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FLEURIEU PENINSULA FIELD TRIP GUIDE

THURSDAY 19TH NOVEMBER 1998

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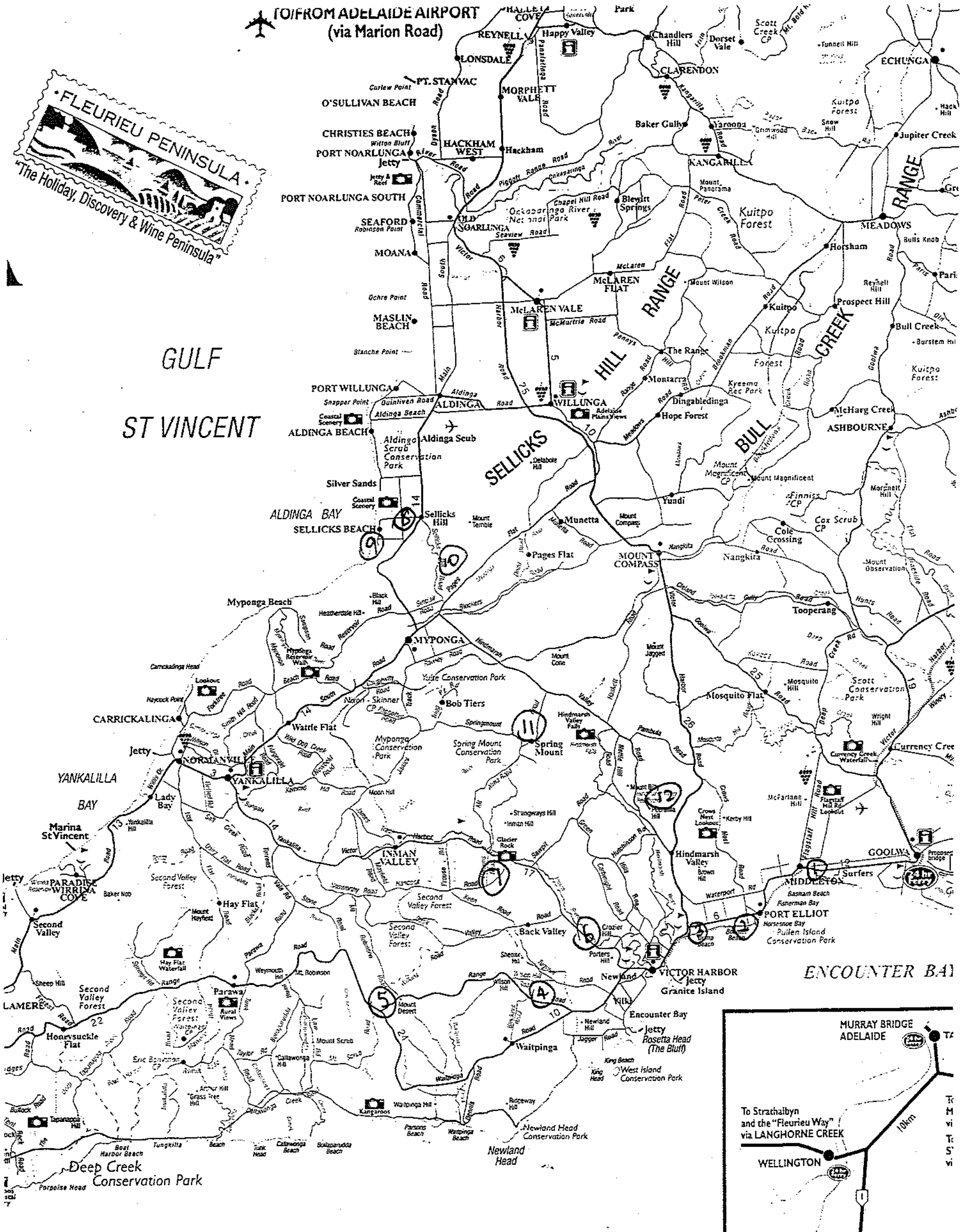

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FLEURIEU PENINSULA FIELD TRIP, THURSDAY 19TH NOVEMBER 1998

Introduction

Fleurieu Peninsula is of great interest to the geologist, geomorphologist and layperson alike because of the great variety of rocks, landforms and scenery which it contains. It embodies remnants of former fold mountain ranges, ancient glaciations, tectonic and igneous activity and metamorphism, the imprints of prolonged weathering, high Tertiary sea levels, a variety of coastal scenery, river landforms including the mouth of the largest river system in Australia, and the imprints of people. It is doubtful that such diversity occurs elsewhere in Australia within an area of comparable size.

Goolwa area

The Goolwa area is situated in the Murray Basin province of South Australia in relatively close proximity to the boundary with the Mount Lofty Range province. In general terms the Mount Lofty Ranges are underlain by relatively old (500 million years and older) resistant metamorphic and crystalline rocks. Granites crop out at Port Elliot and the Middleton Sandstone occurs at and to the west of Middleton Beach. In contrast, the surface of the Murray Basin is underlain by much younger rocks and sediments, as the older, harder rocks have been downfaulted to considerable depths **(Fig. 1)**. For example, a bore hole on Hindmarsh Island, not far from the Murray Mouth penetrated to a depth of 230 m, and ended in Permian glacigene sediments, 280 million years old, without reaching the older harder rocks. Within deposits related to the Permian glaciation there are many different types of rocks present, having been transported by ice as erratics from distant sources to the southeast of the study site. These sediments do not appear to crop out at the surface in the study area. Consequently, isolated rocks found within this area of the Murray Basin such as pebbles and boulders of granites and Kanmantoo Group metasedimentary rocks have been transported by waves along the present shoreline, former shorelines, or are Aboriginal artefacts.

The majority of sediments underlying this area of the Murray Basin are Tertiary limestones and Pleistocene limestones and other coastal sediments including dune deposits. Many of these coastal sediments are capped by well developed calcretes. Calcrete is a surface and near surface, white coloured and very resistant capping of calcium carbonate, typically formed on calcareous sediments after their deposition. Shelly material within the original sediment has been dissolved by soil water and reprecipitated at the surface as the calcium carbonate in solution is precipitated following the upward movement of the solution through the soil as it is drawn towards the surface by evaporative processes and concentration through plant activity.

Approximately 125,000 years ago, during the Last Interglacial, sea level was at least 2 metres above the present level of the sea, during a time when glaciers melted, retreated and provided additional water to the ocean basins. Fossil shell beds of that former shoreline can be found sporadically along the shores of Encounter Bay **(Fig. 2)**. and variations in their elevation along the shoreline reveal that the tectonic processes responsible for the uplift of the Mount Lofty Ranges and the depression of the Murray Basin are still operating. For example, the last interglacial shell beds occur at up to 6 m above present sea level (apsl) at Victor Harbor and up to 10 m (apsl) near Chiton Rocks, within the ranges, but on Hindmarsh Island they occur at only 1 m apsl **(Fig. 3)** . Consequently, the study area is undergoing subsidence (Bourman *et al.*, 1998), and this is finding expression in the active coastal erosion along the shoreline at Middleton, Surfers Beach and along Sir Richard Peninsula (Bourman, 1979).

de Mooy (1959) named the calcreted aeolianite sand dune that forms the northern half of Hindmarsh Island and underlies the township of Goolwa, including the Goolwa Dump area, as the Alexandrina Range and he correlated it with the West Naracoorte Range in the South East. Subsequently, the West Naracoorte Range was noted by Cook *et al* (1977) to correspond to a major magnetic reversal some 780,000 years ago, suggesting that the Alexandrina Range was of an equivalent age (Bourman and

Murray-Wallace, 1990). However, more recent investigations involving geomorphic mapping and dating shelly coastal deposits and old calcareous and now consolidated sand dunes (aeolianite) in the area demonstrate that the majority of the higher northern section of Hindmarsh Island is considerably younger than 780,000 years; all of the data suggest that it is actually of last interglacial age (125,000 years old) (Oxygen isotope substage 5e) and that the mouth of the River Murray at this time occurred in the area between the ferry and the Goolwa barrage. At this time the western end of Hindmarsh Island was the equivalent of the western extremity of Younghusband Peninsula, and the Goolwa side of the river was the equivalent of Sir Richard Peninsula. This former peninsula can be traced as a calcreted aeolianite dune from near the river, through the housing area of Goolwa Beach, through the Goolwa Golf Club and the Goolwa Dump, almost to Middleton, with the back edge of the fossil dune being easily visible from the main Goolwa-Middleton road. Inland of this fossil, 125,000 year old dune is an extensive fossil sand flat of equivalent age that is variably calcreted and is underlain by sands and shell deposits. During last interglacial times, longshore transport of sediment along the coastline was from the southeast, as it is today. The accumulation of sand at the northeastern extremity of the beach pushed the outlet of the River Murray to the west, partly accounting for the large elbow in the river at Goolwa.

A younger, fossil calcareous sand dune occurs along Surfers Beach and extends almost to Middleton. The aeolianite dune at Surfers Beach has been dated at approximately 103,000 +/- 6,000 years before present (BP) (Oxygen isotope substage 5e). Thus it is younger than the calcreted dune of the Goolwa Dump area, and lies seaward of it. Remnants of this younger dune are occasionally exposed on the beach near the Goolwa Beach carpark, and occur at a couple of sites on Sir Richard Peninsula. There is no evidence of the actual shoreline when this dune formed as the shoreline was below the level of present sea level. It was built up to its present level by the wind, and subsequently it has been eroded into a cliffline following its cementation and the rise of sea level to near its present position.

Younger, unconsolidated and non calcareous sand dunes occur in the area. This sand is red to yellow in colour and occurs over the consolidated, calcareous aeolianite dunes, so that it is younger than them. These dunes also occur on Hindmarsh Island and in the areas surrounding Lakes Alexandrina and Albert. These dunes have been dated by thermoluminescence techniques (a dating method that reveals the last time that the sand grains were exposed to sunlight, and therefore indicates the age of deposition), in a couple of localities revealing that they are from 16,000 to 18,000 years old. At this time, the time of a Glacial Maximum, sea level was much lower than at present; the shoreline was up to 120 metres lower than at present and at this time the River Murray extended across the continental shelf and it would have been possible to walk from the mainland to Kangaroo Island. During this time the climate was much colder, drier and windier than at present and it is generally agreed that the red-yellow dunes are former desert dunes, which can be recognised over much of the Australian continent. In the study area these former desert dunes appear to have been favoured sites for Aboriginal occupation, possibly because they were relatively high and well drained sites.

Following the last Glacial Maximum of 18,000 years, sea level rose rapidly to near its present level, reaching that position approximately 6,000 years ago. The old desert type dunes that extended across the continental shelf were swept up by the advancing sea, incorporated with marine shell hash, and formed into the modern coastal dunes of the area. It is primarily within this Holocene coastal dune system that there is ample evidence of Aboriginal occupation in the form of shell middens, comprised dominantly of the Goolwa cockle, *Donax deltoides* (Bourman and Murray-Wallace, 1990). Radiocarbon dates on these middens fall in the range between about 3,500 and 200 years. Some of the dunes of the Encounter Bay coastline were active at the time that Matthew Flinders sailed along the coast almost 200 years ago, but the stability of the dunes worsened with the impact of European grazing and the introduction of rabbits. In general terms the modern coastal dunes are now more stable than they were 50 years ago, due to better management strategies.

The youngest sediments of the area appear to comprise brown coloured soil and sand dune materials. These have been established to be approximately 3-4,000 years old and they carry much evidence of Aboriginal occupation.

A tea tree swamp area occurs in an interdune area between the old last interglacial calcareous dune in which the Goolwa Dump has been established, and the modern coastal dune to the east and the 100,000 year old dune at Surfers Beach to the west. This low lying region is underlain by a calcareous marl that may have formed in the freshwater swamp.

STOP 1: Middleton cliffs

The coastline east of Middleton township has suffered considerable erosion since the turn of the century. Hodge (1932) wrote:

"Up to about 20 years ago Middleton was noted for its wonderful beach. At low tide it was probably nearly a quarter of a mile (400 m) wide from sandhill to sea, and so firm that vehicles could be driven for miles along its reaches in an easterly direction. But the sea encroached quite suddenly and there is now comparatively but little beach and ordinary high tides practically reach the sand hills."

Photographs taken of the beach in the late 19th century confirm that it was of extensive width. Today there are no sand dunes backing the beach and the sea now sporadically erodes a line of low cliffs at high tide. Old residents of the area have claimed that the coastline has been eroded by as much as 400 m since 1897, but the extent of this erosion is not wholly supported by independent evidence. Nevertheless, aerial photographs taken in 1949 and 1972 clearly indicate that erosion of terrestrial alluvial deposits have formed a cliff line up to 10 m high and that there was a coastal retreat of many metres in the 23 year period.

The oldest accurate map of the area was prepared in the 1860s when surveys were made to within 150 links (29.7 m) of high water level. Measurements from fixed points in September 1974, 106 years after the first survey revealed that the cliff line had eroded by as much as 45 m, equivalent to a rate of 0.4 m yr^{-1}. Landowners in the affected area provide evidence of the truncation of fence lines at a rate of 0.3 m yr^{-1} over the period 1944-1974, erosion of the same order of magnitude as that determined by resurveying. Even greater erosion has occurred to the west of the resurveyed line. Comparison of the original map with aerial photos suggests that near the mouth of Middleton Creek some 200 m of erosion has occurred, an average rate of 1.9 m yr^{-1} for the 106 year period.

Glacio-eustatic rises in sea level, increased storminess, diminished sand supplies and human interference have all been cited as possible causes of erosion. As there are no records of major coastal work and as the removal of beach material has been of minor importance, the coastal recession at Middleton does not seen to be related to human interference. Similarly there is no evidence for a suddenly decreased sand supply either from offshore or alongshore. Increased storminess and a slight rise in relative sea level may have contributed to the erosion, but the spatial distribution of the erosion focussing on the Middleton shore does not appear to relate to these general causes of erosion. The main cause of the erosion may be related to tectonic subsidence as there was a series of earth tremors around the turn of the century.

Middleton Beach lies within the Murray Basin Province, which based on the elevation of the last interglacial shoreline, is subsiding relative to both the Mount Lofty Ranges and the Mount Gambier area. A postulated fault follows the eastern flank of the Mount Lofty Ranges and passes through the Middleton-Port Elliot region. Gravity contours also indicate a fault-like structure at depth. Thus, the cause of the extensive erosion at Middleton is possibly related to tectonic subsidence as marked erosion has been noted to the east of the suspected fault but not the west.

Erosion of the Middleton cliffs has been accomplished largely by storms, during which the lower cliffs of the eastern end of the beach, some 2-4 m high are often overtopped by waves. The area backing the beach was originally farm land but it is now a housing development. A buffer zone of about 45 m has been left between the cliff top and the housing development, which seems reasonable in light of the present reduced erosion of the cliff line. From time to time small sand dunes accumulate at the base of the cliffs and become partly vegetated suggesting that a new equilibrium condition may be developing. However, renewed subsidence could see a new phase of accelerated coastal erosion.

STOP 2: Port Elliot

The locality of Boomer Beach (also known as Knights Beach) provides evidence of considerable geological and geomorphological change **(Fig. 4)**. The pink granite, with its characteristic opalescent blue quartz crystals is part of the Encounter Bay group of granites, which extend as far as Kangaroo Island. They were emplaced about 500 Ma years ago during the Delamerian orogeny which culminated in the formation of a mountain range some 10 km high. Occasional xenoliths, occurring as roof pendants reveal that the roof of the pluton was close to the present land surface. Pods of tourmaline also occur within the granite.

The granites were exposed at the surface by the time of the Permian glaciation, 280 Ma ago, revealing a rate of landscape lowering of some 36 m Ma^{-1}. No doubt a great deal of this was accomplished during the Permian glaciation. A glaciated granite surface, the only one known from the area, glacigenic sediments and the profusion of granite erratics throughout Fleurieu Peninsula demonstrate that the granite was exposed during glaciation, which approached from the southeast and moved in a westerly direction across Fleurieu Peninsula. The islands and headlands of Encounter Bay are sometimes regarded as Permian glacial landforms, but this is difficult to demonstrate with certainty. However, it does appear that the glaciation was responsible for the dissection of an extensive pluton, forming the present broad scale outcrop distribution (Milnes and Bourman, 1972). The glaciated surface, for best viewing requires brushing and washing with water to bring out the details of the smooth, striated and grooved character of the feature. The direction of glacial movement was approximately from the east to the west, pointing to a huge whale backed hill (Crozier Hill) in the Inman Valley. Glacigenic silts cover part of the glaciated surface, and at one stage it is possible that the entire granite outcrop was once buried by Permian deposits. The granite has now been largely exhumed from beneath this protective cover, which accounts for the preservation of a delicate surface some 280 Ma old.

During Pleistocene times the granite mass was once more buried by aeolianite of Pleistocene age. TL dating has generated an age of 266±34 ka, an isotopic stage 7e, or penultimate last interglacial age. It is of interest that this consolidated dune, which formed above sea level, now forms shore platforms in the intertidal zone. The equivalent dune in the southeast of South Australia lies well inland and comparatively, is well above sea level. Occasional pods of aeolianite cling to the granite surface suggesting that it was once covered with aeolianite, which is now largely stripped off.

STOP 3: Chiton Rocks

The bench and cliff line of the last interglacial shoreline is followed by the railway line between Chiton Rocks and the mouth of the Hindmarsh River, varying in elevation between about 6 and 10 m asl. Stranded shell beds including the sub-fossil *Anadara trapezia* occur at about 6 m asl in the railway cutting immediately northeast of the Hindmarsh River mouth, and at the landward edge of the Newland Lowland and the Victor Harbor Lowland which are backed by a pronounced sea cliff). At this time both the Newland Lowland and the Victor Harbor Lowland would have been permanently sub-tidal **(Fig. 5)**. These shells have been dated by various techniques. Radiocarbon analyses indicate an age of about 30,000 years B.P.[GaK-5561: 33,170 + 3,180 - 2,270; GaK-6099: >30,320), but Uranium-Thorium techniques suggested an age of 100,000-150,000 years B.P., which was supported by amino-acid racemisation studies (Kimber & Milnes, 1984). Radiocarbon techniques appear to be quite reliable for young materials but with older materials give ages that are far too young (Gill, 1974). In this instance the 30,000 BP age for the Anadara is probably the result of the incorporation of carbon with a different origin and activity, a problem characteristic of marine fauna (see Belperio & Murray-Wallace, 1984; Bowman & Harvey, 1983). The higher sea level may be equated with the Last Interglacial high sea level, for which a broad range of ages has been assigned. The most commonly accepted age is 125,000±10,000 years

BP, based on Uranium-Series disequilibrium data (Stearns, 1984). It is also possible that there were two separate sea stands at the time of the last interglacial rather than a single high sea stand (Veeh, *et al.*, 1979), but this has not been resolved for the Victor Harbor area. The present elevation of the Last Interglacial high sea level is partly due to tectonic uplift of Fleurieu Peninsula.

The shell beds of the last interglacial deposits contain about a dozen different species, including *Anadara* and *Ostrea*. Colin Murray-Wallace has correlated Anadara from this site with last interglacial shells around the South Australian coast, including shells at 12 m asl near Normanville on the western side of Fleurieu Peninsula (Bourman *et al.*, 1999) using AAR. An intriguing feature of these deposits is the occurrence of pebbles and boulders, probably derived from reworking of Permian glacigenic sediments, and clear and smoky quartz, which is quite angular, in a former estuarine environment. Some people have suggested that these materials are of Aboriginal origin, but the diversity of shell species in different stages of growth together with their last interglacial age argues strongly against this influence.

Other evidence for the last interglacial high sea level includes paired river terraces, which have been mapped along the Hindmarsh and Inman Rivers and which grade to the coast at a height of 6 m asl (Bourman, 1969) **(Fig .6)**. Last interglacial marine deposits interfinger with the alluvial sediments underlying the river terraces **(Fig. 7)**, and TL determinations have demonstrated that the red coloured alluvium, the Pooraka Formation, is of the same 125,000 year age (Bourman *et al.*, 1997).

