## THE CONFIGURATION OF THE LAKES

The configuration of the Gippsland Lakes has been determined partly by the extent of Holocene marine submergence and partly by the shaping of the barriers, deltas, and swamp land that have developed around them. Some of the depositional features are inheritances from a late Pleistocene phase of coastal evolution, but the present configuration is the outcome of a complicated history of erosion and deposition of sediment delivered mainly by fluvial and marine action to the East Gippsland embayment. Changes in configuration still continue around the shores of the lakes (Figure 36), accentuated, as has been shown, by ecological and other changes which have halted the process of delta growth and swamp land encroachment on much of the lakes shore. It is now necessary to analyse the various processes that have determined the outlines of the present morphology of land and lake in this region.

Emphasis has been given to the influence of ocean swell in shaping the outlines of the seaward margin of the coastal barriers. The Ninety Mile Beach has been shaped by patterns of refracted ocean swell, and the beach ridges and dunes on each of the barriers, running roughly parallel to the Ninety Mile Beach, commemorate the alignments of former shorelines. At the present time, ocean swell enters the lakes only in a very limited and much modified fashion, immediately inside the artificial entrance, where it has shaped the outlines of lake-shore beaches on Bullock Island (Figure 16), but with this exception the lake shores are the outcome of erosion and deposition influenced by patterns of waves and currents generated by wind action, and to a lesser extent by tides and river flow, within the Gippsland Lakes.

Plate 22 – Beach accretion, east shore of Lake Wellington (ECF Bird)

The predominant pattern of longshore drifting in the Gippsland Lakes is from west to east in response to waves and currents generated by the prevailing westerly winds. Beach sand has moved along the northern and southern shores (as well as across the floor) of Lake Wellington to accumulate in sandy depositional features on the eastern shore, where spits flank the entrance to McLennan Strait. Plover Point, on the southern side, consists of sand washed up across the margins of an eroded swamp, residual swamps of *Juncus* persisting offshore. On the northern side the long gently-curving beach that extends south from Roseneath shows erosion in its northern half and accretion to the south (Plate 22), where successively-built beach and dune ridges behind the present sandy shoreline diverge into a compound recurved spit, with terminations in the swamp area north of McLennan Strait (Figure 1). In general, sectors of the southern shoreline of Lake Wellington that have westerly aspect are beach-fringed, having an easterly aspect remain swampy, with patches of *Phragmites*.

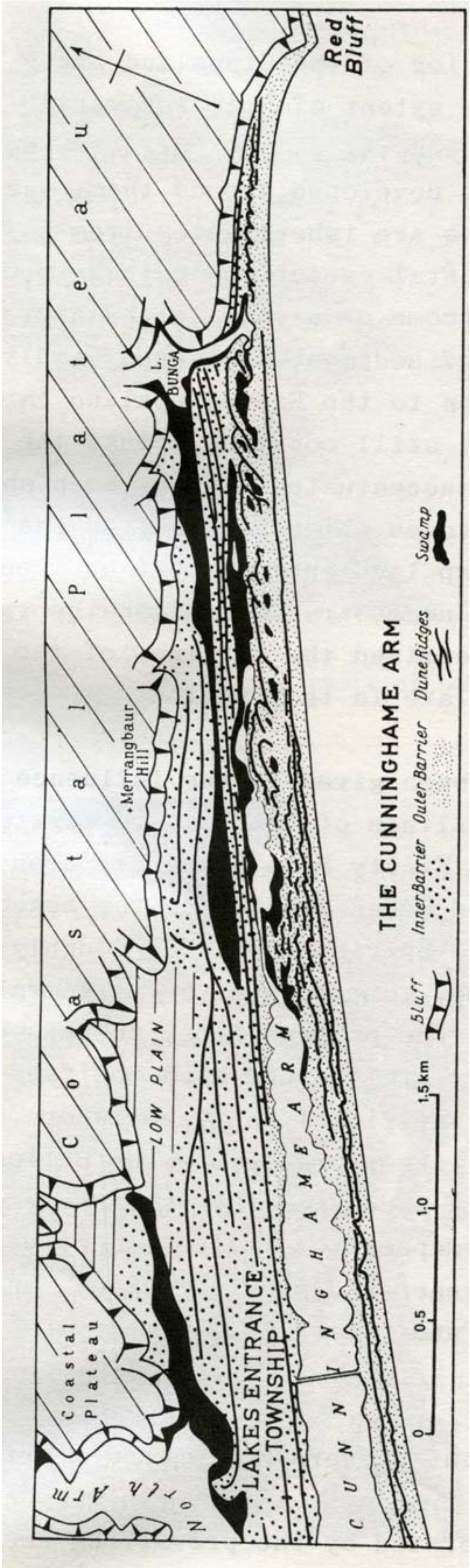
A similar eastward drift of beach material in Lake Victoria is marked by a series of migratory sand bars in the nearshore shallows, aligned at an acute angle to the shore. Again, sand has accumulated on sectors with a westerly aspect, although it has often been driven up by storm waves into the margins of eroding swamps, as on the western sides of Storm point and

