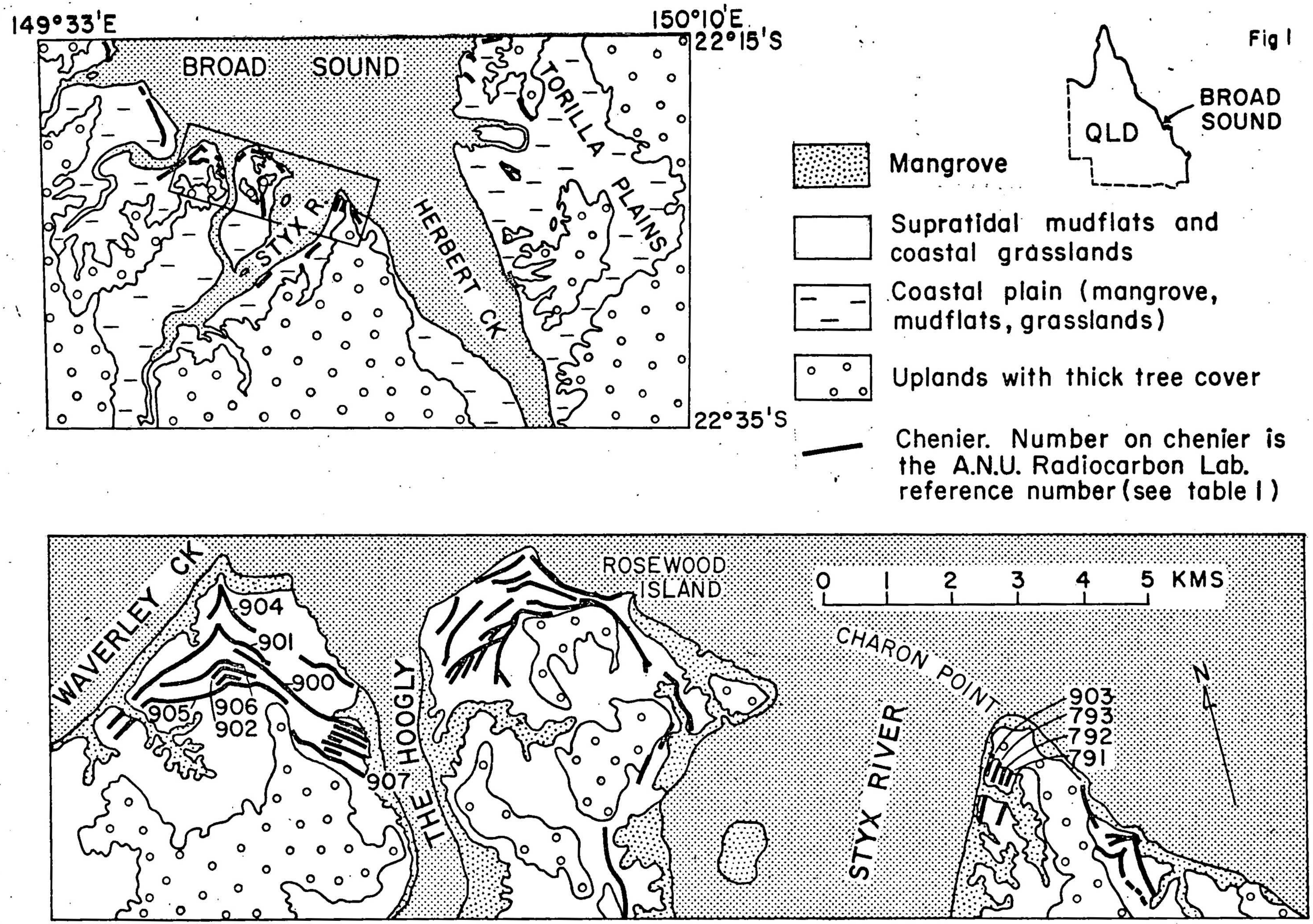
Figure 4. Variation in relative elevation of the base and crest of the Broad Sound cheniers with age.

Figure 5. Variation in the age of cheniers with distance from the shoreline.

Figure 6A. Mangrove mud containing shell material which is being eroded at the present time in the Charon Point area. The hand lens has a diameter of 2 cms.

Figure 6B. Possible modern analog of a chenier with a beach forming as a result of the erosion of mangrove near Charon Point. Dead mangrove trees in the foreground are 3-4 m high.