STOP 4: Regolith on Victor Harbor Cape Jervis Road-Waitpinga area

In the area occupied by the drainage basin of the Waitpinga Creek, ferricrete occurs at an elevation of 100 m, on a sediplain, below which drilling has demonstrated the presence of marine fossiliferous limestone of Eocene age about 36 m below the landsurface and 60 m asl (Bourman & Lindsay, 1973). Grain size analyses of sediments surrounding parts of the Waitpinga drainage basin suggest that they are former aeolian deposits (Bourman, 1973). This area must have been below the level of the Miocene shoreline so that the landsurface here can be no older than Late Miocene to Pliocene. Ferricretes occur in various parts of the Waitpinga drainage basin and around its margins where former fluviatile and aeolian sediments have been variably ferruginised.

On the northern margin of the Waitpinga Creek drainage basin, a road cutting on the Victor Harbor-Cape Jervis road at 100 m asl, exposes a section through ferruginised aeolian sand deposits. At or near the surface is a lag of pisoliths, and, at a depth of approximately 1 m below the surface, other pisoliths occur **(Fig. 8)**. The soil in which the pisoliths occur is an acid duplex soil, Dy4.21.

The surface pisoliths contain 44.9% Fe_2O_3, 41.7% SiO_2, 7.96% Al_2O_3 and had an ignition loss of 3.85%. The iron oxide mineralogy is dominated by hematite and maghemite. Small amounts of kaolinite, smectite and mixed layer clays are also present. In contrast, the pisoliths at depth contained only 5.35% Fe_2O_3,, with 75.5% SiO_2 and 9.1% Al_2O_3; the iron oxide mineralogy is principally goethite, with a small amount of hematite. Kaolinite, smectite and possibly a small amount of gibbsite are also present.

The material in which the pisoliths occur at depth is a silty sandstone that is well sorted and consists of rounded and sub-rounded grains set in a ferruginous clay-rich matrix. The pisoliths are composed of material identical to that in the bulk of the deposit, which contains some grains of tourmaline, felspar, andalusite and polymozaic quartz grains of metamorphic origin. At higher magnifications the iron oxides display a colloform fabric that indicates multiple influxes of iron oxides into pores spaces. Some quartz grains have hematite coatings and laminated goethite and clay occur in the voids. Some fractures in the clay matrix are filled with hematite, which suggests various phases of hematite formation.

STOP 5: 'Lateritic' Plateau at Mount Desert

The complex development of the summit surface of Fleurieu Peninsula is indicated near Mount Desert where a road cut at about 250 m asl has exposed infilled channels **(Fig. 9)**. The channels have been cut into kaolinised and iron-mottled Kanmantoo Group metasedimentary rocks of Cambrian age, and are infilled with detritus that includes fragments of the bedrock mottles and pisoliths with multiple rinds that occur at the base of the channel. The palaeochannel is exposed on both sides of the road cutting thereby demonstrating that it is a true channel and not simply a basin.

The pisoliths at the base of the channel are identical in all respects to pisoliths that occur to the west of this site and at a higher elevation on the summit surface, where they form a 1 m thick deposit in conjunction with bedrock fragments and other detrital materials. The individual pisoliths have characteristic goethitic surface rinds. Undisturbed samples taken across the contact of the channel base and its infill do not reveal any indication of incipient *in situ* development of pisoliths in the weathered bedrock below those in the channel.

The pisoliths in the channel contain maghemite. It can be speculated that perhaps the pisoliths were formerly in a surface or near surface situation, where heating in the presence of organic material can transform goethite to maghemite. Thus the occurrence of maghemite-rich pisoliths at a depth of some 6 m below the present ground surface is interpreted as evidence for transport from a higher section of the summit surface and subsequent burial near the base of a former channel.

It is noteworthy that the mineralogy of the pisoliths varies on opposite sides of the road cut, even though they are in similar positions in the palaeochannel. Pisoliths from both sides are maghemitic, but those on the southern side are soft and have hematite as the dominant iron mineral, whereas those on the north are dominated by goethite and are relatively hard. Goethitic rinds on pisoliths are generally regarded as the result of dissolution and reprecipitation of iron oxides from the pisolith itself or the accretion of fresh layers of iron oxides on the pisolith surfaces (Schwertmann, 1985). Both of these processes are thought to occur in soil environments. Hence it is possible that the hematite-rich pisoliths were not affected by these soil processes, but it would be extremely fortuitous for these pisoliths to have accumulated exclusively in one part of the channel. Another possibility is that the hematitic pisoliths were subjected to a second period of heating after deposition in the stream channel, with heat being concentrated by the burning of a tree stump or root that only affected the pisoliths nearby. This could account for the lack of a goethite rind, which would have been transformed to hematite and/or maghemite. Alternatively, another process involving in situ dissolution of goethite and precipitation of hematite via ferrihydrite may have occurred locally.

Much of the channel fill material near Mount Desert appears to consist of mudflow debris as it contains coarse, angular and randomly dispersed fragments within a clay-rich matrix. The fill material has a relatively fine reticulate mottling pattern, with more goethite present than in the coarse hematitic mottling that affects the surrounding bedrock basement rocks. Uniformly mantling both the channel fill and the mottled bedrock is a yellow duplex podzolic soil (Dy2.41), which contains ferruginous, maghemitic pisoliths in its upper section.

The sequence described here illustrates the complex development of the summit surface **(Fig. 10)** as it provides evidence for weathering being interrupted locally by erosion, transport and sedimentation with modern soil development continuing to modify it. Consequently, it is not possible to interpret this locality simplistically as the mere preservation of an ancient landsurface carrying 'laterite' **(Fig. 11)** of Mesozoic age.

STOP 6: Crozier Hill

Crozier Hill **(Fig. 12)**, a prominent whale-backed hill in the lower Inman Valley near Victor Harbor in South Australia, was named after Captain Crozier, who was struck by its distinctive form when he sailed into Encounter Bay in 1837. The geomorphology of Crozier Hill was first described by Howchin (1926), who regarded it as a huge *roche moutonnée*, nearly 1.6 km long and 158 m high. He interpreted it as a glacial landform on the basis of its pronounced asymmetry, its juxtaposition to glacigenic sediments and the occurrence of an erratic located northwest of the hill and of similar lithology to the bedrock of the hill, from which he assumed it had been plucked. The majority of subsequent workers, including Guppy (1943), Campana & Wilson (1955) and Crawford (1959) supported the interpretation of Howchin (1926). Campana & Wilson (1955) described Crozier Hill as a glacial rockbar, closing off the Back Valley and Inman Valley glacial basins to the east. Bores in Back Valley penetrate to considerable depths where geophysical data confirm the presence of a glacial basin (Morony, 1971). Crawford (1959) regarded the steep, broken and craggy northwestern face of Crozier Hill as the result of glacial plucking and contrasted it with its gentle southeastern or stoss side. Browne & Vallance (1957) used Crozier Hill as a classic example of a *roche moutonnée*, with which they compared apparently similar but smaller forms in the Australian Alps.

An alternative explanation of the morphology of the hill was tendered by Twidale (1968), who conjectured that the disposition of underlying bedrock structures could have given rise to an asymmetrical north-south oriented cuesta-like feature under conditions of non-glacial weathering and erosion.

There is no unequivocal evidence supporting a glacial origin for Crozier Hill and there is no justification in regarding it as a classic example of a *roche moutonnée*. However, there is no doubt that the site occupied by Crozier Hill was transgressed by an ice mass moving in an east-west direction and it is highly likely that it was buried beneath Permian glacigenic sediments that have a demonstrable thickness of over 300 m below Back Valley and occur at elevations up to 330 m asl on the plateau surface of Fleurieu Peninsula. Furthermore, sub-surface evidence of deepening on the predicted western side of Crozier Hill, and an east-west asymmetry, independent of structure and compatible with roche moutonnée morphology, favour the view that glacial processes may have originally influenced its formation. However, there is clear evidence of an unknown amount of non-glacial weathering and erosion of Crozier Hill, it cannot be regarded simply as a resurrected *roche moutonnée* of Permian age.

STOP 6a: Holocene Environmental Change in the Lower Inman River

The Inman River flows largely through unconsolidated Permian glacigene sediments and there is a long history of accelerated erosion, sedimentation and channel change within the valley **(Fig. 13)**. Many metres of PESA attest to this and there are reports of trees, houses and other structures having been buried especially in the area upstream of the Victor Harbor Oval.

Accelerated deposition leads to erosion: masks vegetation and kills it, steepens slopes and sets the stage for channel erosion. Sand mining has recently resulted in the progression of an erosion head upstream causing valley deepening and widening, exposing old channels filled with swamp materials including large red gum trunks, organic materials, casuarina cones etc. The organic materials, red gum log, freshwater snails, fragment of wood incorporated into swamp materials and *casuarina* cones all dated out at 6,000 to 8,000 years BP. Palynology carried out by Andy Rowett reveals vegetation similar to that of today. Calcareous horizons occur within the sediments.

Stop 7: Selwyn Rock

The first evidence of glacial action anywhere in Australia was discovered in the Inman Valley of the Fleurieu Peninsula in 1859 by Selwyn (1860). The major direction of ice movement across southern South Australia was from the southeast towards the northwest. Evidence for this is provided by striated rock surfaces and the provenance of erratics (i.e. location of the source of boulders carried by the ice). For example, boulders of the Encounter Bay Granites, with source areas near the site of the present coastal area of southern Fleurieu Peninsula, have been found well inland and as far to the west as Yorke Peninsula. The orientation of pebbles in lodgement tills that were actively plastered onto the underlying rock by the glacier during its movement also provide evidence of the direction of former ice flow. The ice was channelled in a more westerly direction through the Inman Trough **(Fig. 14)**, a terrestrial equivalent of Backstairs Passage, probably being influenced by pre-glacial relief. Various lines of evidence point to the ice being wet-based and temperate, near pressure melting point and more than 1,000 m thick at its maximum. The subglacial relief on Fleurieu Peninsula extends from almost 300 m below sea level up to 400 m above sea level **(Fig. 15)**. All of the evidence in the Troubridge Basin can be accounted for in terms of the passage and progressive decay of a single ice mass.

Selwyn Rock (Glacier Rock) is the best known and most accessible glaciated rock surface of Fleurieu Peninsula. The first discovery of former glaciation in Australia was made in the Inman Valley of Fleurieu Peninsula by the Victorian Government Geologist, ARC Selwyn who wrote : " At one point in the bed of the Inman River I observed a smooth, striated and grooved rock surface, representing every indication of glacial action... strongly reminding me of the similar markings I had so frequently observed in the mountain valleys of North Wales" (Selwyn, 1960)

It is developed on dense, metasandstone of the Cambrian Backstairs Passage Formation, which is ideal for recording and preserving the small scale features of glacial erosion. The direction of glacial movement as indicated by grooves and striation is approximately east-west. Some of the vertical bedrock wall east of the main exposure is also striated.

Sediments associated with Selwyn Rock include blue-grey coloured lodgement till and ablation till formed during melting. A huge erratic of Encounter Bay Granite resting on contorted sediments is being exposed in the river bank by stream erosion **(Fig. 16)**.

Stop 8: Sellicks Gullies

Exposures in Sellicks Creek **(Fig. 17)** reveal a series of cut-and-fill events in Pleistocene alluvial fan deposits **(Figs 18 and 19)**. Two sets of paired river terraces which occur on the alluvial fan fronting the ranges, converge in elevation downstream and cross over, with the younger, grey-black alluvium (Waldeila Formation) washing out over and completely covering the older, red alluvium in the lower section of Sellicks Creek. Closest to the Willunga Escarpment, the base of the creek is occupied by a lithified resistant breccia, the Kurrajong Formation of Ward (1966). The Kurrajong Formation may simply be a more lithified part of the Ochre Cove Formation of Middle Pleistocene age, with induration resulting from silica in solution introduced at the head of the alluvial fans. Its distribution is restricted to these locations.

The Taringa Formation rests on the so-called Kurrajong Formation and the Ochre Cove Formation. It comprises a columnar, green-grey clay containing angular clasts, including local bedrock, and usually has calcium carbonate mottles in the upper part of the sequence. In places it may be a mud flow deposit. The red-brown Christies Beach Formation (equivalent to the Pooraka Formation) rests unconformably on the Taringa Formation and underlies the high, paired river terraces. There has not been general agreement concerning the age of the Christies Beach Formation and equivalent units but it has been established that it extends back to the Last Interglacial

A very minor, unnamed unit is light grey in colour and occupies a former channel fill cut into the Christies Beach Formation. The erosional contact between the two units is clearly indicated by a definite break in sedimentary structures. The light grey-coloured sediment has a very limited distribution, but also occurs downstream of the main occurrence on the left bank as well as subsurface in the lowermost reaches where it has been exposed by gullying.

The grey-black Waldeila Formation occupies a small channel developed largely in the Christies Beach Formation and underlies the second and lower set of paired terraces. The Waldeila Formation is considered to be a mid-Holocene deposit as estuarine shells, collected from within it, in the lower reaches of the Onkaparinga River, returned a radiocarbon age of 4580 ± 160 years B.P. (Bourman, 1979). Cobbles, pebbles and boulders up to 30 cm across occur 1 m below the surface. Coarse layers such as this may represent past channel bottoms formed by torrential deposition.

In the lower reaches of Sellicks Creek, gullying has exposed a layer-cake stratigraphic sequence of Pleistocene sediments with associated palaeosols indicating times of landsurface stability.

Waldeila Formation -	Holocene
Un-named grey unit	
Christies Beach Formation -	Late Pleistocene (Last interglacial)
Taringa Formation	
Ochre Cove Formation -	Middle Pleistocene. Contains Bruhnes/Matuyama geomagnetic reversal of 780,000 years B.P. (Pillans and Bourman, 1995)
Kurrajong Formation (?)	
Seaford Formation -	
Burnham Limestone	Early Pleistocene

Table 1 Pleistocene stratigraphy in the Sellicks Creek area.

GULLYING IN THE LOWER SECTION OF SELLICKS CREEK

Section from Main South Road to Justs Road

Downstream of the Main South Road gullies occur in relatively unconsolidated, Pleistocene alluvial fan sediments and are separated from the hard rocks of the upper section by the Willunga escarpment. Within this section, however, there are still important base level influences, which impose limits on future downcutting. For example, immediately downstream from the Main South Road crossing, the floor of the channel is composed of resistant, silicified breccia; the so-called Kurrajong Formation. At this point the hard-floored valley is relatively shallow and wide. There have been some micro-forms eroded into the siliceous breccia (Location 6), including an entrenched meander, a waterfall with an associated plunge pool and a natural bridge. However, the amount of incision is quite restricted. This resistant unit has been incised upstream of the Main South Road crossing and is exposed on the valley side, displaying a tilt of about 7° to the west. This tilt continues downstream and the resistant unit eventually dips below the base of the channel, at which point the gully deepens and narrows, reaching a minimum width of 2 m. Here the gully, developed largely in the Waldeila Formation with the Ochre Cove Formation at its base, is some 9 m deep, with a further 3 m to the top of the red alluvium (Christies Beach Formation) (Location 7). From this point the gully gradually shallows, being graded to the level of the concrete flume below the Justs Road bridge (Location 8). While downcutting has been inhibited by this artificial base level, lateral erosion and gully widening have been accentuated by meander development. Re-surveying of a meander immediately upstream of Justs Road bridge (Location 15) reveals that it has eroded about 3 m in 15 years and it has the potential to threaten a major fence line.

Section between Justs Road and Sellicks Beach Road

Downstream of the Justs Road bridge severe erosion has occurred. King (1980) reported that for 50 m upstream of the bridge the channel had ponded and infilled. However, immediately downstream of the bridge accelerated erosion caused valley widening and deepening of some 4 m. The culvert under the bridge, which was built during the 1920s (Willunga District Council), constricts water flow. In turn, according to Benoulli's Law, this increases flow velocity. Consequently, upon discharge from the culvert the high velocity water scours the channel. A fence line has been undercut on the northern side of the stream near the bridge and whilst the outflow has been buffered with rocks, the channel is now more than 10 m deep. Howchin (1923) reported that the lowest part of the present Sellicks Creek gully system had been eroded in 1911, along the original Sellicks Beach Road. However, he also noted in 1923 that the creek did not reach the sea but dissipated into gravels. This suggests that the bridge was not present in 1923 and that a fully integrated gully network did not exist at that time.

For a distance of approximately 120 m upstream of the artificial base level of the culvert drainage pipe at the Sellicks Beach Road crossing, considerable aggradation has occurred. In this section the gully is flat-floored and thickly covered with the aggressive Kikuyu grass (*Pennisetum clandestinum*), which assists sedimentation. Once established, Kikuyu grass can contend with heavy grazing and tolerate considerable trampling. It has been recommended for stabilising gullies and exposed banks (Lamp *et al.*, 1990, p 223-224). It is not known if Kikuyu grass was deliberately planted in this section of Sellicks Creek for these reasons. Sedimentation upstream of the crossing is indicated by the progressive burial of a fence line at location (10). A photograph, taken in 1983 shows two partially buried star droppers, which by 1995 have been buried, indicating a rate of sedimentation of about 5 cm yr^{-1}. The thick cover of vegetation on the channel floor indicates a lack of erosion and suggests that the channel floor is stable or aggrading. Nevertheless, minor bank erosion is still proceeding in this locality as evidenced by bare, steep, collapsing banks. This section of Sellicks Creek between Justs Road and Sellicks Beach Road has been fenced off from stock and appears to be reasonably stable, trending towards a quasi-equilibrium condition.

Stop 9: Sellicks landslump

A coastal rotational landslump of Late Holocene age occurs in the seacliffs immediately north of Sellicks Trig. **(Fig. 20)** (May and Bourman, 1984). The slump is some 350 m long with a maximum central width of about 50 m. The crenulated surface of the slump, which lies at about 20 m asl is backed by a steep and arcuate backwall that rises a further 30 m to the aggradational surface of the alluvial and colluvial deposits that front the Willunga escarpment. At least 300,000 m^3 of sediment have been lost from the cliff line as a result of the slump and the total amount of material involved in the slip would have been almost double this. Lobes of sediment must have flowed across the beach to be reworked by wave action.

The slump was initially identified on the basis of its morphology; the arcuate backwall is steep, the surface of the slump is stepped downward from the north to the south in four major levels due to differential settling during slumping, and the seaward edge of the slump is marked by irregular and hummocky pressure mounds. Exposure in gullies that dissect the slump surface reveal that the Pleistocene sediments which had an initial dip of 5° to the north have been tilted in a rotational fashion to dip at up to 45 ° to the east. Seaward of these tilted beds the original bedding has been destroyed in places by flowage of the sediments in a saturated condition.

At the site of the rotational slump the Pleistocene sediments consist of at least six distinctive lithostratigraphic units , all of which have been involved in the failure **(Fig 20)**. Occasional inclusions of older units within younger sediments demonstrate considerable fluidity and deformation within the slump. At least 15 m of the oldest terrestrial formation involved in the slump, the Early Pleistocene Seaford Formation were completely removed by the failure. The rotational movement appears to have thrust the youngest sediments, the Christies Beach Formation into an unstable position from which they flowed, entraining blocks of older sediment as they did so.

The Pleistocene sediments involved in the failure rest on Miocene limestone of the Port Willunga Formation, which reach up to 7 m asl. However, depressions within the limestone extend below beach level in places and it seems that the slumped sediments were funnelled through these minor valleys. At the base of the Pleistocene sequence there is a 3 m thick layer of dark coloured clays and a marly fossiliferous Early Pleistocene limestone, the Burnham Limestone with its distinctive *Hartungia* fauna. These sediments probably acted as a relatively impermeable layer and assisted the saturation of the overlying sediments. The clays are rich in the expansive mineral smectite and the swelling of the clays may have acted as a catalyst for the slump, which appears to have acted along this horizon.

Paradoxically the Sellicks Beach landslump is underlain and buttressed by resistant limestone of the Port Willunga Formation, but this may have facilitated the acquisition of steeper slopes than if the unconsolidated Pleistocene sediments were directly exposed to coastal erosion. The limestone has had two other effects on the landslump. A shore platform cut in the limestone concentrates wave attack at the base of the slump, and as the depression in the limestones acted as funnels for the flow there was possibly more internal deformation than is normal in rotational shear slips.

