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CAINOZOIC HISTORY OF THE PENINSULA EAST OF BROAD SOUND, QUEENSLAND

by

W.A. Burgis

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SUMMARY

Tertiary faulting and uplift followed by erosion produced the ranges which now form the backbone of the peninsula east of Broad Sound. Detritus from the ranges spread particularly westward to form extensive alluvial deposits. Some alluvium and bedrock were partly lateritized, probably in the late Tertiary. Quaternary erosion stripped some laterite, and new soils developed in response to a variety of climatic, floral, and groundwater regimes.

Sea cliffs were formed at the height of a Holocene marine transgression and are now preserved inland. Progradation of the shoreline since their formation has led to the seaward migration of successive sedimentary environments - shallow marine, intertidal, mangrove, supratidal - as reflected in the sedimentary sequence.

INTRODUCTION

Stratigraphic drilling and surficial mapping were undertaken on the peninsula east of Broad Sound, Queensland, to establish its Cainozoic history and to provide a detailed picture of late Quaternary and Holocene land-sea level relationships. This information is essential background for the current detailed environmental study of the Broad Sound estuary.

Three and a half days were spent mapping surficial sediments and geomorphic features along the eastern edge of the coastal grasslands between Torilla Plains homestead and The Hollins (Figs. 1, 4). Traverses were also made to the headwaters of Spencer and Couti Uti Creeks and from Couti Uti homestead to Macdonald Point. Detailed information was also obtained about surficial deposits on the forested upland between drill holes BMR St Lawrence Nos. 1 and 2 west of Torilla Plains homestead (Figs. 1, 4).

Drilling sites were selected before the 1971 field season to provide traverses across the coastal grasslands at several latitudes. The summer of 1971 was very wet, however, and treacherous conditions on the clayey coastal grasslands severely restricted the mobility of the Mayhew drilling rig. Consequently, sites of the seven diamond-drill holes sunk in May were chosen primarily on the basis of very limited 1971 accessibility and give a poor scatter of data points.

In June 1971, however, 16 hand auger holes were sunk by P.J. Cook and W. Mayo at geologically significant sites from Fort Cope south almost to Fernlea. These holes greatly improved the geographic distribution of data points (Fig. 1).

Because this study is especially concerned with Quaternary history, diamond drilling was terminated in bedrock or Tertiary laterite. Lack of time prevented drilling BMR Port Clinton No. 5 to bedrock or laterite. In the seven holes a total of 79.96 m was drilled, and 24.00 m were cored. Individual holes range from 1.83 to 35.97 m deep. Table 1 presents diamond-drill hole statistics.

The depth of hand auger holes was restricted by the capabilities of the instrument and high water content of the lower sediments which limited recovery. A total of 45.22 m of sediment was augered in 16 holes which range from 1.79 to 4.20 m deep and have an average depth of 2.83 m. Table 2 summarizes auger hole statistics.

The Geological Society of America Rock-Color Chart has been used for soil and rock colour determinations.

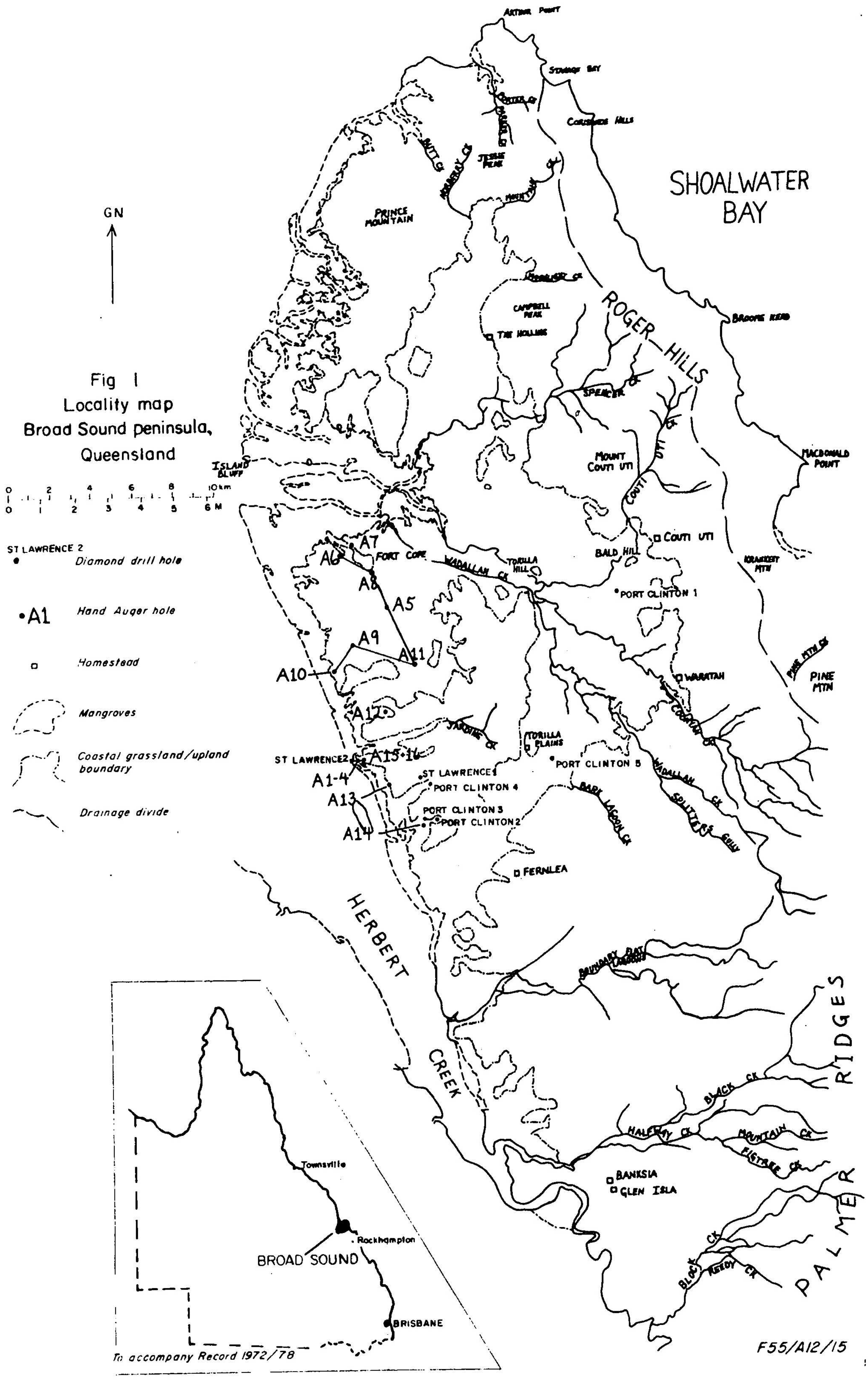

Fig 1
Locality map
Broad Sound peninsula,
Queensland

TABLE 1

DIAMOND DRILL HOLE STATISTICS

DIAMOND-DRILL HOLE	TOTAL DEPTH (m)	TOTAL RECOVERY CORE	THICKNESS OF UNCONSOLIDATED SEDIMENT (m)		THICKNESS OF CONSOLIDATED SEDIMENT (m)	THICKNESS OF LATERITE (m)	UNIT IN WHICH HOLE TERMINATED	MINIMUM THICKNESS OF TERMINAL UNIT (m)	REMARKS
			TOP OF HOLE	BOTTOM OF HOLE					
Port Clinton 1	5.79	2.59	3.56	-	-	1.99	Weathered granite	0.27	
Port Clinton 2	13.72	2.41	0.56	-	-	13.16	Laterite	13.16	Circular structure
Port Clinton 3	9.17	3.61	2.08	1.54	5.55	-	Gravel + sand	0.16	Consolidated sedimen = 'grey' mottled and nodular sandstone
Port Clinton 4	4.64	3.07	2.87	0.95	0.61	-	Gravel	0.95	Consolidated sedimen = 'grey' sandstone
Port Clinton 5	35.97	6.45	35.97	-	-	-	Sandy clay + fine gravel	13.11	
St Lawrence 1	1.83	-	1.22	-	-	0.60	Laterite	0.60	Edge of circular structure
St Lawrence 2	8.84	5.87	5.10	0.14	3.12*	-	Greyish yellow mottled sand-stone + conglomerate	0.48	Consolidated sedimen = 'grey' sandstone a mottled sandstone an conglomerate

*Excluding terminal greyish yellow sandstone

TABLE 2

AUGER HOLE STATISTICS

AUGER HOLE	TOTAL DEPTH (m)	THICKNESS OF UNCONSOLIDATED SEDIMENT (m)	THICKNESS OF LATERITE (m)	UNIT IN WHICH HOLE TERMINATED	MINIMUM THICKNESS OF TERMINAL UNIT
1	3.38	3.04	0.34	Laterite	0.34
2	2.38	2.38	-	Gy mangrove clay	0.80
3	2.74	2.74	-	Dk gy inter-tidal (?) clay	0.61
4	2.90	0.45	2.45	Laterite	2.45
5	2.04	2.04	-	Lt olv gy mangrove clay	0.21
6	1.79	1.79	-	Gravel	0.74
7	2.87	2.87	-	Gn-gy inter-tidal silt + clay	0.13
8	3.67	3.67	-	Dk gn-gy inter-tidal clay	1.47
9	3.06	3.06	-	Dk gn-gy inter-tidal clay	1.24
10	3.06	3.06	-	Dk gn-gy inter-tidal clay	1.55
11	2.96	2.88	-	Weathered metamorphic rock	0.08
12	2.00	1.82	0.18	Laterite	0.18
13	2.51	1.80	1.32	Gy sand + slightly weathered bedrock?	0.11
14	4.20	4.20	-	Olv gy inter-tidal clay	1.76
15	2.46	0.61*	1.85	Laterite	1.85
16	3.20	0.84*	2.36	Laterite	2.36

*Red earth soil profile?

General Geography

The study area lies within the St Lawrence and Port Clinton 1:250 000 Sheet areas. It encompasses the peninsula between Broad Sound and Shoalwater Bay, Queensland (Fig. 1).

The area has a subtropical, subhumid climate. Rainfall averages 1 000 mm per annum and is mainly concentrated in the summer months, much of it falling in thunderstorms (Malone, 1970). Flooding is restricted to summer, and streams are lowest in late winter and early spring (Comm. Bur. Meteorology, 1965). Sea breezes considerably lower the high temperatures common most of the year farther inland. The tidal range at the head of Broad Sound is approximately 10 m (Maxwell, 1968).

Geomorphology

The peninsula lies in the coastal highlands and coastal plains landform zones of the Fitzroy region (Galloway, 1967). The boundary between them runs roughly southeastward down the peninsula from Prince Mountain to Waratah homestead (Fig. 1) and separates hilly land with peaks rising to 375 m in the east from a broader area of plains and rolling country in the west.

Lower (?) Palaeozoic metamorphic rocks form Prince Mountain in the highland zone (Fig. 2). The Roger Hills are composed of the same resistant metamorphic rocks and form the most prominent section of the drainage divide which runs along the eastern edge of the peninsula (Fig. 1). South of Couti Uti homestead alluvium covers highland slopes west of the drainage divide (Fig. 4). Relatively high land is close to the shore on the western coast of Shoalwater Bay. The development of mangrove swamps, supratidal flats, and coastal grassland there is thus restricted to small areas in sheltered inlets (Galloway, 1967). Some inlets are protected by old beach ridges which line sections of this shore (Fig. 4).

Coastal grassland, alluvial plains, supratidal flats, and mangrove swamps are extensively developed in the lowlands of the western two-thirds of the peninsula (Fig. 4, Pls. 2, 3, 6, 9). Coastal grassland grows over large flat areas of unconsolidated marine sediments from the highlands westward to supratidal flats and mangrove swamps on the eastern coast of Broad Sound and Herbert Creek. These grasslands are cut by a complex pattern of supratidal channels. Supratidal flats occupy small patches on the flanks of the relatively steep highland topography of the Prince Mountain area but are extensive adjacent to the low rolling uplands of the coastal plains south of Fort Cope.

Low hills protrude through broad alluvial flats in the southern part of the lowlands zone (Fig. 4). The upland area west of Torilla Plains homestead stands above coastal grassland and supratidal flats and is developed on the Lower (?) Palaeozoic metamorphics common in the highlands zone (Fig. 2). The uplands between Wadallah and Block Creeks are underlain by the Permian or Mesozoic Pyri Pyri Granite. The Palmer Ridges are a line of fairly rugged granite hills and knobs which extend into the coastal plains from the highlands.

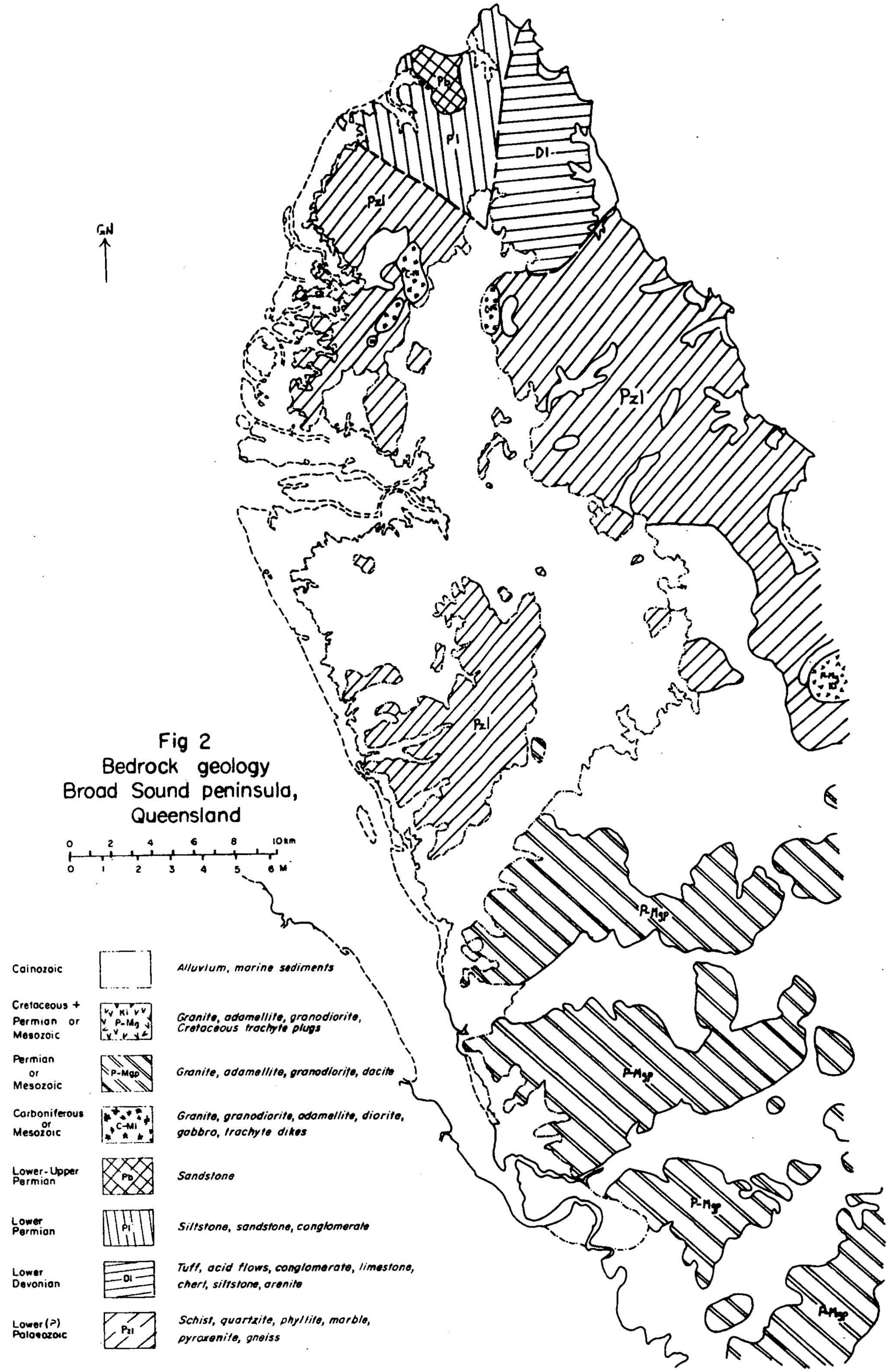

Fig 2
Bedrock geology
Broad Sound peninsula,
Queensland

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F55/A12/16

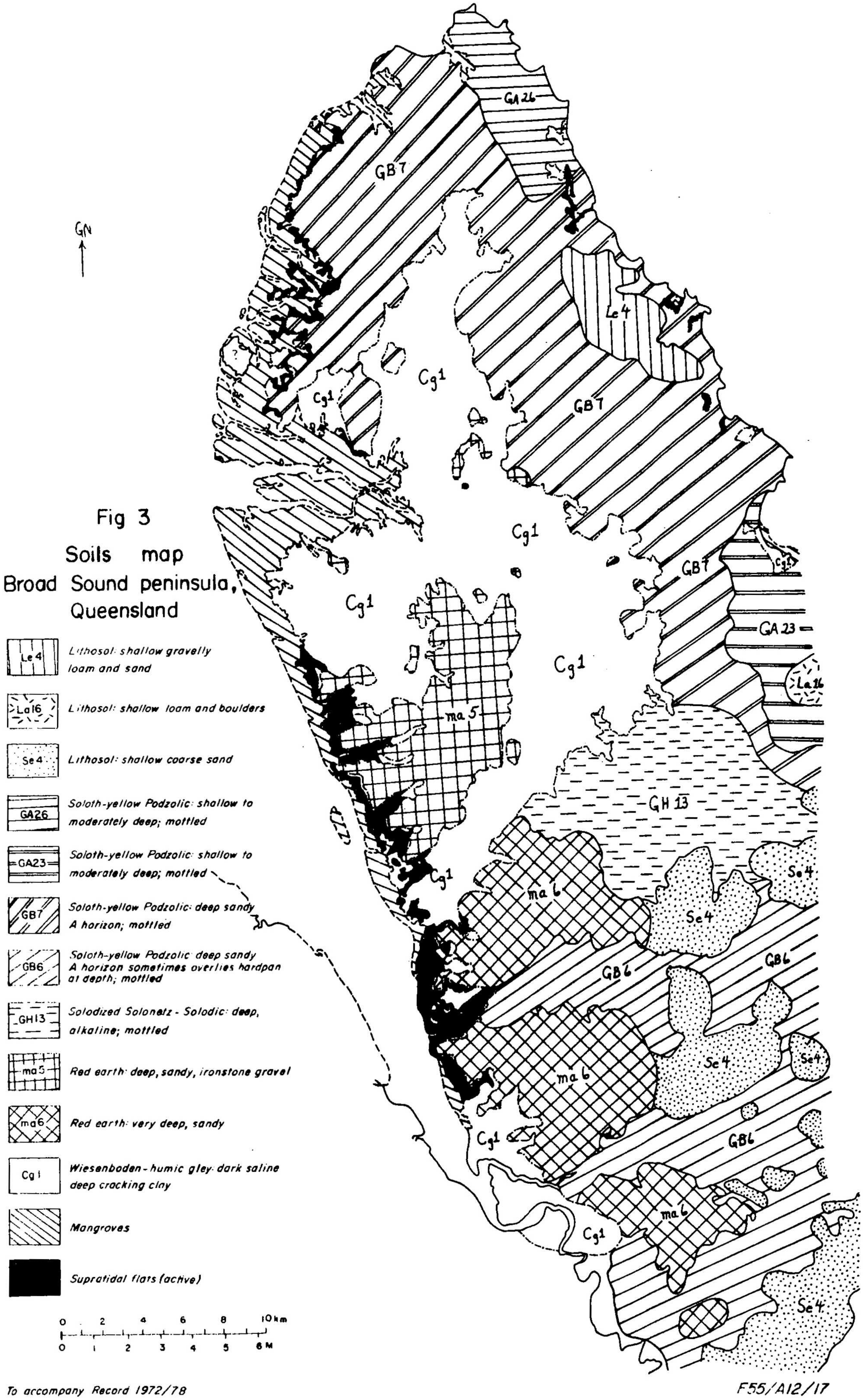

Fig 3
Soils map
Broad Sound peninsula,
Queensland

To accompany Record 1972/78

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Broad alluvial plains occupy the Coonyan-Wadallah-Bark Lagoon Creek, Boundary Flat Lagoons, Halfway Creek, and Block Creek valleys (Figs. 1, 4); alluvium shed from the eastern highlands during the Cainozoic was deposited in the western lowlands.

Soils

The mapping of soils by CSIRO has provided important clues to the Cainozoic history of the area. Figure 3 is a modification, based on airphoto interpretation, of part of the map accompanying Isbell & Hubble's (1967) report on soils of the Fitzroy region. Soil descriptions and symbols are also taken from this pamphlet.

Lithosols occur on the moderate to steep slopes of the Roger Hills (Le4), the steep slopes of Pine Mountain (La16), the granite hills of the Palmer Ridges (Se4), and on the eastern, higher sections of the uplands between Bark Lagoon and Halfway Creeks (Se4). Differences in bedrock and slope have produced different soils in these areas. The occurrence of lithosols on the highest hills of the peninsula indicates that erosion has been intensive, and consequently only a thin soil cover derived directly from bedrock is present (Stace et al., 1968). These hills have been and still are the source of much of the clastic material deposited on the broad alluvial flats south of Couti Uti, in the narrow valleys of Spencer and Couti Uti Creeks, and on the coastal grasslands.