Figure 7. Comparison of the age of the Broad Sound cheniers with other chenier and beach ridge sequences. 1 - Broad Sound data from this publication; 2 - Firth of Thames, New Zealand - after Schofield (1960, 1964); 3 - North-west Gulf of Mexico - data taken from Thomson (1958, Fig.35); 4 - South-western Louisiana - after McFarlan (1961).



To accompany Record 1972/94

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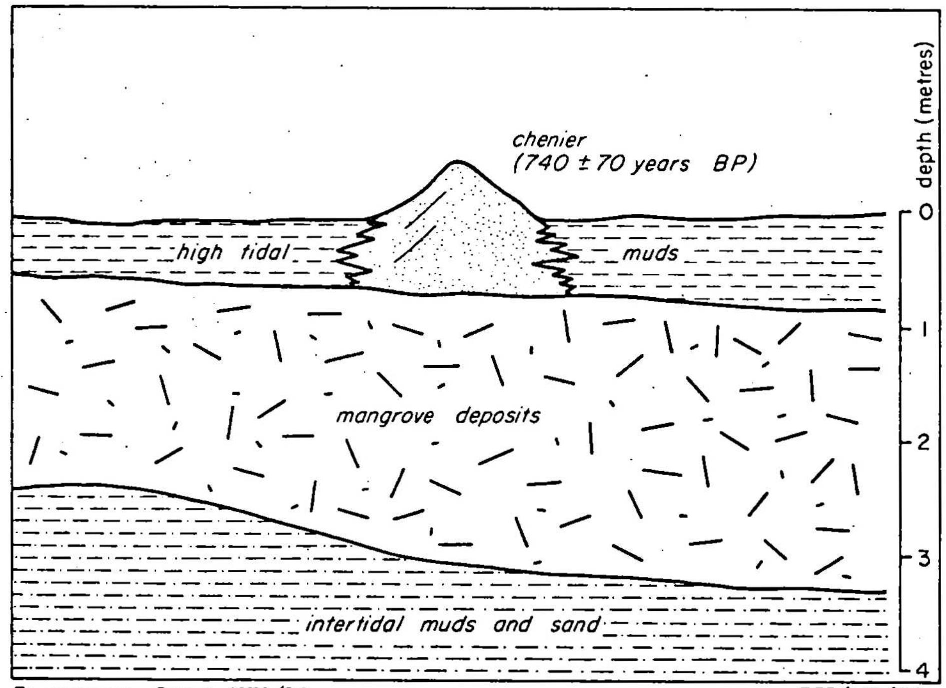
Fig 2