The slump appears to be of Late Holocene age. The Late Pleistocene Christies Beach Formation has clearly been disrupted by the failure and these backward tilted sediments are overlain by a 30 cm thick layer of recent colluvium that dips seawards. As the slump is adjacent to the active Willunga Fault (Fig. 20), the failure of the water saturated sediments could have been triggered by a seismic event.

Palaeomagnetic work has also been carried out on the Pleistocene sediments at Sellicks Trig, identifying the Brunhes Matuyama reversal and the Jaramillo Subchron (Pillans and Bourman, 1995) **(Fig. 21)**.

Stop 10: Upper Sellicks Creek

Upstream of the Main South Road crossing (Location 6), the drainage basin has developed in basement rocks and gullying is restricted to valley-fill materials. The erosion is most dramatic in the colluvium-filled bedrock depressions in the far southeastern tributaries near the Old Sellicks Hill Road (Victory Road). Initially, there would have been no streams in the CBD areas, which would have been zero-order, sub-basins. The CBDs are characterised by smooth, rounded bottoms. It is possible to reconstruct the morphology of the former unchannelled valley bottoms by projecting from one side of the valley floor to the other. In places the CBD areas remain intact, such as upstream of location (1) and at location (4) ,where the drainage downstream of the CBD occupies a bedrock valley. In these locations the un-gullied CBDs are indicated by rush-type vegetation dominated by *Isolepis nodosa* and *Juncus kraussii.* Both plants have been associated with saline areas and their presence here may be an indicator of future dryland salinity, which, as yet, is not obvious. The presence of ferrihydrite in some of these localities is also suggestive of saline conditions.

The gullies cut in the colluvial material did not exist in 1854 as indicated on the map **(Fig. 22)** produced by Dragovich (1966), but developed sometime subsequently. A cursory mention of 'gullies and waterways' was made in reference to the completion of the Victory Road (Old Sellicks Hill Road) in 1859 (Linn, 1991, p.75-76). In addition, a photograph of Victory Road (Williams, 1991, p.76) showing a post-and-rail fence and a four-horse coach, indicates that the gully at location (2) had developed before the photograph was taken. Whilst no date was given for the photograph it must of been taken subsequent to the road opening in 1859. The photograph also reveals that the tree cover was quite sparse and the presence of sheep tracks indicates that the area was being grazed. Comparison of 1949, 1979 and 1993 aerial photographs demonstrates that there have been only minor changes to the gullies in the 44 year period, suggesting that there is a trend towards a new quasi-equilibrium situation. Changes detectable include minor headward erosion at location (1) and the up-valley migration of a knickpoint at location (2). Some of this erosion may be related to the impact of the road culvert immediately upstream.

The head of the gully at location (1) appeared to be relatively stable in February, 1995, with some vegetation such as *Senecio* spp. occurring around its margins. However, there is some evidence that the gully head may have cut back slightly, exhibiting potential for minor retreat with some undercutting occurring on the most northerly section of the gully. Tunnel erosion occurs at several points along the margin of this gully. A substantial example of this type of erosion, clearly illustrating the contribution of this process to channel widening, occurs about 95 m downstream from the gully head. In contrast, gully incision is inhibited by a bedrock outcrop about 70 m downstream.

Gully deepening may have stabilised as there is a significant bedrock base level control on further downcutting immediately downstream of the junction of the tributaries at locality (3). A channel, about 2 m wide and 0.5 m deep, occurring in this area has been carved into metasiltstone bedrock. It displays sculptured features that resemble plastically-moulded surfaces, the formation of which has been associated with debris-laden melt-waters under high hydrostatic pressure at the sole of glacier ice. There is no suggestion that this is a glacial feature, but it does indicate high flow velocities and the presence of large amounts of bed load, perhaps even involving erosion by sediment slurries. Bedrock base level control on erosion continues sporadically from this locality downstream to the Main South Road crossing. In particular, prominent bands of quartzite cut transversely across the valley and are exposed in the valley floor, where they inhibit valley incision.

Although the major phase of gully development has passed, the gullies continue to undergo minor modifications such as gully widening and headward erosion. In the upper reaches, small tributary gullies, with rounded headwater sections, are working their way upslope, widening the main gully and lowering the gully-side slopes. The colluvial material is readily eroded but possesses sufficient strength to maintain steep slopes and support tunnelling, which occurs both within the main channel and on its margins.

Causes of gullying

The initiation of the gullies is related to many factors and different parts if the gully system have developed at different times in response to various factors such as drainage works, bridge and culvert construction and agricultural practices. It has been suggested that the impact of clearance of valley sides alone is insufficient to initiate gullying and that there must be channel disturbance by stock to degrade the channel vegetation. Such channel disturbance has no doubt initiated much erosion, but no doubt climatic factors such as heavy summer rainfall following a period of pronounced drought are also significant. Especially in the upper section of Sellicks Creek there is clear evidence that land clearance played an important role in gully development. Overlying former swamp sediments are considerable thicknesses of PESA, derived from the valley sides following clearance. These sediments blanketed and killed existing channel vegetation and steepened slopes, which subsequently lead to accelerated erosion, cutting back down through the PESA sediments and the underlying units that were no longer protected by vegetation. Gully development was initially very rapid, but the gully system has been relatively stable for the past 40 years or so, with only minor changes occurring, and appears to be developing a new quasi-equilibrium condition.

Stop 11: Via Myponga Basin and Upper Hindmarsh Valley

The Myponga Basin and the Upper Hindmarsh Valley are two intramontane basins **(Figs 15 and 23)** that were originally formed by glacial erosion during Permian times and invaded by the sea during the Miocene after which Fleurieu Peninsula was tectonically uplifted. At Sellicks Beach the Miocene limestone of the Port Willunga Formation occurs below sea level, but 12 km away at Myponga the same limestone outcrops at some 240 m.

The relationships of ferricretes to Miocene limestones in the Upper Hindmarsh Valley **(Fig. 23 and 24)** were used by Horwitz (1960) to establish a Pliocene age for the 'lateritisation' of the summit surface of the Mount Lofty Ranges. He maintained that the 'laterite' of the summit surface of Fleurieu Peninsula was contiguous with lower level 'laterite' in the Upper Hindmarsh Valley, where, by extrapolation, the 'laterite' overlies limestone of Miocene age. Consequently he attributed both the summit surface and the lower level 'laterites' to the same post-Miocene or Pliocene age.

This relationship was questioned by Brock (1964; 1971) and Bourman (1969), both of whom considered that the lower level crust had formed after the withdrawal of the Miocene seas and the breakup of the high level crust. Bourman (1973) also reported upon the occurrence of ferruginous colluvial material occurring on the steep slope separating the upper and lower level ferricretes. The elevation of the Upper Hindmarsh Valley ferricrete is approximately 300 m asl. In general terms, it has now been well established that continuity of 'laterite' does not necessarily indicate contemporaneity (McFarlane, 1976), which has led to misinterpretations of landscape evolution in the past.

The character of the upper level ferricrete of Spring Mount is vermiform to nodular in character. Colluvial material on the steep slope flanking Spring Mount contains quartz clasts and iron oxides largely in the form of goethite with minor hematite. Small amounts of kaolinite and smectite were also detected. The mineralogy and chemistry of the colluvial material is thus quite different from the ferricrete of the summit surface which suggests different modes of genesis for the two ferricretes. The colluvial material was cemented in a scarp foot situation by iron oxides derived from above.

Ferricrete in the Hindmarsh Valley overlies sands, and is of a different character to both the high level and the colluvial ferricretes. Samples analysed consist primarily of quartz and goethite with some hematite and kaolinite. The chemistry, mineralogy and macro-morphology of these samples suggest an origin by iron oxide impregnation of pre-existing sandy sediments. No gibbsite was detected in the lower crust but it is common in the summit surface ferricretes. Ferricrete similar to that of the Upper Hindmarsh Valley occurs a short distance away in the Myponga Basin at a similar elevation of 300 m asl. A sample from this site has a similar chemical and mineralogical composition to those in the Upper Hindmarsh Valley. Some of these outcrops of ferricrete form prominent benches at about 290 m asl. It comprises goethite-impregnated sandy sediments that may mark the approximate level of a Miocene shoreline.

Gradients in the Upper Hindmarsh Valley are quite gentle and the original drainage consisted of swamps and pools (Fig. 25). Today the drainage is completely integrated.

STOP 12: Peeralilla Hill

At an elevation of about 290 m on the summit surface of Fleurieu Peninsula there occurs the most massive accumulation of iron oxides in the South Mount Lofty Ranges. Superficially the mine and quarry exposures on Peeralilla Hill resemble profiles described in the literature as 'lateritic', and Heath (1962) regarded the ferricrete at Peeralilla Hill as a 'more ferruginous variant of the Tertiary laterites which cap many of the hills and ridges of the Mount Lofty Ranges' and commented that the 'high alumina, water and moderate silica contents' are characteristic of 'laterite' deposits. However, close field inspection and laboratory analyses reveal that the materials comprise a stratigraphic sequence of deposits of different ages.

The thick ferricrete crust at Peeralilla Hill does not occur near the summit of the hill, but in a bedrock depression at a lower elevation. The crust near the surface is composed dominantly of vesicular to massive ferricrete, but at depth, in places, takes on a more earthy texture, and indurated iron oxides are concentrated along steeply dipping laminar structures (10 mm thick), with intervening ferruginous clay-rich zones, that are composed of smectite, kaolinite, hematite and goethite. The laminated structures are similar to features commonly noted in association with many karst bauxite deposits. Large isolated blocks and boulders of vesicular ferricrete as well as smaller clasts of ferruginous material also occur within this lower zone of iron enrichment. Many ferricrete fragments and pisoliths at the surface contain maghemite, as indicated by magnetic attraction. Magnetic clasts are particularly prevalent near sites affected by burning during modern bushfires.

Sands and included pebbles and larger clasts of quartzite are exposed in a dam site to the north of the iron crust, and may be Permian glacigenic sediments. Drilling through the surface crust has established the occurrence of sandy sediments below it. A surface scrape cut through the crust has exposed white and green, calcareous clays, and XRD analysis has revealed the presence of both barite and calcite in them. The white clayish sediments in thin section contain rounded to sub-rounded and sub-angular quartz grains ranging from silt to sand-sized, set in a matrix of calcite plus smectite and kaolinite, which coats the grains and fills cavities and fractures The green coloured clays consist dominantly of kaolinite and barite ($BaSO_4$).

The presence of calcite and barite may argue against leaching and the operation of intensive weathering processes in the formation of the ferricrete crust, although they may have precipitated out of ground waters after the ferricrete developed. Nevertheless the high total Fe2O3 contents of almost 70% and the low degree of aliminium substitution in goethite suggest iron oxide influx from lateral sources into a depression. Thus the sequence at Peeralilla Hill indicates that the deposition of iron oxides here occurred in a depression (a peat swamp?) in an ancient landscape. Comparison of the Peeralilla crust with samples of vesicular ferricrete collected from the modern valley floor at Mount Compass reveals similarities in both mineralogy and chemistry. In thin section the Mount Compass ferricrete is shown to consist principally of iron oxides with occasional sand to silt sized quartz grains. Elongated and rectilinear cavities occur through the groundmass. At high magnifications very distinctive cellular structures represent former plant material entirely replaced by iron oxides.

Thin sections of samples of ferricrete from Peeralilla Hill reveal similar elongated rectilinear cavities and features that generally resemble plant cells replaced by iron oxides, but these are not as clear as those in the Mount Compass samples.

The chemical, mineralogical, thin section, topographic and stratigraphic evidence favours a view that the crust at Peeralilla Hill formed essentially as a sedimentary deposit, primarily from the precipitation of iron carried in solution, but with some physical concentration of iron as well, in a depression on an old landsurface. However, since its formation and exposure the original deposit has been modified by weathering, erosion, burning, deposition and remobilisation and reprecipitation of iron oxides.

Some of the complex history of the Peeralilla Hill crust is reflected in its mineralogy. Typically iron oxides, chemically precipitated in freshwater swampy environments are composed exclusively of goethite, exhibiting low aluminium substitution (Fitzpatrick & Schwertmann, 1982), and while this is the dominant mineral in the Peeralilla Hill crust, small amounts of hematite, kaolinite, quartz and smectite are also present. The quartz is probably detrital as may be the kaolinite and smectite, but these may also have formed by weathering of primary detrital minerals after the deposition of the sediments. Hematite is not usually associated with such 'bog-iron ore' deposits in Europe and its occurrence at Peeralilla Hill may reflect slightly warmer conditions that favoured the crystallisation of some hematite from ferrihydrite that precipitated from Fe(II) influxed in solution. No maghemite was detected by XRD, but all samples showed a very slight reaction to a strong magnet. The presence of maghemite in the near surface layers could have resulted from heating by bushfires, by which process goethite can be transformed to maghemite. Microscopic examination of thin sections of the Peeralilla Hill crust provides further evidence for its complex development as small hematite pellets occur in a goethite matrix, and voids lined with crystalline goethite suggest various modifications to the crust, representing several generations of iron oxide mobility.

Despite the fact that the Peeralilla Hill crust is considered to have developed essentially by chemical precipitation of iron oxides, there had been some physical incorporation of iron-rich materials into the depression. Moreover, the crust is of some antiquity. There is no direct evidence for the age of the Peeralilla crust, nor for the origin of the calcium carbonate or barite, which underlie it. However, the surviving outcrops of Miocene limestone in the adjacent Upper Hindmarsh Valley stand only some 50 m below the ferricrete crust at Peeralilla Hill. The amount of erosion of the Miocene limestone is unknown as is the precise level to which the Miocene seas reached in this area. However, ferricrete benches near Myponga range up to 290 m asl, and they may represent former Tertiary backshore deposits, now ferricreted. Thus it is possible that the calcite is related to that former higher sea level, which would place the initiation of crust formation here into the Middle to Late Tertiary. Thus it may be younger than the higher sections of the summit surface, which were exposed to epigene processes prior to this time.

Return via Cut Hill to Goolwa, with views over the Murray Basin

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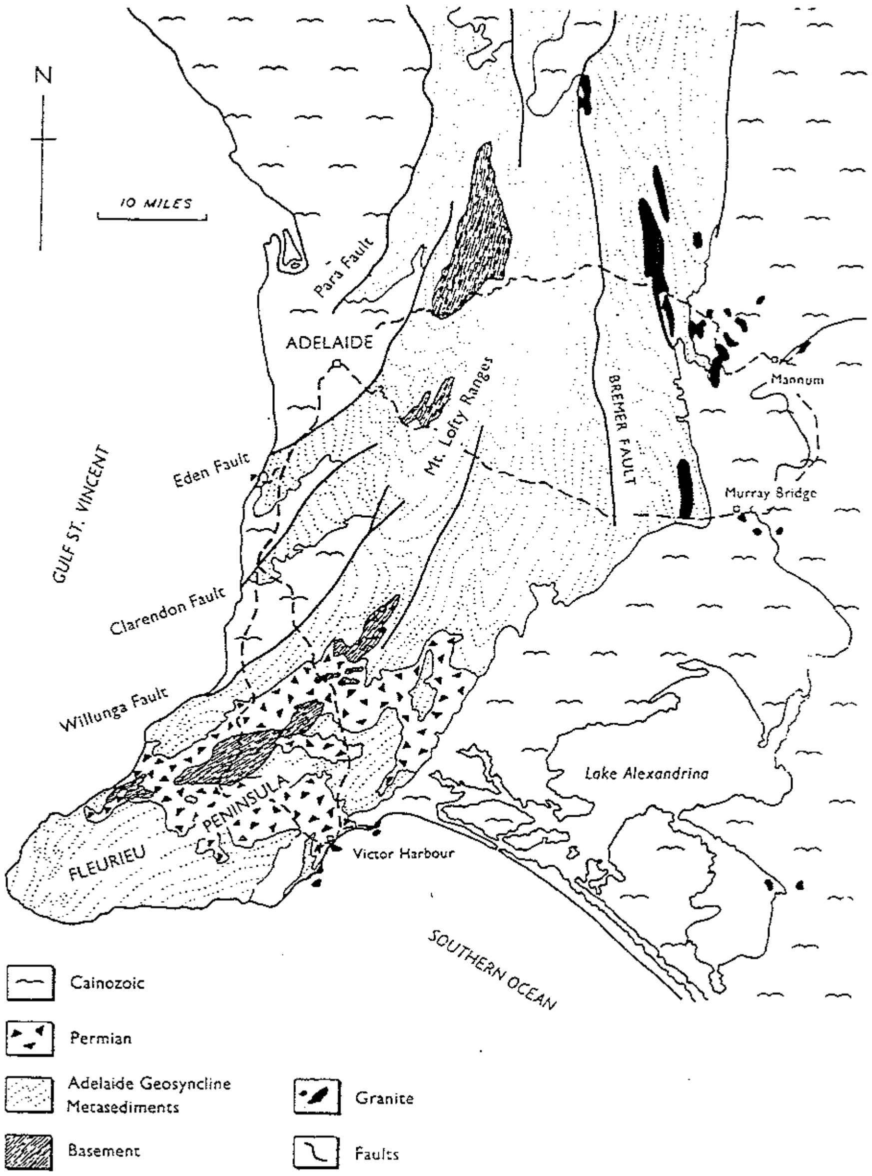


Figure 1 Geological map of Fleurieu Peninsula (Source: Talbot and Nesbitt, 1968)

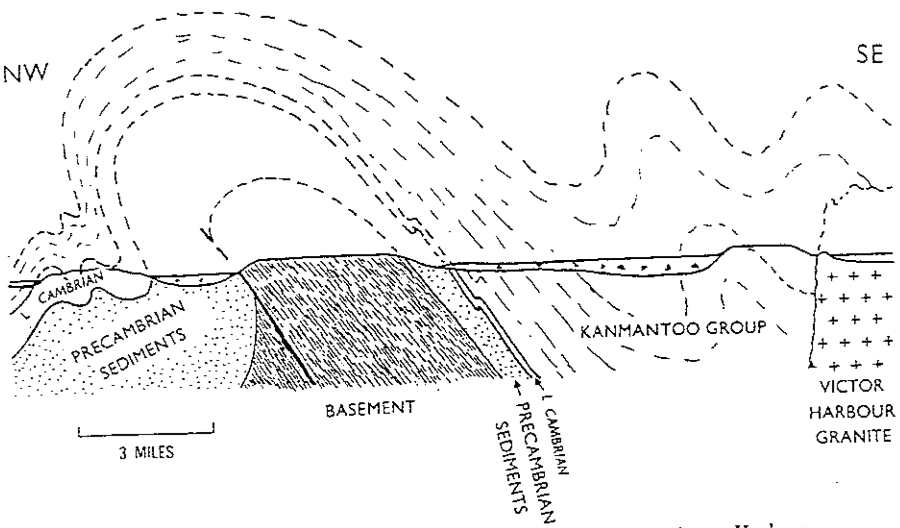


Figure 1a *Diagrammatic cross section from Normanville to Victor Harbour. Note the marked thinning of the Precambrian sediments and the thickening of the Cambrian sequence from West to East*