Soloths and yellow podzolic soils are widespread in the highlands and plains. These acid soils have sandy to loamy surface soils with a bleached A_2 horizon abruptly overlying mottled, tough clay subsoils (Isbell & Hubble, 1967, p. 39). They are shallow to moderately deep on the low hills on the northern tip of the peninsula (GA26) and around Pine Mountain (GA23). The soils have a deep, fine, sandy A horizon (GB7) on low hills near Prince Mountain, the Hollins, Couti Uti, and Waratah. Deep, sandy surface soils have developed on gently undulating alluvial plains around and south of the Boundary Flat Lagoons, and in places they overlie hardpans at depth (GB6). Solodized solonetz and solodic soils cover the alluvial flats between Bark Lagoon and Coonyan Creeks (GH13). Their sandy surface soils are acid, but alkaline subsoils contain carbonate. Soloths, yellow podzolic, solodized solonetz and solodic soils all occur in subhumid to seasonally humid lands which have about 500 to 1 000 mm annual rainfall (Stace et al., 1968). These soil types are in equilibrium with the present climatic regime of the Broad Sound area.

The red earths which cover low uplands in the coastal plains zone are genetically associated with relict soils (Stephens, 1971). These red earths are porous and massive, and their texture becomes more clayey with depth. Deep red surface soils (ma 5) are developed on the Lower (?) Palaeozoic metamorphic upland west of Torilla Plains homestead, and ironstone gravels are present on its upper slopes. The lower, flatter western sections of the granitic uplands between Bark

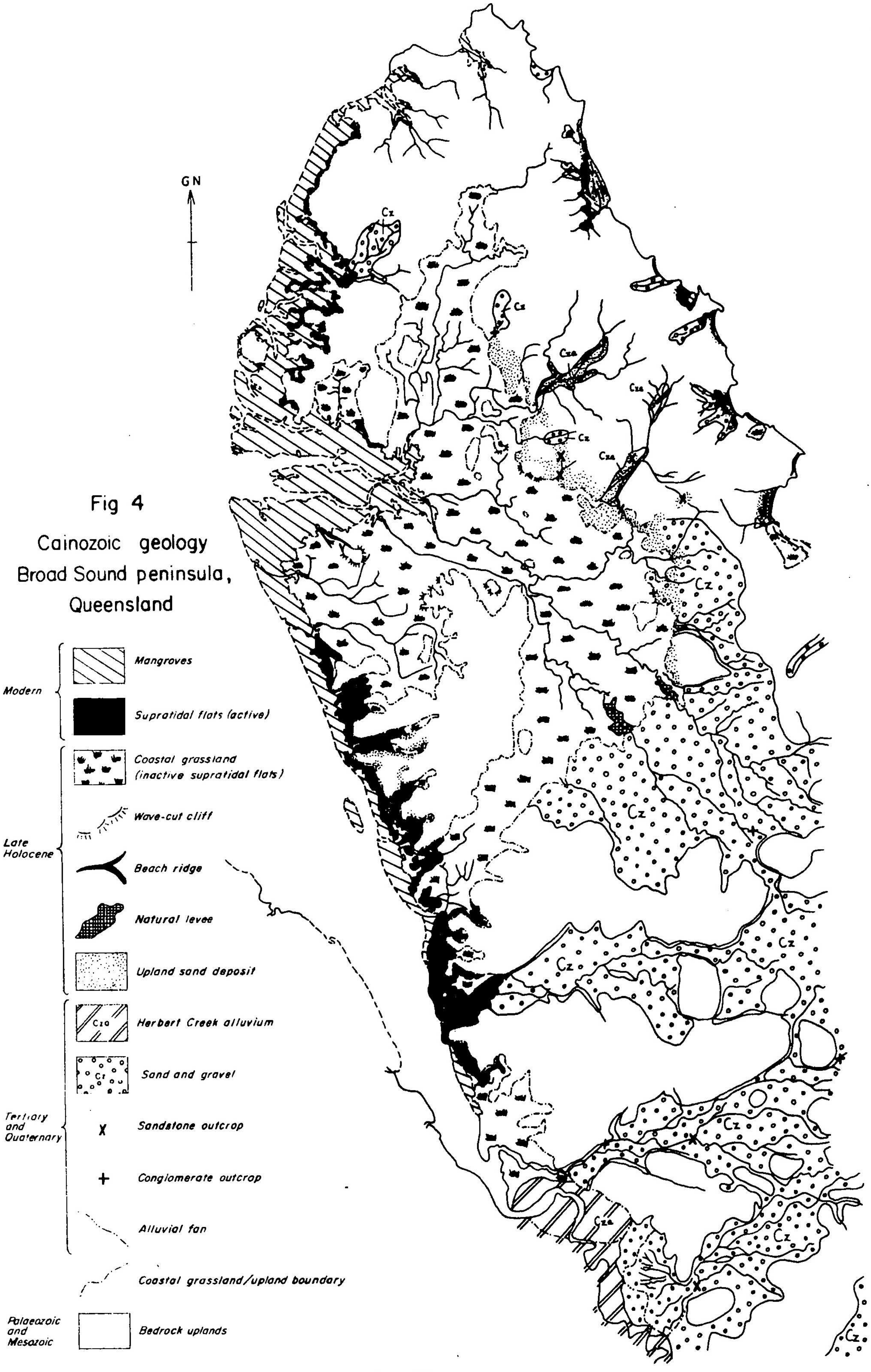


Fig 4

Cainozoic geology
Broad Sound peninsula,
Queensland

Lagoon and Halfway Creeks are covered by very deep red earths (ma 6), as are the uplands near Banksia and Glen Isla homesteads. Ferromanganiferous nodules are scattered throughout or in distinct horizons in red earth profiles. Red earths form in mild to warm subhumid or humid climates which have alternate wet and dry periods (Stace et al., 1968) and are commonly associated with remnants of old land surfaces. Truncation of the lateritic profile and weathering under different climatic conditions after lateritization have produced the red earths (Stephens, 1971, p. 13). The red earth uplands in the Torilla Plains area constitute part of an old lateritized land surface.

Dark saline deep cracking clays (Cg1), also known as wiesenboden or humic gley soils (Isbell & Hubble, 1967), cover the coastal grasslands of the Torilla Plains area. The dark colour of the surface soil is caused by large amounts of organic matter. The salt-water table fluctuates in these soils but is generally shallow. Subsoil horizons are mottled, and the clay cracks upon drying. Freshwater runoff from the uplands floods the grasslands during the wet summer season. Distribution of these soils is controlled directly by topography and groundwater levels and indirectly by climate.

MODERN SEDIMENTARY ENVIRONMENTS

During the 1970 field season modern sedimentary environments were sampled on a 2 km^2 grid which covered Broad Sound and its shores. At each sample site the environment was identified, sediment described, and the geomorphology and vegetation noted. A generalized sediment type for each environment was compiled from the field data, and sedimentary characteristics which discriminate among environments were recognized. These criteria are essential to identification of sedimentary environments in the subsurface record and therefore to reconstruction of the Cainozoic history of the area. Modern environments will be briefly described, but emphasis will be placed upon the suite of sedimentary characteristics which distinguish each environment.

Supratidal Sediments

The supratidal zone is defined by Lucia (1972, p. 160) as '.... that area of tidal-flat sedimentation out of reach of the daily tides. Its elevation could be higher or lower than the mean high-tide mark. This environment is covered only by spring or storm tides and lies exposed subaerially for long periods of time'.

Spring tides flood supratidal flats in the Torilla Plains area (Fig. 4, Pl. 9). In places their ebb and flood are guided by channels which frequently overflow (Pls. 10, 11); elsewhere high spring tide is restricted to supratidal channels which cut into coastal grasslands (Pls. 2, 3, 6). Small supratidal claypans occur in grassland near supratidal channels. The supratidal flats are generally barren except for sporadic patches of 'pig-weed' and grass (Pl. 1).

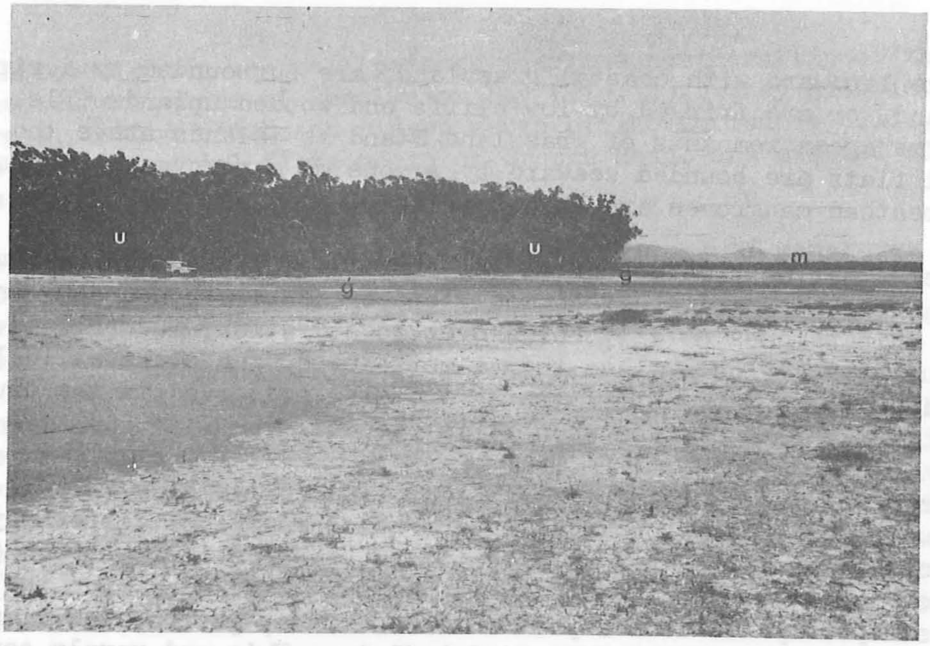


Plate 1: Active supratidal flats on east side of Herbert Creek. Wooded upland (u) surrounded by fringe of eroded grassland (g) in middle ground, mangrove (m) in right distance.

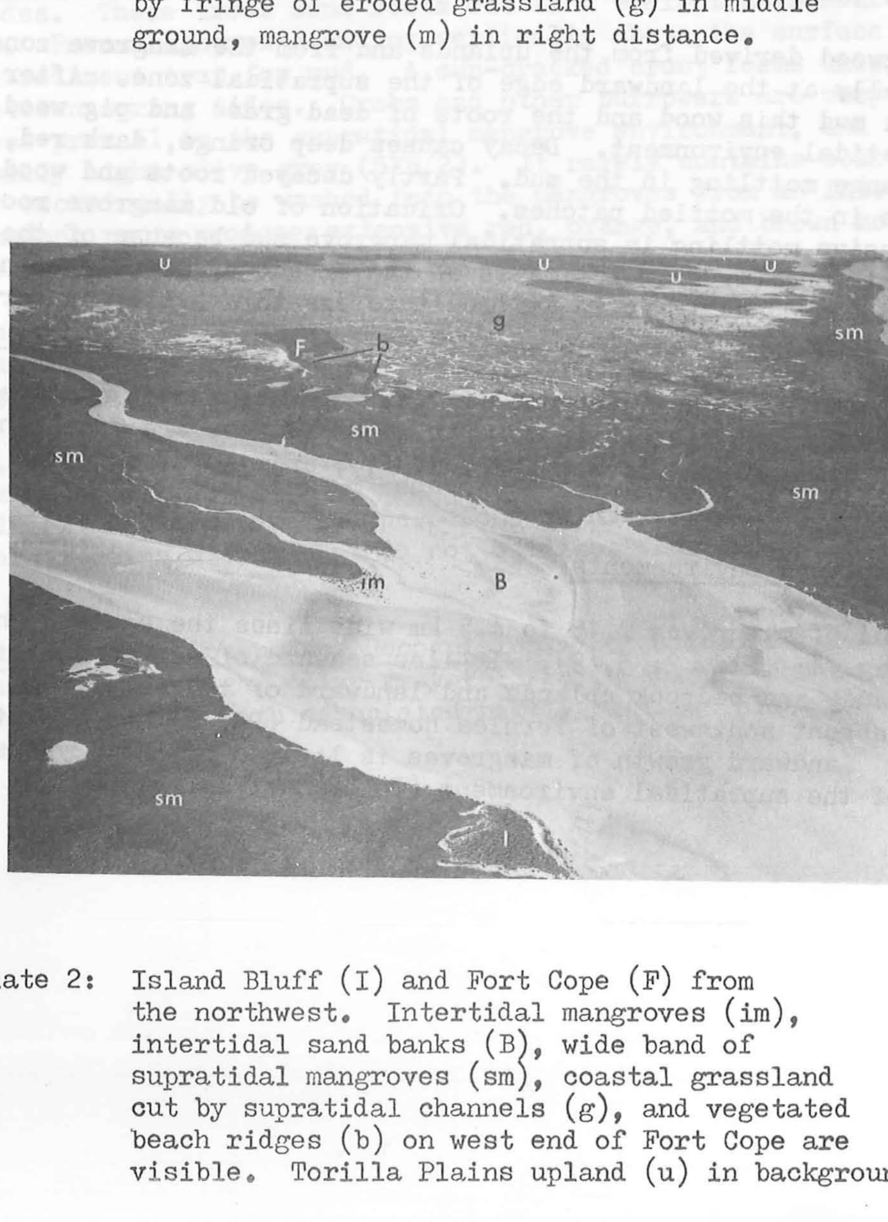


Plate 2: Island Bluff (I) and Fort Cope (F) from the northwest. Intertidal mangroves (im), intertidal sand banks (B), wide band of supratidal mangroves (sm), coastal grassland cut by supratidal channels (g), and vegetated beach ridges (b) on west end of Fort Cope are visible. Torilla Plains upland (u) in background.

The flats merge landward with coastal grassland, are surrounded by a rim of eroded grassland, or are fringed by low cliffs and wooded uplands (Pls. 1, 3, 6, 9, 11). In some areas remnants of grassland stand as islands above the flats. The supratidal flats are bounded seaward by a zone of mangroves, but southwest of Fernlea homestead mangroves are absent (Pls. 3, 4, 6, 9, 10, 11).

After a spring tide ebbs from the supratidal flats, the wet surface mud gradually dries. A hard crust commonly cut by dessication cracks and veneered with thin patches of salt forms over moist, sticky mud (Pl. 1). Euhedral gypsum crystals occur less than a metre below the crust. Tidal current lineations, bird tracks, and animal trails are also preserved in the crust. Algal mats commonly grow on the surface when it is flooded.

Supratidal mud is characteristically light olive grey (5Y5/2, 5Y6/1). Localized reducing conditions or additions of humus and plant litter may cause darker colours such as olive grey (5Y4/1, 5Y3/2), dark yellowish brown (10YR4/2), and olive black (5Y2/1). Supratidal mud is commonly laminated, but the lamination is locally destroyed by the activity of numerous crabs, gastropods, bivalves, and other burrowers which live on the supratidal flats. This mud rarely contains coarse particles except near uplands where sand, quartz pebbles, and iron nodules are washed onto the flats during the wet season.

Driftwood derived from the uplands and from the mangrove zone is common, especially at the landward edge of the supratidal zone. After incorporation into supratidal mud this wood and the roots of dead grass and pig weed decay in the oxidizing supratidal environment. Decay causes deep orange, dark red, and yellowish and greyish orange mottling in the mud. Partly decayed roots and wood generally remain as cores in the mottled patches. Oxidation of old mangrove roots produces even more extensive mottling in supratidal mangrove mud because of the thick cover of trees in that zone (p. 13). Estimates of the extent of mottling tend to be subjective, and consequently it is difficult to use this criterion for distinguishing supratidal mud from supratidal mangrove mud.

Criteria for Subsurface Recognition. Characteristic features shown by supratidal sediments and visible in core or auger samples are mud lithology, generally light olive grey colour (5Y5/2, 5Y6/1), and the presence of slight mottling.

Sediments of Mangrove Environments

A band of mangroves 0.15 to 4.5 km wide lines the eastern shore of Broad Sound (Fig. 4; Pls. 2, 3, 9). It lies seaward of active supratidal flats, coastal grassland, and bedrock uplands and landward of the intertidal zone. Mangroves are absent southwest of Fernlea homestead (Pl. 9) and near the mouth of Halfway Creek. Landward growth of mangroves is limited by the dryness and high salt content of the supratidal environment (Coleman et al., 1966).

Mangroves occur in small patches near the northern tip of the peninsula and along the western shore of Shoalwater Bay (Fig. 4). They grow in the mouth of Parker Creek, behind old beach ridges south of the Corisande Hills, next to beach ridges and supratidal flats north of Broome Head, and seaward of coastal grasslands south of Macdonald Point.

This study distinguishes two morphologic types of mangroves which grow in different environments and are adapted to different tidal levels. Supratidal mangroves are predominent in the Torilla Plains area; intertidal mangroves occur in only a few places, such as northwest of Fort Cope (Pl. 2).

Intertidal mangroves grow seaward of supratidal mangroves, but this zonation does not imply a successional relationship. It is not certain whether intertidal mangroves with their superior sediment-trapping ability have caused construction of new land on which supratidal mangroves can grow, or whether pre-existing coastline geomorphology has influenced the distribution of mangrove types (Thom, 1967). Intertidal mangroves are absent along much of the east coast of Broad Sound. They may have been eroded from the area, or they may have never grown there.

Supratidal Mangrove Environment. Supratidal mangroves are flooded only by spring tides. These trees send roots out from their trunks near or below ground level. Pneumatophores standing vertically above the surface function as an effective sediment trap for mud. A sun-cracked crust forms under the supratidal mangroves between spring tides. Crabs and other burrowers are very active. Oxidizing conditions prevail in the supratidal mangrove environment, and consequently the mud is typically light olive grey (5Y5/2). It rarely contains coarse particles, but sand may occasionally be washed into the mangroves from an inlet channel (Pl. 2). Decay of abundant roots produces extensive red, orange, and brown mottling in the mud. Mottled patches commonly have cores of partly oxidized wood.

Intertidal Mangrove Environment. Stilt roots protrude from the trunks of intertidal mangroves above ground level and provide oxygen to the trees which grow in poorly aerated soil (Aust. Cons. Foundation, 1972). The stilt roots also function as effective sediment traps. Mud is the characteristic deposit of this environment, but in places sand is washed into the intertidal mangroves from the intertidal zone (Pl. 2). Field Eh measurements show that reducing conditions prevail in intertidal mangrove swamps. Consequently, sediments are dark, and the abundant plant remains blacken but do not oxidize. Burrowers are active in this zone.

Criteria for Subsurface Recognition. Supratidal mangrove sediments are typically mud, usually light olive grey (5Y5/2) in colour, and extensively mottled (red, orange, and brown) with associated partly oxidized plant remains.

By contrast, intertidal mangrove sediments are mud to sandy mud, dark in colour, and rich in black plant remains. Oxidation of an old intertidal mangrove deposit would produce a sediment very similar to unaltered supratidal mangrove mud. Such oxidation may have occurred with fluctuations in the water table, and some subsurface sediments identified as old supratidal mangrove deposits may be old, oxidized intertidal mangrove mud.

Intertidal Sediments

Intertidal sediments in Broad Sound consist of mud and sand. Intertidal mud occurs seaward of the mangrove zone in a band 90 m wide between Island Bluff and Fernlea homestead and along some mangrove inlets (Pls. 3, 4). Intertidal sand occurs in Herbert Creek in a zone of elongate banks about 0.8 km wide (Pls. 2, 3, 4, 9, 10). Intertidal mud and sand may be separated by a zone of shallow marine sediments up to 90 m wide.

Mud. Intertidal mud consists of eroded mangrove mud which is redeposited in a band adjacent to either the supratidal mangrove or supratidal zone. Like its source material, intertidal mud is generally grey to dark grey and is commonly laminated. Plant debris from dead, eroded mangroves is abundant, and in places large blocks of supratidal mangrove mud covered by trees break from cut-banks and lie in intertidal mud. Mud balls form during erosion and re-working of supratidal mangrove mud and are abundant at the base of scarps. They are occasionally deposited seaward on intertidal sand banks. Thin sand interbeds and crab burrows are loci of oxidation and become mottled red, orange, and brown. Nodules, shells, and coral are rare in intertidal mud.

Sand. Intertidal sand is generally clean, fine to medium-grained, and pale to dark yellowish brown (10YR6/2 to 10YR4/2) or light olive grey (5Y6/1) in colour. Small nodules, whole and broken shells, mud balls, and mud layers occur in the sand. Small ripples are commonly superimposed on megaripples on intertidal sand banks. Dark, plant-rich interbeds and driftwood are present in a few places in these banks.

Criteria for Subsurface Recognition. Modern intertidal mud is sandy, finely laminated, grey to dark grey, and rich in plant remains. It has a depositional dip and contains thin sand interbeds.

Modern intertidal sand is generally fine to medium-grained and clean; pale to dark yellowish brown (10YR6/2 to 10YR4/2) or light olive grey (5Y6/1); rarely interbedded with mud and mud balls; and contains scattered nodules, shells, and plant remains.

Plate 3: View south toward head of Herbert Creek showing uplands (u), coastal grassland (g), supratidal flats (s), mangroves (m), and intertidal sand banks (B). A band of intertidal mud (i) lies seaward of mangroves along the east shore of Broad Sound and Herbert Creek.

Plate 4: View west across Herbert Creek. Cross-section D6-A16 (Fig. 17) parallel to causeway in left foreground cuts wooded upland (u), grassland (g) being eroded by spring tides, vegetated crescentic beach ridge (b), supratidal flats (s), supratidal mangrove swamp (m), and narrow band of intertidal mud (i). Extensive intertidal sand banks (B) are exposed at low tide.

