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Preliminary Review of

OIL AND GAS POSSIBILITIES

of

ST.VINCENT GULF GRABEN AND ADJACENT

by

R.C. Sprigg M.Sc.

GEOSURVEYS
OF AUSTRALIA LIMITED
GEOLOGICAL AND GEOPHYSICAL CONSULTANTS
Managing Director: R. C. SPRIGG, M.Sc., A.M.Aus.I.M.M., M.Am.A.P.G., M.G.S.Am.

Laboratories—
57 Todville Street
Woodville West
Telephone Nos.—
Registered Office: W 7088
Depot & Laboratories: JL 4624
Telegrams—
"Geosurveys", Adelaide
Secretary—
Rennie F. Middleton,
F.A.S.A., A.C.A.A., J.P.

Seventh Floor
DA COSTA BUILDING
GRENFELL STREET
ADELAIDE
SOUTH AUSTRALIA

G.P.O. Box 1479 L

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PLANS TO ACCOMPANY REPORT

I INTRODUCTION

Until recently little attention has been paid to the St. Vincent Gulf region in the search for commercial oil and gas. Earlier workers (Wade 1915, Ward 1913, 1944) looked on it as a region of shallow Tertiary sedimentation, and such few oil showings that were reported in shallow drilling both on Yorke Peninsula, and nearer Adelaide, were discounted as unconvincing or of dubious origin.

On Yorke Peninsula, "showings" of oil were reported from several bores drilled principally in the Minlaton - Stansbury area or near Maitland. Both are areas of Cambrian limestone, although more than one bore was drilled wholly in neighbouring basement. Following the discoveries of ozokerites in comparably thick Cambrian limestones about 200 miles to the north of Wilkatana in 1956, the South Australian Mines Department carried out check drilling in the Minlaton - Stansbury area. "Showings" of oil and petroliferous gas were verified in association with the limestones. Marine accumulations were discovered in the (?Upper) Permian glacigene succession for the first time in South Australia during these operations.

Near Port Gawler, approximately 27 miles N.N.W. of Adelaide, a bore in 1923 was reported (Jack 1923) to have had a "showing" of oil which, at the time, could not be officially verified. Showings were reported at 504'6" and 603 feet. The bore was abandoned at 603' in Turritella beds, and a strong brine (13 oz. per gallon) was issuing at the surface. This reported association of "oil showings" with strong brine requires further investigation.

Very few holes have been sunk in the Adelaide Plains area in the conscious search for oil. Prior to the 1950s the official attitude to possible oil potential in the Adelaide area was essentially negative.

An "oil bore" put down several hundreds of feet at Semaphore (near Port Adelaide) was located to test for the source of gas escaping on the beach. The gas proved to be from decomposing seaweed buried in the beach sands and the bore was abandoned in Pliocene marine sands.

More recently the Mines Department have carried out reconne-aissance geophysical surveys in the Adelaide vicinity and established presumed shallow sedimentary section along the lines investigated. The investigations were directed principally to brown coal exploration and to underground water studies.

The Adelaide Plains nearer Adelaide have been extensively drilled for shallow artesian water in the Pliocene sands, and also in the shallower developments of Miocene limestones. These shallow, porous marine sediments are extensively flushed by fresh waters which replenish rapidly following early winter rains. Only one bore has gone to bedrock in the plains area, notably the Croydon bore which is reported to have bottomed in Upper Protero-ozoic at 2069 feet. This is situated slightly more than one mile from the Para fault which brings bedrock into outcrop a few miles further north east.

Drilling for oil has also been carried out in Peezy swamp on Southern Yorke Peninsula following reports of escaping (marah) gas. The hole entered Permian till at a shallow level, and finally into Pre Cambrian at 661 feet.