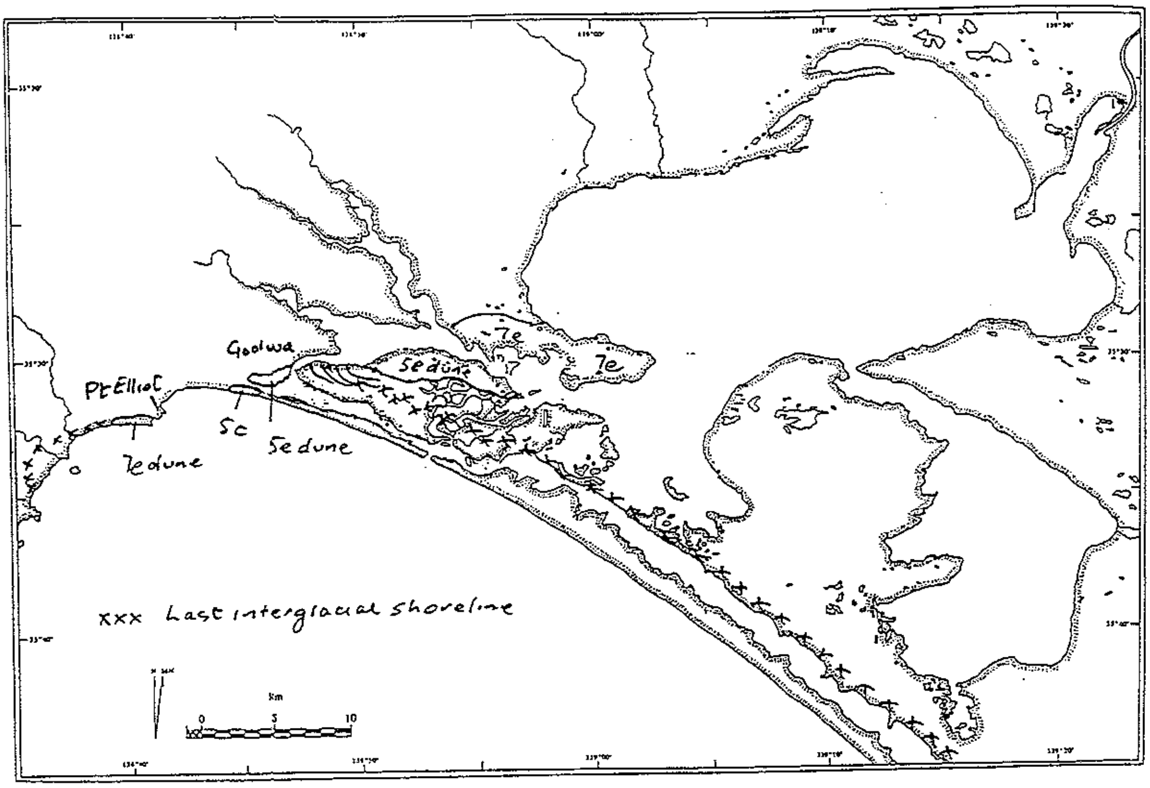


Figure 2 Last interglacial shoreline, associated dune and penultimate interglacial dune (Source: Bourman *et al.*, Unpublished data)

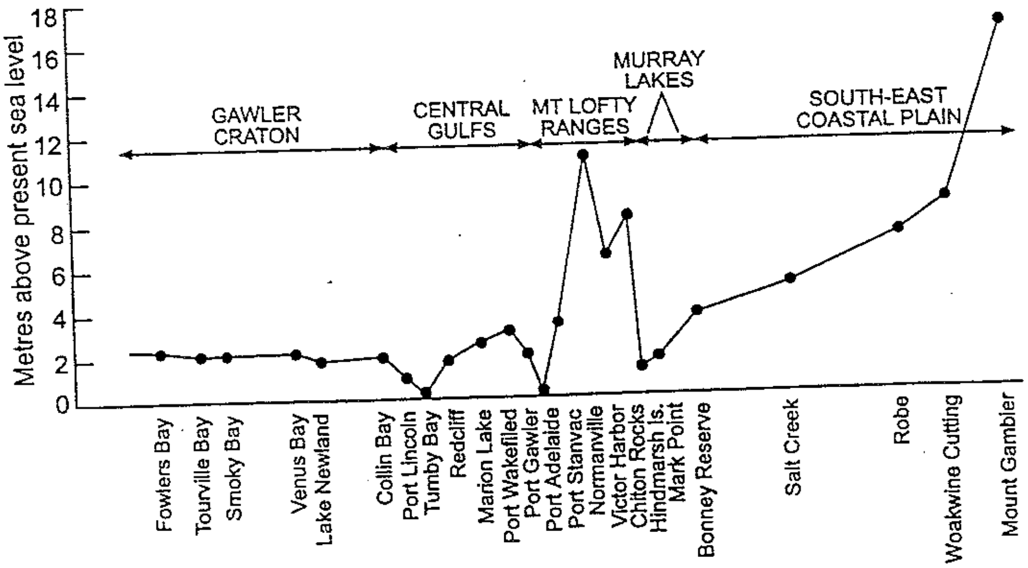
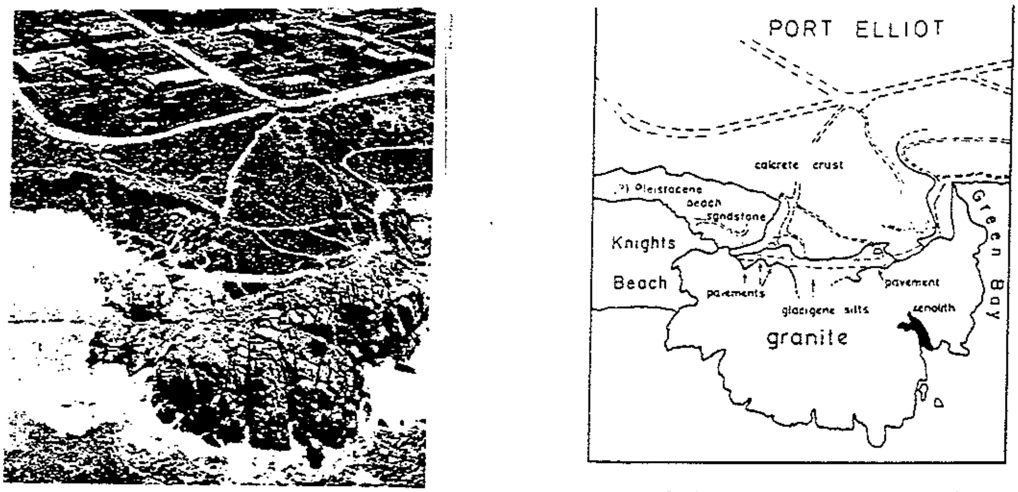


Figure 3 Tectonic dislocation of last interglacial shoreline (Source: Bourman *et al.*, 1999).



Low level oblique aerial photograph of the promontory between Knights Beach and Green Bay, Port Elliot, on which the glaciated granite pavement is exposed.

Geological sketch of the same locality

Figure 4 Port Elliot photograph and geological sketch (Source: Milnes and Bourman, 1972)

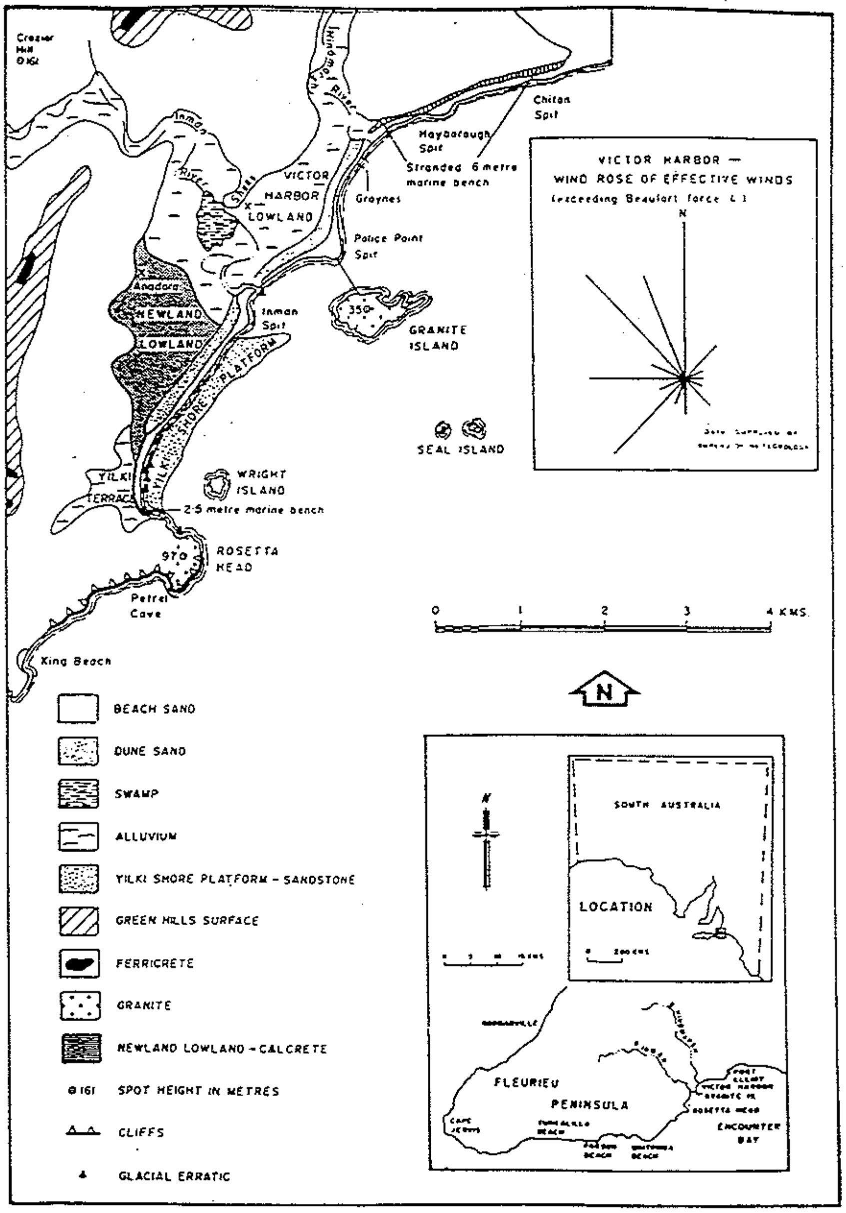


Figure 5 Map of Victor Harbor area

(Source: Bourman *et al.*, 1990).

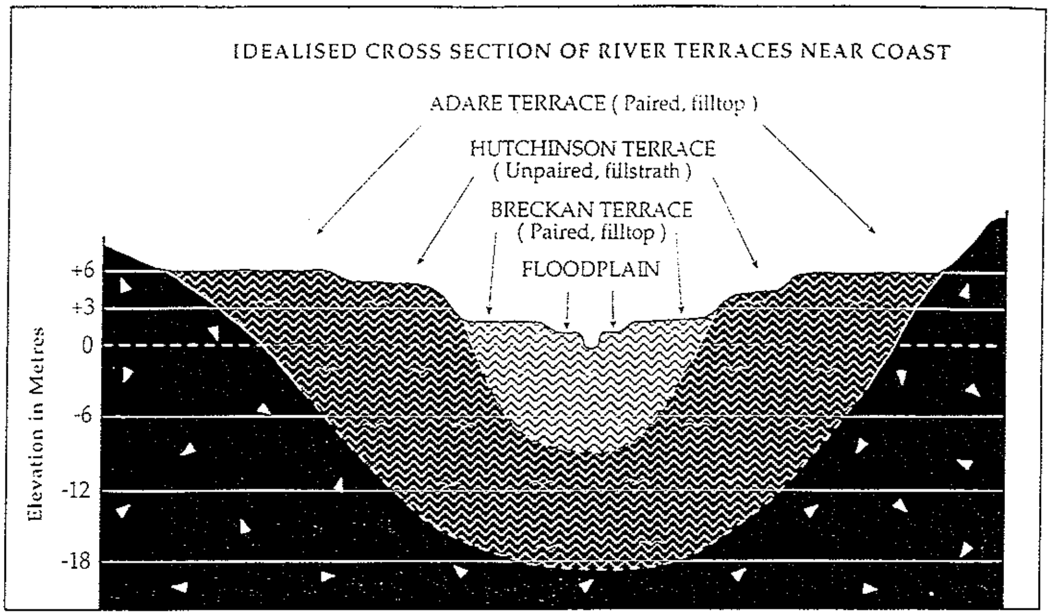
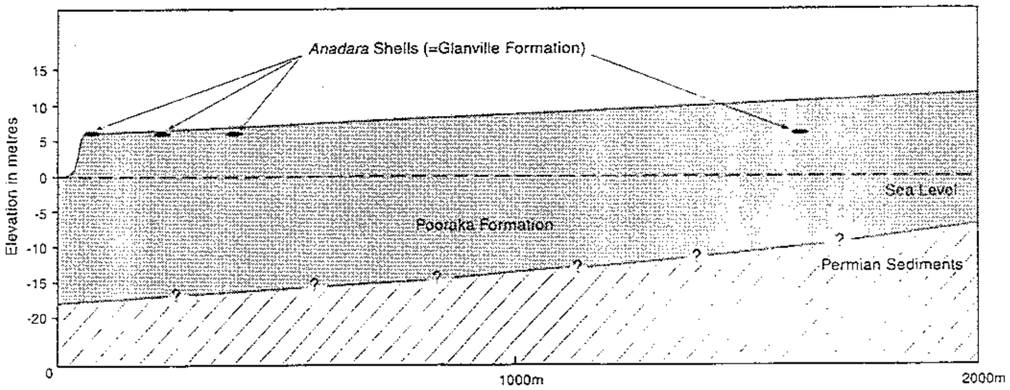


Figure 6 Paired river terraces of Hindmarsh River (Source: Bourman, 1969)



Sketch section showing the interfingering relationships of the Glanville Formation and the Pooraka Formation in the lower Hindmarsh River at Victor Harbor.

Figure 7 Last interglacial marine deposits (Glanville Formation) interfingering with the alluvial sediments (Pooraka Formation) underlying the river terraces of the Hindmarsh River (Source: Bourman et al., 1997).

. Road cutting on the Victor Harbor-Cape Jervis road west of the Waitpinga road, exposing bands rich in pisoliths, at a depth of about 1 m, in ferruginous sandy sediments of probable Pliocene age and of aeolian origin. Other pisoliths occur at the ground surface and in the upper soil mantle. The pisoliths at depth contain only goethite, whereas those at the surface have higher iron contents and contain dominantly hematite and maghemite. Geological hammer 33 cm long.

Figure 8 Pisoliths in road cut, Victor Harbor-Cape Jervis road (Source: Bourman, 1995)

Section in road-cutting showing channel cut into kaolinized and mottled Cambrian metasediments (*c*) and filled with weathered and mottled colluvial and alluvial sediments which contain ferruginous pisoliths (some maghemitic) and clasts of hematite mottles eroded from adjacent bedrock. Base of channel partly outlined in white. Landsurface mantled by *ironstone gravelly duplex soil*. Depth of cutting about 6 m.

Figure 9 Palaeochannel at Mount Desert (Source: Milnes *et al.*, 1985)

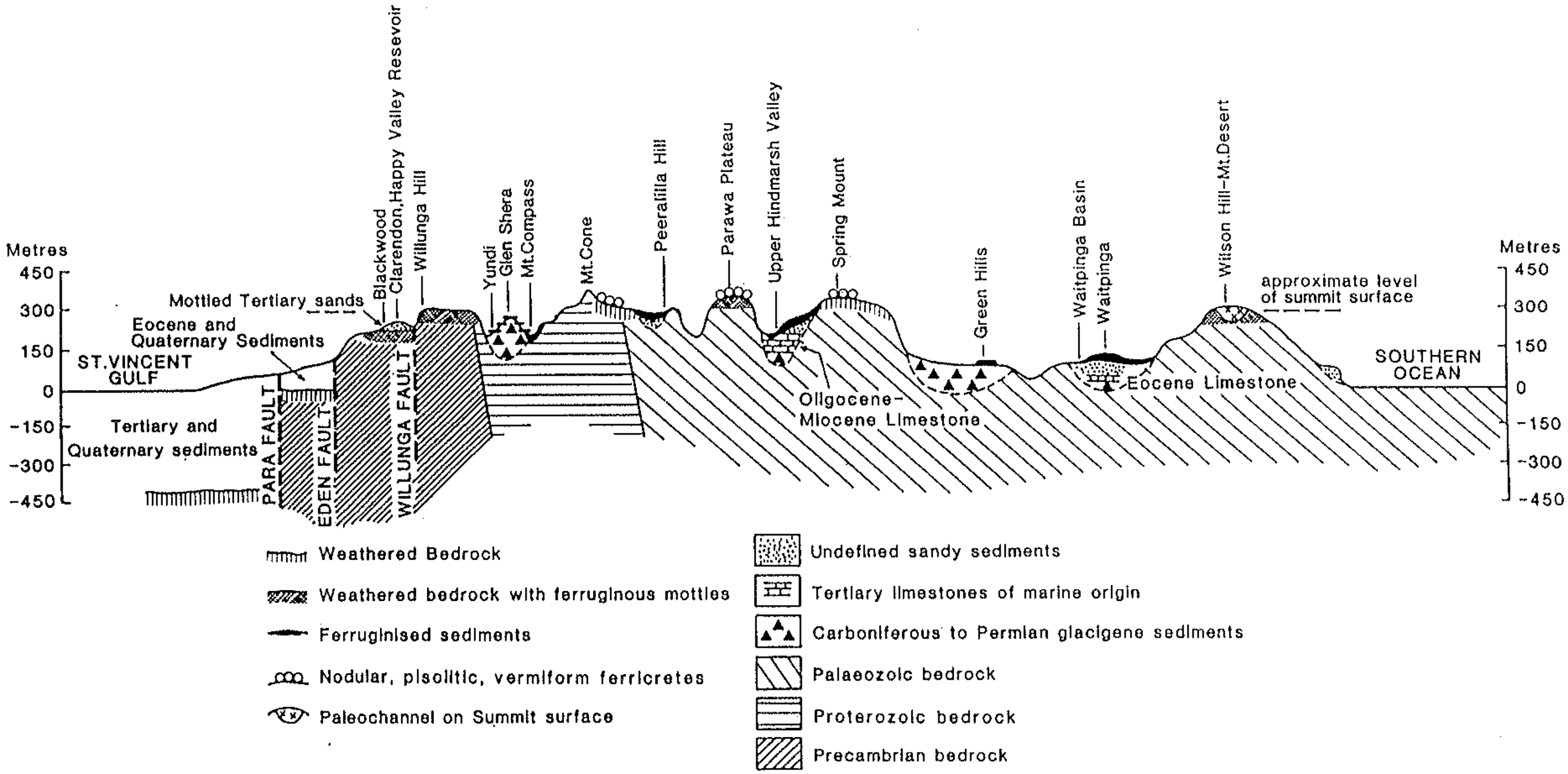
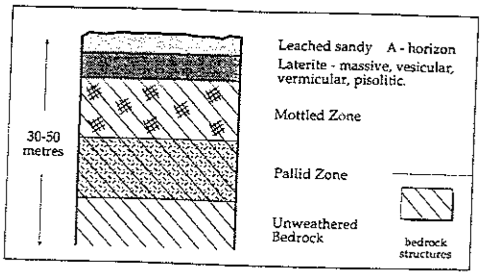


Figure 10 Relationships of regolith to bedrock and topography on Fleurieu Peninsula (Source: Milnes *et al.*, 1985)



Sketch of the pedogenic model of the normal or standard laterite profile incorporating a sandy, bleached A horizon above a laterite horizon, successively underlain by companion materials of mottled and bleached bedrock (Stephens 1946), considered to have developed on a peneplain under humid tropical conditions.