The Broad Sound estuary changed shape as sea level fluctuated during the Quaternary. Elongate intertidal sand banks may not have existed until the estuary assumed the V-shape which now funnels tides down its length. Sediments of the modern intertidal mud type would not have been deposited unless the sea was eroding mud deposited in supratidal mangrove and supratidal environments. Sediment types now being deposited in the intertidal zone are a function of the present stage of the estuary's evolution and may not have been deposited in the past.

Shallow Marine Sediments

Shallow marine gravel, sand, and mud have been sampled in Broad Sound west of Island Bluff and Fort Cope. Marine sand interfingers southeastward with intertidal sand.

Sand. Unlike intertidal sand, shallow marine sand is covered even by low tide. It is usually clean, fine to very coarse-grained, and moderate yellowish brown (10YR5/4). It contains variable amounts of small brown nodules and coarse shell fragments. 'Shingle banks' of pebbles, large nodules, coral, shells, and living plants occur sporadically in the zone of shallow marine sand.

Mud. Two types of shallow marine mud have been distinguished on the basis of colour. Greenish grey (5GY6/1, 5G6/1) to dark greenish grey (5GY4/1, 5G4/1) mud was penetrated in 24 of 31 short submarine cores averaging 22 cm in length. It is commonly shelly and sandy and at some localities becomes tough and hard below the top few centimetres. This mud covers much of the sea bed but is overlain in places by up to 10 cm of coarse nodule and shell gravel with a fine to coarse sand matrix. The greenish grey colour and abundance of shells and sand indicate that this mud was deposited under shallow marine conditions. Winnowing of the mud by tidal currents has produced the overlying lag gravel.

Light olive grey (5Y5/2, 5Y6/1) shelly and sandy mud was collected in some short submarine cores and grab samples. As well as covering parts of the bottom, in several cores it forms the matrix of the lag gravel which overlies the greenish grey shallow marine mud. The light olive grey mud is probably eroded supratidal mud and supratidal mangrove mud recycled to shallow marine environments via the intertidal zone. Development of lag gravels on the greenish grey mud and subsequent deposition of light olive grey mud in them suggest that the greenish grey shallow marine mud is a relict sediment. Light olive grey mud is probably the shallow marine sediment now being deposited. Tidal scour has also produced lag gravels on some light olive grey mud.

Criteria for Subsurface Recognition. Shallow marine sand is clean, fine to very coarse-grained, generally moderate yellowish brown (10YR5/4), and commonly rich in shell fragments and nodules.

Shallow marine mud is commonly sandy; greenish grey (5GY6/1, 5G6/1) to dark greenish grey (5GY4/1, 5G4/1) or light olive grey (5Y5/2, 5Y6/1); and rich in shells and nodules. Greenish grey shallow marine mud is probably a relict sediment. The light olive grey shallow marine mud now being deposited in the estuary depends upon the erosion of supratidal and supratidal mangrove deposits for its parent material.

Fluvial Sediments

Upland stream sediments consist of poorly to moderately sorted, medium to very coarse-grained, angular sand. Angular vein quartz and rock fragment gravel is a common component of these fluvial sediments. Wood, bark, roots, and humus are generally abundant in the sand, and sediment colours vary from greyish orange (10YR7/4) to dark yellowish brown (10YR4/2). Pea-sized iron nodules eroded from old laterite profiles are very abundant in the alluvium of some streams. During the dry season the creeks become sluggish or stop flowing; their fairly coarse load reflects higher energy flow conditions during the wet flood season.

AUGER AND DRILL HOLE STRATIGRAPHY

A sequence of unconsolidated mud and sand extends from the surface to varying depths in all Torilla Plains auger and drill holes. In some holes these sediments are underlain by laterite, 'grey' and mottled sandstone, coarse gravel, or Palaeozoic or Mesozoic bedrock. Because they occur in all holes and were studied in some detail, the young unconsolidated sediments will be discussed first.

Criteria established from the study of surface environments were used for recognition of modern sedimentary environments in the subsurface. BMR Port Clinton No. 4 is described first, as all the local modern coastal and marine environments are represented in its stratigraphy.

BMR Port Clinton No. 4 (Fig. 5)

Dark greenish grey (5GY4/1) clay to sandy clay occurs between 2.18 and 2.84 m in BMR Port Clinton No. 4. Its texture and distinctive colour identify it as shallow marine mud. Olive grey (5Y4/1) sandy clay and clay overlie the shallow marine mud. Its texture, plant remains, and pockets of sand mark this unit as intertidal mud. Deposition in a sheltered area under reducing conditions before mangroves migrated may account for the atypical dark intertidal mud colour. This unit is overlain by medium dark grey (N4) clay which contains abundant black plant remains and is easily identified as intertidal mangrove mud. Light olive grey (5Y5/2) mottled clay overlies intertidal mangrove deposits and contains rare to abundant brownish black and black plant remains. This supratidal mangrove mud is overlain by supratidal mud in which a humic gley or wiesenboden soil (Gg1) has developed under coastal grassland. Grass became established on the flats when supratidal deposition had ceased. Shallow marine, intertidal, intertidal mangrove, supratidal mangrove, and supratidal environments succeeded each other at this point during deposition of the unconsolidated sequence.

TABLE 3

ABBREVIATIONS USED IN LITHOLOGICAL LOGS

Abundant	abd
Amount	Amt
And	+
Angular	ang
At	@
Band (ing) (ed)	Bnd, Bndg, Bndd
Becoming	Bcmg
Bed (ing) (ed)	Bd, Bdg, bdd
Bedrock	Bdrk
Black (ish)	blk
Blue (ish)	bl
Brown (ish)	brn
Calcite (areous)	Calc, calc
Carbonaceous	carb
Cement (ed)	Cmt, cmtd
Chert	Cht
Clay (ey)	Cl, cl
Claystone	Clst
Coarse	c
Cobble	Cbl
Common (ly)	com
Concretion (ary)	Conc, conc
Conglomerate (ic)	Cgl, cgl
Crumbly	cmb
Crystal (line)	Xl, xl
Dark (er)	dk
Decrease (ing)	Decr, decr
Downward	down
Feldspar (thic)	Fld, fld
Fine (ly)	f
Flake (y)	Flk, flk
Fragment (al)	Frag, frag
Grade (ed) (ing)	grd, grdd, grdg
Grain (ed)	Grn, grnd
Granule	Grnl
Gravel	Gvl
Green (ish)	gn
Grey (ish)	gy
Gypsum (iferous)	Gyp, gyp
Hard	hd

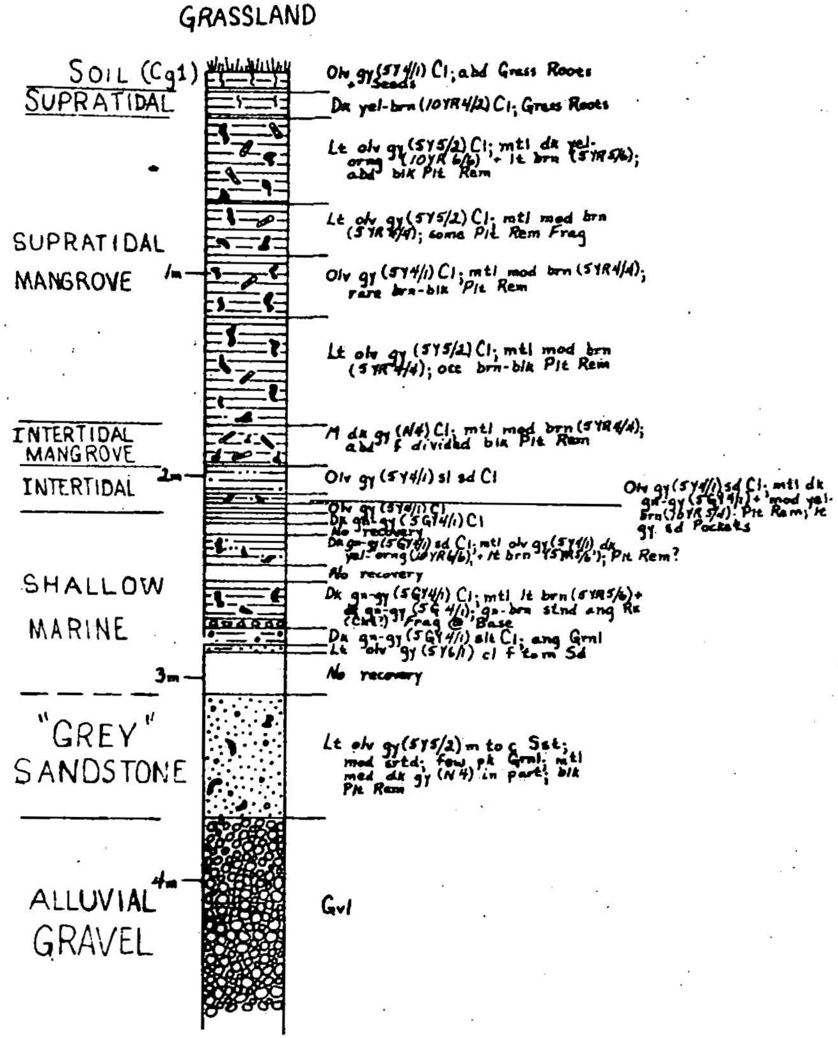
TABLE 3 (Cont'd)

Igneous	ig
Interbed (ed)	Intbd, intbdd
Iron	Fe
Ironstained	festnd
Irregular	irreg
Large	lrg
Layer	Lyr
Lens (ticular)	Len, len
Light	lt
Lower	low
Material	Matl
Matrix	Mtx
Medium	m
Mica (ceous)	Mic, mic
Moderate	mod
Mottled	mtl
Near	nr
Nodule (ar)	Nod, nod
Numerous	num
Occasional	occ
Olive	olv
Orange	orng
Organic	org
Pebble (y)	Pbl, pbl
Pelecypods	Pelcp
Pink (ish)	pk
Plant	Plt
Plant remains	Plt Rem
Platy	plty
Poor (ly)	p
Predominate (ant)	pred
Purple (ish)	purp
Quartz (itic) (ose)	Qz, qtz, qzs
Quartzite	Qzt
Rock (y)	Rk, rk
Round (ed)	rnd, rndd
Sand (y)	Sd, sd
Sandstone	Sst
Scattered	scatd
Silt (y)	Slt, slt
Siltstone	Sltst
Slight (ly)	sl
Small	s
Sorting (ed)	Srtg, srtd
Stain (ing) (ed)	Stn, Stng, stnd

TABLE 3 (Cont'd)

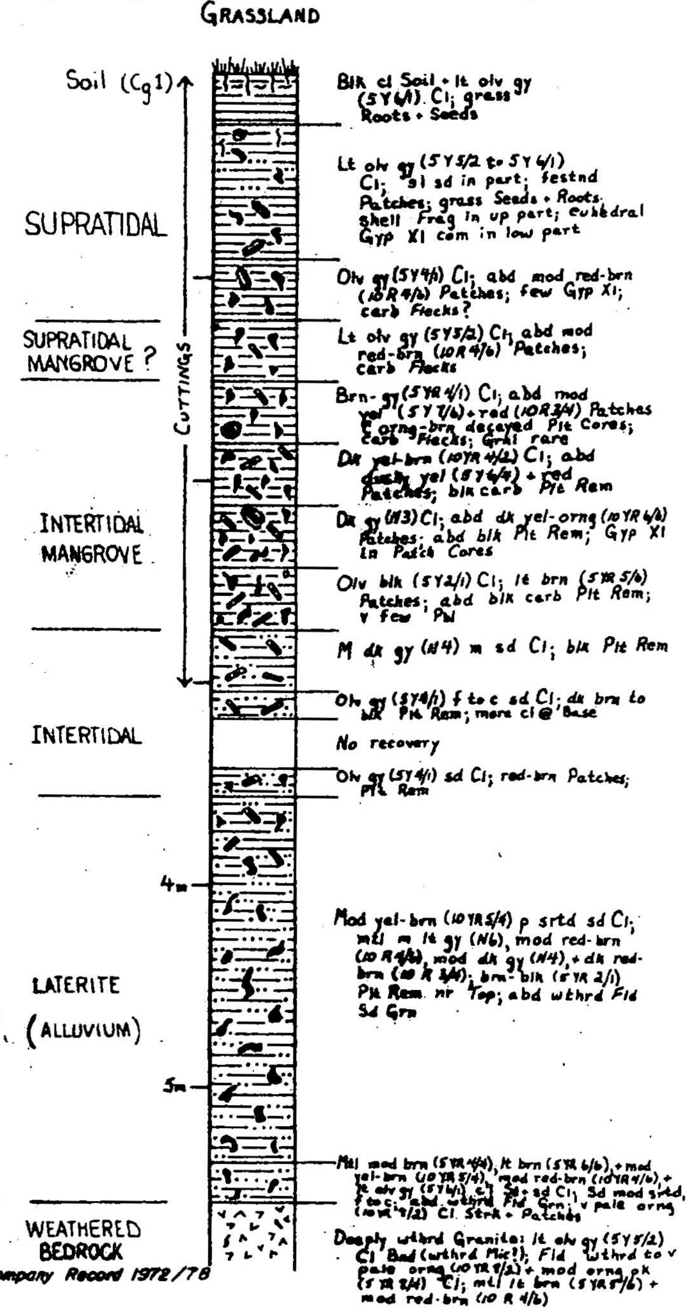
Streak (y)	Strk, strk
Subangular	subang
Subrounded	subrndd
Surface	Surf
Thick	tk
Thin	tn
Upper	up
Variety (ous)	Var, var
Very	v
Weathering (ed)	Wthrg, wthrd
Well	w
White (ish)	wh
With	c̄
Wood	Wd
Yellow (ish)	yel

Lithological log of BMR Port Clinton No 4 Fig 5



F55/A12/19

Lithological log of BMR Port Clinton No 1 Fig 6



To accompany Record 1972/78

-21-

A marine regression* is recorded by the unconsolidated sediments in this and almost all other auger and drill holes. The upward sequence of environments is frequently less complete than that in BMR Port Clinton No. 4, with units missing because of non-deposition, erosion, or difficulties in interpretation.

BMR Port Clinton No. 1 (Fig. 6)

Intertidal, mangrove, and supratidal environments occur in upward succession in BMR Port Clinton No. 1. Shallow marine sediments are absent. In this hole the lack of sand and concentration of black plant remains in dark intertidal mangrove mud differentiate it from dark intertidal mud. Supratidal sediments are mottled and contain small euhedral gypsum crystals and shell fragments. The small amount of sand in some supratidal mud horizons was probably washed from the uplands onto the flats during flood seasons. Supratidal mangrove mud cannot be positively recognized in this hole. Since the sea retreated from this site, grassland has occupied the former supratidal flats, and soil (Cg1) has formed.

Auger Holes 9, 10 and 11 (A9, A10, A11) (Fig. 7)

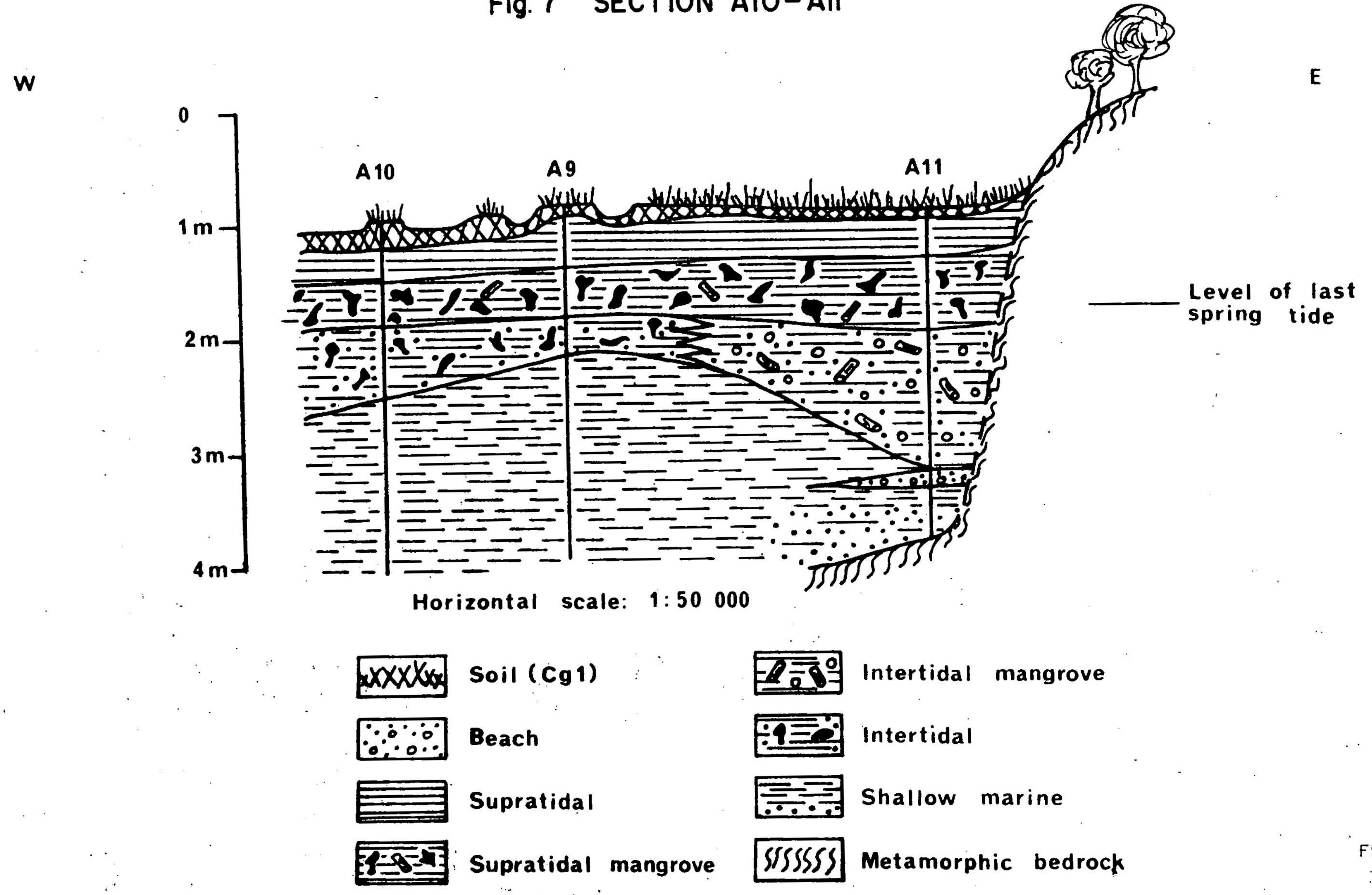
An east-west cross-section through auger holes 9, 10, and 11 (Fig. 1) runs roughly perpendicular to the present Broad Sound shoreline and is shown in Figure 7. The section is projected to intersect the metamorphic rocks which form the upland and were penetrated in the A11 hole (Fig. 10).

A lens of greenish grey shallow marine mud occurs at the base of the section. It thickens to at least 1.72 m in A9 (Fig. 9) but thins eastward to 0.45 m in A11, where a facies change to greenish black clayey sand occurs in the lower part of the unit. The mud texture coarsens from slightly silty in A10 (Fig. 8) to slightly sandy in A11 where it overlies the greenish black sand. This grainsize trend, the facies change from mud to sand in the lower part of the unit, and the abundant black wood fragments indicate deposition close to the shore of the eastern upland. A thin lens of pebbles, sand, and large wood fragments above the shallow marine mud in A11 may represent a beach which formed on that shore.

Intertidal mangroves grew at site A11 after deposition of the beach gravel. Quartz and rock fragment pebbles in the intertidal mangrove mud were derived from upland sources and reworked beach deposit. Light olive grey intertidal mud containing black plant remains overlies shallow marine mud in A10 and A9 and is the lateral facies equivalent of the intertidal mangrove mud in A11; during intertidal deposition mangroves grew near the small uplands. Intertidal mangroves did not migrate to sites A9 and A10. A layer of typical supratidal mangrove mud overlies intertidal deposits in A10, A9, and A11. Supratidal mangroves succeeded intertidal mangroves near A11 and migrated seaward across intertidal muds as the sea retreated. Drier and more saline conditions caused by further retreat of the sea killed supratidal mangroves, and supratidal mud was deposited on the flats from A11 westward to A10. With continued regression grass colonized the supratidal flats as they became inactive, and dark organic soil (Cg1) has formed.

*The term 'regression' is used throughout this report to describe a retreat of the shoreline; a relative lowering of sea level is not necessarily implied.