Waddy Point. East from Waddy Point the drifting sediment includes pebbles as well as sand, the proportion of gravel increasing east of the eroding cliffs at Tannin Point, with accumulation in embayments such as Mason Bay. Cuspate forelands on the north shore of Lake Victoria (Storm Point, Waddy Point, Wattle Point, Point Turner on the Banksia Peninsula, and Point Scott on Raymond island) each show beach accretion on their eastern flanks, with beach ridges built up during periods of easterly wave action, and erosion on their western flanks, subject to the stronger waves generated by prevailing westerly winds: The points have thus migrated eastward in recent years.

Plate 23 – Sandy depositional feature in Lake Bunga
Formed where sand has been washed or blown over the outer barrier (N Rosengren)

Long shore drifting is also evident in Lake King. Sand washed out through The Cut by the Mitchell River into Jones Bay drifts eastwards to Point Lardner, and the mouth of Salt Creek has been deflected eastwards by spit growth. Sand arriving from the west has accumulated as bars in the embayments on either side of the Tambo delta. On the southern shore of Lake King, Purran Corner is a west-facing re-entrant into which sand has been drifting, and similar features are seen at Kelly Head, south of Flannagans Island. Point Wilson, projecting from Sperm Whale, James point, a similar feature on the Banksia Peninsula, and Butlers Point, near Paynesville, have all been built by northward drifting produced by south-easterly wave action on shores facing away from the prevailing westerlies.

In Bunga Arm and Cunninghame Arm sand supplied by blowouts moving in across the outer barrier is re-worked by wave action, and built into spits and cusps. The direction of drifting in these narrow lagoons is much influenced by local configuration, the predominant eastward drift being reversed on sectors that are sheltered from prevailing westerly winds. In several places, longshore growth of a spit has separated off a minor lagoon, salt marsh development. Mullacky Lagoon, south of Bunga Arm, is an example of such a spit-enclosed lagoon (Plate (). Several of the sandy depositional features along the southern shores of Bunga Arm are derived from triangular fans of sand washed and blown through temporary breaches in the narrow barrier, probably when storm surges swept through low-lying corridors on the alignments of major blowouts. There have been several such events those of 1893 and 1932 being within the recall of older residents. The triangular fans are subject to re-shaping by waves and currents within Bunga Arm, and show various stages in the development of more asymmetrical features, including marginal spits (Plate 23).



THE CUNNINGHAME ARM
Coastal Plateau
Coastal Plateau
Red Bluff
Merrangbaur Hill
L. BUNGA
LOW PLAIN
LAKES ENTRANCE TOWNSHIP
CUNNINGHAME ARM
North Arm
N
0
0.5
1.0
1.5 km
Bluff
Inner Barrier
Outer Barrier
Dune Ridges
Swamp