A

B

C

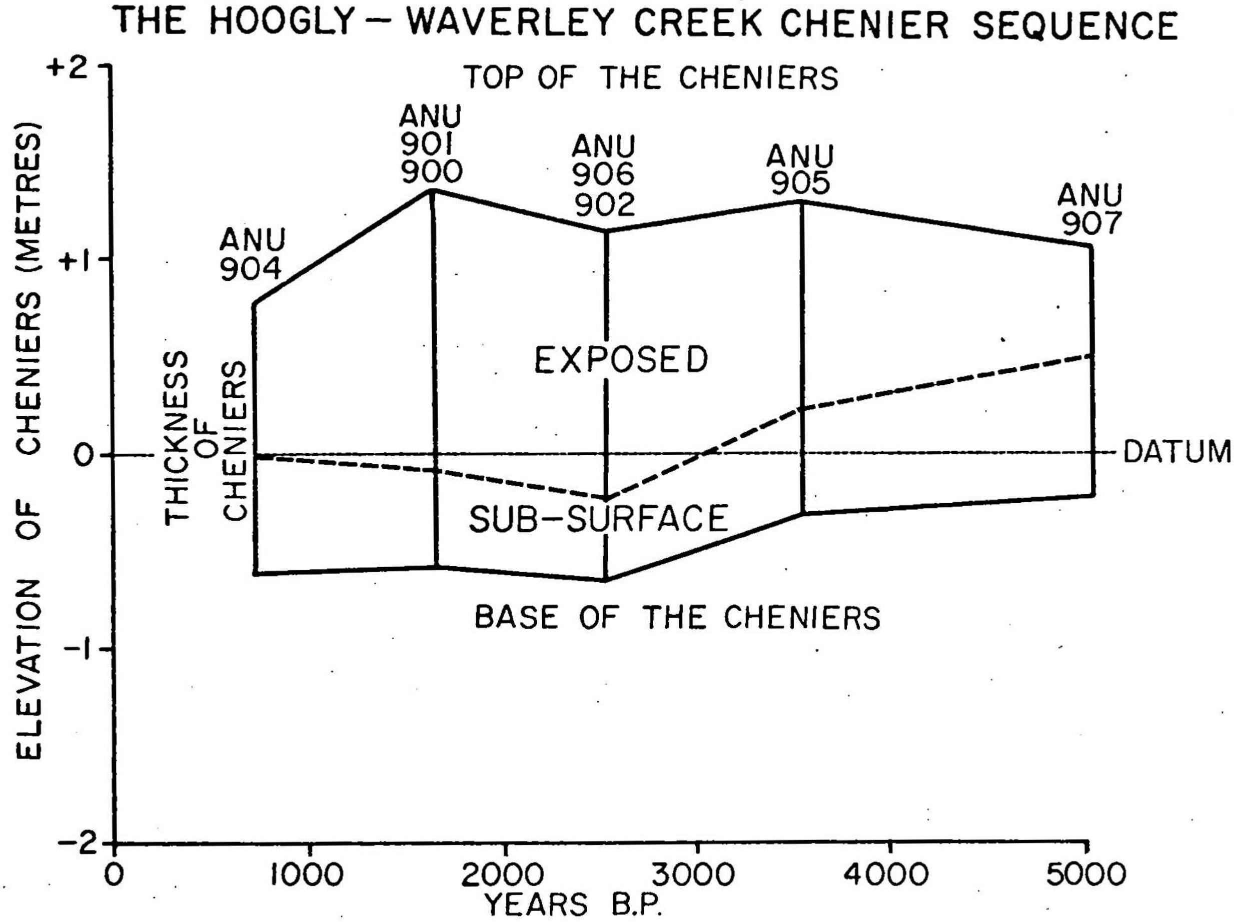
Fig 3

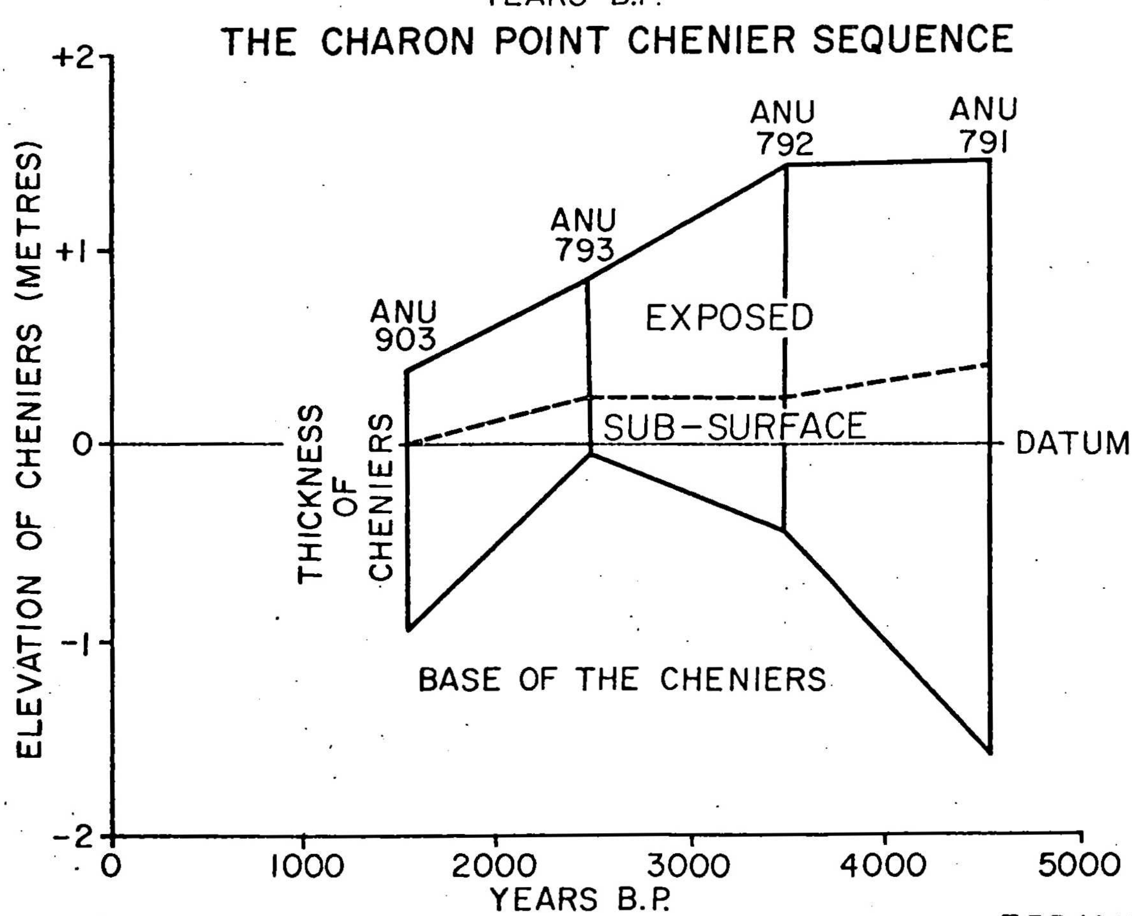


To accompany Record 1972/94

F55/A12/39

Fig 4