Fig. 7 SECTION A10-A11



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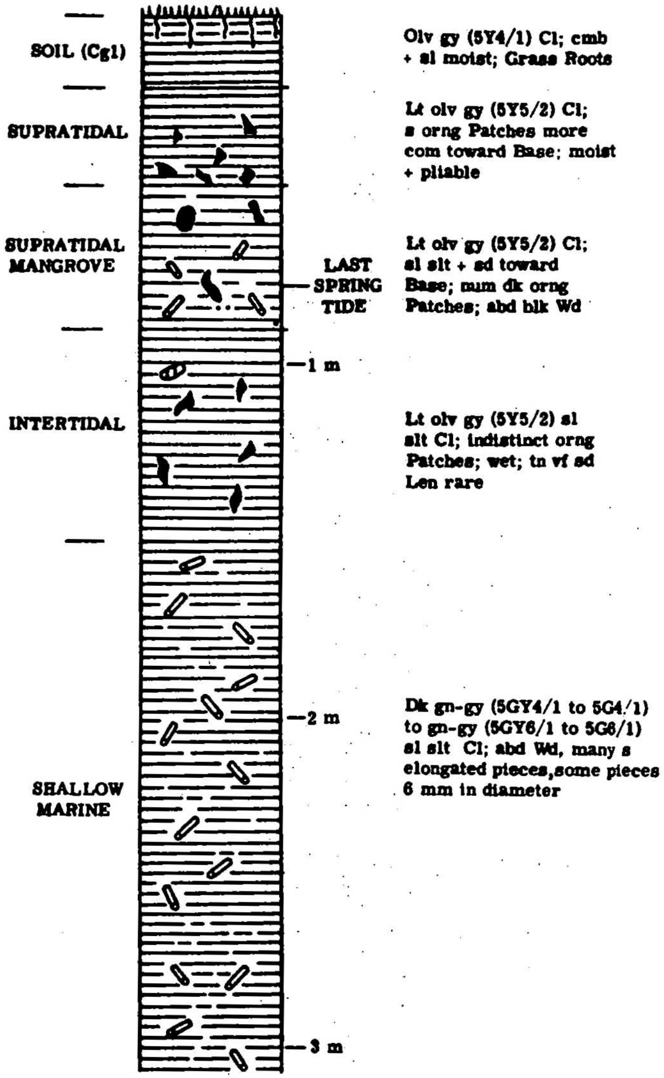
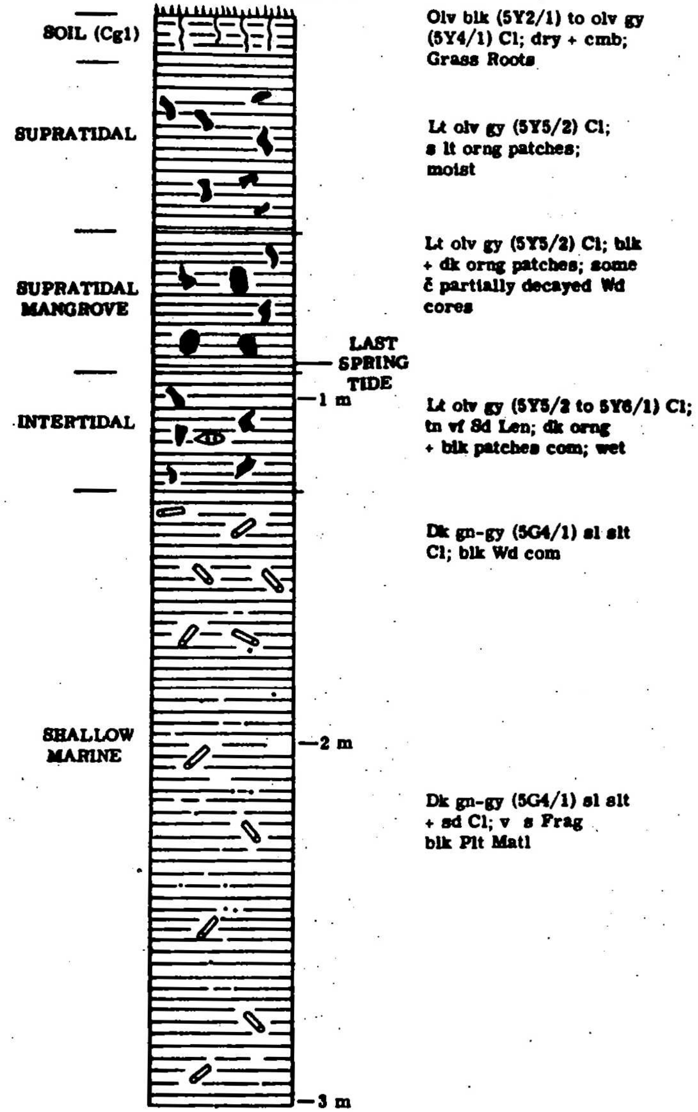
To accompany Record 1972/78

FIG. 8
AUGER HOLE 10
ERODED GRASSLAND
ISLAND



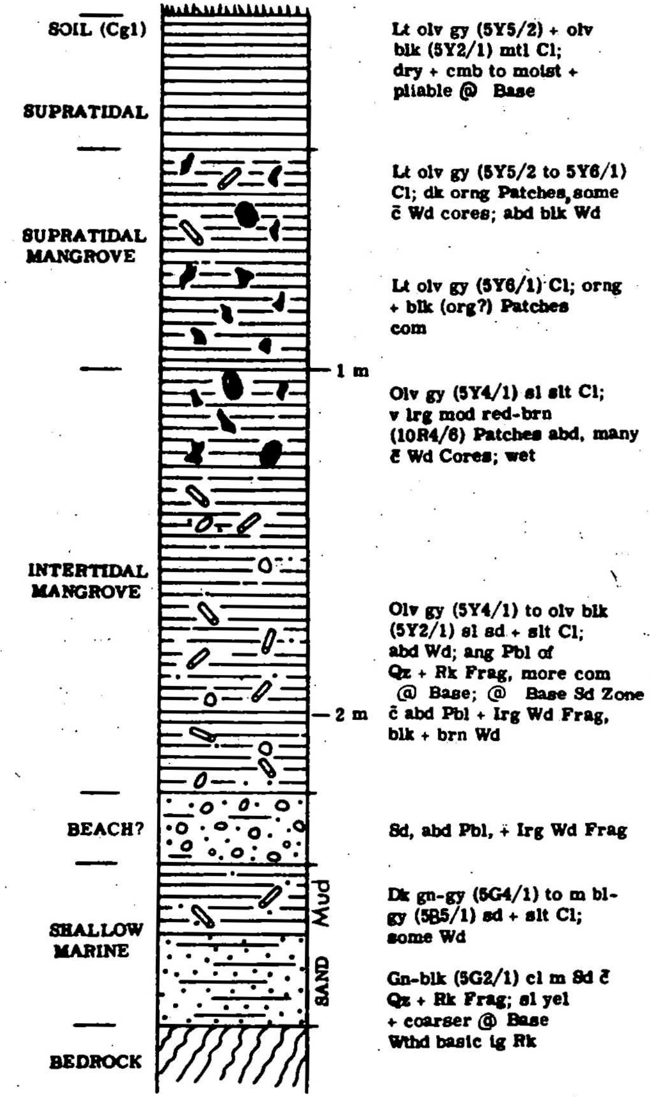
LITHOLOGICAL LOG OF AUGER HOLE 10

FIG. 9
AUGER HOLE 9
GRASSLAND
BETWEEN
TWO SUPRATIDAL CHANNELS



LITHOLOGICAL LOG OF AUGER HOLE 9

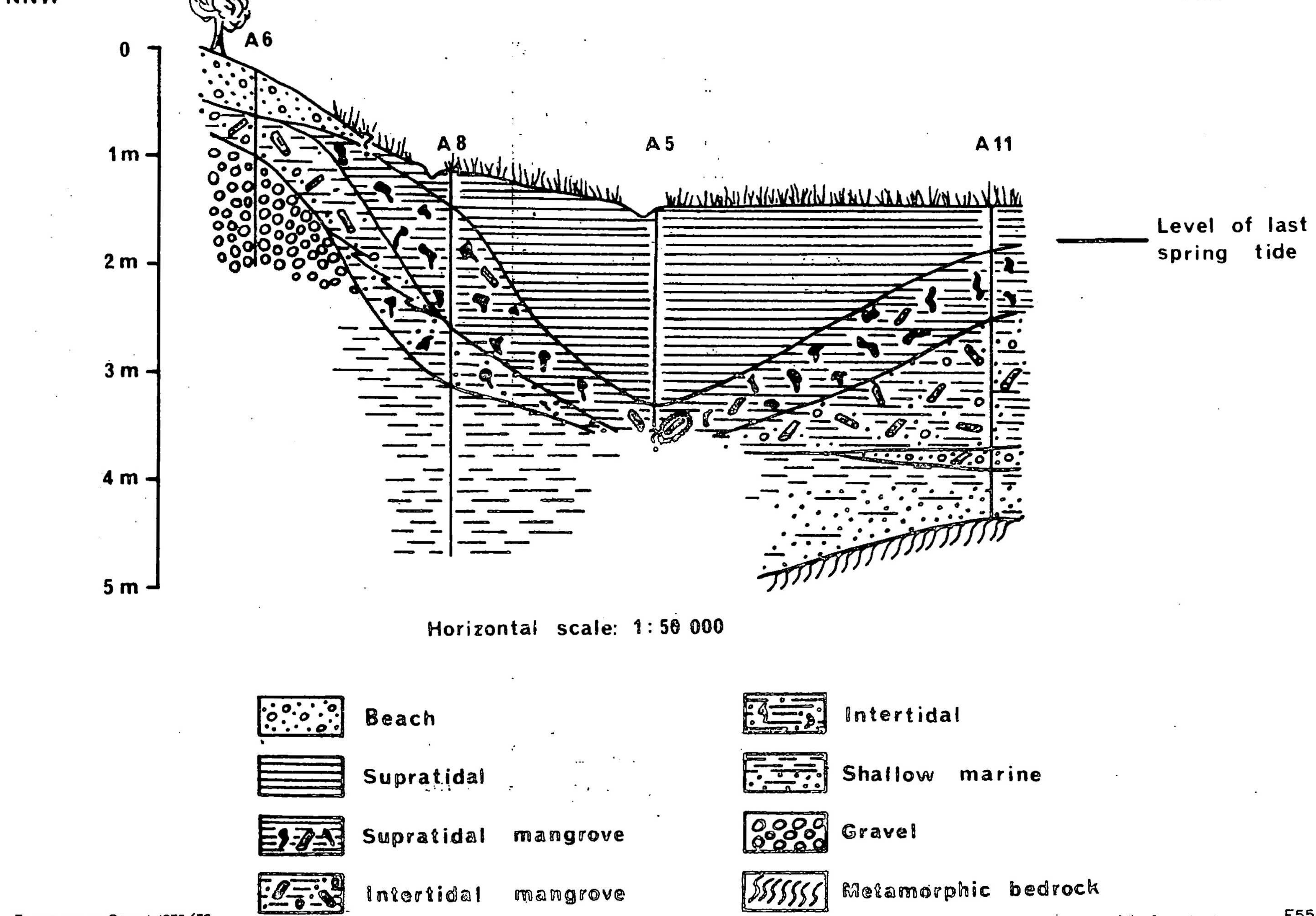
FIG. 10
AUGER HOLE 11
GRASSLAND



LITHOLOGICAL LOG OF AUGER HOLE 11

To accompany Record 1972/78

Fig II SECTION A6 - AII



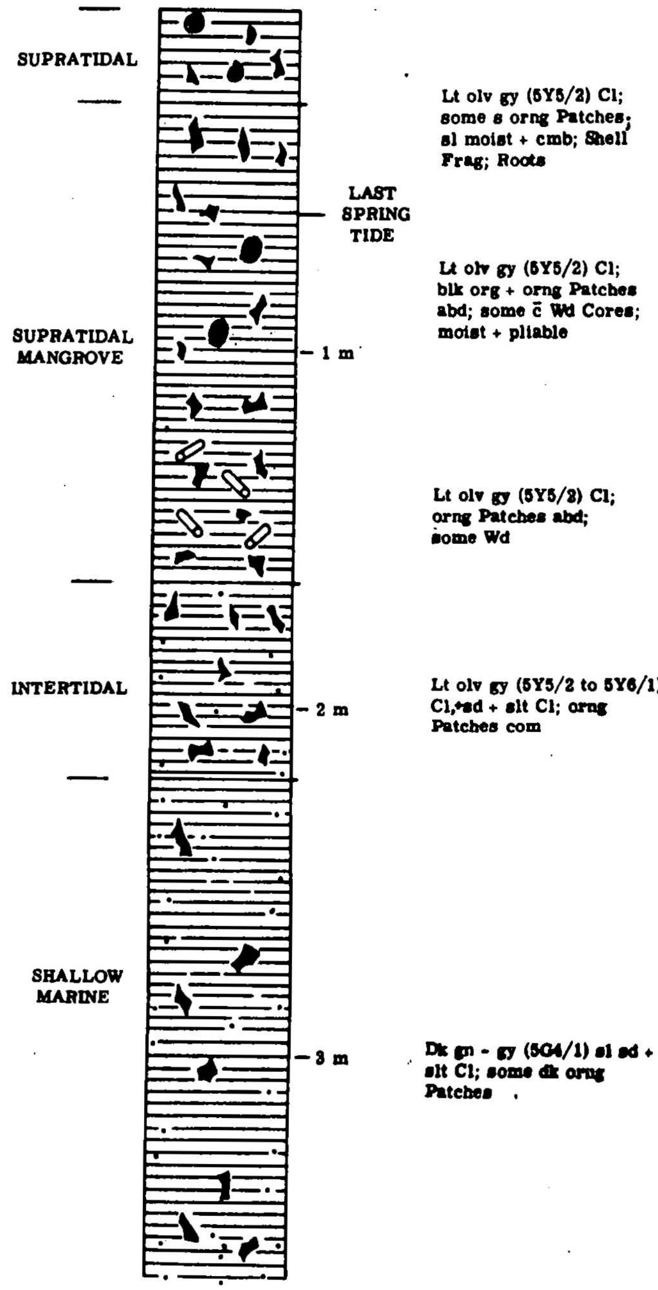
To accompany Record 1972/78

F55/A12/22

FIG. 13

AUGER HOLE 8

GRASSLAND NEAR SUPRATIDAL CHANNEL

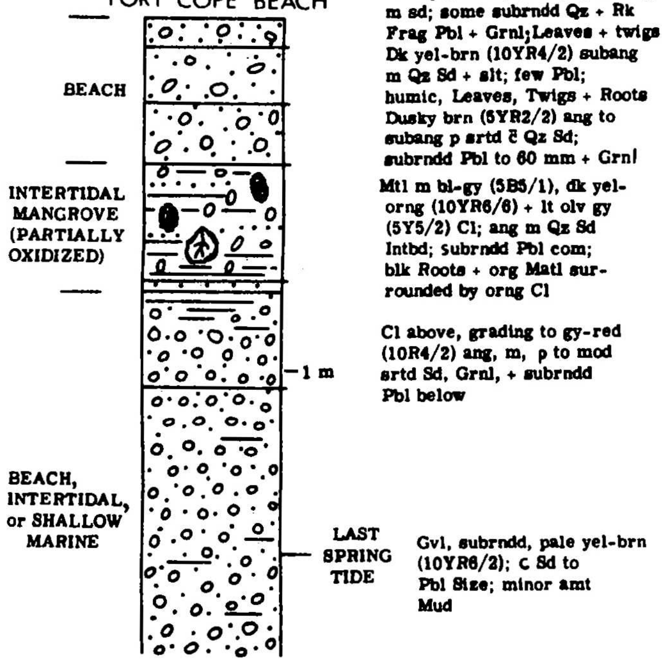


LITHOLOGICAL LOG OF AUGER HOLE 8

FIG. 12

AUGER HOLE 6

SOUTHWESTERN FLANK OF FORT COPE BEACH



LITHOLOGICAL LOG OF AUGER HOLE 6

Auger Holes 6, 8, 5 and 11 (A6, A8, A5, A11) (Fig. 11)

This cross-section runs north-northwest to south-southeast, roughly parallel to the present Broad Sound shoreline.

Greenish grey shallow marine sediments in A8 (Fig.13) and A11 (Fig. 10) overlie metamorphic bedrock penetrated in A11. Slightly sandy intertidal mud overlies shallow marine mud in A8 and may be the lateral facies equivalent of intertidal mangrove sediments in A11 and A6. Supratidal mangroves grew over intertidal mangrove mud in A11 and over intertidal mud in A8. Thickening of the succeeding supratidal mud deposit from 0.33 m in A8 to 1.83 m in A5 (Fig. 14) and thinning again to 0.38 m in A11 probably reflect filling of a pre-existing channel. In A6 (Fig. 12) pebbly beach sand overlies intertidal mangrove mud on the southwestern flank of a Fort Cope beach ridge. The age relationship of this beach sand with the supratidal mud in A8 is unknown. The sand and gravel at the base of A6 may be of beach, intertidal, shallow marine, or fluvial origin. This cross-section records a marine regression after which grassland developed on old supratidal flats.

Auger Hole 7 (A7) (Fig. 15)

Greenish grey shallow marine silt underlies dark intertidal mangrove mud in A7. Supratidal mangrove and shelly supratidal mud in turn overlie those sediments. Intertidal mangroves pioneered newly emergent tidal flats before the growth of supratidal mangroves only at sites A7 (Fig. 15) and All (Fig. 10) in the Fort Cope area. At A8 (Fig. 13), A9 (Fig. 9) and A10 (Fig. 8) supratidal mangroves grew over intertidal mud.

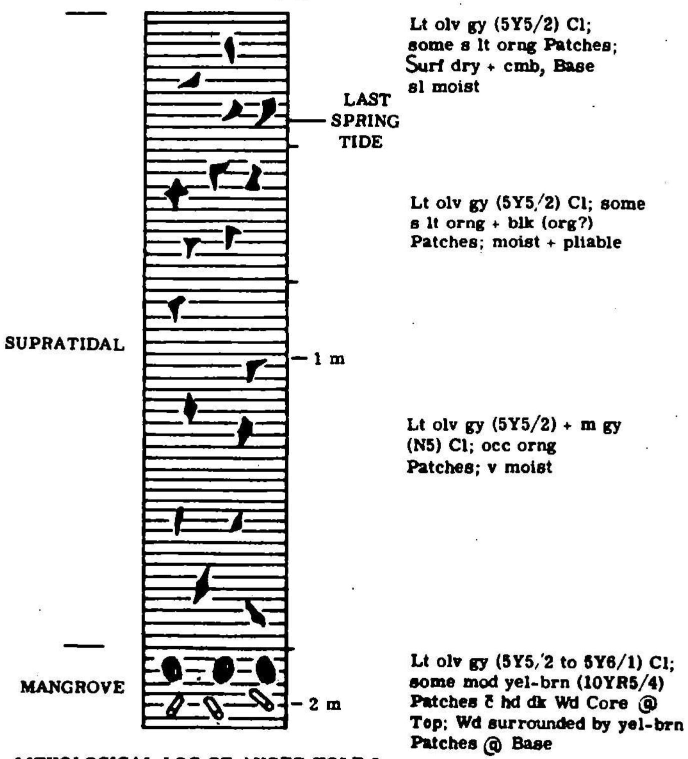
Auger Hole 12 (A12) (Fig. 16)

Hole A12 was sunk in a grassed circular depression which was flooded during much of its history. Olive grey, slightly sandy intertidal mud containing only rare wood fragments overlies laterite at the base of the hole. The overlying shallow marine mud was probably deposited in an ephemeral marine pond between intertidal sand banks. With further regression and drainage of the pond, supratidal mangroves grew at the site to be succeeded by the deposition of supratidal mud. The circular depression was filled with 1.83 m of sediment during the regression.

BMR St Lawrence No. 2 and Auger Holes 1, 2, 3, 4, 15 & 16 (A1, A2, A3, A4, A15, A16) (Fig. 17)

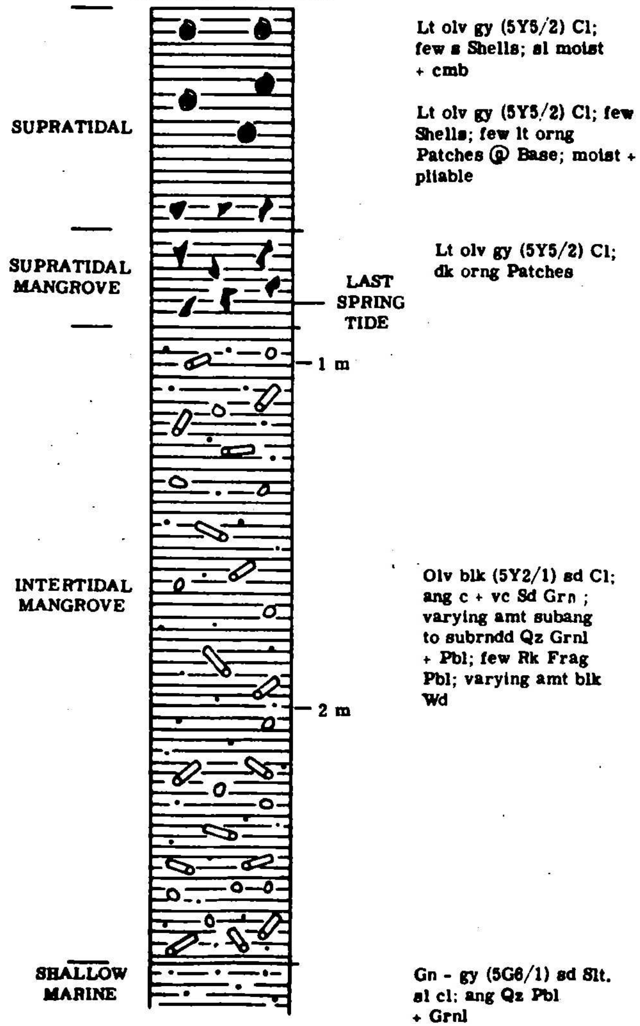
This cross-section begins in the east on an upland underlain by laterite and capped by red earth soil (ma5) and seaward cuts grassland, an old beach ridge, active supratidal flats, modern supratidal mangrove swamp, and modern intertidal mud deposits (Fig. 17, Pl. 4).