II <u>THE AREA, ACCESS AND OPERATIONAL PROBLEMS.</u> (fig. 1)

O.E.L. 24 comprises an area of approximately 12,500 square miles. Of this approximately half is land area, and the remainder is shallow sea. St. Vincent Gulf as the principal marine area of interest is mostly less than 15-20 fathoms in depth. From the east (opposite Adelaide) it shelves very gently and is in fact a remarkably flat submarine plain with gradients rarely in excess of a few feet per mile in the deeper areas. Navy survey ships report it to be extremely monotonous, and the bottom sediments are highly calcareous. Paralelling the coast of Yorke Peninsula, and extending out about ten miles from it, the Orontes Bank forms a well developed platform mostly less than 5 fathoms in depth, except in the MacDonnell Sound area near Edithburgh where it extends down to ten fathoms. Generally the deepest sections of St. Vincent Gulf tend to hug the presumed "tectonic" coast south of Adelaide, giving it (the Gulf) a somewhat assymetric pattern, despite the fact that most active sedimentary deposition is expected to occur in this eastern aspect.

Adelaide lies at the foot of the Mt. Lofty Ranges towards the east of the concession, and is a city populated by more than half a million people, and its population is increasing rapidly.

Arterial highways radiate north, south and east from the city, and main roads circuit north around St. Vincent Gulf to the foot of Yorke Peninsula. Access on land is everywhere easy. Kangaroo Island in the extreme south is isolated, but like the mainland is well developed agriculturally, and easy to traverse.

Gulf St. Vincent which is of principal interest in the search for oil receives shipping principally in the south, otherwise is quite open for marine exploration operations. Winter winds are from the west and south west, and gulf waters may be choppy and rough during this season, during which time occasional violent storms may occur. For the remainder of the year weather conditions are mostly fair to excellent permitting the widest range of exploration activities.

III REGIONAL GEOMORPHOLOGY

The Adelaide region is an excellent example of a relatively deep graben confronting an ancient fold-mountain range now rejuvenated as a block-mountain system. The mountain range is in itself a zone of ancient Palaeozoic overthrusting to the west, and it is probable that "echoes" of these tendencies persist to the present day and compound with tendencies to isostatic readjustment. In general the deepest gulf waters lie opposite the known zones of more ancient thrusting, and also opposite the higher ranges which would suggest that this tectonic belt is still active.

Beyond the St. Vincent Gulf graben, to the west, Yorke Peninsula appears as a horst block confronted by the intervening relatively depressed Orontes platform. To what extent the present east Yorke Peninsula coast is structural is debatable.

The structures have been extensively described by Benson (1911) Fenner (1931) and Sprigg (1945) and are outlined here only in broader detail.

In their present expression, the Mt. Lofty Ranges are a gently rising "horst" system consisting of a number of differentially elevated fault blocks, which fan out and plunge marginally beneath the local plains, and, or, the sea. The greatest local elevation is at Mt. Lofty near Adelaide which is 2384 feet above sea level. Arcuate concavity of the ranges in plan view is directed westwards towards the gulf-graben system, and the margining western fault blocks diverge, and break off more south-westerly in turn, in their final plunge below sea level or the enveloping plains. These fault blocks each generally encompasses a "bedrock" anticline plunging in the same direction, and are obviously generically related. The fault block surfaces themselves tilt eastward in the direction of the local bedrock syncline. In the past this has been interpreted as a typical pressure "relief" pattern, but may well be one of continuing directed pressure against the graben. Resolution of directed, confining, or over-riding forces would tend to be vertically downwards in the "overridden" blocks, leading to active depression in these graben zones. These would be comparable in effect with the implication of gravity settling in the operation of "relief" tectonics. This new concept implies more dynamism during the Tertiary-Mesozoic than previously claimed, but is more in keeping with newly emerging seismic information in the Adelaide Plains area, and in the South east of South Australia, and also with studies in late Cretaceous - early Tertiary folding in the Great Artesian Basin.

IV REGIONAL GEOLOGY

The Mount Lofty Range "horst" and St. Vincent Gulf graben margin the Westralian Pre-Cambrian Shield. (fig. 1). Upper Proterozoic to Cambrian rocks were originally deposited in a deep meridional trough along this marginal shield trend to thicknesses of 40,000 feet or more comprising the Adelaide geosyncline. Internal unconformities and depositional breaks in sedimentation were generally inconspicuous or absent with the exception of the middle Cambrian episode (see later). Principally the sediments were shallow-water developments characterised by thick platform sands, massive limestones (biohermal in the Cambrian), shales, and major glaciofluvial tillites during Sturtian (Upper Proterozoic) times.