Figure 11 Classic 'laterite profile' of Stephens (1946)

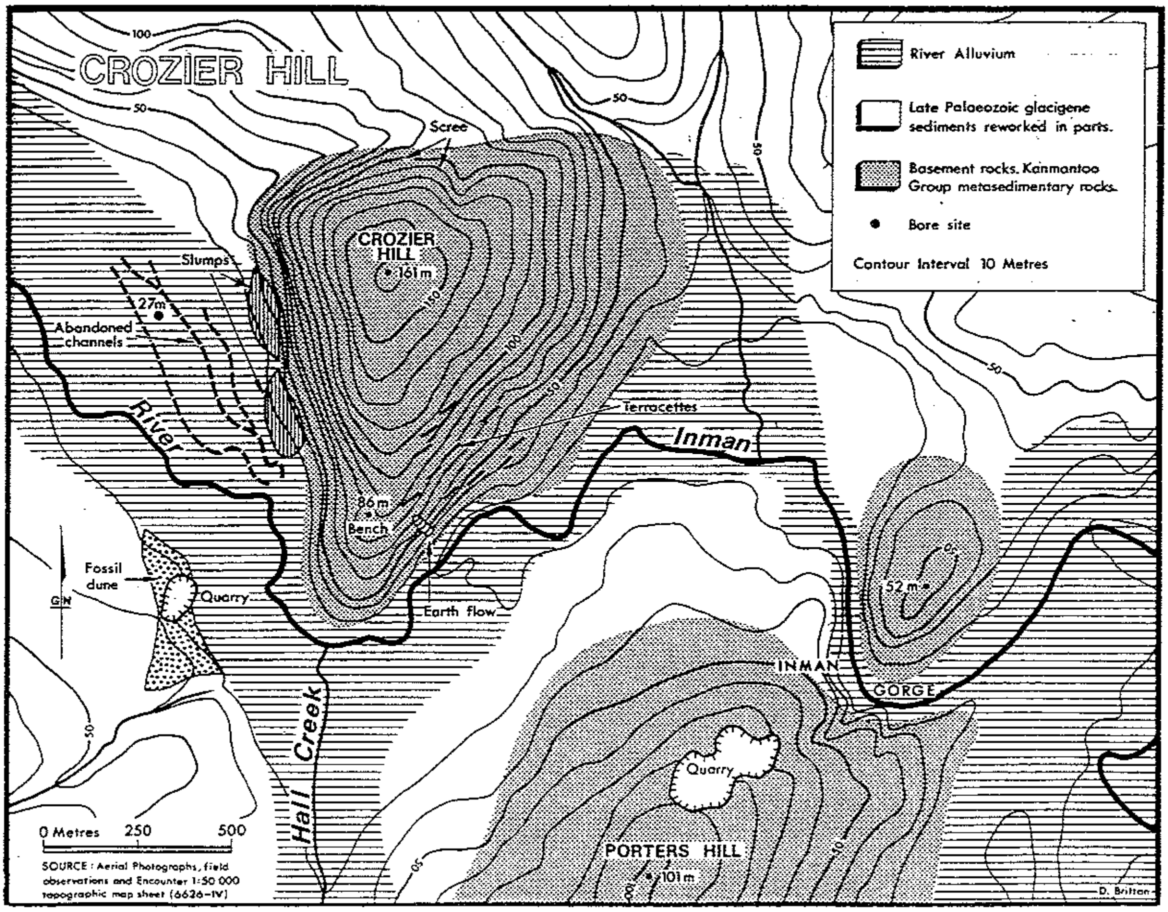
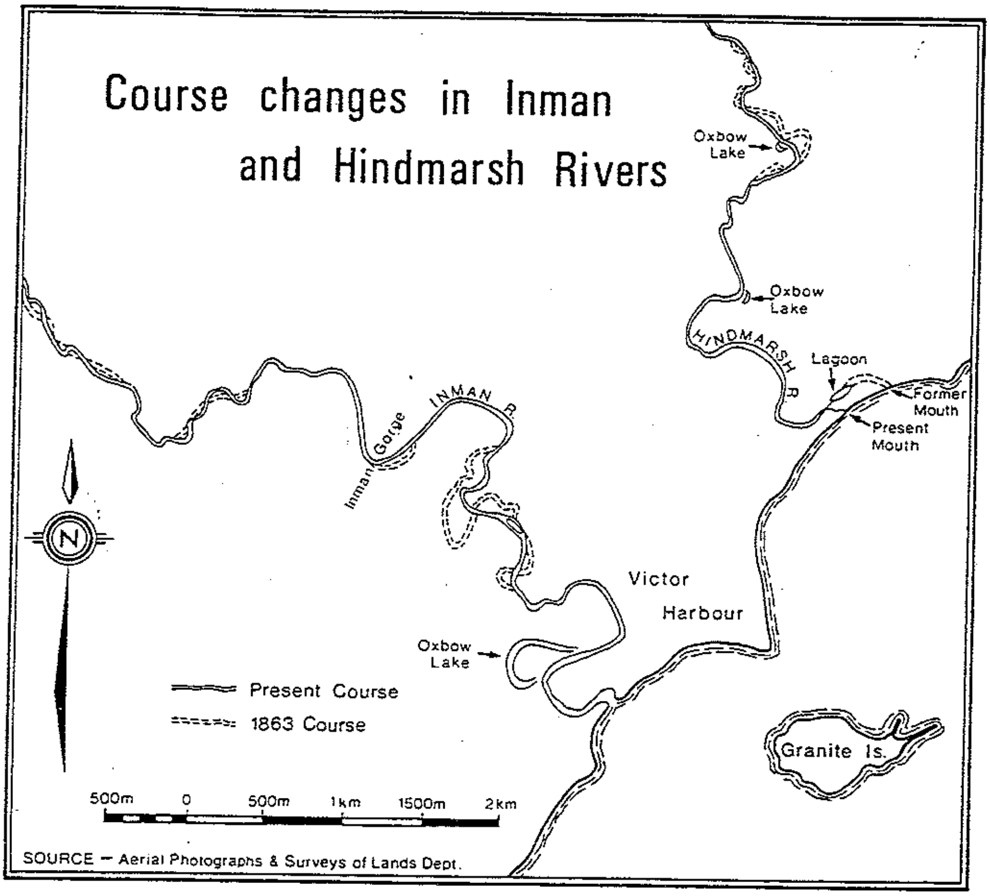


Figure 12 Crozier Hill (Source: Bourman. unpublished data).



SOURCE – Aerial Photographs & Surveys of Lands Dept.

Figure 13 Course changes in Inman and Hindmarsh Rivers (Source: Bourman, 1976)

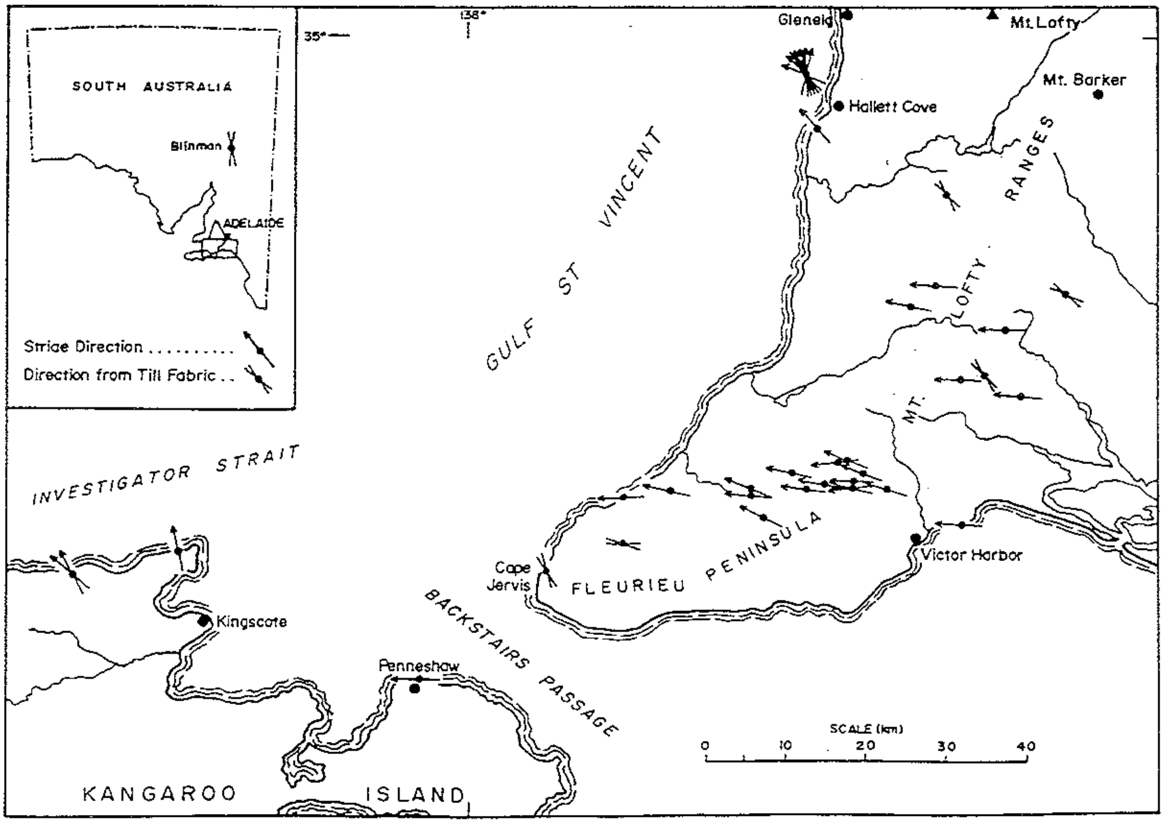
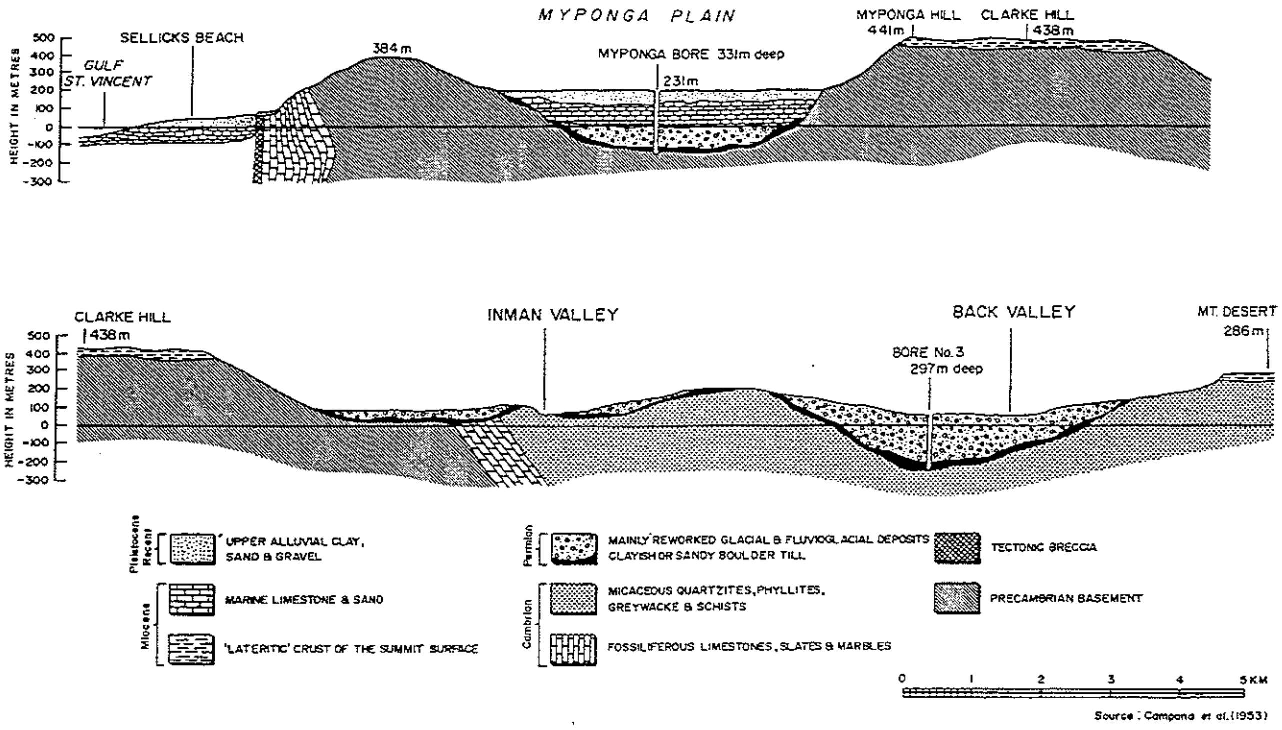


Figure 14 Movement of Permian ice across Fleurieu Peninsula (Source: Bourman, 1987)



Source : Campana et al.(1953)

Figure 15 Permian glacial valleys of Fleurieu Peninsula (Source: Campana and Wilson 1953)

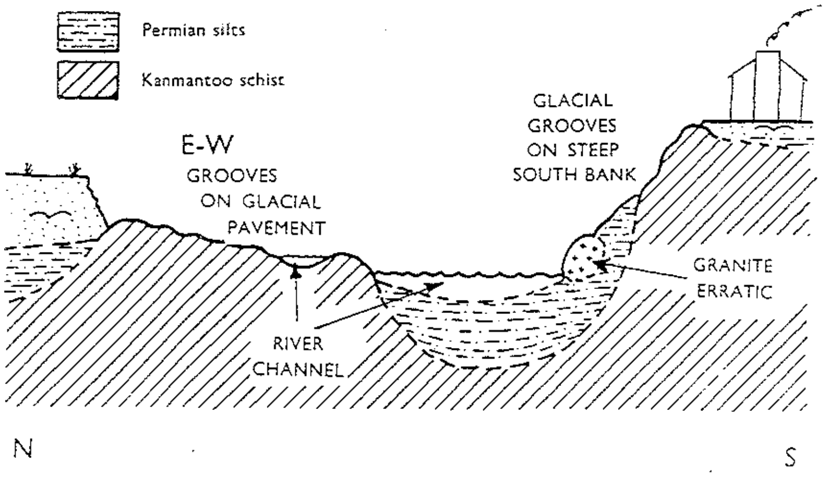
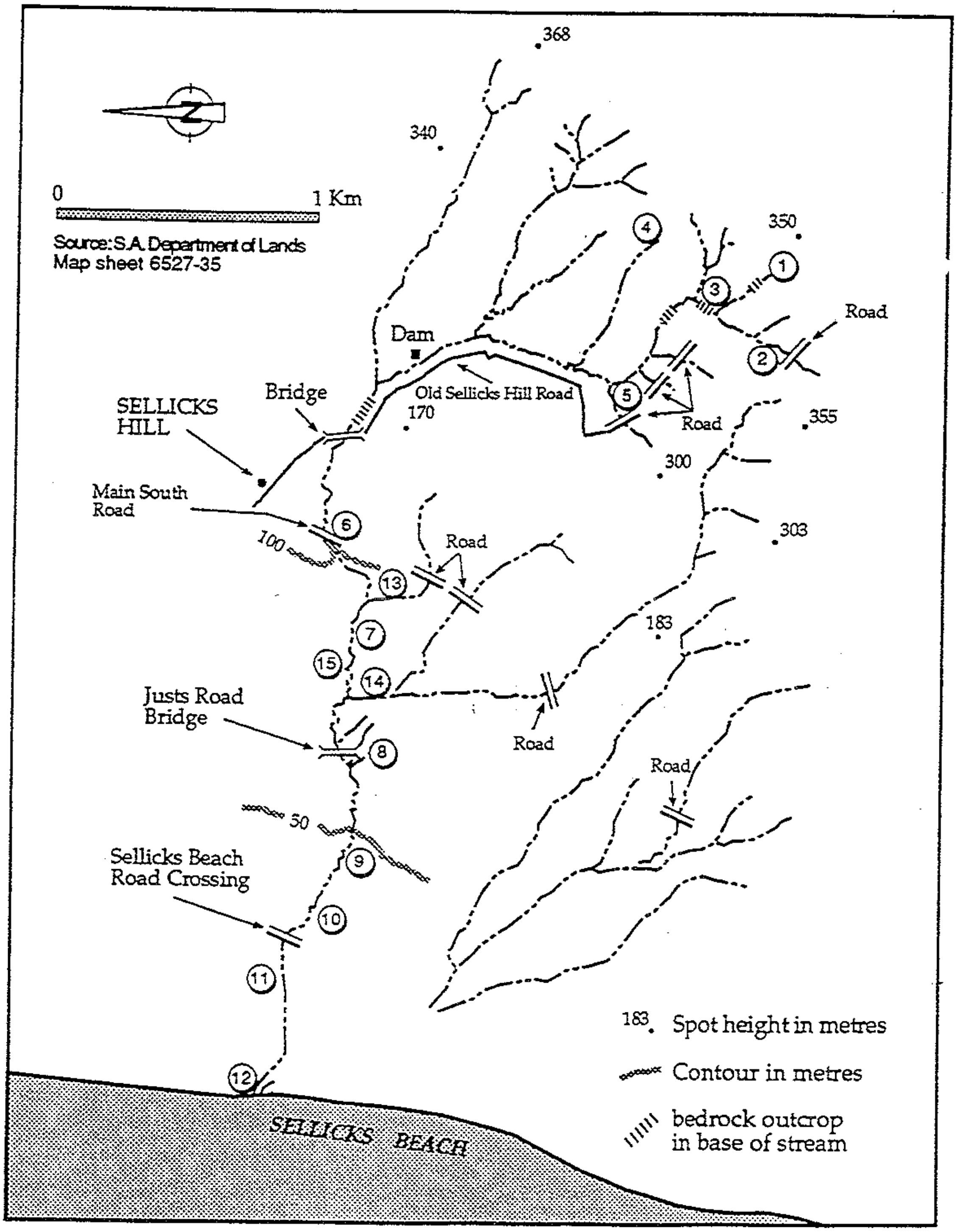
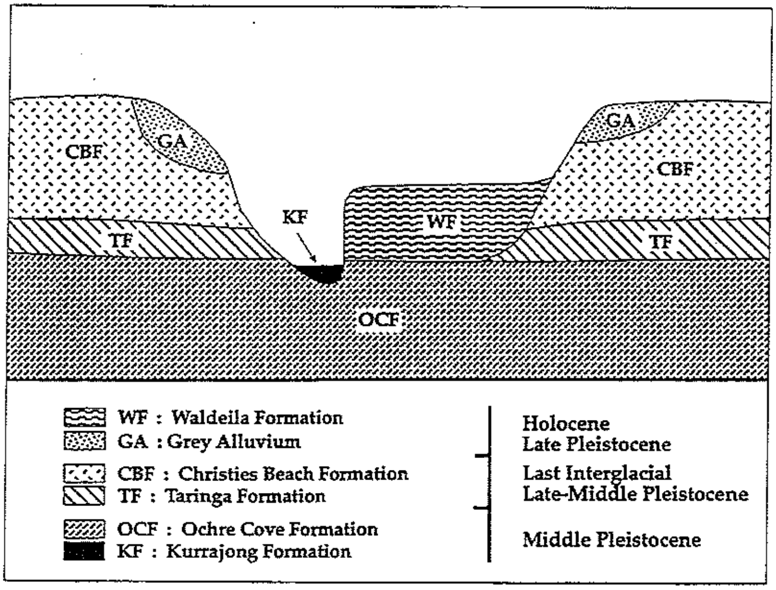


Figure 16 Sketch of Glacier Rock section (Source Talbot and Nesbitt, 1968)



Drainage of the Sellicks Creek showing localities referred to in the text. Base map: South Australia 1:10 000 Series, SA Department of Lands 6527-35.

Figure 17 Map of Sellicks Creek (Source: Bourman and James, 1995)



Sequence of Quaternary alluvial fan sediments revealing a sequence of cut-and-fill events (Source: Bourman and James, 1995).