Figure 35

According to Lewis (1943) lake-shore beaches are built in such a way that they become orientated at right angles to the direction from which the largest (or dominant) waves approach the shore; that is to say, beach alignments become parallel to the crests of approaching dominant waves. The largest waves approaching such a shore tend to come from the direction of maximum fetch, but allowance must be made for the direction, frequency and strength of the winds that generate the waves. Dominant waves often arrive from the direction of stronger or more frequent winds than from the direction of maximum fetch. Schou (1952) suggested that shorelines become orientated at right angles to the 'direction-resultant-of-wind-work', determined from diagrams of wind vectors, on shorelines where there is little variation in lengths of fetch from particular directions. The critical resultant is the onshore wind resultant rather than the direction-resultant of all winds, for onshore winds are obviously more effective in generating strong waves towards the coast than winds blowing offshore or alongshore.

Where they approach the shore at an angle, dominant waves tend to erode some sections and move sediment along the shore to be deposited on others until the shoreline is realigned parallel with dominant wave crests. Longshore drifting is greatest where wave crests approach a shoreline at an angle of 45º (Zenkovich 1957) and diminishes to zero as the shoreline takes up an alignment parallel to the wave crests.

These considerations are relevant to the question of the shaping of the Gippsland Lakes and of coastal lagoons generally. Lagoons are typically elongated in form, enclosed between a former coastline and a coastal barrier more or less parallel to it or between successively-formed coastal barriers: Lake Victoria, Lake Reeve, Bunga Arm and Cunninghame Arm fall into the second category. Protrusions into the mouths of coastal valleys (e.g. North Arm at the mouth of Mississippi Creek) have been largely reclaimed by the major rivers as valley floors and deltas. There is a tendency for long, narrow lagoons to be re-shaped by wave and current action until their shorelines are adjusted to the characteristic patterns of wind-generated waves. Embayments are eroded while intervening sections of the shoreline are built up as spits (e.g. Shaving Point at Metung) or cuspate forelands (e.g. Storm Point on Lake Victoria and Point Scott on Raymond Island, both with multiple low, closely-spaced beach ridges marking their pattern of growth). In this way the original south-west to north-east trend of the inner shores of the coastal barriers has been modified. On the southern shore of Lake Victoria broad embayments have been cut out, truncating the pattern of beach ridges and parallel dunes, their shore taking up a north-south alignment at right angles to lake waves generated across diagonal fetch by the prevailing westerly winds (Figure 1).

On the shores of lakes and lagoons every aspect is represented and each section is tending to become oriented at right angles to the approach of dominant waves for that section. Eventually the configuration conforms with the characteristic wave patterns generated on the lakes, and is then related to the local wind regime. If winds from all directions occurred with equal frequency, the shorelines would be modified until the lake was circular, but where winds from a certain direction prevail, the lake will develop an elongated or oval form. With a long axis parallel to that direction (Livingstone 1954). The shape of Lake Wellington is roughly oval, with a longest axis (18.5 kilometres) WSW to ENE, and a shortest axis (8 kilometres) north to south; it is thus elongated in the general direction of the prevailing winds, and its shape is clearly a reflection of the wind-regime (Figure 5). As has been stated, its western and southern shores, sheltered from the strongest wind and wave action, have tended to advance by swamp encroachment, whereas the more exposed eastern shores are bordered by sandy beaches.