FIG. 14
AUGER HOLE 5
ACTIVE SUPRATIDAL CHANNEL BANK IN GRASSLAND



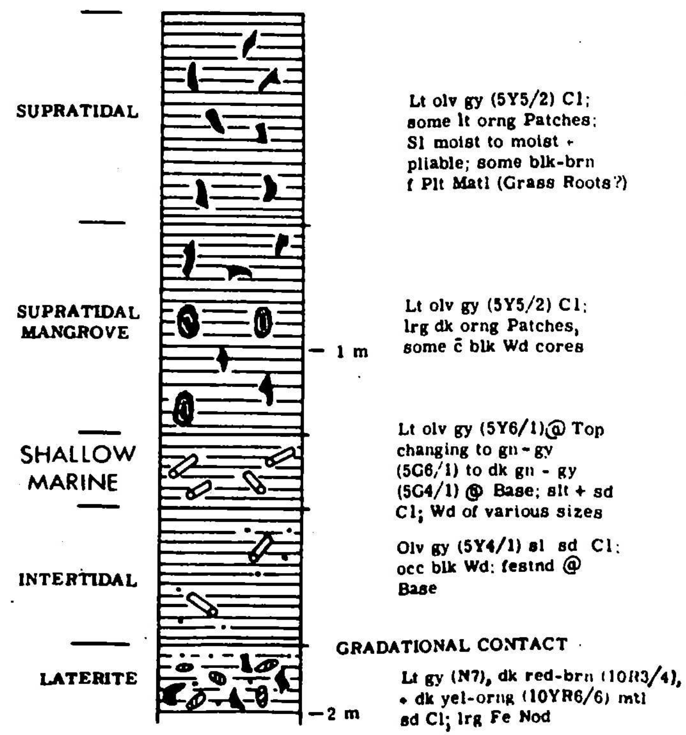
LITHOLOGICAL LOG OF AUGER HOLE 5

FIG. 15
AUGER HOLE 7
ACTIVE SUPRATIDAL FLAT



LITHOLOGICAL LOG OF AUGER HOLE 7

FIG. 16
AUGER HOLE 12
GRASSLAND



LITHOLOGICAL LOG OF AUGER HOLE 12

Shallow marine sediments overlie claystone in BMR St Lawrence No. 1 (Fig. 18) and pinch out west of A1 (Fig. 19). They consist of light olive grey to greenish grey shelly sand with blue bands and sandy clay with sand pockets containing mud balls. Intertidal sediments overlie shallow marine sand in BMR St Lawrence No. 2 and laterite in A1. This unit becomes finer landward, grading from light olive grey and bluish grey shelly sand in BMR St Lawrence No. 2 to sandy clay and clayey sand in A1 and to clay in A3. This grainsize trend may be analogous to the modern environmental zonation of intertidal mud deposits landward of intertidal sand banks.

Intertidal mangroves grew on intertidal mud near A2 (Fig. 20), but their development was interrupted by formation of a beach ridge composed of layers of shells (oysters and other bivalves), sand, and shelly sand. A thin wedge of beach gravel and shells extends seaward from the ridge itself over intertidal mangrove and intertidal sediments. Intertidal mangroves re-established themselves along the new shoreline after deposition of the littoral gravel. While supratidal mangroves succeeded them near BMR St Lawrence No. 2, supratidal mud has been deposited directly over intertidal mangrove mud between the present mangrove zone and beach ridge.

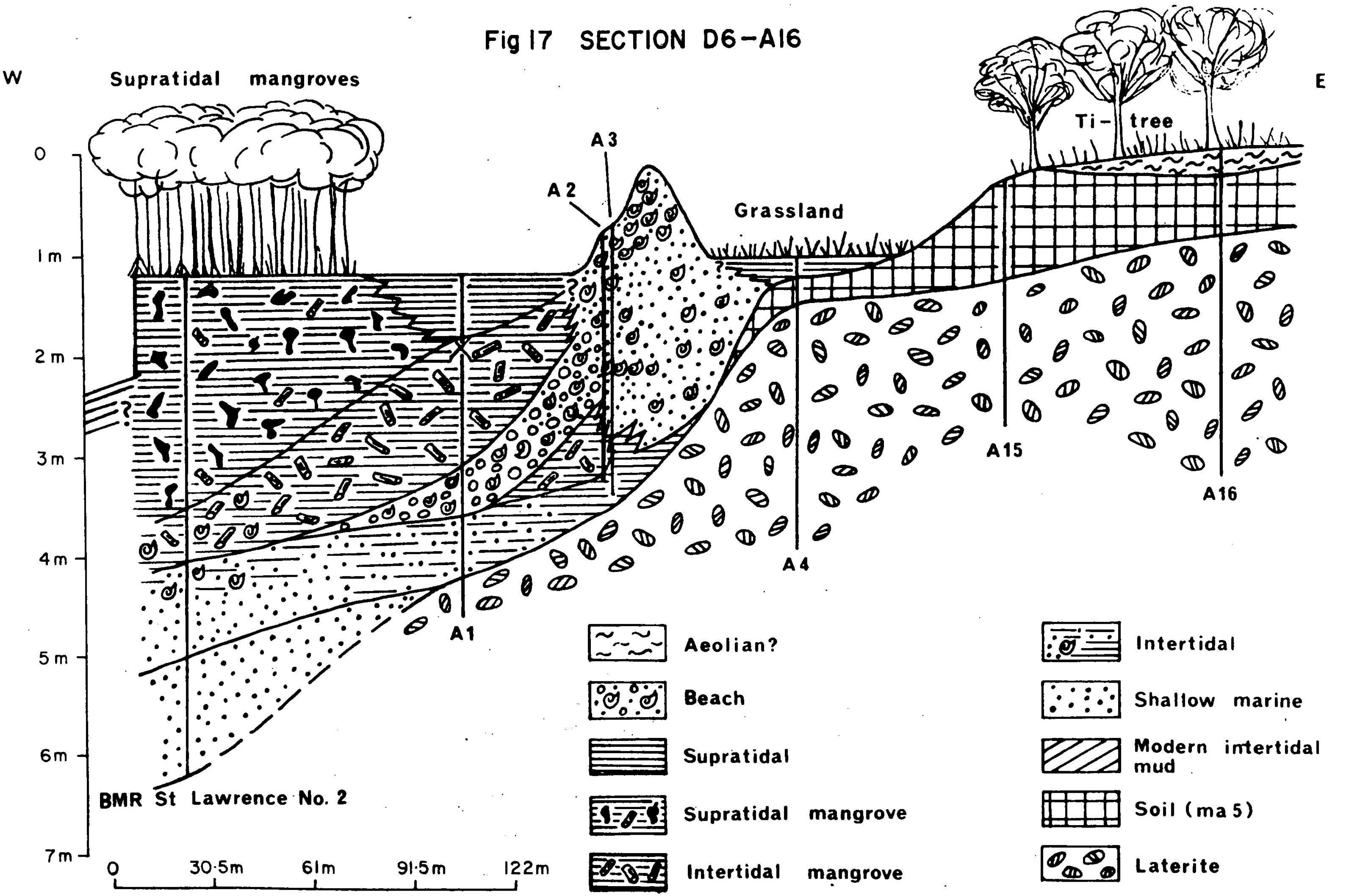
Grassed, inactive supratidal flats between the upland and beach ridge lie above the modern, active supratidal flats (Fig. 17) and were penetrated in A4 (Fig. 22). This evidence and the stratigraphic sequences of A3 (Fig. 21), A2 (Fig. 20), A1 (Fig. 19), and BMR St Lawrence No. 2 (Fig. 18) record the marine regression.

Black wood fragments from bluish grey clay at the top of intertidal mangrove mud in A1 (Fig. 17,) have given a radiocarbon date of 170± 110 years B.P. (H. Polach, pers. comm). This date, which is much younger than expected, requires that the overlying 0.61 m of supratidal mud has been deposited in the last 60 to 280 years. Observations have indicated, however, that sedimentation in the supratidal flats is slow. Contamination by modern roots seems unlikely because no roots occur in the overlying supratidal mud; but conceivably, humic acids derived from adjacent modern mangrove swamps may have migrated laterally in groundwater into old mangrove sediments, contaminating plant remains and causing dates that are too young.

Auger Hole 13 (A13) (Fig. 25)

Only 1.08 m of unconsolidated sediments overlie laterite in A13, which was sunk in grassland on the seaward edge of an upland. Intertidal sediments overlie the laterite. They are overlain by supratidal mangrove mud which is sandy, reflecting the close upland source of terrestrial clastic sediment. An olive black soil (Cg1) has developed under grass in the supratidal mud which caps the sequence. Once again a marine regression is recorded.

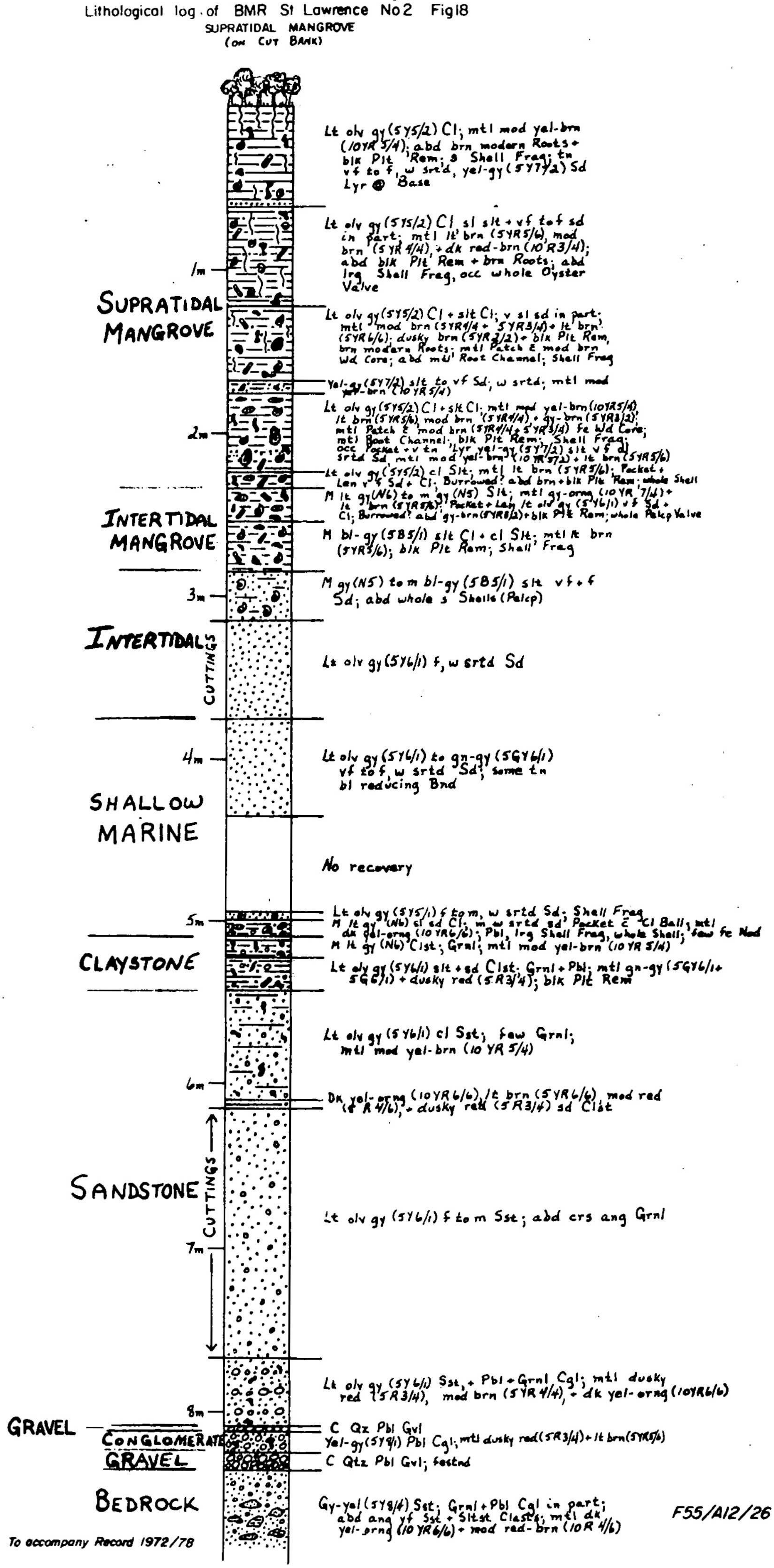
Fig 17 SECTION D6–A16



To accompany Record 1972/78

F55/A12/25

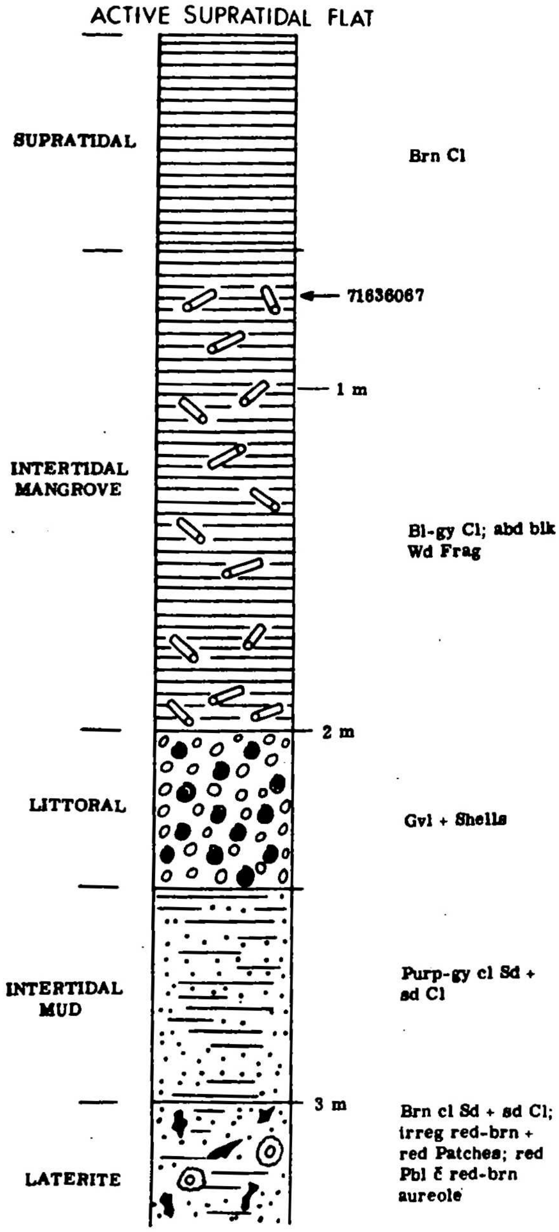
Lithological log of BMR St Lawrence No 2 Fig 18