Sedimentation was generally continuous, but slow, in the Adelaide geosyncline, so that sands tend to be well washed, and prolonged periods of nonclastic deposition, represented by massive limestone interludes, were not infrequent (Sprigg 1952). This trend changed abruptly, however, at about Middle Cambrian times, when in the southern or Adelaide region, deforming pressures acted relatively from the south east. These iniated ~~caused~~ local uplift, and erosion of earlier deposits nearer the shield margin, but accelerated deep trough sinking in the zone of Kangaroo Island and the eastern Mt.Lofty Ranges.

Sedimentation accelerated in this more negative zone of sub greywacke-type deposition, strongly evidencing slumping and sub-aqueous sliding and gliding (Sprigg and Campana 1952). To the west, the earlier Upper Proterozoic and Lower Cambrian deposits were being deeply eroded and dumped rapidly eastwards into the trough to thicknesses of 30,000 feet or more. On Kangaroo Island flysch-conglomerates are packed full of Cambrian limestone boulders along with basement rocks typical of central Yorke Peninsula (Sprigg 1955, Daily 1957).

Orogeny followed this dynamic phase of sedimentation in presumed late Cambrian times, with the development of marked thrusting towards the continental block.

Overfolding accompanied imbricate faulting, and generally the principal anticlinorial axis of the folded geosyncline branched off southward-diverging and south-pitching satellite folds in the general Mt. Lofty sector. Further to the north, folding was more typically open and symmetrical ("Jura" type), but en-echelon folding along the margin of the Pre Cambrian Shield indicates a strong degree of resolution of movement "east-block-north" along the shield edge. The Mt. Lofty Ranges is part of the southern, or Olary, sigmoidal fold arc, and is opposed in the north by the Copley fold arc in the Northern Flinders Ranges (Sprigg 1953).

Granitic intrusion accompanied geosynclinal deformation, but was restricted mostly to the outer (eastern and southern) margins of the Mt. Lofty-Kangaroo Island sector of the fold arc. Igneous intrusion is presumed to be late Cambrian, but may also include extensive Devonian activity.

Regional metamorphism appears to have been concentrated along the outer arcuate peripheral fold zone, although localized effects of dynamo-metamorphism persist through the range to be concentrated more particularly in the zone of the western range escarpment. Stress effects in the nature of fold limb attenuation, shearing, and fault imbrication, are particularly marked in the coastal cliff section near Yankalilla, but can be traced north to, and beyond, the Torrens Gorge near Adelaide. Mostly the regional metamorphism in these areas is low. Local phyllite zones are the products of thrust shearing.

The imbricate fault zone is well developed in the en-echelon anticlinorial core zones, and in the more westerly regions of the Ranges to the south of Adelaide. The numerous faults repeat some members of the Adelaide system many times, which fact explains the numerous repetitions of the prominent <u>thick Quartzite</u> north along the front of the Mt. Lofty Ranges opposite Adelaide.

On Yorke Peninsula, "basement" granites and gneisses outcrop widely, while the isolated developments of Upper Proterozoic rocks represent thin sedimentary sections. The Proterozoic outcrop near Pine Point, and more extensively in the extreme north east about the Hummocks; they have been encountered in drilling through the Cambrian at Minlaton. While the sections are thin near the Hummocks they include the Tillite horizon, and some well-developed sandstones. These latter are overlain conformably by thick Cambrian dolomites, fossiliferous limestones and shales. They are mostly quite unaltered except via the normal processes of lithification.

The Proterozoic-Cambrian sediments are only gently deformed across the back of the Peninsula block, but in the approaches to the Kulpara zone of compound faulting become steeply dipping, and suffer thrust dislocation (Horwitz 1959).

Younger sediments are principally Permian and Cainozoic deposits. Permian glacigenes are preserved as infillings in deep fossil valleys lying transverse to the earlier geosynclinal trends. Deeper Tertiary sections occupy the Gulf graben area, and may be underlain by Mesozoic sediments. These ~~latter~~ Tertiaries are extensively block faulted, and vary rapidly in thickness in relation to the relative elevations of respective fault blocks at the time of deposition, and to original "bedrock" topography, over which they ~~grade~~ extend and tongue into continental deposits.

V STRATIGRAPHY

Outcropping post early Pre-Cambrian (metamorphic) rocks in the area are Upper Proterozoic, Cambrian, Permian and Cainozoic in age (figs. 2, 3 and 5). Evidence is accumulating that a thick Mesozoic section may also be present in depth below the Gulf region.