/the conversion of a long, narrow lagoon into a rounded or oval lagoon with configuration reflecting the wind-regime is also in progress along Lake Victoria, and is clearly demonstrable in Cunninghame Arm (Figure 35). The conversion is achieved by means of the process of segmentation, whereby a lagoon is divided into smaller water areas by the formation of intervening strips of depositional land, usually spits or forelands that have become enlarged, growing until they coalesce. The process has been described by Price (1947) from shallow coastal lagoons in Louisiana and Texas on the Gulf Coast of North America, by Fisher (1955) from a coastal lagoon on St Lawrence Island off Alaska, and by Zenkovich (1967) form coastal lagoons in the Soviet Union (see also Gierloff-Emden 1961). In the Gippsland Lakes it has happened on a small scale along Cunninghame Arm, where at the eastern end a series of eroded embayments and enlarged spits passes transitionally to a chain of segmented lagoons (the Warm Holes), linked by a residual channel (Figure 35), and on a large scale for the separation of Lake Wellington from Lake Victoria, where a large recurved sandspit has grown southwards from the prior barrier, restricting the channel that links these lakes to McLennan Strait. Eroded embayments and growing spits and forelands along the shores of Lake Reeve and Bunga Arm, are further indications of the process of segmentation in its earlier stages, a process that has already led to the separation of Hidden Lake from the eastern end of the Bunga Arm. The process is here attributed largely to wave action and adjustment to characteristic wind-generated wave patterns in the lakes, but currents associated with wave action play a subordinate role, tending to smooth the outlines of the shore. Zenkovich commented that currents are more often the consequence than the cause of the formation of the spits that grow to divide a lagoon. In the later stages, current action becomes strong enough to maintain channels and straits that prevent complete segmentation of a lagoon, as in McLennan Strait. Where current action is stronger and more regular, in lagoons influenced by the ebb and flow of tides, there is a tendency for spit growth to become asymmetrical, with elongated spits trailing in the direction of the dominant current (Price and Wilson 1956): there is a suggestion of this on the tidal shores of Cunninghame Are (plate 2), where Miles (1977) traces asymmetrical growth of the spits shown on air photographs taken in 1940, 1963 and 1976.

The process of segmentation depends on the erosion, transportation, and deposition of sediment (chiefly sand in the Gippsland Lakes) around lake shore; it is impeded where shoreline vegetation is present because a reedswamp fringe protects the shoreline form erosion, prevents longshore drifting, and promotes the encroachment of swamp land. As the previous analysis has shown, shoreline reedswamp was widespread around the shores of the Gippsland Lakes in the nineteenth century, and when Gregory observed the process of swamp land encroachment in 1901 he predicted that it would continue, the lakes gradually shrinking in area until finally the various rivers would meander through a swampy coastal plain, uniting to find an outlet to the sea at Lakes Entrance. It appears that segmentation had been taking place at an earlier stage, and that it was arrested by the development of shoreline reedswamp, probably when the outer barrier became sufficiently well established to reduce sea water influx to small and intermittent proportions. Eroded shores became stabilised when swamps developed in front of them, and the evolution of spits and forelands cam to a halt as swamps developed to enclose them. Shrinkage, within this system of partly sheltered lagoons, took place most rapidly on the more sheltered shores, the shrinking lagoons retaining a configuration related to characteristic wave patterns on the lakes, and hence to the wind regime. However, swamp land encroachment has been halted on much of the lake shore, and erosion had been halted on much of the lake shore, and erosion of swamp land has led to the revival of processes leading towards segmentation within the Gippsland Lakes. It is deduced that in lagoon where ecological conditions are suitable for the development of shoreline reedswamp, especially where sediment supply is sufficient to sustain swamp land encroachment, shrinkage will dominate the changing configuration whereas in lagoons without shoreline vegetation, where waves and currents work unimpededly on shoreline sediments, eroding some sectors and building up others, segmentation will dominant.

An intermediate case is illustrated in Lake Reeve a long, narrow lagoon that is very shallow, and frequently dries out altogether. Sand and shelly material present on the lagoon floor are re-worked by wave action as the water level alternates, and moved towards the shoreline as the lagoon rises, to be built into a beach ridge by wave action at the edge of the bordering salt marsh (Plate 24). This ridge is left stranded as the lagoon dries out, and salt marsh encroachment then takes place until the next rise of lagoon level brings in more sand to form another ridge. In this way a succession of parallel ridges has been built up at intervals of less than 40 metres, and standing only a few centimetres above the intervening swales (Plate 25). Some ridges are underlain by sandy deposits; others, emplaced on lacustrine clay or marsh deposits, are form of beach known as a chenier. Jenkin (1968) described than as ‘concentric ridges’ but their pattern is complex, including spits and cuspate forelands that indicate a trend towards segmentation as the lagoon area shrinks, and it is here suggested that they be termed ‘contraction ridges’ (Figure 24)