To accompany Record 1972/78

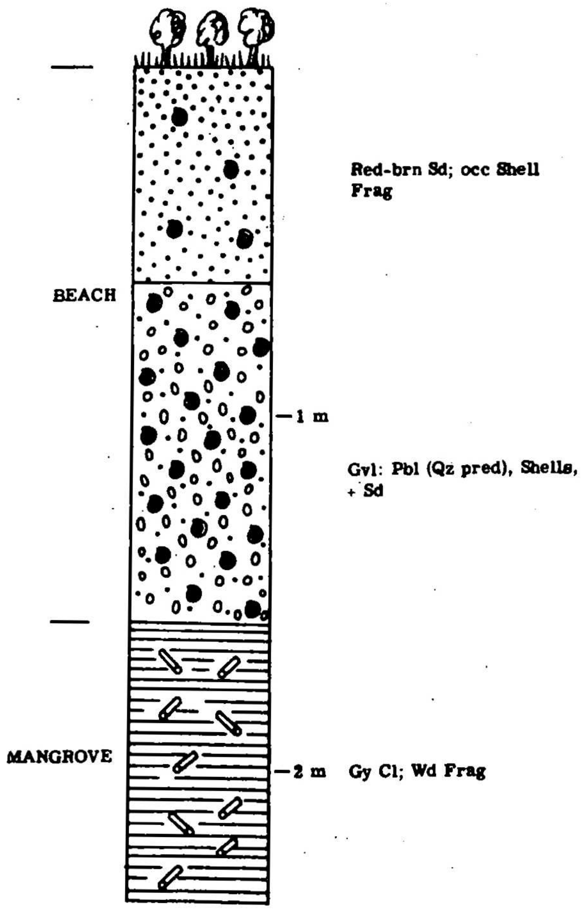
F55/A12/26

FIG. 19
AUGER HOLE 1
ACTIVE SUPRATIDAL FLAT



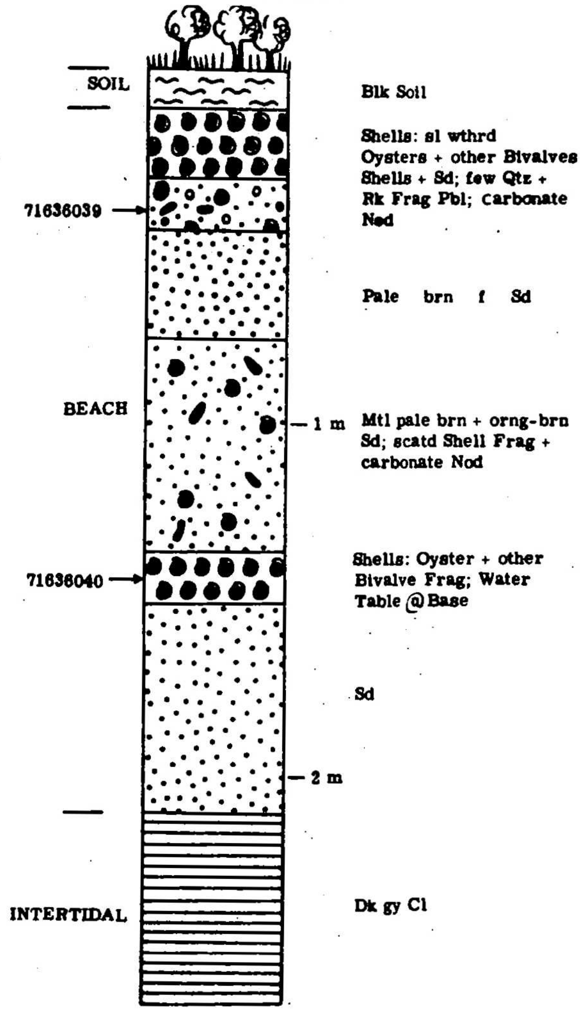
LITHOLOGICAL LOG OF AUGER HOLE 1

FIG. 20
AUGER HOLE 2
VEGETATED BEACH RIDGE



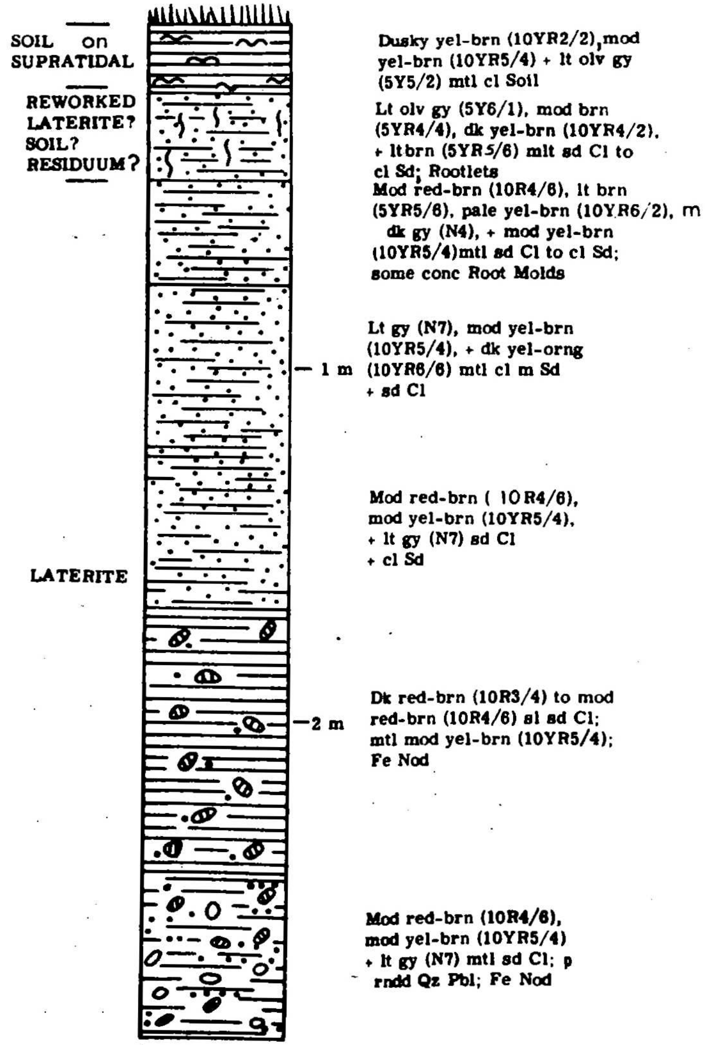
LITHOLOGICAL LOG OF AUGER HOLE 2

FIG. 21
AUGER HOLE 3
VEGETATED BEACH RIDGE



LITHOLOGICAL LOG OF AUGER HOLE 3

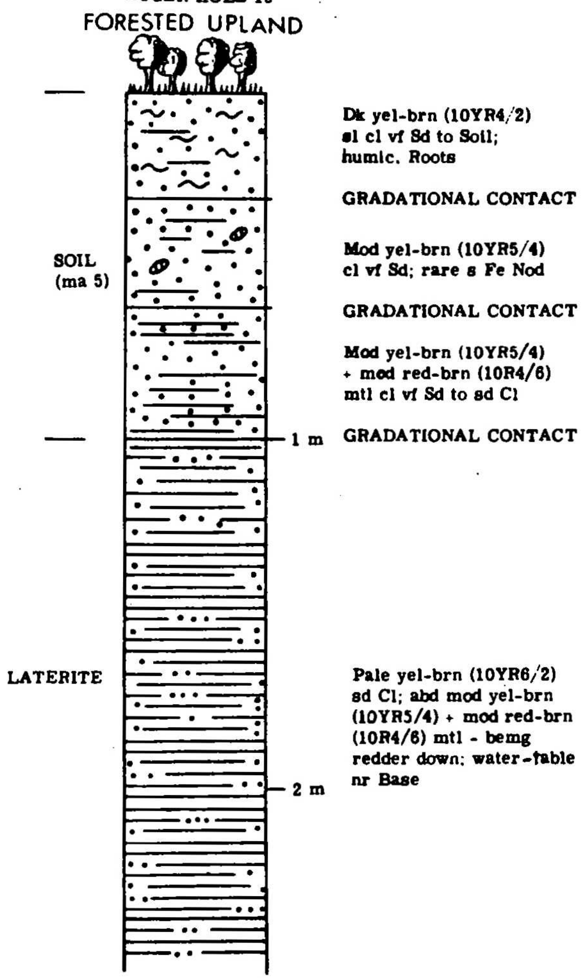
FIG. 22
AUGER HOLE 4
GRASSLAND



LITHOLOGICAL LOG OF AUGER HOLE 4

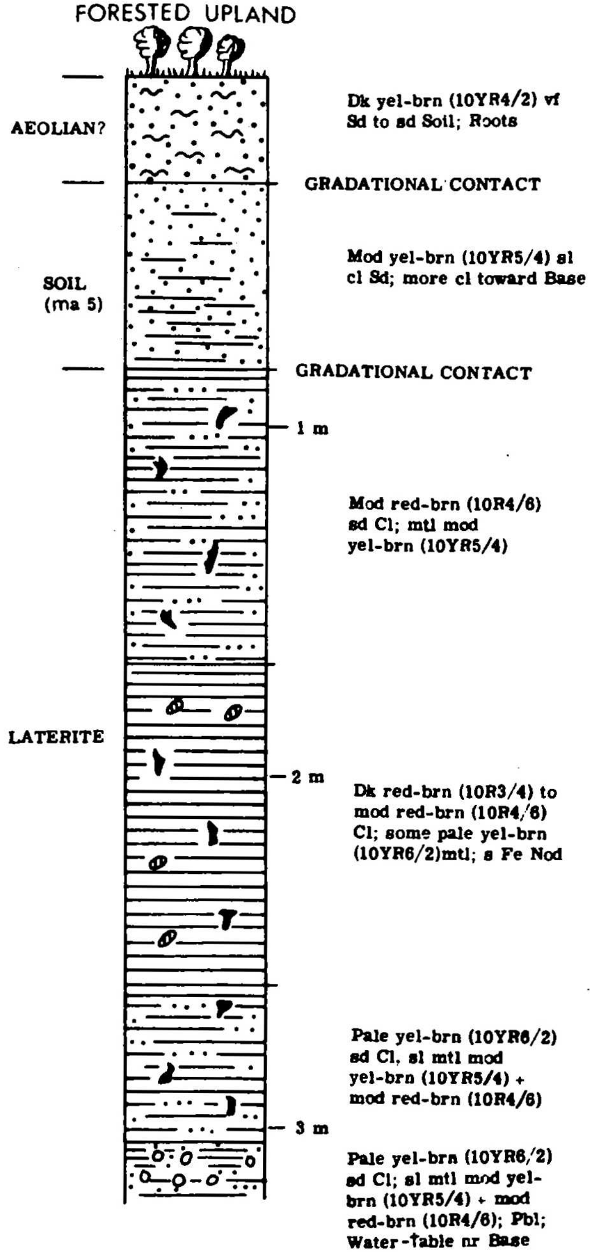
To accompany Record 1972/78

FIG. 23
AUGER HOLE 15



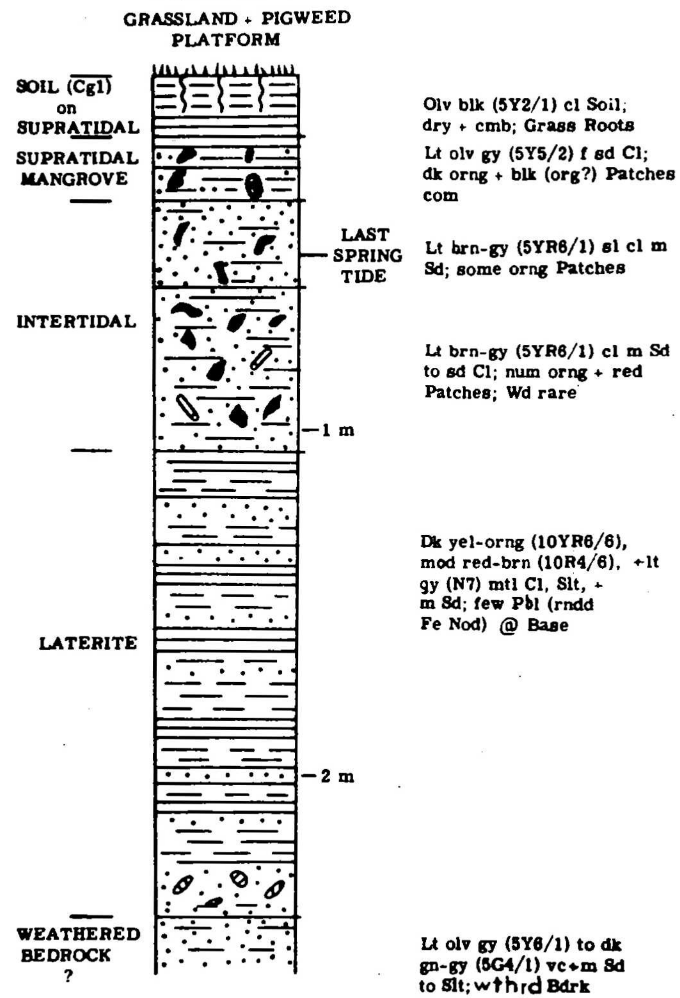
LITHOLOGICAL LOG OF AUGER HOLE 15

FIG. 24
AUGER HOLE 16



LITHOLOGICAL LOG OF AUGER HOLE 16

FIG. 25
AUGER HOLE 13



LITHOLOGICAL LOG OF AUGER HOLE 13

To accompany Record 1972/78

BMR Port Clinton No. 3 (Fig. 26) and Auger Hole 14 (A14) (Fig. 27)

BMR Port Clinton No. 3 and A14 were sunk in a large circular depression which was flooded during much of the regression. A thicker sequence of unconsolidated sediment was deposited at A14 near the centre of the depression than at BMR Port Clinton No. 3 on the rim of the depression. Intertidal mud overlies rock in A14, but at BMR Port Clinton No. 3 closer to the old shoreline intertidal sediments are woody, clayey to clean sands. Intertidal mangrove mud overlies intertidal deposits in both holes and is succeeded in turn by supratidal mangrove and supratidal mud. Dark soil (Cg1) developed in the supratidal mud after the sea retreated from these sites, but a thin layer of sand and silt has been deposited over the soil. This alluvium was laid down by modern wet season floods which wash sediment from the upland onto the flats. The alluvium is now grassed.

BMR Port Clinton No. 2 (Fig. 28)

BMR Port Clinton No. 2 was drilled in a circular depression modified by the sea. Unconsolidated sediments are thinner in it than in BMR Port Clinton No. 3 (Fig. 26) and A14 (Fig. 27) because this more eastern circular depression is higher, and the sea stood for less time there. In BMR Port Clinton No. 2 laterite is covered by 0.56 m of unconsolidated sediments, a lower intertidal sand and an upper supratidal mud. Soil formation under grassland has darkened both units.

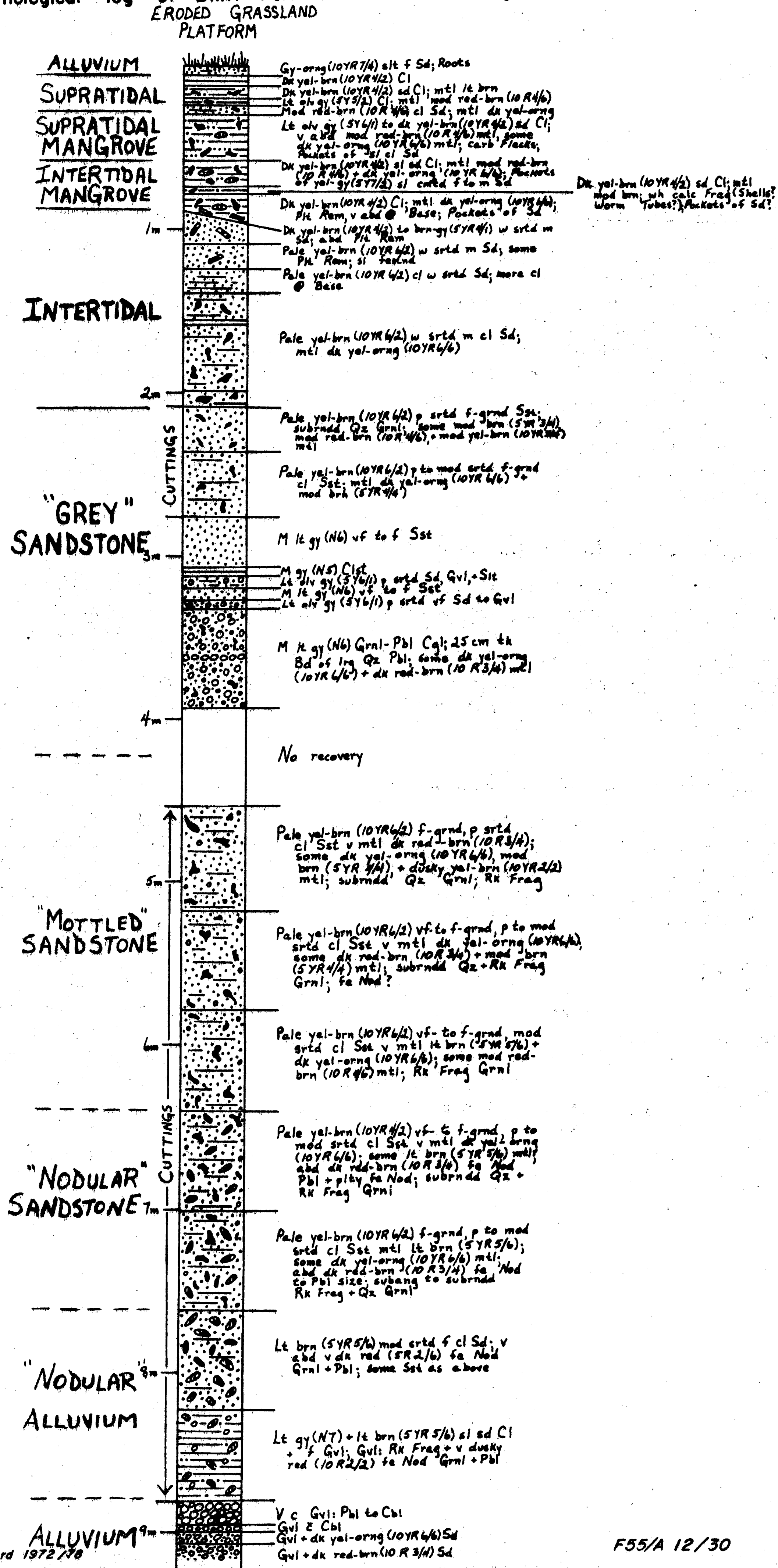
BMR Port Clinton No. 5 (Fig. 29)

BMR Port Clinton No. 5 did not penetrate solid rock or laterite in 36 m of drilling. The upper 3.89 m of unconsolidated sediment record the marine regression: greenish grey shallow marine mud is overlain in turn by intertidal, supratidal mangrove, and supratidal mud. Gypsum is common in supratidal mud just below the soil profile (Cg1) which has formed under grassland.

Summary

The regressive marine sediments recognized in 22 auger and drill holes in the Torilla Plains area have an average thickness of 2.65 m (Table 4); they are thin near uplands and thicken seaward. Various regressive sequences of shallow marine, intertidal, intertidal mangrove, supratidal mangrove, and supratidal sediments are recorded in the subsurface. Intertidal mangrove mud is missing from many holes which contain supratidal mangrove mud. Therefore, intertidal mangroves were probably not pioneers essential to the subsequent growth of supratidal mangroves, and in several places supratidal mangroves did not succeed intertidal mangroves.

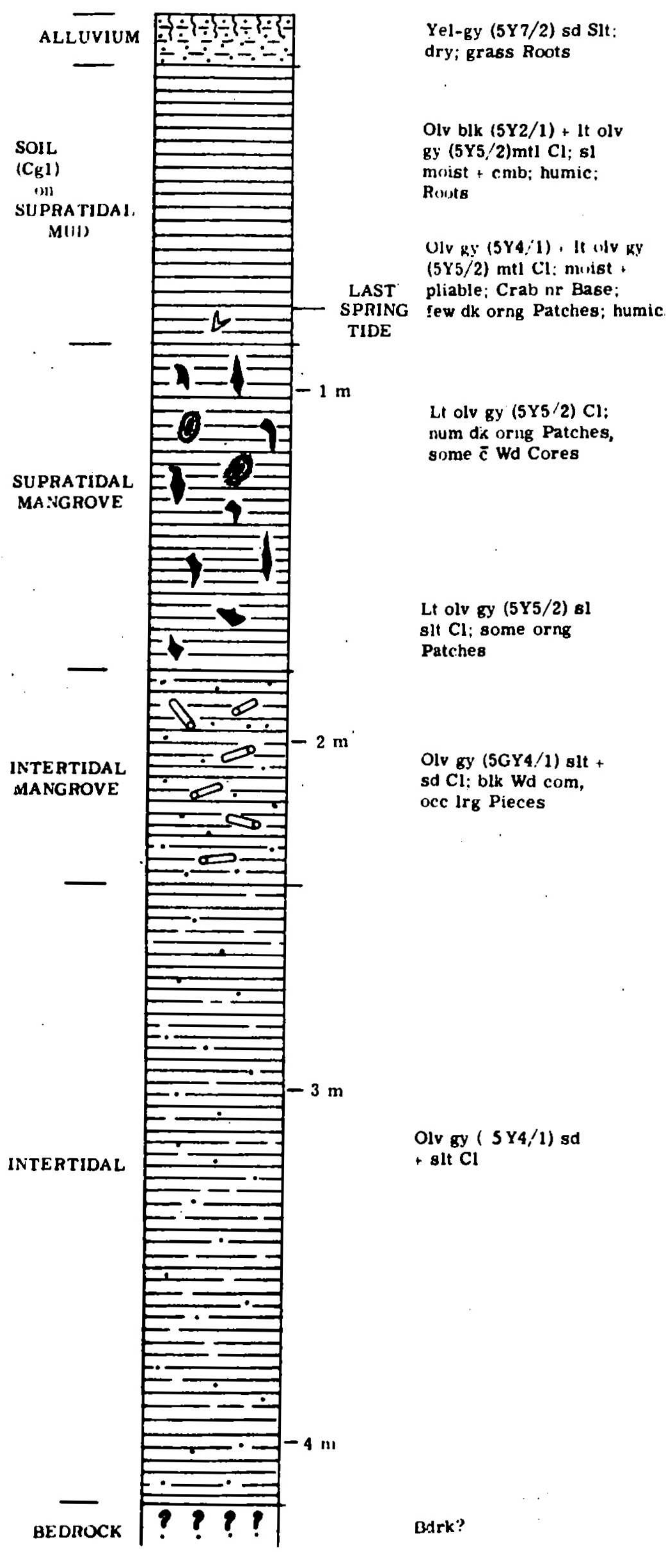
Lithological log of BMR Port Clinton No.3 Fig 26



To accompany Record 1972/78

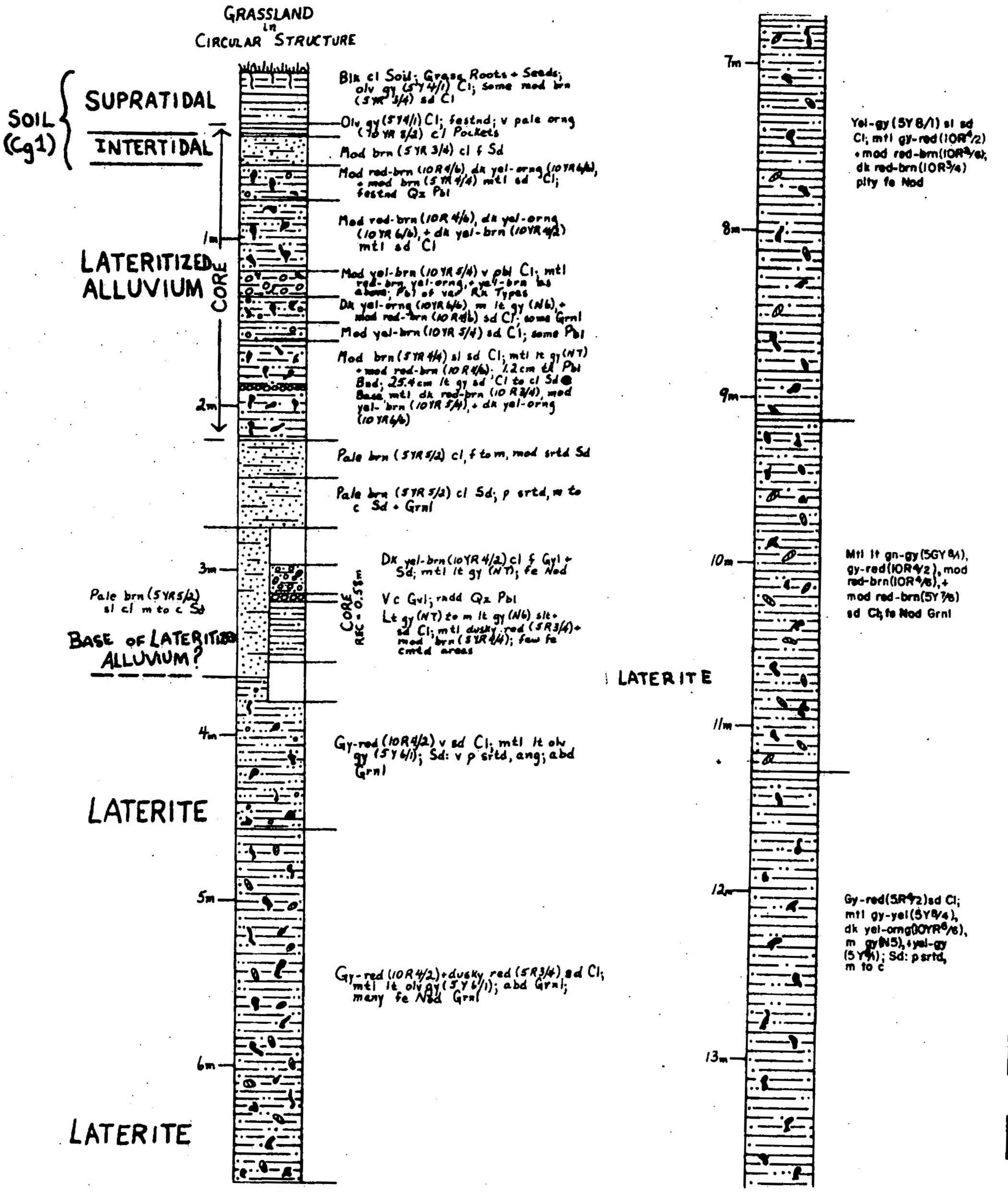
F55/A 12/30

FIG. 27
AUGER HOLE 14
ERODED GRASSLAND ISLAND



LITHOLOGICAL LOG OF AUGER HOLE 14

Lithological log of BMR Port Clinton No 2 Fig28



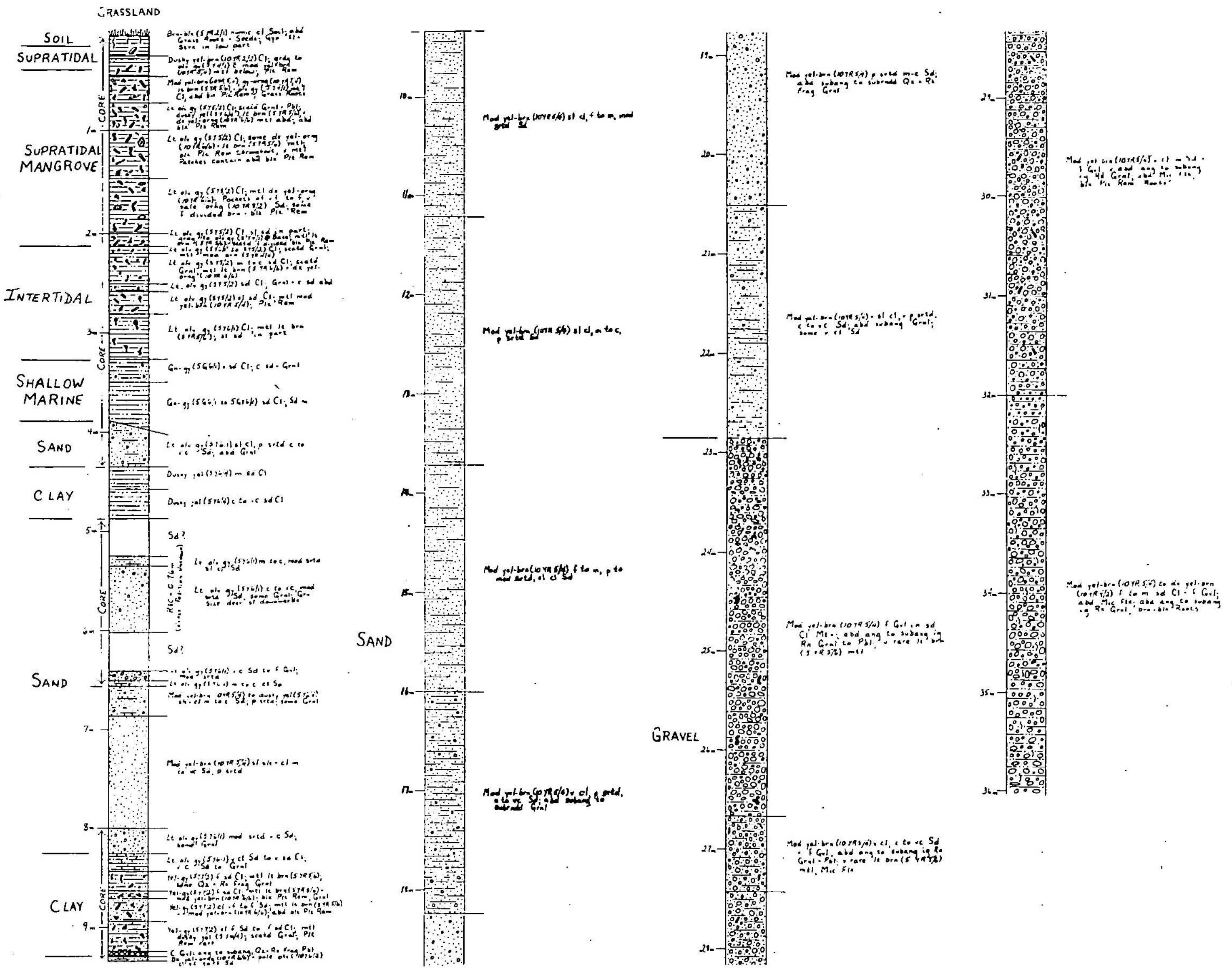


Fig 29 Lithological log of BMR Port Clinton No.5

To accompany Record 1972/78

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GEOMORPHIC EVIDENCE OF REGRESSION

Geomorphic features attributable to coastal processes are common throughout the Torilla Plains area.