To accompany Record 1972/94

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To accompany Record 1972/94

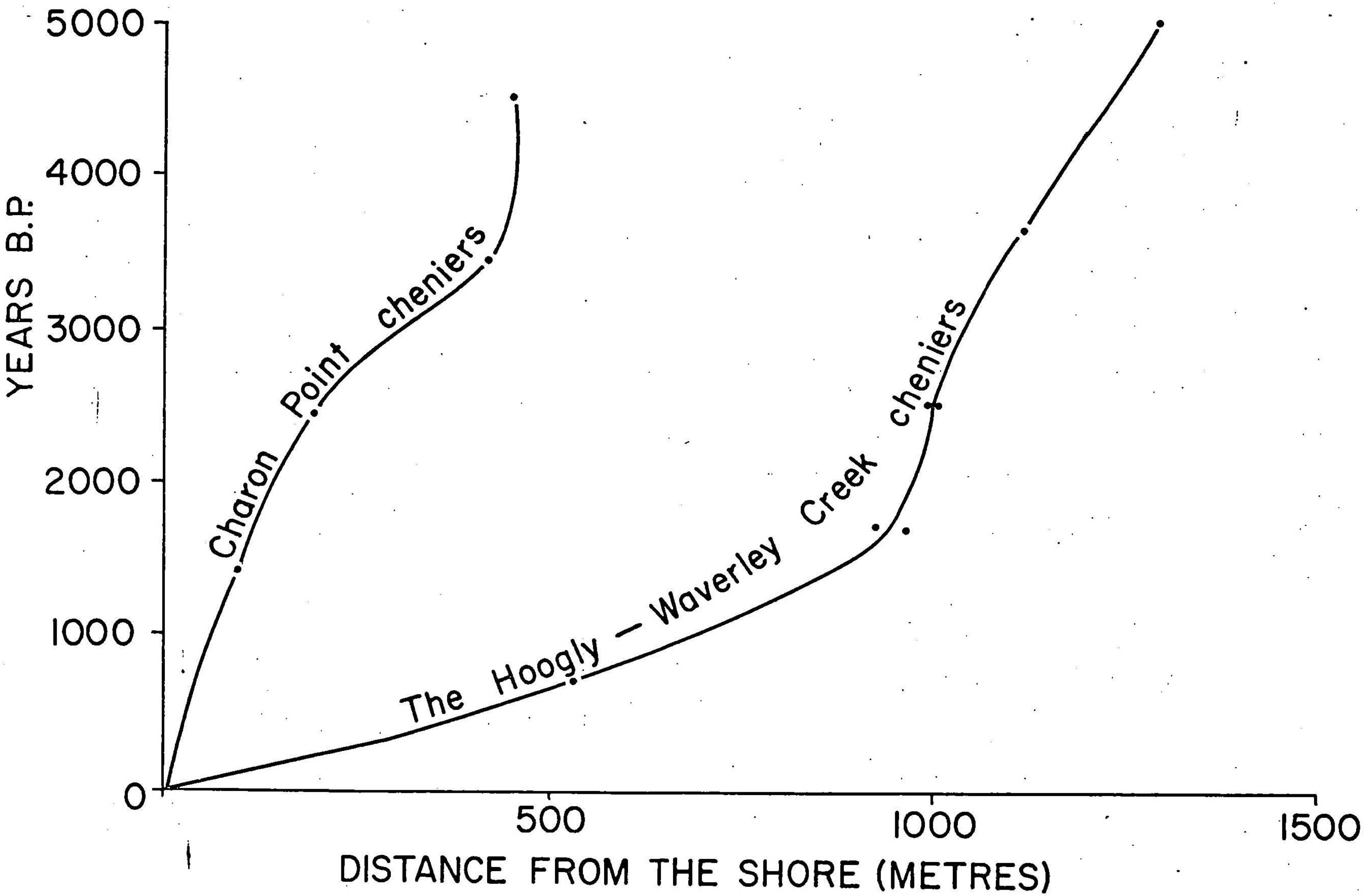