1. Metamorphic "basement" Complexes.

Basement rocks comprise principally granite-gneisses, gneisses and intrusive granites in the Yorke Peninsula area, and gneisses and schists in the core regions of the Mt. Lofty Ranges. Mostly the gneisses and schists are of sedimentary origin; locally high proportions of scapolite, actinolite and epidote indicate calcareous facies for considerable sections, particularly on southern Fleurieu Peninsula of northern Yorke Peninsula.

2. Upper Proterozoic (Adelaide System)

Thicknesses of the local Proterozoic measured by Sprigg (1946) in the type Adelaide area exceed 26,000 feet near Adelaide. Three subdivisions are recognised (Mawson & Sprigg 1950) comprising in ascending order, the Torrensian, Sturtian and Marinoan groups.

The Torrensian is dominated by shallow water (? estuarine) conditions favourable to the deposition of limestones, dolomite and sedimentary magnesite, the latter commonly evidencing prominent intraformational (sedimentary) breccia structure. These calcareous deposits are interbedded within thick shale sections, although associated sandstones may locally exceed 1,000 feet in thickness. Arkosic sandstones, and "ilmenitic" grits, and sandstones are well development overlying the basal "ep-Archaean" unconformity.

The Sturtian group are lithologically quite dissimilar from underlying or overlying beds, being essentially glacial and glaciofluvial accumulations. The earlier beds are alternating sandstones and shales which give way abruptly to massive water-deposited tillites, and glaciofluvial sands and conglomerates. The tillite locally exceeds 1,000 feet in thickness, and gives way above to many thousands of feet of delicately laminated shales that become more calcareous, and finally grade into massive limestones and eventually dolomite.

The highest or Marinoan group is characterised by prominent red bed deposition. The sediments are principally shales, but include flysche-type (macigno) shale-sandstones, also clean white sandstones, and thin limestones, and an occasional arkose.

Above they become somewhat more sandy towards the base of the (conformable) Cambrian.

The respective measured thicknesses of the three groups is

Marinoan	6,950 feet
Sturtian	12,600 "
Torrensian	7,450 "

These sediments thickened rapidly to the northward along the geosynclinal trough to more than 40,000 feet in the central Flinders Ranges. To the south they thin to only a thousand or two feet near Yankalilla, and are comparably thin on to Kangaroo Island.

3. Cambrian (Fig.2)

Sediments of this age are essentially non-metamorphosed. The outcrop in the Mt. Lofty Ranges south of Adelaide, on Yorke Peninsula, and on Kangaroo Island (fig.2). With the exception of the enormous thicknesses of unfossiliferous sub-greywackes of later Cambrian age developed in the more south easterly zones. (Kanmantoo province), regional sedimentation was dominated by thick calcareous and argillaceous deposits except in the Kangaroo Island region (fig.4).

Cambrian sediments are conformable with the immediately proceeding "Pound Sandstone", or its equivalent, in all but the Kanmantoo (eu-geosynclinal) province. The Stokes Bay sandstone of Kangaroo Island may also be of this association.

Cambrian beds not of the Kanmantoo facies are best developed on Yorke Peninsula, outcropping at Kulpara, Ardrossan and Curramulka. The succession is deeply eroded in all outcrop areas, with the result that less than 2,000 feet of Lower Cambrian beds are available for inspection. These are principally limestones, in part dolomitised and porous, but which tend to be more shaley above. The two principal formations recognised by Daily (1957) are essentially limestones. Of these the lower or Kulpara limestone is 1,200 feet in thickness at Kulpara, and overlies the Upper Proterozoic conformably. It is blue, grey, yellow and pinkish white, and is varyingly dolomitised in its upper developments; siliceous sections carry chalcedonic concretions. A few Archaeocythids have been leached by acid from the lower dolomitised sections of this limestone, but mostly fossils are conspicuous only in the higher horizons. These include prolific archaeocyathids, but also brachiopods and pteropods.

The overlying Parara limestone is 450 feet or more in thickness at Kulpara, and, as elsewhere, is typically dark-blue grey, massive or rubbly, and varyingly interbedded with calcareous shaley sections. Trilobites are very prevalent in this zone, which is characterised by Yorkella Australis. Brachiopods and pteropods are also present and occasional archaeocyathids. The uppermost sections of the Parara limestone are distinguished by the trilobite Pararaia tatei.