Figure 18 Sequence of Quaternary alluvial fan sediments (Source: Bourman and James, 1995)

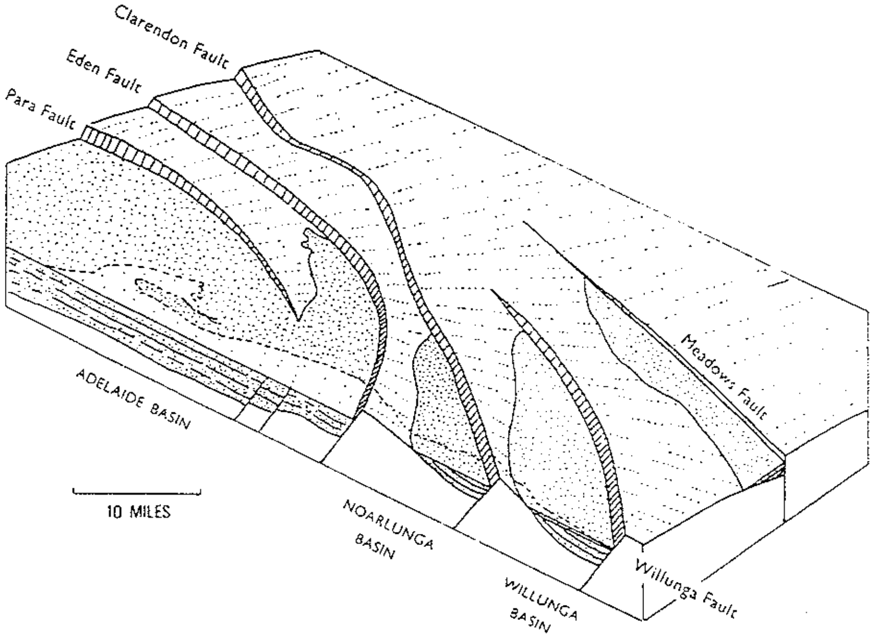


Figure 18a *Simplified block diagram of Adelaide region showing the uplifted fault blocks and the Tertiary Basins*

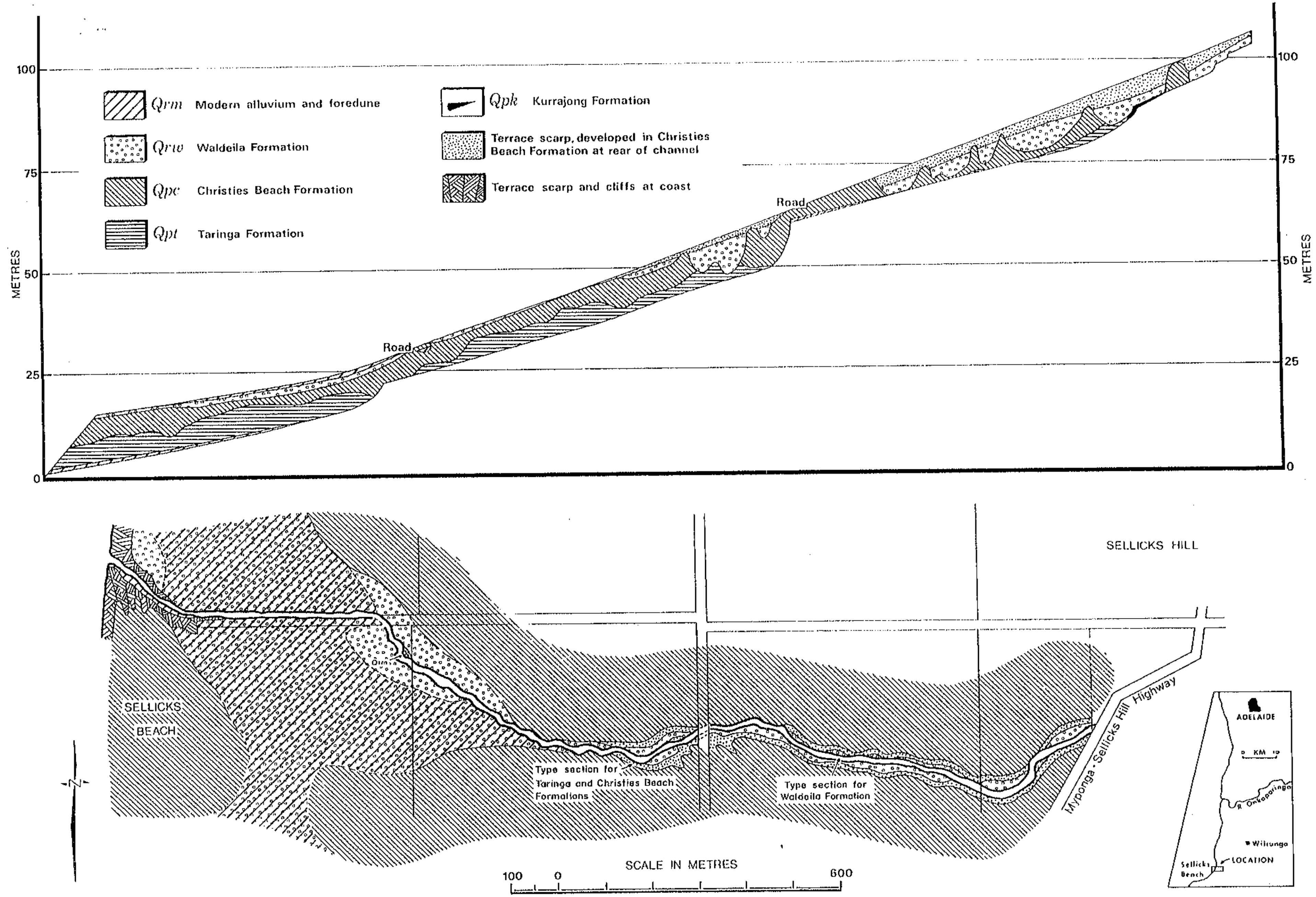
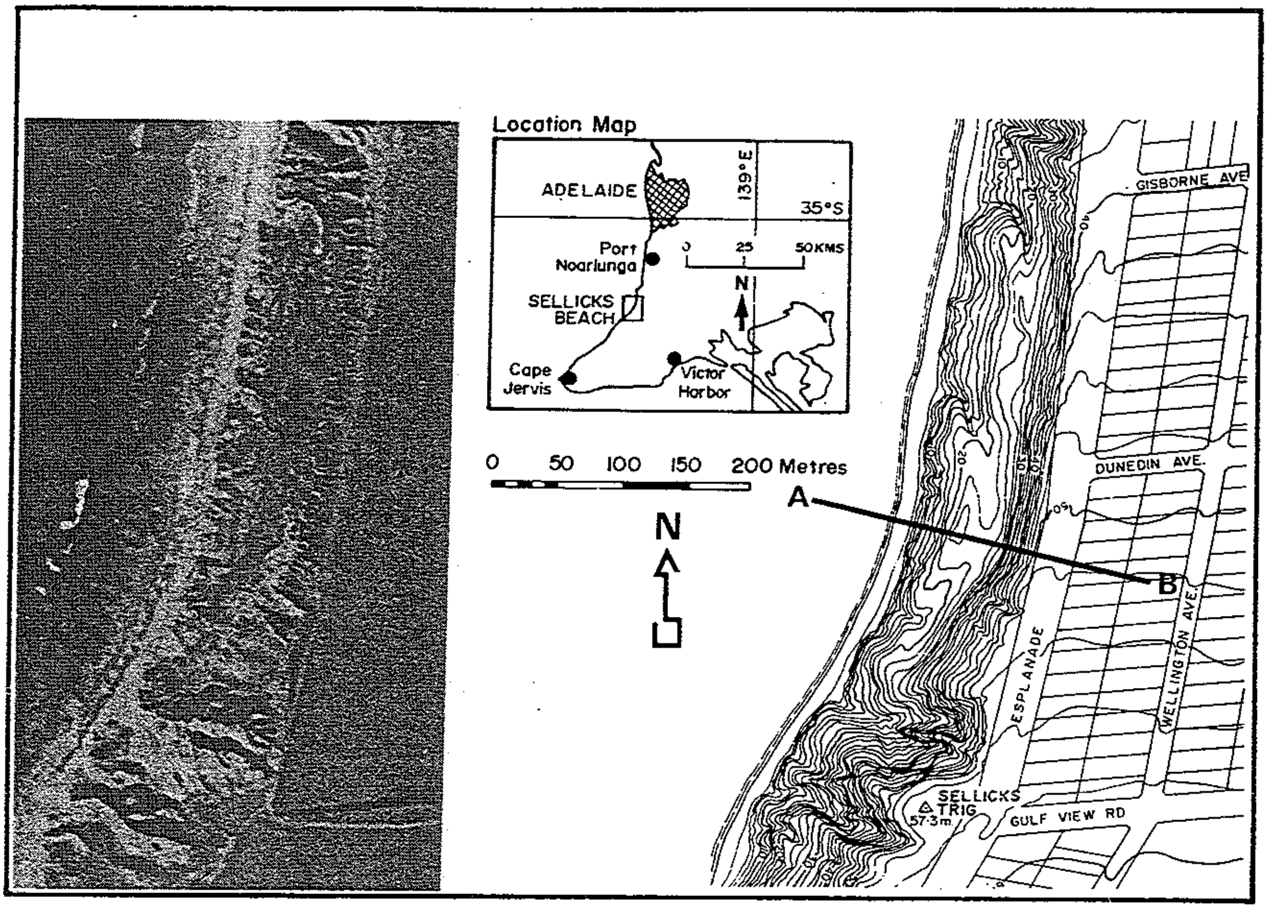
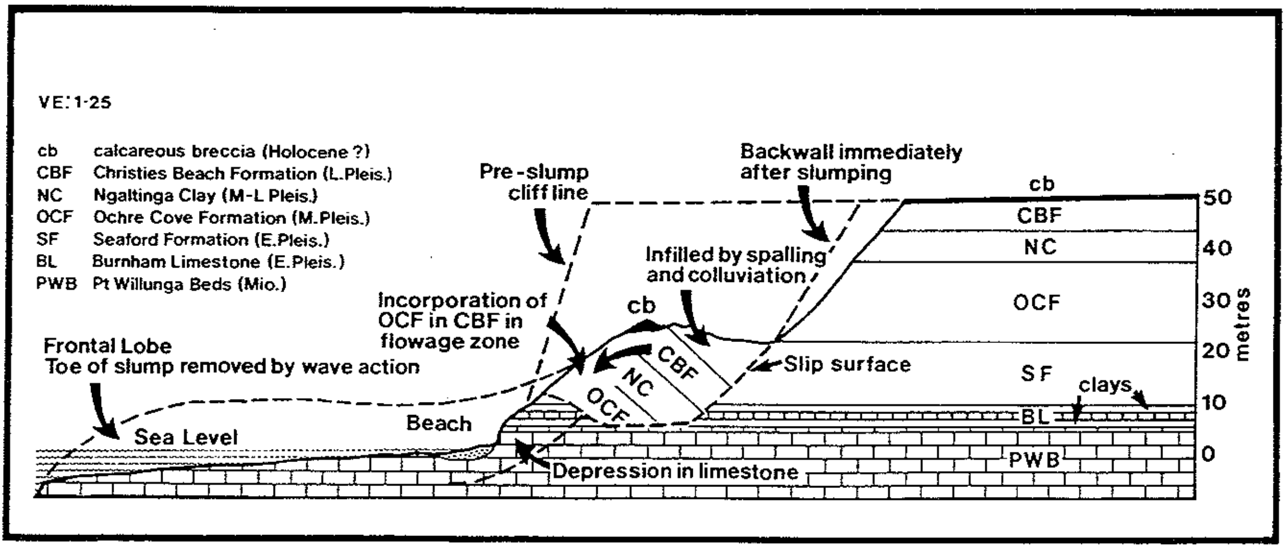


Figure 19 Plan of Sellicks Creek and sketch of sediments exposed on north face of channel (Source: Ward, 1966)

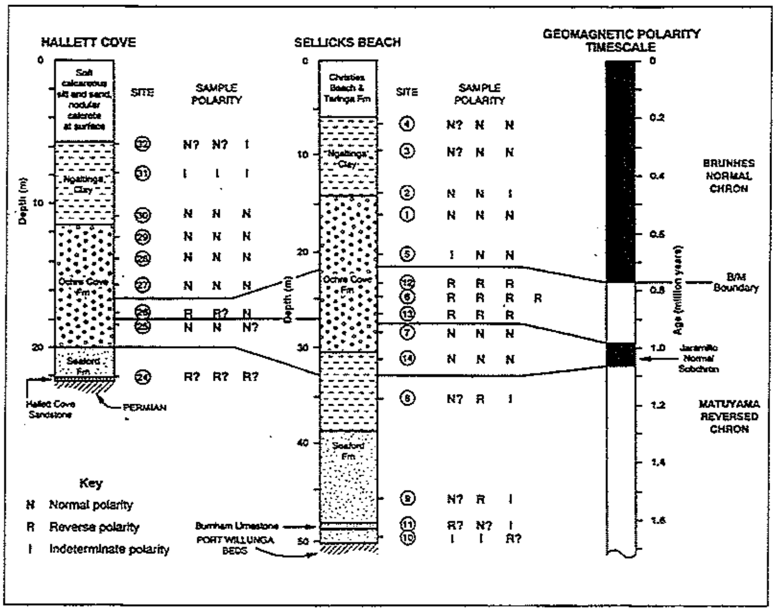


Coastal rotational landslump at Sellicks Beach. *Source:* 1949 Aerial photograph survey 42 photo 20; 1:2500 topographic sheets 6527-35-k and q. S.A. Dept. of Lands (with permission)



Cross-section through coastal landslump at Sellicks Beach. Line of section A-B on Figure 1

Figure 20 Sellicks Beach coastal landslump (Source: Bourman and May, 1984)



Pleistocene stratigraphy at Hallett Cove and Sellicks Beach sections, showing positions of palaeomagnetic samples and polarities, together with correlation with the geomagnetic time scale (Source: Pillans and Bourman, 1996)

Figure 21 Palaeomagnetism of Pleistocene sediments at Sellicks Trig (Source: Pillans and Bourman, 1996)

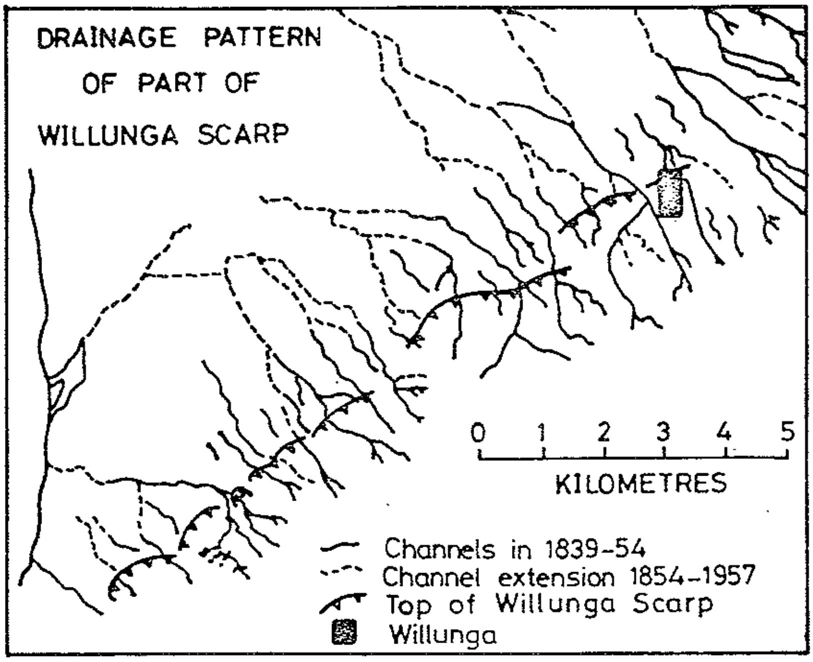


Figure 22 Gullies on Willunga scarp (Source: Dragovich, 1966)

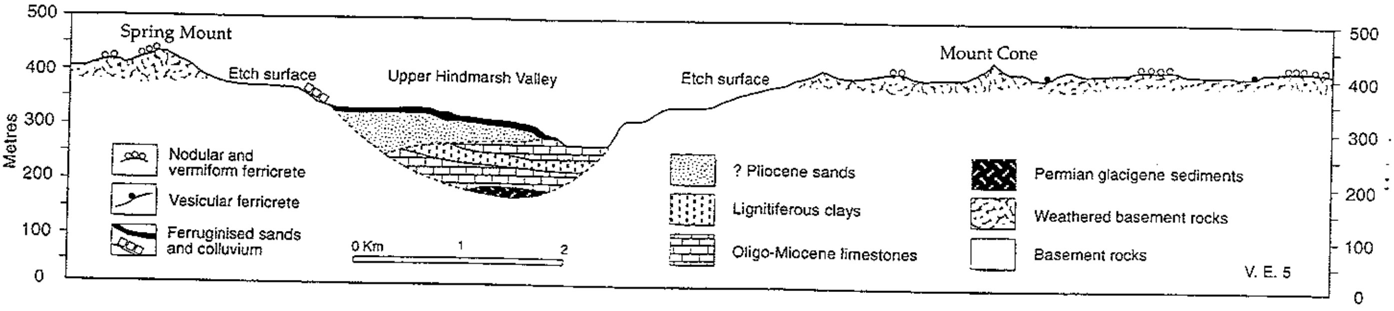


Figure 23 The relationships of ferricretes to Miocene limestones in the Upper Hindmarsh Valley (Source: Bourman, 1995)

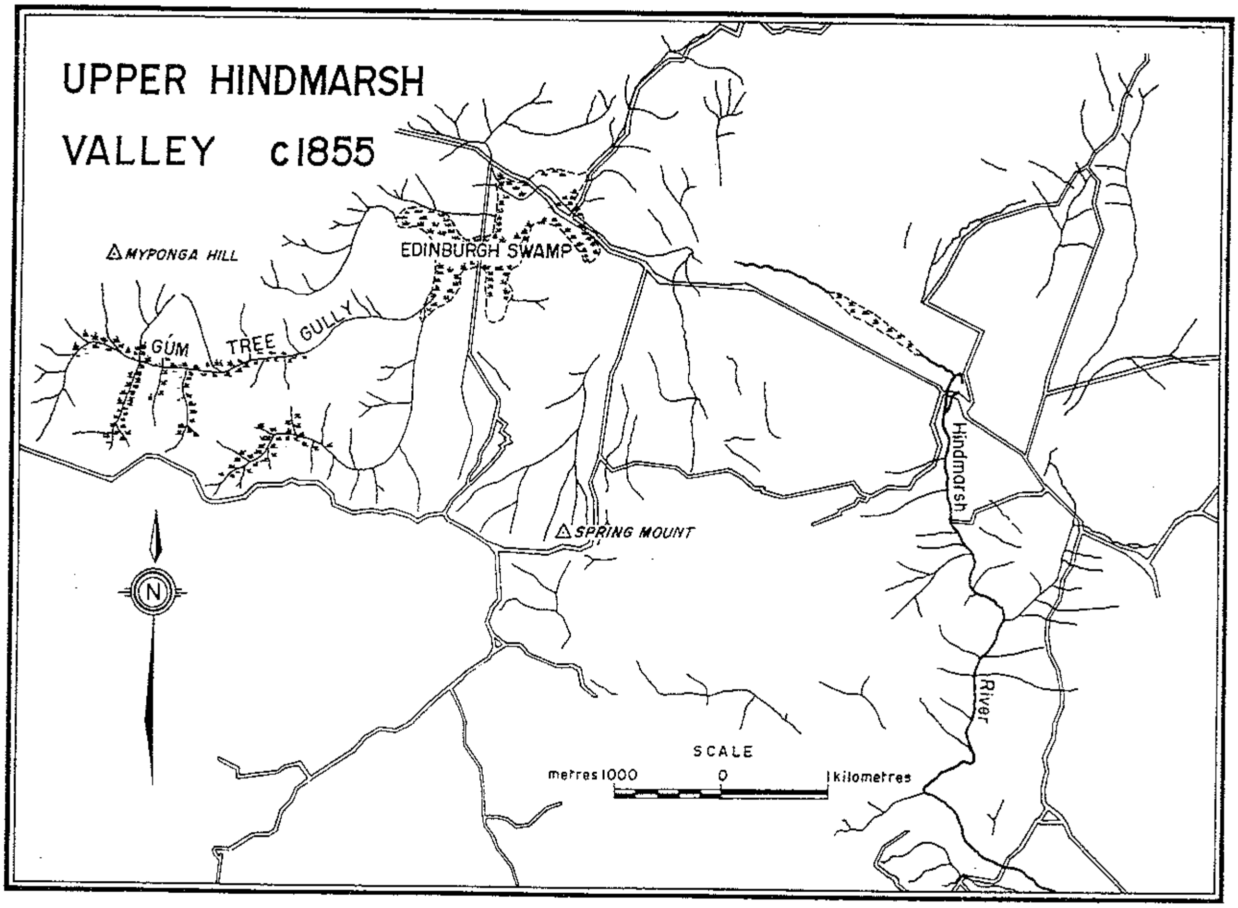


Figure 25 Drainage in the Upper Hindmarsh Valley circa 1855 (Source Bourman, 1976)

Spur-line cross-section through the Spring Mount-Upper Hindmarsh Valley-Mount Cone area showing the relationships of ferricretes to Tertiary limestone.