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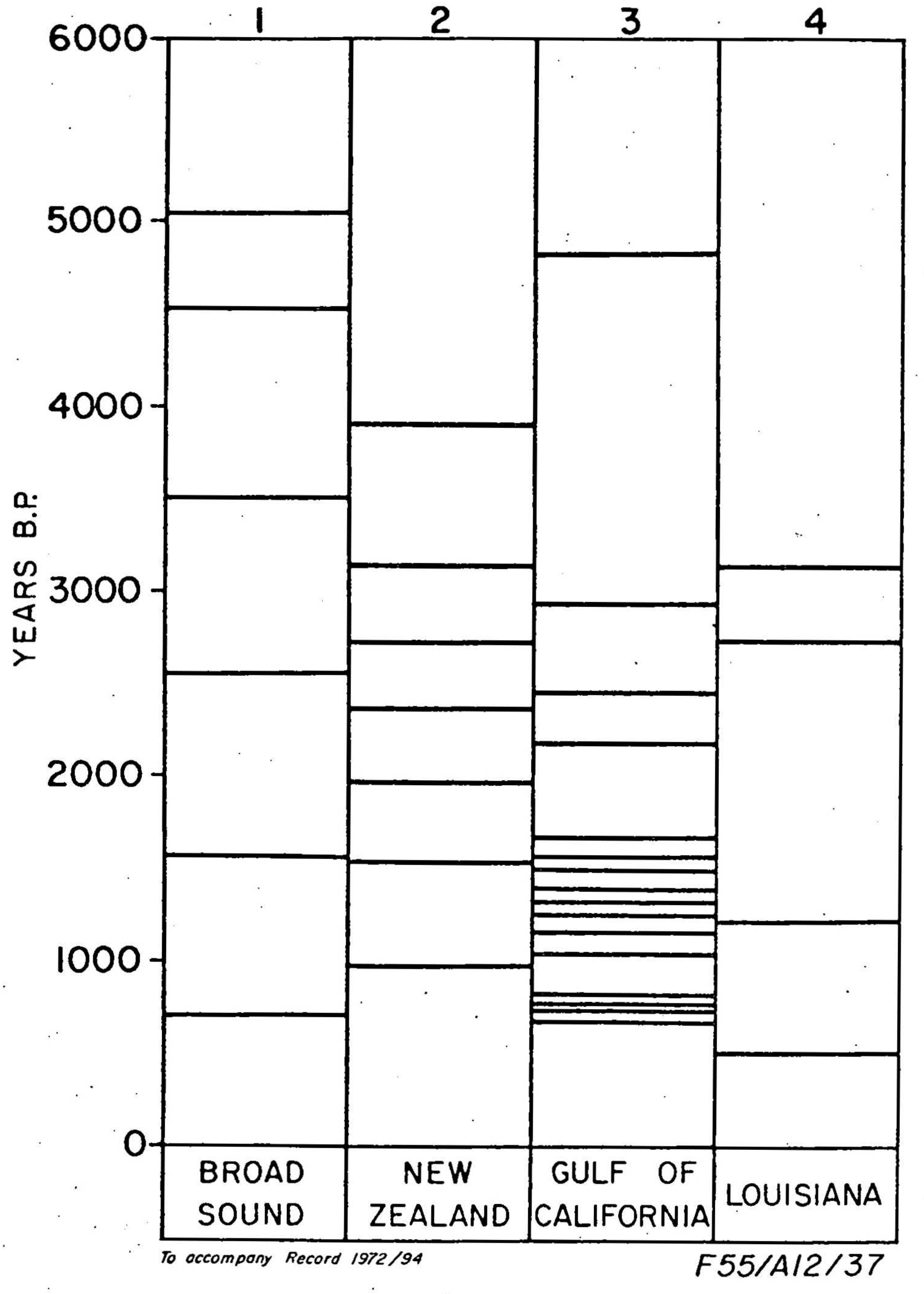
Fig 5

Fig 6

A

B

Fig 7



To accompany Record 1972/94

F55/A12/37