At Sellicks Hill, South of Adelaide, comparably thick Cambrian limestones are again present, carrying plentiful archaeocyathids in restricted zones. These are described in detail by Abele and McGowran (1959). The basal beds comprise the Wangkonda formation which is a shaley, sandy and carbonate association containing Hyolithes in the more shaley bands. The formation is very variable in facies and thickness along the strike, and contains strong limestone developments in some sections. Its maximum thickness is about 400 feet. This is overlain by the Sellick Hill limestone ranging to 580 feet in measured thickness and considered by Daily (personal communication) to be the equivalent of the Yorkella beds at Ardrossan. It is characteristically an alternation of bands of pale or dark grey crystalline limestone with buff, shaley bands. The next overlying or Fork Tree Limestone contains the principal Archaeocyatha member. The lower massive Archaeocyatha limestone member is remarkably uniform, fine grained and greyish in colour, but also locally brownish and whitish. The maximum measured thickness (at Myponga Beach) is 700 feet, and at Sellicks Hill about 570 feet. The upper mottled limestone member is typically an association of dark blue to almost black angular nodules of limestone surrounded by yellow brown more shaley limestone. Maximum measured thickness (near Carrickalinga Head) is approximately 100 feet.

The uppermost formation which is incompletely exposed in the area, exceeds 1050 feet in observed thickness. These Heatherdale shales are principally an alternation of dark blue friable calcareous shales and thin limestones (250 feet thick) which pass abruptly up into black shales with prominent phosphatic nodules. These shales are highly carbonaceous in some bands, sufficiently to soil the hands.

Madigan (1937) noted the plentiful occurrence of elongate black inclusions of a phosphatic nature in these beds which he concluded were coprolites. Their origin is still in dispute. Madigan also described prolific worm burrowings in these shales near Myponga Beach.

To the south these shales give way to greywackes (Madigan 1927) presumed to suggest increasing geosynclinal activity in the area which is typified by the ensuing Kanmantoo developments (see below).

On Kangaroo Island the presumed (Sprigg 1955) Cambrian basal bed is the Stokes Bay sandstone, and is more than 1,000 feet thick. While it may possibly be immediate pre-Cambrian in age, it is characterised by the marked internal slumping (Sprigg 1954-55) which is also typical of overlying fossiliferous beds of undoubted Cambrian age. It is followed by the Kangaroo Island group (Daily 1957) about 4,500 feet in thickness. This group comprises an unnamed basal sandstone and shale succession 450 feet in thickness, and characterised by chocolate shales, which are succeeded by the White Point Conglomerate, the Emu Bay Shale and the Boxing Bay Formation respectively. These have been described in detail by Daily (1957).

The White Point Conglomerate, approximately 1,250 feet in thickness, is a succession of conglomerate beds in which boulders and pebbles of blue, grey and pink limestones and dolomites are conspicuous, and may be present to the almost total exclusion of other rock types. These limestone pebbles contain many well preserved archaeocyathids. Other rock types include red quartzite, quartz, and igneous and metamorhphic rocks. Certain black biotite gneisses and very red granitic rocks are remarkably like those outcropping at Port Victoria on Yorke Peninsula to the north. Shale bands in this formation contain unidentified trilobites.

The Emu Bay shale is a 350 foot sequence of brown and purplish micaceous shale, and flagstones, with minor interbedded reddish sandstones and occasional thin conglomerates. Fossil horizons contain plentiful remains of the trilobites Redlichia and Lusatiops, and also pteropods.

The uppermost Boxing Bay Formation has so far proven unfossiliferous. It exceeds 2,500 feet in thickness of red coloured sandstones and interbedded shales, flagstones and conglomerates. As with lower sands, cross-bedding, and slump structure is well developed.

The Kangaroo Island group spans the Lower-Middle Cambrian boundary, the division being presumed (Daily 1957) to be within the Boxing Bay or Emu Bay shale formations. There is little doubt that the conglomerate facies represents a stripping of earlier Cambrian limestones down to older pre-Cambrian bedrock, somewhere to the north, in the direction of Yorke Peninsula.