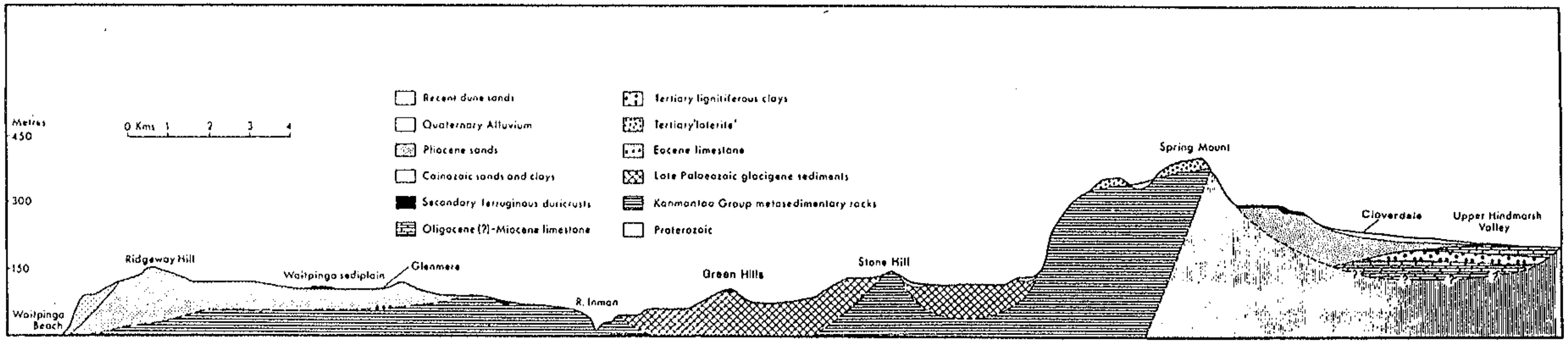


Figure 24 Spur line profile showing topographic relationships of Tertiary limestones and ferricretes.

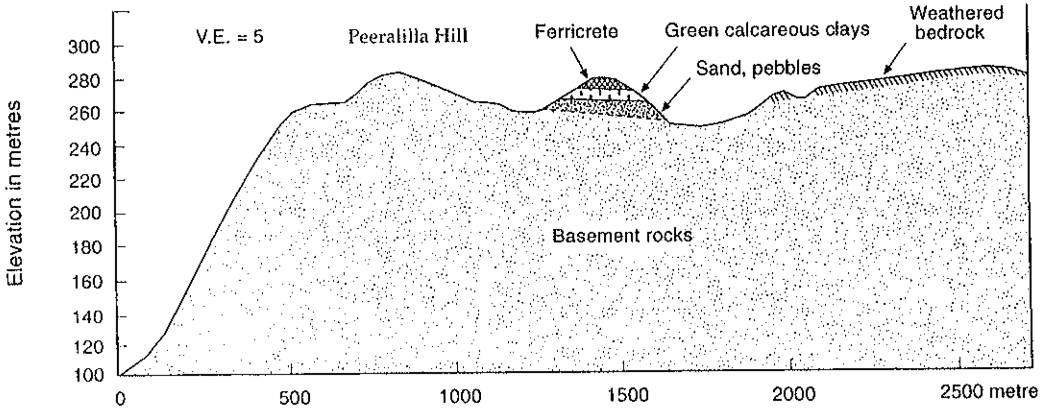
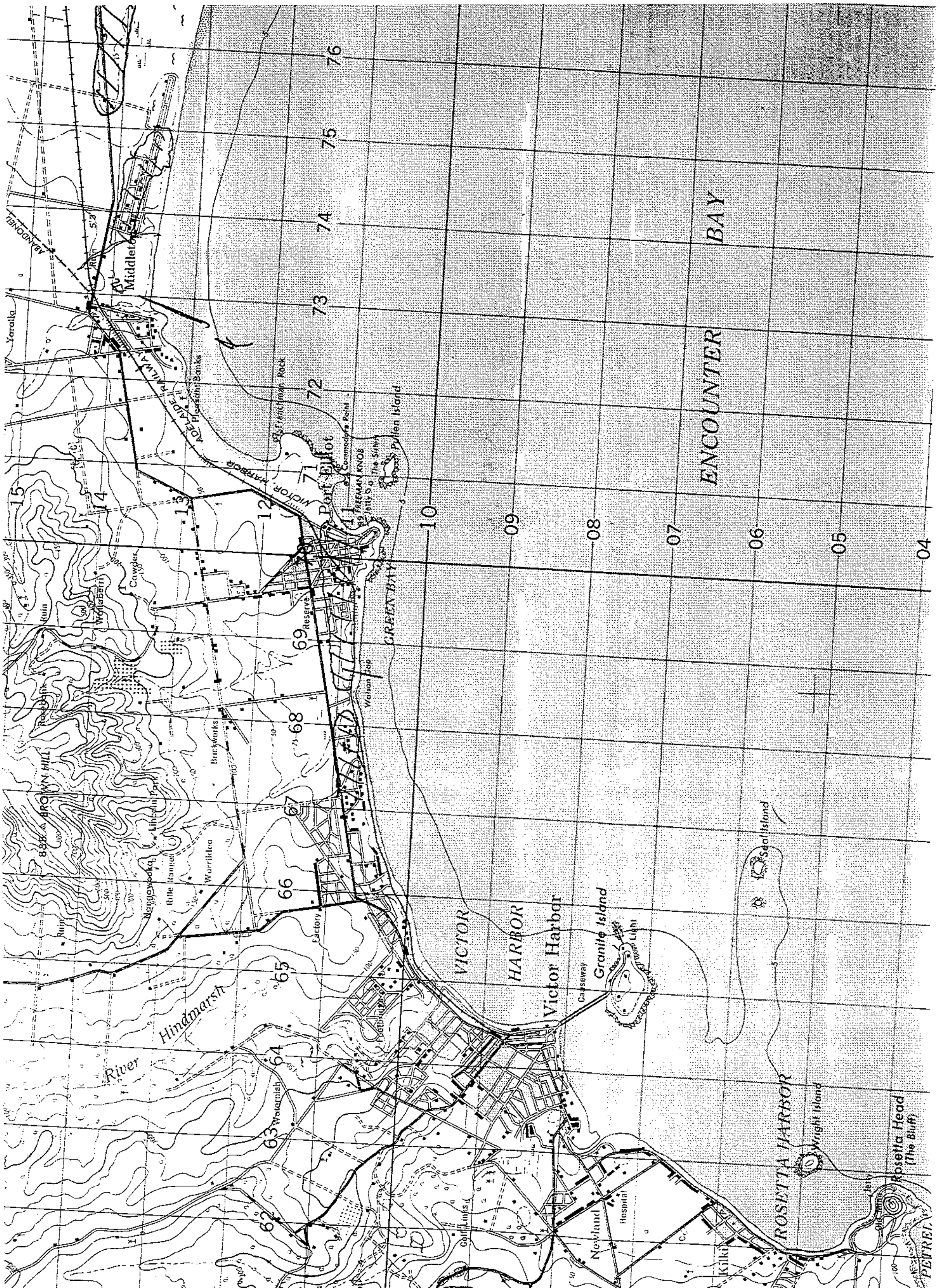


Figure 6. Cross section through Peeralilla Hill in the South Mount Lofty Ranges of South Australia. A thick vesicular ferricrete successively overlies green, calcareous clays, sands and pebbles and weathered Cambrian metasediments. It occupies a relatively low-lying position in the landscape and was a former peat swamp that acted as a sink for iron oxides brought in in solution, forming bog-iron ore as the iron oxides replaced organic material.

Figure 26 Cross section through Peeralilla Hill (Source: Bourman, 1995)

97
98
99
300
01
02
03
50'
04
305
06
07
08
09
310
Goolwa
Goolwa Beach
South Goolwa
ADELAIDE RAILWAY
VICTOR HARBOR
Corio
Golf Course
Ferry
Wharf
Causeway
Kiosk
Boat Ramps
Jetty
Reeds
Bird Sanctuary
LOWER MURRAY
CAPTAIN STURT ROAD
Caravan Park
Mazowsze
Narnu Park
Numerous Shacks
Mooroobra
RANDELL ROAD
Monument
MONUMENT ROAD
Sturt Farm
Tutanguldan
McLEAY ROAD
BARKER ROAD
Narnu Bay
NARNU BAY DRIVE
Sheds
Conwood
HINDMARSH
ISLAND
CHAPEL ROAD
Yards
Cemetery
Candwindra
Brecon
SEMASCHKO ROAD
Chaparral
Vaudan
Thaldanay
BONG A LONG ROAD
MURRAY MOUTH ROAD
Ruin
Ruins
Haddwch
Creek
Wyngate
Goolwa Barrage
Lock
Shed
GOOLWA
Landing
Ramp
Kiosk
Reedy Island
Llewen Island
Rushy Island
CHANNEL
Swan Point
SIR RICHARD PENINSULA
Jetty
Numerous Shacks
Car Park
Port Pullen
Pullen Spit
MURRAY MOUTH DRIVE
MUNDOO CHANNEL
Vaucer Island
Mundoo Barrage
Scab Channel
Bird Island
Flagstaff
Point Blenkinsop
National Bank
Murray Mouth
Mundoo
COORONG


ENCOUNTER BAY
VICTOR HARBOR
Victor Harbor
Granite Island
Causeway
Light
Seal Island
ROSETTA HARBOR
Wright Island
Rosetta Head (The Bluff)
Jetty
PETREL
Kilkie
Newland
Hospital
Golf Links
River Hindmarsh
Watermill
Factory
Warrikee
Rifle Range
Nangawooka
Lincoln Park
888 △ BROWN HILL
Brickworks
Reserve
Watson Gap
GREEN BAY
Port Elliot
FREEMAN KNOB
Commodore Point
The Sisters
Pullen Island
Frenchman Rock
Pleasant Banks
ADELAIDE – VICTOR HARBOR RAILWAY
ABANDONED
Cawler
Worlaberri
Yarralla
Middleton
61
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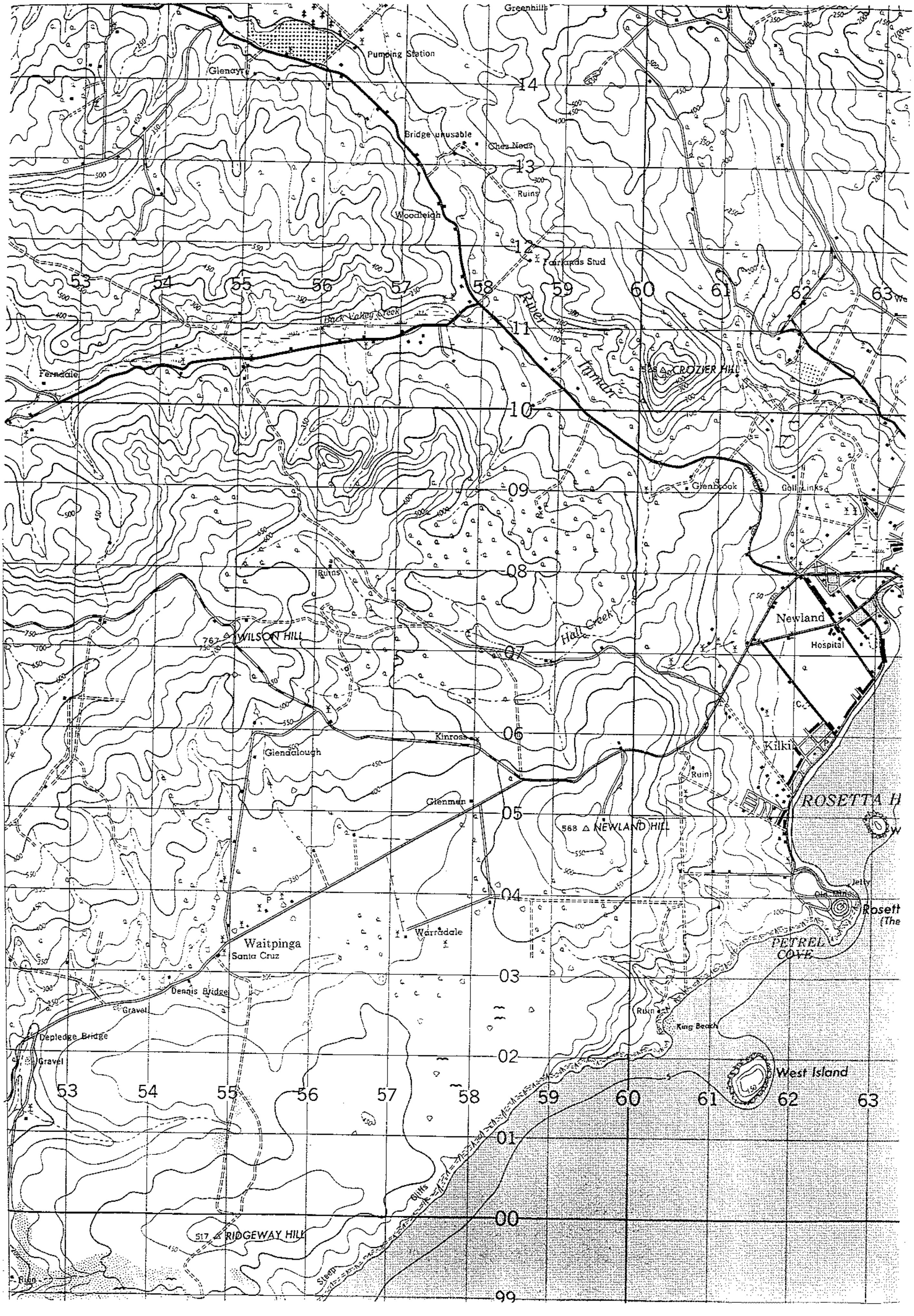
Greenhills
Pumping Station
Glenayr
14
Bridge unusable
Ches Nous
13
Ruins
Woodleigh
12
Fairlands Stud
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63
Back Valley Creek
River
Inman
11
Ferndale
528 CROZIER HILL
10
Glenbrook
Golf Links
09
Ruins
08
Newland
Hospital
Hall Creek
767 WILSON HILL
07
Kinross
06
Glendalough
Kilkit
Ruin
ROSETTA H
Glenmen
05
568 NEWLAND HILL
Jetty
Old Mine
Rosett
(The
04
Warradale
Waitpinga
Santa Cruz
PETREL COVE
03
Dennis Bridge
Gravel
Depledge Bridge
Gravel
02
Ruin
King Beach
West Island
53
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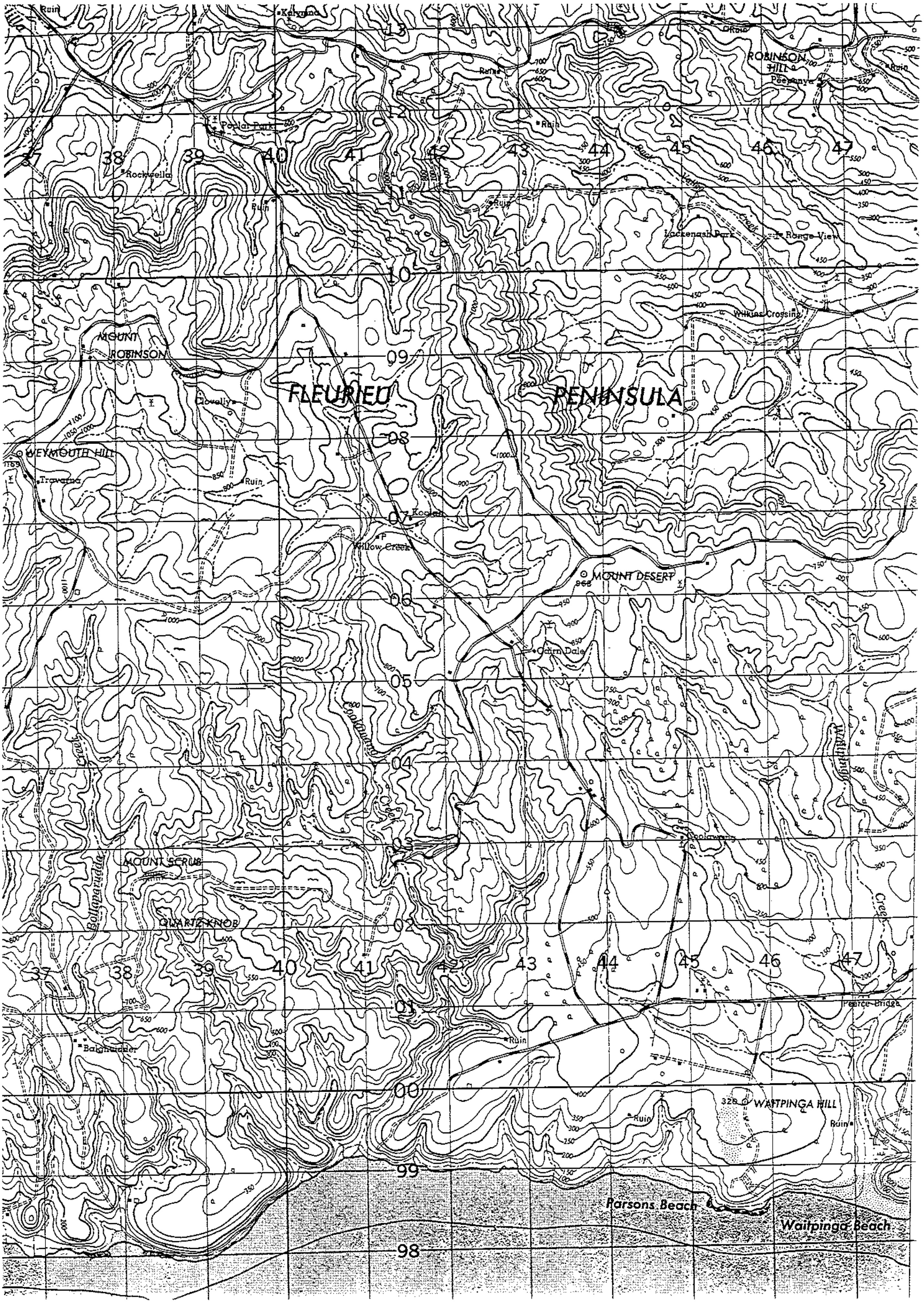
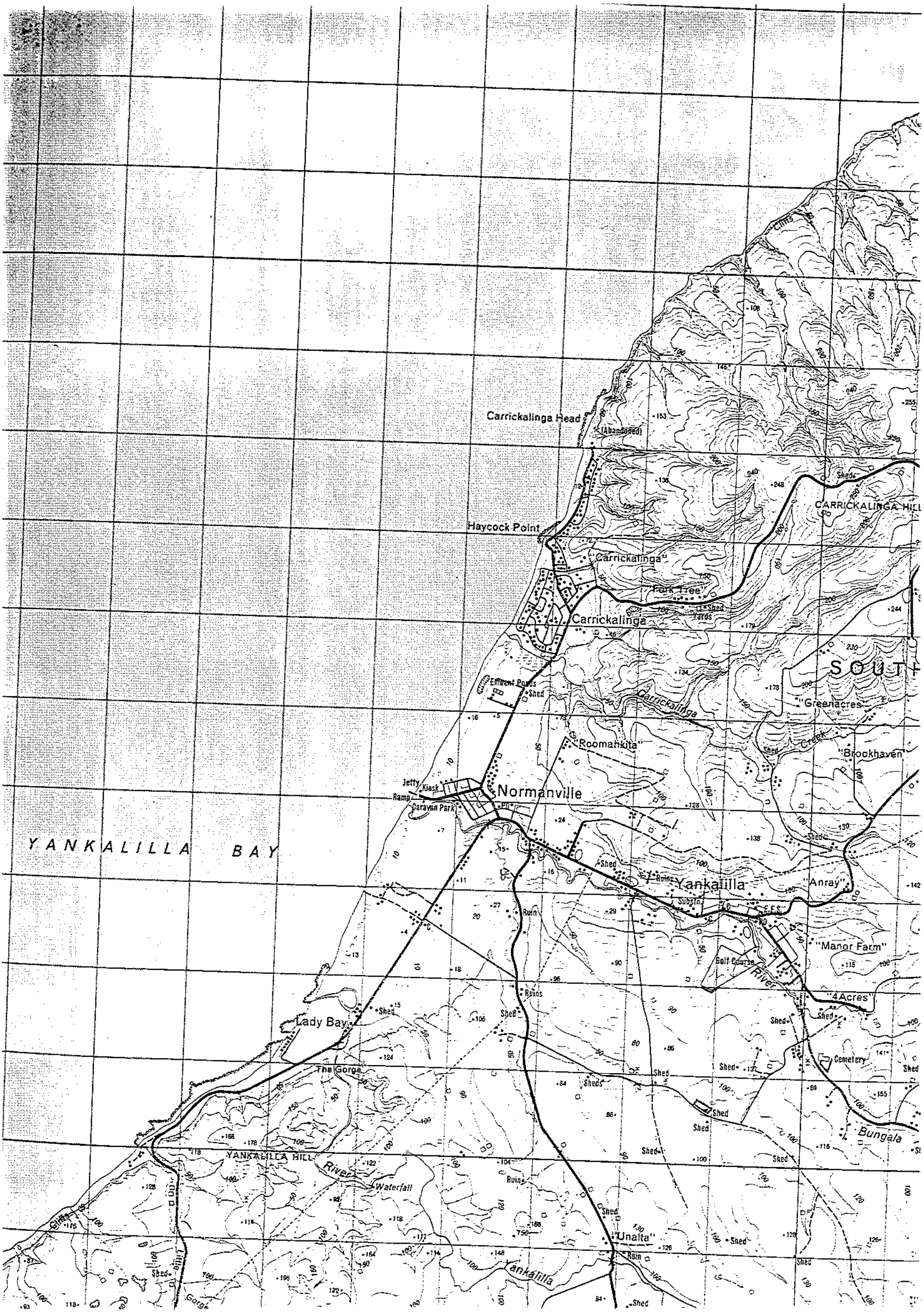
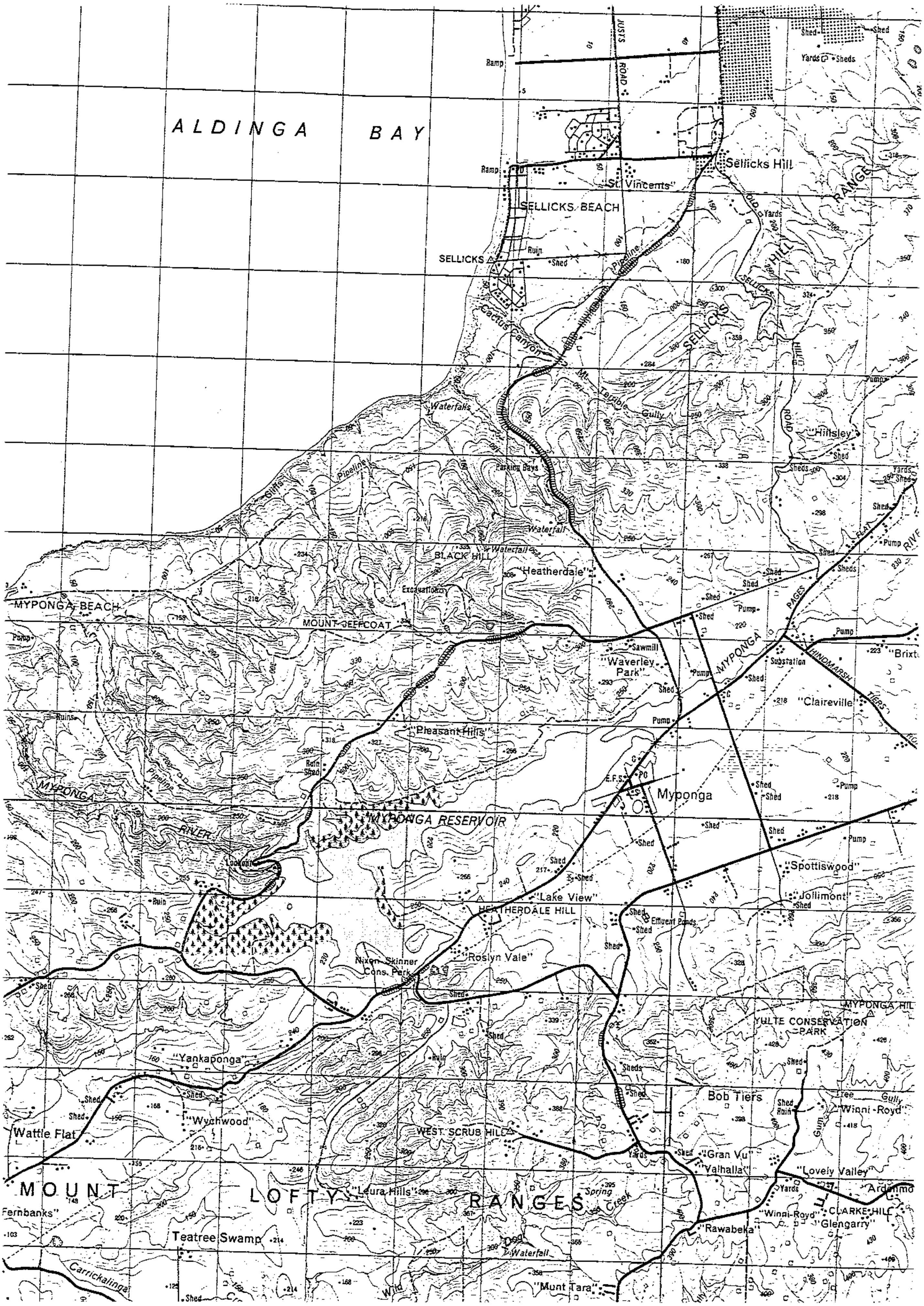
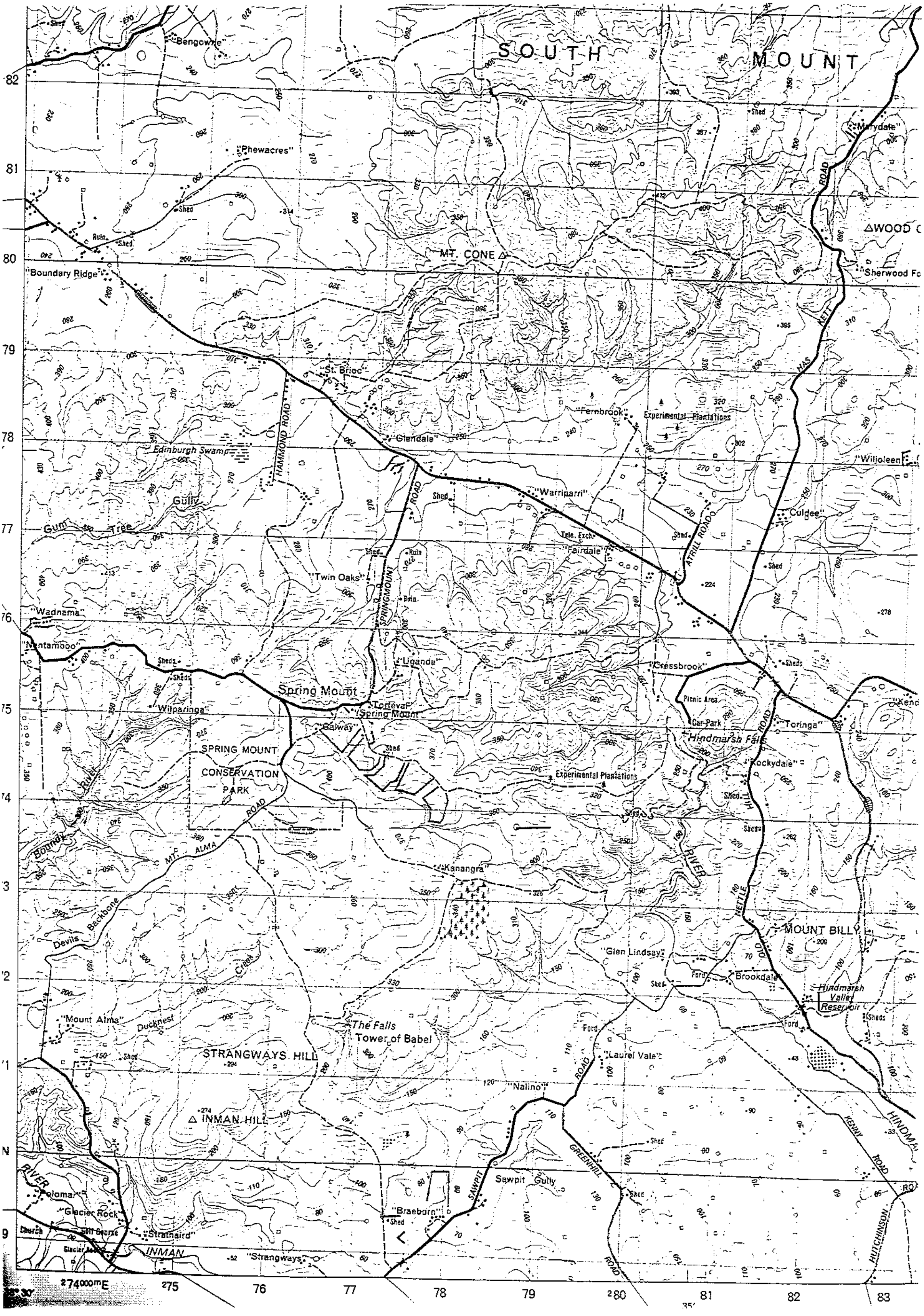
Cliffs
00
517 RIDGEWAY HILL
Steep
Ruin
99