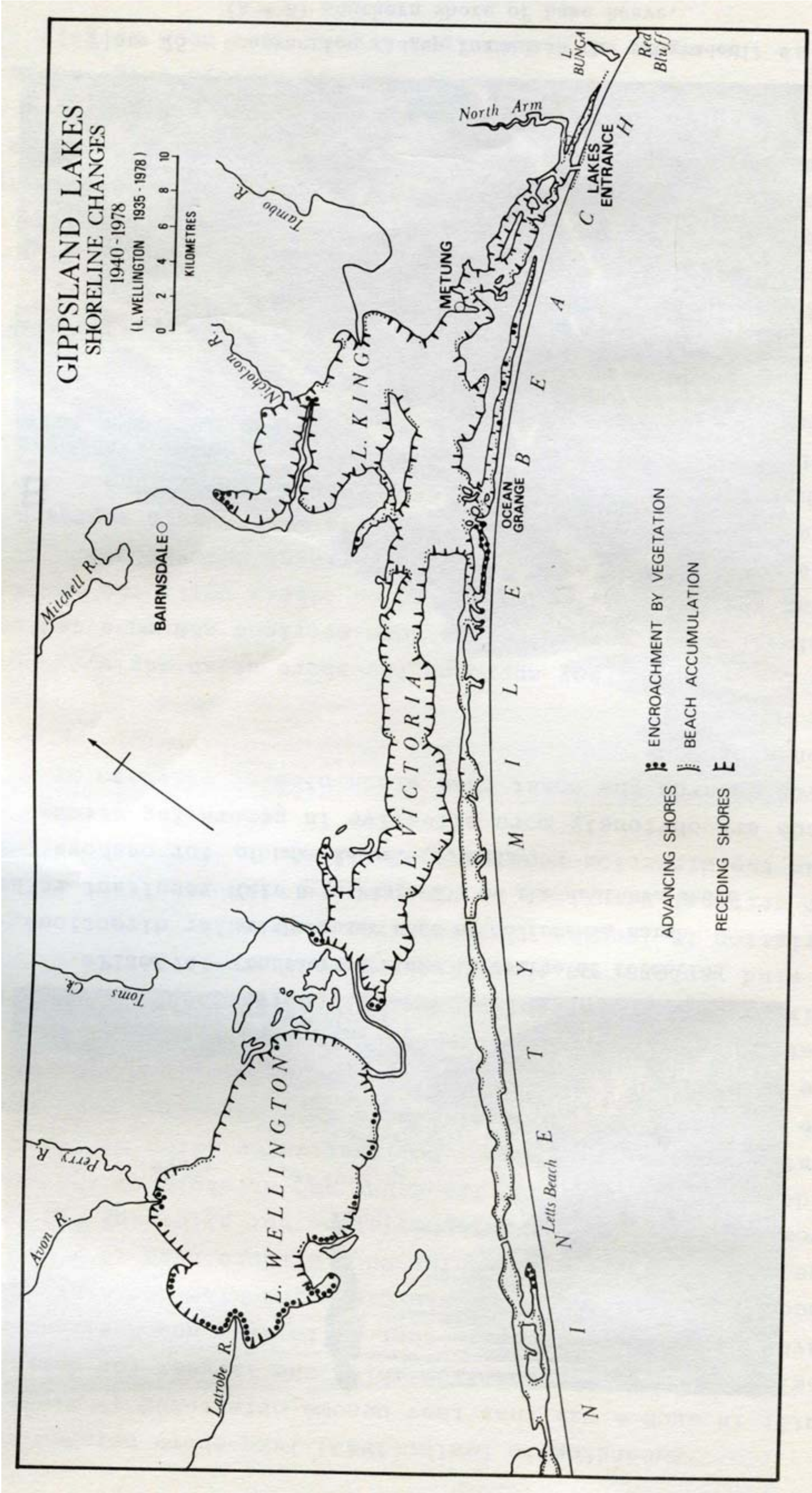

GIPPSLAND LAKES
SHORELINE CHANGES
1940 - 1978
(L. WELLINGTON 1935 - 1978)
KILOMETRES
0 2 4 6 8 10
BAIRNSDALE
Mitchell R.
Nicholson R.
Tambo R.
North Arm
L. BUNGA
Red Bluff
LAKES ENTRANCE
METUNG
OCEAN GRANGE
L. KING
L. VICTORIA
L. WELLINGTON
Toms Ck.
Perry R.
Avon R.
Latrobe R.
Letts Beach
NINETY MILE BEACH
ADVANCING SHORES
ENCROACHMENT BY VEGETATION
BEACH ACCUMULATION
RECEDING SHORES