Coastal Grassland/Upland Boundary

Wooded, flat to rolling uplands slope sharply 1 to 2 m down onto flat grassland throughout the Torilla Plains area (Figs. 7, 17; Pls. 2, 3). The grassland/upland boundary marks the lower limit of eucalypt woodland and the edge of the area occupied by humic gley or wiesenboden soil (Cg1) (Fig. 3), known from subsurface records to form in old supratidal mud. The boundary marks the maximum marine transgression (Pl. 6); coastal grasslands developed on extensive supratidal flats when they became inactive as the sea retreated westward. Supratidal mud deposits form a time-transgressive unit which becomes younger seaward toward modern, active supratidal flats.

There is no break in slope where wooded Cainozoic alluvial flats meet the coastal grassland (Pl. 9). This boundary marks the maximum marine transgression in those areas.

Wave-cut Cliffs

Wave-cut cliffs up to 5 m high form the coastal grassland/upland boundary in some places (Pl. 5). Their presence several kilometres inland above old supratidal flats proves marine regression. During the maximum marine extension, cliffs were cut southwest of Spencer Creek on the edges of the uplands, near Torilla Hill, and west of Torilla Plains homestead (Figs. 1, 4). The cliffs surrounding Fort Cope are particularly prominent. Old sea cliffs are probably much more common on the Broad Sound peninsula than brief reconnaissance indicated.

Natural Levees

Two bodies of fluvial sediment which stand slightly above the coastal grasslands extend northwestward from the coastal grassland/upland boundary along Coonyan and Wadallah Creeks (Fig. 4; Pl. 6). On the western body surface soil texture becomes finer downstream and toward the flanks. The streams are incised into these deposits, which are probably natural levees.

Coonyan and Wadallah Creeks had probably long been depositing alluvium northwest of the present grassland/upland boundary when sea level rose during the Holocene, drowning their lower sections. When the shoreline retreated, deposition of regressive marine sediments had disrupted their courses so that sheets of sediment-laden water flooded over the old supratidal flats during the wet season.

TABLE 4

THICKNESS OF REGRESSIVE SEQUENCE

HOLE	THICKNESS OF REGRESSIVE SEQUENCE	SITE DESCRIPTION
Port Clinton No. 1	3.56 m	Coastal grassland
Port Clinton No. 2	0.56 m	Grassland in centre of circular structure
Port Clinton No. 3	2.08 m	Eroded grassland platform near rim of circular structure
Port Clinton No. 4	3.09 m	Grassland near head of re-entrant in upland
Port Clinton No. 5	3.89 m	Coastal grassland
St Lawrence No. 1	-	Rim of circular structure on upland
St Lawrence No. 2	5.10 m	Supratidal mangrove swamp
Auger hole 1	3.04 m	Active supratidal flat
Auger hole 2	2.38 m+	Vegetated beach ridge
Auger hole 3	2.74 m+	Vegetated beach ridge
Auger hole 4	0.20 m	Grassland at upland edge
Auger hole 5	2.04 m+	Active supratidal channel bank in coastal grassland
Auger hole 6	1.78 m+	Flank of vegetated beach ridge at Fort Cope
Auger hole 7	2.86 m+	Active supratidal flat
Auger hole 8	3.67 m+	Coastal grassland near supratidal channel
Auger hole 9	3.06 m+	Coastal grassland between two supratidal channels
Auger hole 10	3.06 m+	Eroded grassland island on active supratidal flat
Auger hole 11	2.88 m	Coastal grassland near upland
Auger hole 12	1.82 m	Grassland in centre of circular structure
Auger hole 13	1.08 m	Eroded grassland platform at upland edge
Auger hole 14	4.20 m	Eroded grassland island on active supratidal flat
Auger hole 15	-	Forested upland
Auger hole 16	-	Forested upland

During a series of floods these streams have confined and extended their courses on the flats by building natural levees. The section of Wadallah Creek which leaves the natural levee has no clear channel connection with the long supratidal channel of that name which cuts the coastal grasslands (Fig. 4). The natural levees are now covered by grass and trees (Pl. 6).

Couti Uti Creek has deposited 0.6 m of alluvium over dark organic soil (Cg1) in old supratidal mud beyond the grassland/upland boundary. Like Coonyan and Wadallah Creeks it is extending its deposits onto the old supratidal flats. Deposition of fluvial sediments over old supratidal mud constitutes the final step in the regressive sequence.

Upland Sand Deposits

Surface deposits of loose sand lie just east of the coastal grassland/ upland boundary between Waratah and The Hollins (Fig. 4). Brief reconnaissance did not permit delineation of the eastern boundary of this sand unit or precise location of loose sand patches observed along the road between The Hollins and Stanage Bay. The grey and brown, fine to medium-grained, moderately to well sorted sand varies from 0.3 to 1.0 m thick and commonly overlies laterite. This sand deposit can be distinguished from sandy A horizons of the soloths and yellow podzolic soils (GB7, GA26) (Fig. 3) which develop from Waratah homestead to Stanage Bay.

Similar loose sand deposits overlie red earth soil (ma5) around the southwestern edges of the upland west of Torilla Plains homestead (Figs. 3, 4, 17). Scrubby Ti-tree grows preferentially in this loose sand and borders the upland. Tall eucalypt woodland grows on the central parts of the upland where the loose sand is absent and red earth soil covers the surface.

Distribution of this sand along the coastal grassland/upland boundary suggests that it is a strandline deposit. The unit may consist of aeolian sand blown ashore during and just after the maximum marine extension.

Supratidal Channels

A complex, intricate system of supratidal channels has been incised into the old supratidal mud of the coastal grasslands during the regression (Pls. 2, 3, 6). Fresh flood waters draining from the uplands follow these channels in places.

Beach Ridges

Abandoned beach ridges occur on both sides of the peninsula and are further evidence of a young marine regression. Beach ridges are especially common along the western shore of Shoalwater Bay (Fig. 4). Beaches occur at upland edges adjacent to mangrove swamps and to active supratidal flats on the Broad Sound side of the peninsula (Pls. 4, 6). The old beaches at Port Cope are now surrounded by coastal grassland (Pl. 2).

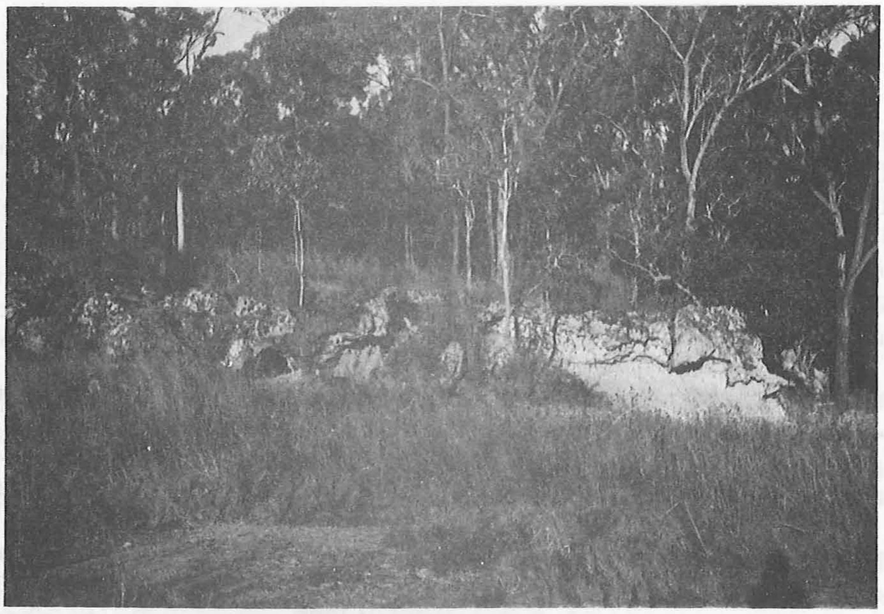

Plate 5: Old sea cliff cut in lateritized, mottled bedrock standing above coastal grassland on the southwestern edge of Port Cope.

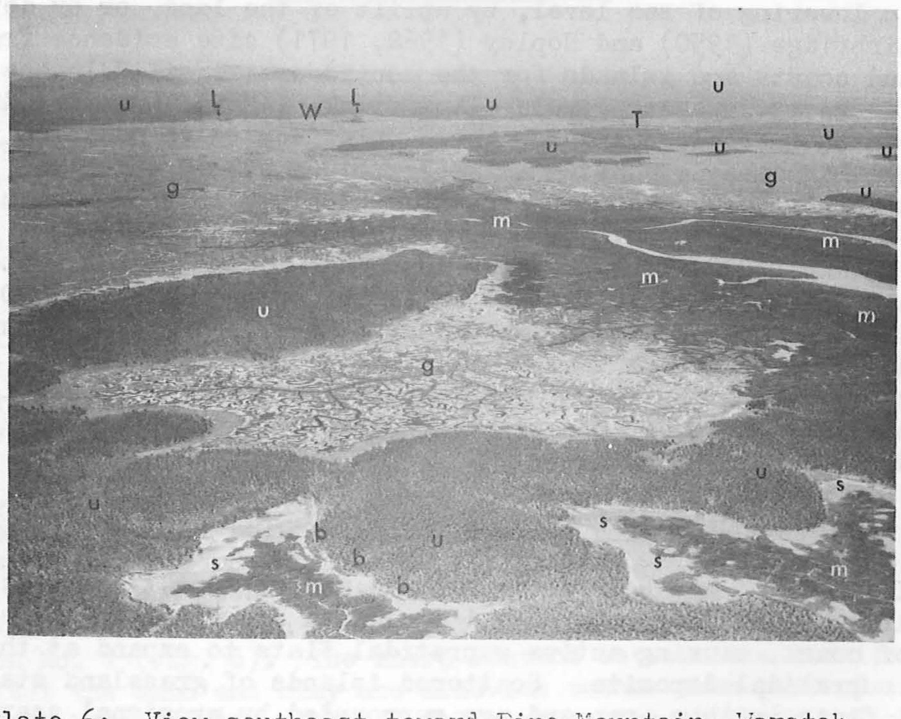

Plate 6: View southeast toward Pine Mountain, Waratah homestead (W), and Torilla Plains homestead (T). In the foreground beach ridges (b) are preserved on the northern flanks of wooded uplands (u) above active supratidal flats (s) and mangroves (m). A complex pattern of supratidal channels cuts coastal grassland (g) in the middle distance. The boundary between extensive coastal grassland (g) and wooded uplands (u) marks the maximum Holocene transgression. Natural levees (L) extend onto coastal grassland.

AGE OF THE REGRESSION

The stratigraphic position of the regressive sediments, lateral continuity of various units with modern deposits, and associated youthful geomorphic features suggest a Holocene age for the regression.

Sediments from the peninsula east of Broad Sound have not yet been dated by the radio-carbon method. The one exception, intertidal mangrove wood from A1 (Fig. 17) gives a date (170 ± 110 years B.P.) which is thought to be too young but which probably indicates a Holocene age for the enclosing sediment.

Oyster shells from two series of beach ridges on the western shore of Broad Sound have been dated. Four beach ridges on Charon Point, west of Fort Cope (Fig. 1), decrease in age seaward from about 4 520 years B.P. to about 3 465 years B.P., about 2 480 years B.P., and about 1 410 years B.P. (Cook & Polach, 1972). At The Hoogly, also west of Fort Cope, beach ridges decrease in age seaward from about 5 020 years B.P. to about 740 years B.P. (Cook & Polach, 1972). These beach ridges occur in the same general environmental setting as those on the peninsula east of Broad Sound. Jardine (1928) believed that relative sea level has dropped 4.5 to 6.0 m during the last 4 500 years in the Herbert Creek area, but he gave no evidence to support this estimate.

Retreat of the western shoreline of the peninsula could have been caused by eustatic lowering of sea level, by uplift of the land, or by depositional progradation. Fairbridge (1950) and Hopley (1968, 1971) cite evidence from northern Queensland coasts and islands for the controversial mid-Holocene high stand of the sea above its present level. Thom et al. (1969), however, draw upon data from the southern Queensland and New South Wales coasts to question the existance of such a high sea level stand. Hopley (1968, 1971) and Bird (1971) record regression in northern Queensland in the last 4 500 to 3 500 years.

Cook & Polach (1972) conclude from the beach ridges on the western side of Broad Sound that the sea reached its present level approximately 5 000 years ago and since that time sea level has not fluctuated by more than ± 1 m. Consequently, it would seem reasonable to assume that regression in the Torilla Plains area is due to depositional progradation rather than a relative lowering of sea level, although the possibility of localized vertical movement of the peninsula cannot be completely excluded.

LOCALIZED MODERN TRANSGRESSION

Coastal grassland has been eroded in the modern supratidal zone from A10 almost to Halfway Creek (Figs. 1, 4). A localized transgression is occurring on that stretch of coast, causing active supratidal flats to expand at the expense of old, grassed, supratidal deposits. Scattered islands of grassland stand above active supratidal flats in this area and are surrounded by erosional scarps up to 1 metre high. Remnant strips of grassland 10 to 20 m wide lie between the upland west of Torilla Plains homestead and active supratidal flats and have similar erosional scarps on their seaward edges (Pls. 1, 4, 10). Spring tides have eroded coastal grassland within circular depressions at BMR Port Clinton No. 2 and south of Fernlea homestead (Pls. 9, 10, 11). Encroachment of intertidal sand banks on mangroves south of Island Bluff, erosion of a steep bank in supratidal mangrove mud near BMR St Lawrence No. 2 (Fig. 17), and the erosion of modern intertidal mud from mangrove deposits are also suggestive of a modern transgression.

Three factors may have combined to initiate transgressive conditions in this area:

1. possible contemporary eustatic sea level rise of approximately 1 mm/year (Flint, 1971, p. 322);
2. independent tectonic movement of the western part of the peninsula south of Fort Cope; and
3. changes in estuarine circulation which concentrate tidal currents on the eastern shore of Broad Sound and possibly cause locally higher tides.

The last two factors would explain localization of this modern transgression. The pattern of tidal circulation has probably changed as the shoreline has prograded, altering the shape of the estuary.

PRE-HOLOCENE DEPOSITS

Laterite

The St Lawrence and Port Clinton Sheet areas were lateritized during the Tertiary (Malone, Olgers & Kirkegaard, 1969; Malone, 1970). Lateritized bedrock and alluvium are exposed in stream beds, gullies, and wave-cut cliffs (Fig. 30) and were penetrated in 3 drill holes and 6 auger holes in the Torilla Plains area.

Lateritized Bedrock. Lateritized bedrock forms cliffs that were cut into red earth uplands during the maximum Holocene extension of the sea (Pl. 5). It is extensively mottled red, reddish brown, and white. The presence of lateritized bedrock below red earth soils (Figs. 3, 30) proves that the red earth uplands are remnants of an old lateritized land surface.

Lateritized Alluvium. Unconsolidated, lateritized alluvium occurs in some exposures and drill holes. In cores from BMR Port Clinton No. 2 (Fig. 28) it consists of interbedded sandy clay, gravel, and sand. Interbeds of alluvial gravel and clayey sand have been lateritized south of The Hollins (Figs. 1, 30). Weathered granite is overlain by lateritized clayey sand and sandy clay in BMR Port Clinton No. 1 (Fig. 6). The sharp contact between the granite and sediments indicates that the sand and clay are alluvium rather than part of an in situ soil profile. The abundance of weathered feldspar grains in these sediments suggests that the alluvium was derived from the granitic source area of the Palmer Ridges to the south (Fig. 1).

Iron nodules in the alluvium (BMR Port Clinton No. 2, Fig. 28) may have been eroded from pre-existing soil profiles and been deposited with the sediment or may have formed in situ during lateritization. The irregular shape of iron nodules in ferruginized conglomerate near the head of Spencer Creek (Figs. 1, 30) suggests that they grew in and were cemented with this alluvium during lateritization.

Sandstone and Conglomerate

Sandstone and conglomerate are exposed in upland creek beds from The Hollins south to Block Creek (Figs. 1, 4) and were penetrated below the late Holocene regressive sediments in 3 drill holes on the coastal grasslands.

'Grey' Sandstone. Two sandstone ledges are overlain by modern fluvial sediments in the bed of Couti Uti Creek (Figs. 1, 4). The northern ledge is 0.75 m thick and consists of yellowish grey (5Y8/1), slightly muddy, moderately sorted, very fine to fine-grained sandstone. Numerous brown root channels, a few small pieces of fossilized wood, blebs of clay, and disturbed bedding suggest that this fluvial sediment was part of a soil profile before and possibly during induration. The ledge is underlain by unconsolidated clayey sand. The sandstone which forms the southern ledge is pale yellowish brown (10YR6/2), slightly mottled, poorly to moderately sorted, and medium to coarse-grained; it contains quartz pebbles and clay-filled root channels.

Mottled Sandstone. Some sandstone exposures are mottled moderate reddish brown (10R4/6), dark yellowish orange (10YR/6), greyish orange (10YR8/4), very light grey (N8), light grey (N7), and light olive grey (5Y6/1). In a creek bed between Spencer and Couti Uti Creeks clayey, fine to medium-grained sandstone is mottled grey, and clean, medium-grained sandstone is mottled red (Figs. 1, 4, 10; Pl. 7). Clay was translocated from red to grey areas as the mottles formed during lateritization. Interbeds of angular quartz pebbles indicate that this sandstone is an alluvial deposit. Elsewhere, lateritization caused the formation of iron nodules surrounded by stained rings as well as the development of mottling in alluvium. The age relationship of sandstone induration and lateritization is unknown.

Lateritized, clayey and pebbly sand overlies lateritized, mottled sandstone in the creek bed between Spencer and Couti Uti Creeks. This sand is coloured by alternate red and grey bands about 7.6 cm thick (Pl. 8). Springs discharge in a bank cut in this sand, and groundwater may have produced the banding by remobilizing and selectively concentrating iron along certain horizons in the lateritized parent alluvium. Elsewhere in this exposure the lateritized sand is absent, and modern, light grey and brown alluvium containing iron nodules eroded from old soil profiles directly overlies the mottled sandstone (Pl. 7).

Conglomerate. Pale yellowish brown (10YR6/2) granule conglomerate with a fine-grained matrix occurs in the beds of Wadallah, Halfway, and Block Creeks (Figs. 1, 4). The granules are angular to subangular and consist predominantly of quartz with some rock fragments; weathered feldspar grains are common close to granitic uplands. The conglomerate is rarely mottled. Granule conglomerate is interbedded with pebble conglomerate and 'grey' sandstone at the westernmost exposure in Halfway Creek. The similarity of these rocks to the modern fluvial sediments which overlie them indicate that the conglomerate and sandstone are alluvial deposits.