Ruin
Kalyrana
13
Ruin
ROBINSON HILL
Peeronye
Ruin
12
Poplar Park
Ruin
37
38
39
40
41
42
43
44
45
46
47
Rockwella
Ruin
Ruin
Lackenash Park
Range View
Back Valley Creek
10
Wilkins Crossing
MOUNT ROBINSON
09
FLEURIEU
PENINSULA
Clovelly
WEYMOUTH HILL
1163
Travanna
Ruin
08
07
Koolea
Willow Creek
MOUNT DESERT
868
06
Cairn Dale
05
Coolawang Creek
04
Coolawang
MOUNT SCRUB
03
Bollaparudda Creek
Travanna
QUARTZ KNOB
02
37
38
39
40
41
42
43
44
45
46
47
01
Pearce Bridge
Balgowan
Ruin
00
326
WAITPINGA HILL
Ruin
Ruin
99
Parsons Beach
Waitpinga Beach
98


SOUTH MOUNT LOFTY RANGES
MYPONGA CONSERVATION PARK
YULTE CONSERVATION PARK
MYPONGA HILL
CLARKE HILL
HEATHERDALE HILL
WEST SCRUB HILL
CARRICKALINGA HILL
KEMISS HILL
MOON HILL
BARN HILL
SUGARLOAF HILL
Yankalilla
INMAN RIVER
Boundy
Lake View
Jollimont
Roslyn Vale
Bob Tiers
Gran Vu
Valhalla
Lovely Valley
Winni-Royd
Glengarry
Rawabeka
Clovidene
Munt Tara
Leura Hills
Teatree Swamp
Wild Creek
Kymian
Carrickalinga
Carrickalinga Creek
Fernbanks
Wattle Flat
Wykhwood
Yankaponga
Lindisfarn
Greenacres
Brookhaven
Anray
Manor Farm
Hope Farm
Coolawinda
Jumbuck
Caracla
Cadhoorn
Rockingham
Illoura
Currahmore
Galloway
Carisbrooke
Rycroft
Bella Vista
Brookland
Coomooloo
Woodvale
Bungala
Eagle Hawk Gully
Cemetery
Ord Acres
Spring Creek
Dog
Waterfall
Effluent Ponds
Dixon Skinner Conservation Park


Carrickalinga Head
(Abandoned)
Cliffs
CARRICKALINGA HILL
Haycock Point
"Carrickalinga"
"Fork Tree"
Yards
Carrickalinga
SOUTH
Effluent Ponds
Shed
Carrickalinga
Creek
"Greenacres"
"Brookhaven"
"Roomahkita"
Jetty
Kiosk
Ramp
Caravan Park
Normanville
PO
YANKALILLA BAY
Ruins
Yankalilla
Substn
E.F.S.
"Anray"
Ruin
"Manor Farm"
Golf Course
River
"4 Acres"
Ruins
Lady Bay
Cemetery
The Gorge
Sheds
Bungala
YANKALILLA HILL
River
Waterfall
Ruin
"Unalta"
Cliffs
Little
Gorge
Yankalilla


ALDINGA BAY
JUSTS ROAD
Ramp
Sellicks Hill
"St Vincents"
SELLICKS BEACH
SELLICKS
Ruin
Shed
Yards
Sheds
Pipeline
Cactus Canyon
OLD SELLICKS HILL ROAD
SELLICKS HILL RANGE
Mt Terrible Gully
Waterfalls
Cliffs
Parking Bays
"Hillsley"
Waterfall
BLACK HILL
"Heatherdale"
Excavations
MYPONGA BEACH
MOUNT JEFFCOAT
Sawmill
"Waverley Park"
Pump
MYPONGA
PAGES FLAT
HINDMARSH TIERS
Substation
"Brixt
"Claireville"
Ruins
"Pleasant Hills"
Ruin
MYPONGA RIVER
E.F.S.
PO
Myponga
MYPONGA RESERVOIR
Lookout
"Spottiswood"
"Lake View"
"Jollimont"
HEATHERDALE HILL
Effluent Ponds
"Roslyn Vale"
Nixon-Skinner Cons. Park
MYPONGA HILL
YULTE CONSERVATION PARK
"Yankaponga"
Bob Tiers
Tree Gully
"Winni-Royd"
Wattle Flat
"Wychwood"
WEST SCRUB HILL
"Gran Vu"
"Valhalla"
"Lovely Valley"
Ardenmo
MOUNT LOFTY RANGES
Fernbanks"
"Leura Hills"
Spring Creek
"Winni-Royd"
CLARKE HILL
"Glengarry"
"Rawabeka"
Teatree Swamp
Dog
Waterfall
Carrickalinga
Wild
"Munt Tara"
Gum



SOUTH MOUNT
"Bengowrie"
"Phewacres"
"Marydale"
WOOD
MT. CONE
"Boundary Ridge"
"Sherwood Fo
St. Brioc
"Glendale"
"Fernbrook"
Experimental Plantations
Edinburgh Swamp
HAMMOND ROAD
"Wiljoleen"
Gully
Gum Tree
"Warriparri"
ATRILL ROAD
HAS KETT ROAD
"Culgee"
Tele. Exch.
"Fairdale"
"Twin Oaks"
SPRINGMOUNT ROAD
Ruin
"Wadnama"
"Nuntamboo"
"Uganda"
"Cressbrook"
Spring Mount
"Torteval"
"Spring Mount"
"Wilparinga"
"Galway"
Picnic Area
Car Park
Hindmarsh Falls
"Toringa"
"Kend
SPRING MOUNT CONSERVATION PARK
Experimental Plantations
"Rockydale"
Boundy River
MT. ALMA ROAD
"Kanangra"
RIVER
NETTLE HILL ROAD
Devils Backbone
MOUNT BILLY
"Glen Lindsay"
Ford
"Brookdale"
Hindmarsh Valley Reservoir
"Mount Alma"
Duckenest Creek
The Falls
Tower of Babel
STRANGWAYS HILL
"Laurel Vale"
"Nalino"
ROAD
INMAN HILL
KENNY ROAD
HINDMA
GREENHILL ROAD
Sawpit Gully
SAWPIT
RIVER
"Polomar"
"Glacier Rock"
Church
"Strathaird"
"Braeburn"
INMAN
"Strangways"
HUTCHINSON
RO
Shed
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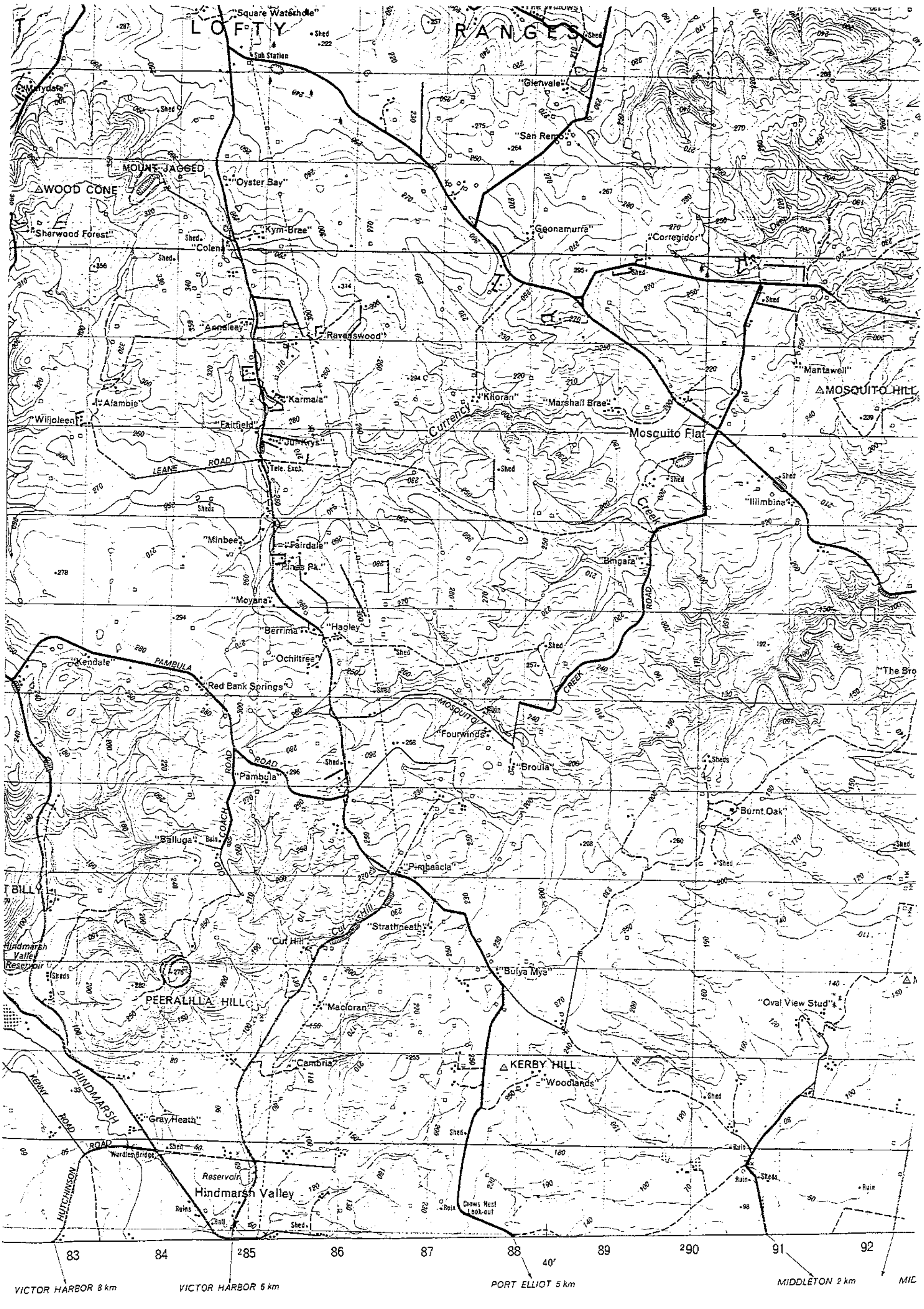
82
83


LOFTY RANGES
"Square Waterhole"
Sub Station
"Marydale"
MOUNT JAGGED
WOOD CONE
"Oyster Bay"
"Sherwood Forest"
"Colena"
"Kym-Brae"
"Glenvale"
"San Remo"
"Geonamurra"
"Corregidor"
Deep
"Annaleey"
"Ravenswood"
"Mantawell"
MOSQUITO HILL
"Afambie"
"Karmala"
"Kiloran"
"Marshall Brae"
"Wiljoleen"
"Fairfield"
"Jul-Krys"
Currency
Mosquito Flat
LEANE ROAD
Tele. Exch.
Creek
"Illimbina"
"Minbee"
"Fairdale"
"Pines Pk."
"Bingara"
ROAD
"Moyana"
"Berrima"
"Hagley"
"Ochiltree"
"Kendale"
PAMBULA
"Red Bank Springs"
CREEK
MOSQUITO
"The Bro
"Fourwinds"
"Broula"
ROAD
"Pambula"
OLD COACH ROAD
"Burnt Oak"
"Balluga"
"Pimbaacla"
BILLY
Cut Hill
"Strathneath"
"Cut Hill"
Hindmarsh Valley Reservoir
"Bulya Mya"
PEERALILLA HILL
"Macloran"
"Oval View Stud"
"Cambria"
KERBY HILL
"Woodlands"
KENNY ROAD
HINDMARSH
"Gray Heath"
ROAD
Wardles Bridge
HUTCHINSON
Reservoir
Hindmarsh Valley
Ruins
Hall
Crows Nest Look-out
83
84
285
86
87
88
40′
89
290
91
92
VICTOR HARBOR 8 km
VICTOR HARBOR 6 km
PORT ELLIOT 5 km
MIDDLETON 2 km
MID