In the eastern Mt. Lofty Ranges and on southern Kangaroo Island a thick monotonous sedimentary sequence occurs along the outer (eastern and southern) margin of the Mt.Lofty fold arc that is notably different from the foregoing. These comprise the Kanmantoo group. They are varyingly metamorphosed and igneous-intruded in most areas, and form part of a rapidly deposited section that accompanied a more dynamic and localised phase in the geosynclinal evolution. No fossils have been found in this succession, but correlation across the regional anticline is inferred from structural evidence (Sprigg and Campana 1953, Campana and Horwitz 1956), and from facies analogies.

Madigan (1928) had favoured correlation of the Rapid Bay marbles with the *Archaeocytha* beds of Sellicks Hill and Campanas mapping finally demonstrated this correlation beyond doubt. The work of Sprigg and Campana also permitted correlation also with the Macclesfield marble across the Range. Madigan (1937) had previously located the "coprolitic" shales near Cape Jervois, and these are now reliably correlated with those at Sellicks Hill, and which it is understood have recently been traced also extensively to the north along the eastern flanks of the Mt. Lofty Ranges by Department of Mines geologists.

In general the Kanmantoo group above the marble and coprolitic horizons comprise a monotonous alternation of greywackes, phyllite, and impure, quartzite relieved by little other than the Nairne pyritic quartzites.

4. Permian

Glacial and periglacial deposits characterise sediments of this age. True tills, and glaciofluvial deposits are widespread. Excellent examples of varves, and fluted, groved and striated bedrock occur in many areas on Fleurieu Peninsula. Recently marine foraminifera were discovered in drilling on Yorke Peninsula.

The Permian landscape was in no way comparable with that of today. The Mt. Lofty Ranges may well have been re-juvenated during the Middle-Devonian times in response to orogenies in eastern Australia. In support of this there is growing evidence that certain granites of the eastern Mt. Lofty Ranges may be of late Devonian age. (c.f. Grampians intrusions of Western Victoria). Presumably the Mt. Lofty Ranges had prominent topog-raphic extensions into Victoria along the Padthaway horst via Dergholm, and were themselves high mountain ranges.

Glaciers emanating from the direction of Tasmania advanced along deep mountain valleys into south eastern South Australia, thence via the general Coorong zone, across southern Fleurieu Peninsula, and onto and across Kangaroo Island and southern Yorke Peninsula. All that now remains are the deeper valley infillings that have escaped later erosion. Scattered outliers also occur many hundreds of miles to the north (NNW) at Lake Phillipson and about the Peake and Dennison Ranges, and eventially into Northern Territory and Western Queensland. Small outliers also occur north of St. Vincent Gulf (R.C. Horwitz 1959). It is not impossible that across Fleurieu and Yorke Peninsulas ~~region~~ these valleys were fjordic and marine. Dr. Ludbrook has recorded Permian arenaceous foraminifera from blue and grey sandy claystones about 100 feet above the basal unconformity in the Stansbury bore (Mines Department, 1956) immediately above the Cambrian contact. The association attests to marine-deltaic conditions which would be in keeping with a fjordic environment.

Permian sediments in these areas are principally boulder tills in the low lying situations, carrying plentiful erratics that have travelled many tens and perhaps a hundred or more miles. Erratics weighing several tons are not uncommon. Interbedded valley infilling are clays, sands and gravels, with occasional water-deposited erratics. True varves occur widely.

The Permian valley system in the present area trends W.N.W.-E.S.E. (fig.2). It is also noticeable that smaller valleys have trends more consistent with the longitudinal valley systems of the modern ranges suggesting early topographic controls via tectonic structure and ~~any~~ differential (stratal) erosion. Movement of the ice across these smaller valleys is scarcely disturbed in the general W.N.W. progress.

5. <u>Mesozoic</u>

No idisputable sedimentary deposits of this age have located within the Adelaide region. In spite of this lack of surface evidence, there is reason to expect the presence of such sediments beneath the gulf region. St. Vincent Gulf is one of prolonged grabening, and a deep section of sediments has in fact recently been indicated seismically under the immediate metropolitan beaches west of Adelaide. Sediments with subhorizontal reflectors down to 6,000 feet or more have been recorded. Vertical velocities of 8,000 to 9,000 feet per second at these depths accord with Mesozoic sediments. Moreover a mass of evidence now accumulating points conclusively to the fact that the late Mesozoic era in Australia was one of strong tectonic activity (see later section).