Figure 36

A further complication in the evolution of long, narrow lagoons occurs where current action is strong. This is most obvious in the vicinity of the artificial entrance, where the ebb and flow of tidal currents is more vigorous than elsewhere in the Gippsland Lakes. Hopetoun channel, passing south of Rigby Island to the west of the entrance has broad, sweeping meanders, with undercutting on the outer curves. Reeves Channel, passing north of Rigby Island, also meanders slightly, as does the eastern part of Lake Reeve, south of Sperm Whale Head. The slight meandering along the Bunga Arm may be an inheritance from the phase when this was an outflow channel from the lakes, or it may be a consequence of the alternating wind-driven currents that develop here.

The growth and subsequent erosion of the river deltas have been discussed previously, and their dependence on shoreline reedswamp noted. Their growth has interfered with the processes leading towards segmentation by carrying forward sections of swamp-fringed shoreline where land encroachment is (or has been) in progress. The long, narrow Mitchell delta almost achieved segmentation of a different kind in growing across the northern part of Lake King and nearly isolating Jones Bay as a separate lagoon. The scalloped embayments along its southern shoreline are a response to the same patterns of obliquely-arriving waves that have elsewhere led to cusp and bay shaping and the trend towards segmentation. Point Fullarton, on the southern side of Eagle Point Bay, is a swampy protrusion on the site of a sand and gravel shoal which was possibly a spit at an earlier stage: it is now being reduced by erosion.

The configuration of the lake floors is shown in Figure 3. The barriers stand up clearly as embankments on the seaward side, and the deltas are embankments of a different kind. The lake floors are generally smooth, being sandy near the shores of the barriers, sandy with gravel near the marginal bluff, and silt and clay off the swamp-fringed shores and in deeper and quieter water. Where currents are strong, however, the fine0grained sediment has not settled, and the floor is sandy. Deeper holes persist where current scour is accentuated, notably in the curves of the channel in McLennan Strait, and off Shaving Point at Metung, where a strong eddy develops as water passes to and fro along Lake King. The currents here are generated mainly by wind action on the lakes, but there is a slight tidal effect and the flow is strengthened occasionally by escaping floodwaters. The deep hole in the lake floor off Shaving Point (15 metres) is a typical 'tidal colk' (Benson and Raeside 1963).

If land and sea levels remain in their present relative positions, continued sedimentation will eventually fill the Gippsland Lakes, but their future mode of evolution will depend largely on ecological conditions. If they are freshened as the result of natural or artificial changes, shoreline reedswamp will revive to halt much of the erosion that is now going on and promote swamp land encroachment, and consequent shrinkage of the lakes. If they remain brackish, or is their salinity is increased (e.g. if shoreline erosion on the Ninety Mile Beach opens new gaps through the outer barrier), their shorelines will remain without vegetation, and shore processes will tend towards segmentation. Under these conditions, sediment carried into the lakes will not be trapped in bordering reedswamp; it will become modified into chains of smaller and shallower lagoon before sedimentation fills them completely. Whichever course is followed, the Gippsland Lakes will ultimately give place to a depositional coastal plain traversed by the engrafted estuaries of the several rivers.

Plate 24 – Contraction ridge in course of formation at the outer edge of *Salicornia* marsh (cf. B in Plate 25) on the southern shore of Lake Reeve (J McKay)


Plate 25 – Contraction ridges formed on the prograded (A → B) southern shore of Lake Reeve (N Rosengren)