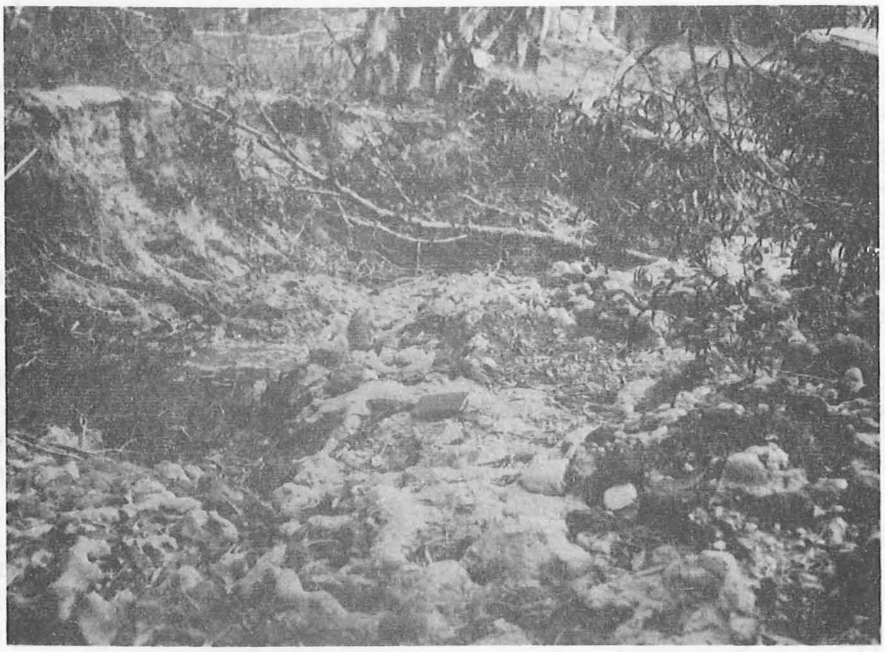

Plate 7: Grey and red mottled sandstone in a creek bed between Spencer and Couti Uti Creeks.

Plate 8: Grey and red banding in lateritized, unconsolidated alluvium in a creek bank between Spencer and Couti Uti Creeks.

Pebble conglomerate in a creek just south of The Hollins (Figs. 1, 4) consists of very angular pebbles of quartzite, vein quartz, and granite; smooth, rounded iron nodules; and irregular, elongate iron nodules in a sandstone matrix. The smooth, sand-sized and pebble-sized iron nodules were rounded chemically or mechanically during weathering and transport from a soil profile; they resemble iron nodules carried by modern streams that are eroding laterite (Fig. 30). Laterite profiles apparently existed before this conglomerate was deposited. The irregular, elongate iron nodules grew in the alluvium during soil formation or induration.

Beds of indurated pebble and granule conglomerate and of loose quartz pebble gravel are common in the sandy alluvial sequence which underlies regressive marine sediments in BMR Port Clinton Nos. 3 and 4 and BMR St Lawrence No. 2 on the coastal plains. Induration of alluvium has been selective; loose gravel underlies 'grey' sandstone in BMR Port Clinton No. 4 (Fig. 5); conglomerate lies between two beds of loose gravel near the bottom of BMR St Lawrence No. 2 (Fig. 18); and the sandstone sequence in BMR Port Clinton No. 3 is underlain by and contains interbeds of unconsolidated gravel, sand, and mud (Fig. 26). The alluvial sequences in BMR Port Clinton No. 4 and BMR St Lawrence No. 2 bear no distinctive signs of lateritization.

Much of the alluvial sequence in BMR Port Clinton No. 3 (Fig. 26) has, however, been lateritized. Ironstained sand and gravel at the bottom of the hole are overlain by 'nodular' alluvium, sandy clay and clayey sand which contain numerous iron nodules of granule and pebble sizes. The 'nodular' alluvium is overlain by 'nodular' sandstone which contains numerous iron nodules of the same type and is mottled. The overlying 'mottled' sandstone is extensively mottled light brown, dark yellowish orange, and dark reddish brown and contains only rare iron nodules. The 'mottled' sandstone and underlying alluvium have been lateritized. Detrital iron nodules derived from pre-existing soil profiles may have been deposited with the 'nodular' alluvium and 'nodular' sandstone, or iron nodules may have formed <u>in situ</u> in those units during lateritization. The restricted vertical occurrence or iron nodules suggests that they formed in a soil profile. The 'grey' sandstone at the top of the alluvial sequence is less mottled and contains no iron nodules. It may have been deposited after lateritization had ceased.

Age and Induration of the Sandstone and Conglomerate

Tertiary, Pleistocene, and Holocene fluvial deposits occur on the peninsula; the sandstone, conglomerate, and associated unconsolidated sediments are alluvial deposits eroded from the uplands. These rocks and sediments unconformably overlie a pre-Tertiary sandstone in BMR St Lawrence No. 2 (Fig. 18). Tertiary uplift and consequent alluviation of the coastal plains of the peninsula continued into late Tertiary time. Development of only shallow lithosols on the higher hills (Fig. 3), continued truncation of old laterite profiles (recorded by abundant iron nodules in modern stream sediment, Fig. 30), and construction of natural levees across old, grassed supratidal flats (Fig. 4) indicate that rivers have continued to erode and deposit to the present.

At least one episode of lateritization, probably Upper Tertiary in age, has affected the peninsula east of Broad Sound (Malone, Olgers, & Kirkegaard, 1969). Therefore, wherever lateritic characteristics can be recognized in the sandstone, conglomerate, or unconsolidated alluvium, deposition of the fluvial parent material can be dated as Tertiary. Lateritized Tertiary alluvium is present in BMR Port Clinton Nos. 2 and 3 (Figs. 28, 26) and in creek bank outcrops northeast of Couti Uti homestead, between Spencer and Couti Uti Creeks, and near the head of Spencer Creek (Figs. 1, 4, 30).

Alluvium, sandstone, and conglomerate which do not appear lateritized are Tertiary or Quaternary in age. Approximately 32 m of unconsolidated sand, gravel, and clay underlie the late Holocene regressive marine sequence in BMR Port Clinton No. 5 (Fig. 29), southeast of Torilla Plains homestead. The lower 13 m consist of fine angular gravel in a clayey sand to sandy clay matrix; this material may be the lower horizon of an in situ soil, a reworked soil, or an alluvial deposit. Nineteen metres of fluvial sand and sandy clay overlie the gravel and probably represent the northwestern extension of the vast alluvial sheet deposited by Bark Lagoon, Wadallah, and Coonyan Creeks (Fig. 4) prior to the Holocene transgression. The upper 19 m of sediment show no distinctive characteristics of laterite, and their deposition probably postdated lateritization.

Induration of alluvium probably occurred in the soil profile. Some Tertiary alluvium became indurated during lateritization. Alluvium deposited after lateritization may have become indurated as a soil hardpan during periods of high groundwater levels caused by Quaternary climatic fluctuations. This mechanism may explain induration of 0.75 m of the soil profile to produce the northern 'grey' sandstone ledge in Couti Uti Creek (Fig. 4). Induration of alluvium may be taking place at the present time; hardpans occur in modern soloth and yellow podzolic soil profiles in alluvium near and south of the Boundary Flat Lagoons (Fig. 3, GB6). Lateritized alluvium may have experienced induration in several different types of soil profiles.

Induration of Tertiary and Quaternary alluvium has been very selective: coarse gravel beds are loose; and no part of the thick alluvial sequence at BMR Port Clinton No. 5 is consolidated, in contrast to indurated alluvial beds in other drill holes and upland creek exposures. Selectivity of induration may be explained by differences in sedimentary texture, groundwater circulation, and the timing of sediment deposition relative to long-term water-table fluctuations.

CIRCULAR STRUCTURES

Circular to elliptical depressions several hundred metres across are present on red earth uplands south of Port Cope (Fig. 30; Pls. 9, 10, 11). These circular structures occur as individual enclosed basins without tributary or exit streams, in strings joined by streams, and as overlapping or coalesced groups without connecting streams (Fig. 30). Most circular structures are grassed and wooded, but a few between Boundary Flat Lagoons and Halfway Creek are often filled by fresh water (Pls. 9, 12). The average depth of the depressions is unknown;

Plate 9: View north along the peninsula east of Broad Sound showing circular structures (c) on red earth uplands, alluvial flats (a), active supratidal flats (s), mangroves (m), and intertidal sand banks (B) in Herbert Creek. Circular structures on upland edges were modified by deposition during the Late Holocene regression. Eroded grassland (g) remains in two modified circular structures.

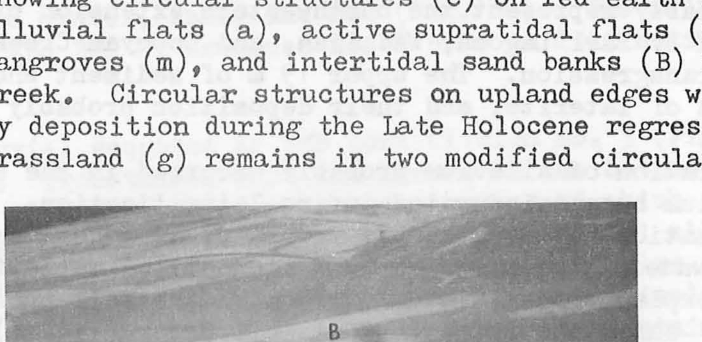

Plate 10: Circular structure at the edge of a red earth upland (u) southwest of Fernlea homestead. Eroded grassland (g) remains in the circular structure and on the upland edge. Supratidal flats (s), mangroves (m), and intertidal sand banks (B) are cut by channels.

but the rim of the circular structure near BMR St Lawrence No. 1 stands about 3 m above water, and near BMR Port Clinton No. 2 the rim of the circular structure is about 6.1 m above grassland. Auger holes and surficial mapping indicate that these circular structures are surrounded by red earth soil and their rims and floors are covered by sand. Circular structures at the edge of active and inactive supratidal flats were flooded by the Holocene transgression (Pls. 9, 10, 11), and intertidal and supratidal sediments overlie this sand cover in places. Dense Ti-tree grows on the sandy rims and aids identification of circular structures on air-photos (Pl. 12). The circular structures have developed in laterite which underlies the sand floor and surrounding red earth soil (Fig. 31).

The geographical restriction of circular structures to red earth uplands suggests an association with lateritization or weathering of relict laterite soil profiles (Fig. 30). Not all red earth uplands are pitted by circular structures, however. Circular structures are confined to flats between 15 and 30 m above sea level on the western areas of the Torilla Plains upland and the two uplands between Bark Lagoon and Halfway Creeks; the structures do not occur on the higher, fairly rugged hills of the eastern sections of these uplands. The red earth upland east of Banksia and Glen Isla homesteads is steeper and higher than the others and displays only one possible circular structure. The restricted altitudinal and topographic distribution of circular structures suggests that groundwater levels relative to zones in the laterite profile may control circular structure formation. Development of teardrop lakes in modern lateritic terrain in Tabasco, Mexico (West, Psuty, & Thom, 1969), and of shallow, flat depressions (baixas) in relict laterite in Amapa, Brazil (Vann, 1963), has been attributed to groundwater sapping at the top of the mottled zone. Groundwater sapping in relict laterite profiles would have been more active during high Quaternary sea level stands and accompanying high water-tables and may have been largely responsible for circular structure formation in the Torilla Plains area. Hundreds of similar circular structures occur on an extensive flat lateritized surface in the Cape York Peninsula (R. Galloway, pers. comm.).

CAINOZOIC HISTORY

Tertiary faulting affected the peninsula east of Broad Sound, and late Tertiary uplift produced most of the present ranges (Kirkegaard, Shaw & Murray, 1970). Alluvium was shed from the hills and deposited unconformably over bedrock in vast sheets between granitic and metamorphic uplands in the coastal plains zone, on the southwestern flank of the highlands, and in valleys in the highland zone. Lateritization occurred during the Tertiary, probably in late Tertiary time. Laterite soil profiles developed in Tertiary alluvium and in Palaeozoic and Mesozoic bedrock. Induration of some alluvium probably occurred during laterite formation.

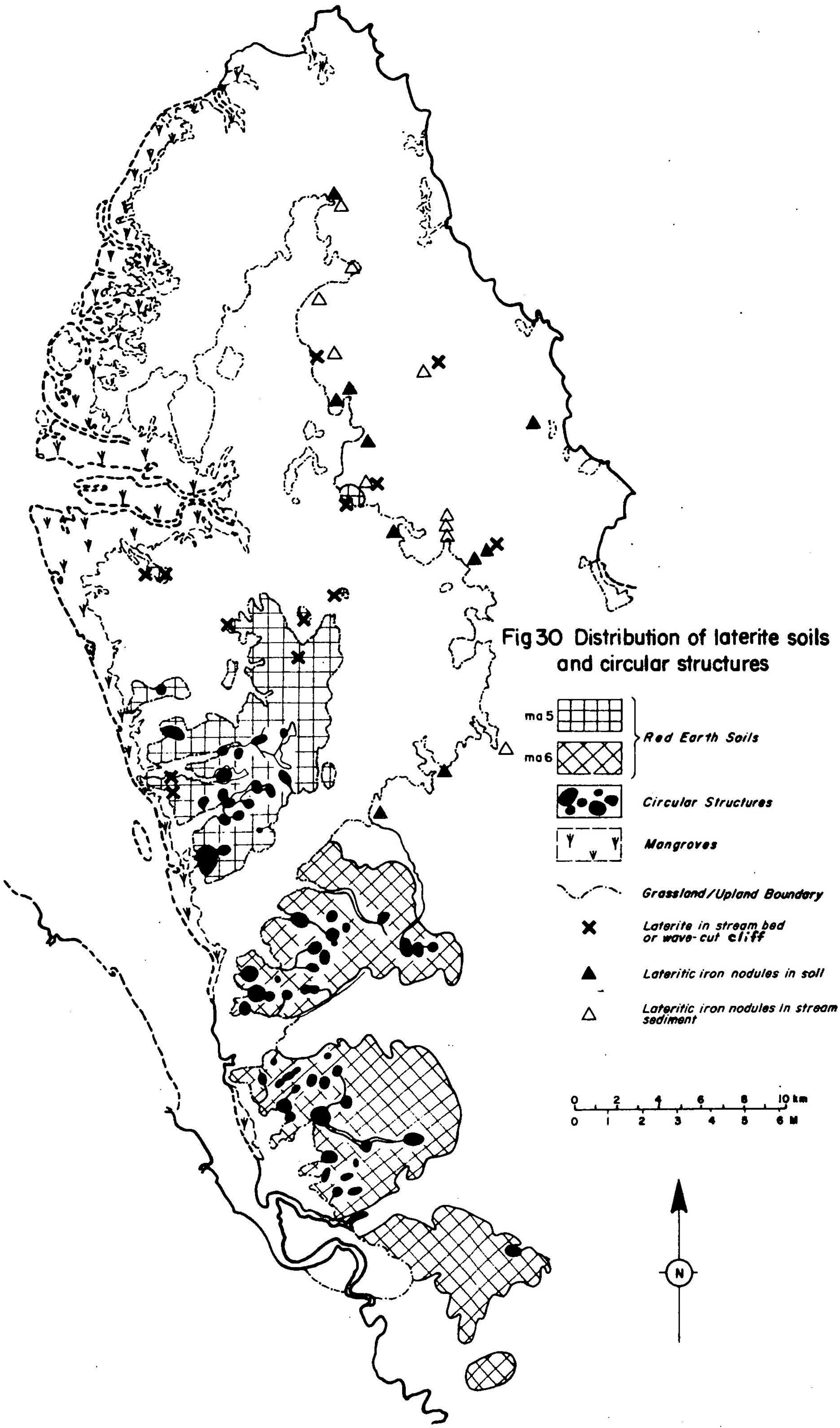

Fig 30 Distribution of laterite soils and circular structures

To accompany Record 1972/78

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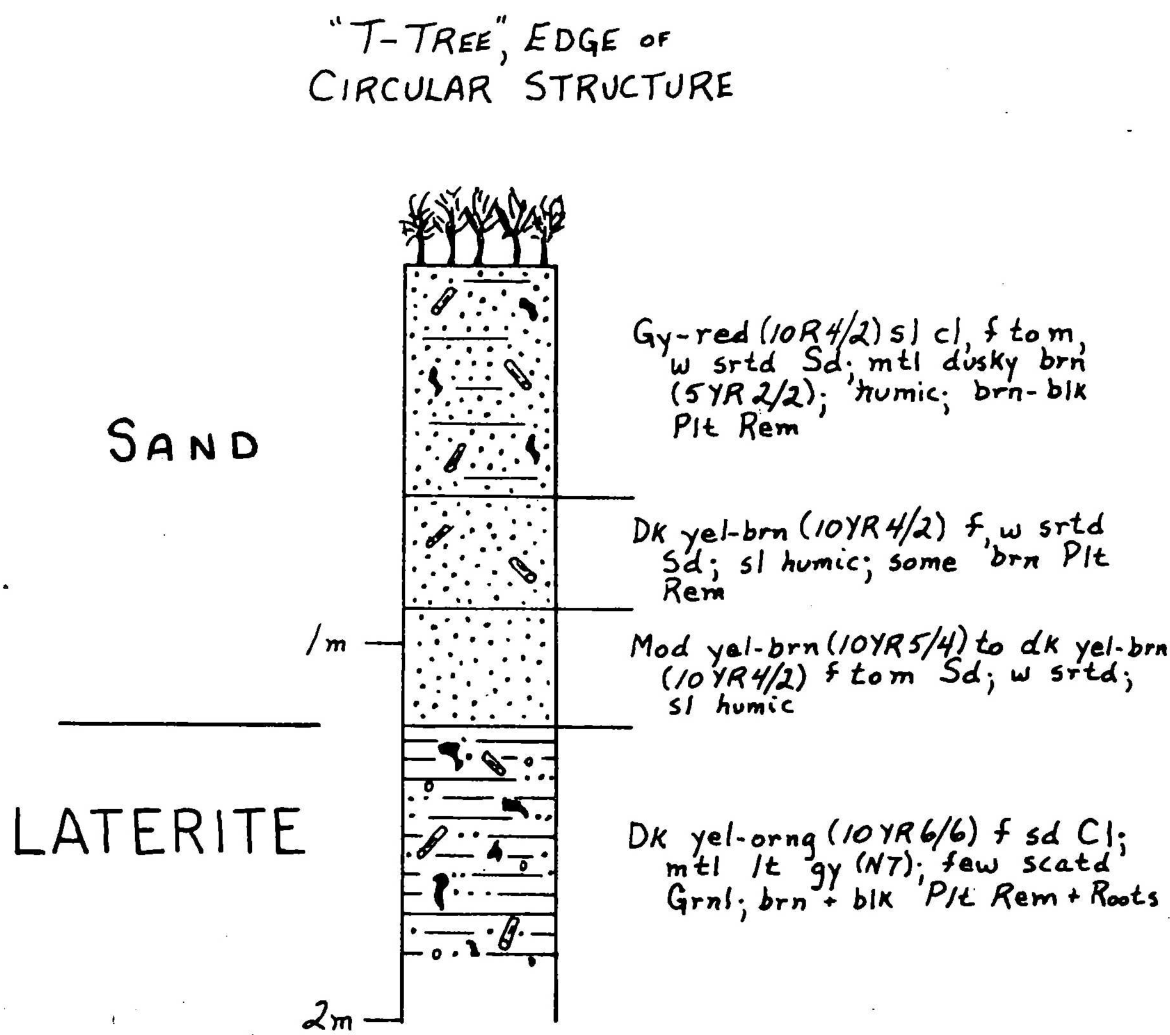
Plate 11: Coalesced circular structures at the edge of a red earth upland (u) southwest of Fernlea homestead. Grassland (g) is being eroded adjacent to supratidal flats (s) at the seaward end of the circular structures. Mangroves (m) grow in the distance.

Plate 12: Grassed floor of a circular structure at the edge of a red earth upland. Short, light-coloured Ti-tree grows on the rim of the circular structure with taller eucalypts behind on the upland.

Lithological log of BMR St Lawrence 1   Fig 31



Alluviation continued through the Tertiary and into the Quaternary. Erosion truncated the laterite profile; various climatic, floral, and groundwater regimes during the Quaternary produced new soil types. Red earth soild developed on relatively undisturbed remnants of the old lateritized Tertiary land surface. Circular structures probably developed on these remnants because of groundwater action in the relict laterite profile during late Tertiary and Quaternary time. Alluvium may have been indurated as soil hardpans during periods of high water-table caused by Quaternary climatic fluctuations.

There is no evidence on the peninsula of Pleistocene sea level fluctuations earlier than the Flandrian transgression which began in the late Pleistocene and continued into Holocene time. The sea transgressed across the lateritized and alluviated coastal plains to the coastal grassland/upland boundary to reach its present level approximately 5 000 years ago. Shallow marine mud was spread across the plains, sea cliffs were cut in lateritized bedrock along the maximum shoreline, and sands of possible aeolian origin were deposited on the uplands along the strandline. The coastline subsequently prograded as sedimentation proceeded. Laterally equivalent sedimentary environments migrated seaward as the sea retreated; the shallow marine environment was generally succeeded by inter-tidal, mangrove, and supratidal environments at many sites. Although growth of intertidal mangroves was often followed by the development of a supratidal mangrove swamp, these two environments were not dependent on each other for their establish-ment. Grass covered the supratidal flats as they becaue inactive. As progradation continued, a complex system of tidal channels was incised into the grassland. Upland streams shortened by the transgression and unable at first to incise a course into the regressive sediments built natural levees out onto the coastal grasslands. Beach ridges were also build during the past 5 000 years.

A local late Holocene transgression has caused erosion of grassland and supratidal mangrove deposits on the eastern shore of Broad Sound, south of Fort Cope. Changes in the pattern of tidal currents and coastline tectonics may be responsible for this transgression, which seems to be continuing at the present time.

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