6. Tertiary

At the onset of Tertiary times the Mt. Lofty Ranges were relatively subdued, probably elevated little more than 1,000 feet differentially in relation to sea level. Pre-Tertiary peneplanation, however was probably not as complete as most authors in the past, including the writer, have suggested. Topographic relief was sufficient to permit continued erosion in the range region, and facilitate irregular sedimentary deposition over marginal down-faulted blocks to relative depths greater than 2000 feet as shown by the Croydon Bore (see figs. 3 & 5). Depositis were probably much thicker beneath Gulf St. Vincent. Moreover, the surface on which the early Tertiary continental deposits were laid down was itself quite irregular, in keeping with the growing indication of considerable topographic relief in the area prior to the Tertiary. Tertiary geology has been well summarised by Glaessner and Wade in the Geology of South Australia (1958) and by Glaessner (1953), Reynolds (1953) and others.

(a) Continental Phase

Early Tertiary sediments are typically sands, clays and gravels with occasional lignites that are presumed to be dominantly lacustrine and fluviatile in origin. These beds are best known at the head of the various plunging tectonic valleys margining the main uplift of the Mt. Lofty Ranges (fig.5). The sediments outcrop extensively in the Hope Valley area north east of Adelaide, about Happy Valley (Mazlin sands) and from Bakers Gully to Yankalilla. Other exposures occur here about the head of the Gulf, and in the Barossa valley. These are all situations where fault blocks are emerging from below extensive plains areas, and continuing into bedrock outcrop. Sedimentary Thicknesses in these more "positive" situations are mostly 250 feet or less, as the sediments are generally pinching-out in gentle overlap, and/or have ~~also~~ been extensively eroded.

Beneath the Adelaide plains these sediments are considerably thicker in the seaward, more negative graben zones. Only two bores have entered these beds, namely at Croydon and Oaklands Park, and only the former penetrated the full section to bedrock (by 2,242 feet). Thicknesses indicated in the bores were 480 feet and 680 (+) feet respectively. The Oaklands bore overlies the plunging Para fault block which is relatively less depressed than the Croydon Block to the north-west, which would suggest that thicknesses of the early Tertiary formations in more westerly extensions of the Croydon block may considerably exceed 1,000 feet in thickness. At Kentown (immediately east of the city of Adelaide limits) and overlying the Para blocks, the continental beds as indicated in drilling have thinned to 142 feet, and less, and have been subsequently deeply eroded. At Hope Valley, to the north, thicknesses of 230 feet have been encountered in drilling for brown coal.

In age these continental beds are presumed to be pre-Oligocene but it is probable that the continental - marine boundary is strongly transgressive, with a prolonging of continental conditions only in the shallower, or up-dip extensions of the blocks. Conversely it can be argued that these beds may grade extensively or completely into marine environments out under the modern gulf. The prospect of a thick Eocene marine section out under the Gulf cannot be disregarded.

(b) Marine Phases

The sea had widespread access to the Gulf areas certainly during the late Eocene to Pliocene times. (1) Early Tertiary: During earlier Eocene times, however, if the sea had access to the Gulf, it was restricted to the topographically more depressed areas beyond the present coastlines. Upper Eocene seas undoubtedly overlapped into the lower zones of the tectonic valley system bordering the ranges, and by early Oligocene times had attained almost their maximum spread. ~~The glauconite basal~~ In the Willunga and Noarlunga sub-"basins" the basal beds, in part glauconitic and fossiliferous, ~~were~~ were principally sands (South Maslin Sands). These are overlain by several feet of glauconite shelly limestones (Tortachilla Limestone) which contains a rich molluscan, and foraminiferal fauna. They are overlain by transitional marls grading up into the fine grained Blanche Point marls (with Hantkenina foraminferal fauna). The latter marls contain layers of silica with abundant siliceous sponge spicules, and molluscan fossils with Turritella aldingae as the dominant gastropod.

On Kangaroo Island at Kingscote the facies is more calcareous and typically bryozoal, but the fossils are like those of the Tortachilla limestones nearer Adelaide. The beds here rest on Permian glacigenes.

On Yorke Peninsula the Eocene marine glauconite sands rest directly on Permian and Cambrian rocks. They are overlain by the Muloowurtie clay with lenses of shelley limestone. At Rocky Point, and elsewhere near Pine Point, these are overlain in turn by brackish water clays with foraminifera, and plant-bearing silicified quartzites. Turritella beds occur at still higher levels and run out in overlap onto more elevated ground. At Clinton and Inkerman the Turritella beds overlie Eocene brown coal measures. Comparable beds known from beneath the Adelaide Plains in water bores are the most widespread of all marine deposits in this area.

The Blanch Point Marls are followed by a short erosional and continental phase, occupied by the Chinaman's Gully beds in the Norlunga and Willunga sub basins. The sediments are principally red, green, brown and yellow clays with interbedded sands which are only a few feet in thickness. They are considered to be Oligocene in age (Reynolds 1953).

The Pt. Willunga beds overlie the Chinaman's Gully beds, and are characterised by bryozoal limestones, calcarenites and clays with pronounced current bedding near the base. They occur widely beneath the Adelaide plains, principally overlying the Croydon block, but also extend onto the lower elevations of the Para-Eden-Moana and Clarendon Ochre Cove fault blocks (fig.5). They are steeply dragged against the re-opened Willunga fault at Sellicks beach, and actually slightly overturned. In Myponga Valley they overlie Permian tillite where three lignite beds are known also to be intercalated with these bryozoal limestones.

In the Kingscote-Cygnet "sub basin" in Kangaroo Island, bryozoal limestones of this association overlie pre-Tertiary clays. They are also present at Cape Willoughby, and on the Cygnet Scarp.

On Yorke Peninsula some of these limestones, especially near Kulpara, are rich in Lithothamnion. Shore-line deposits of cross-bedded sands with gravels, and a few marine deposits and silicified wood bearing Toredo borings, occur high on the hill slopes near Gawler.

(2) Late Tertiary: A gentle, but definite stratigraphic and structural and stratigraphic break preceded the next younger marine formation in the Adelaide to Aldinga zone. Beneath the Adelaide Plains, shelley sands of Pliocene age (Dry creek sands) form the principal aquifer below about 300 feet (figs. 5, 6 and 7). These are normally about 200 to a maximum of about 350 feet thick west of the Para fault block, but beneath Adelaide, overlying this block they are reduced to only about 70 feet. The sands wedge out rapidly to the north, and do not extend much north of the River Torrens on the Para block, or beyond about the Gawler River on the Croydon block.

Outcropping Pliocene strata consist principally of white and yellow sands, and hard fossiliferous arenaceous limestones. Oysters (Ostrea arenicola) and the large foraminifera (Marginopora vertebralis may be abundant, along with Lithothamnion and many other forms. Commonly the uppermost horizons appear to have been travertinised penecontemporaneously, and certain associated fine-medium sands may be dune accumulations.

Ludbrook (1954-58) has shown that the fauna of the Dry Creek sands is essentially tropical-marine, that have been deposited in a shallow water embayment. The absence of current activity is supported by the complete lack of bryozoa which only thrive in circulating waters. The littoral environment is present east of the Para fault scarp in massive shell (?) berms, and at Hallet Cove the northern boundary of the City of Adelaide and elsewhere, as conglomeratic sands.

Pliocene strata outcrop at intervals about eastern St. Vincent Gulf at elevations varying from less than 100 feet above sea level to more than 250 feet. They also extend to 450 feet or more below sea level beneath the Adelaide Plains, indicating extensive tectonic movements since deposition. Some of these elevational differences are due to depression infilling such as at Hallet Cove, for example, where sediments of this age extend from 100 feet to 240 feet or more above sea level in overlap onto pre-Cambrian rock. The beds bear slight angular unconformity (2 to 3 degrees) with underlying Tertiary limestones, and are well exposed in the cliffs from Aldinga to Schnapper Point, and again near Sellicks Beach. Inland a line of outcrops extending from near Hallett Cove, and along the ridge west of Clapham across onto the Clarendon-ochre cove block are preserved which appear to mark an old coastal dune. Inland from this the deposits are continental. Outcrops of Pliocene marine sediments also occur in the River Light near Mallala, and extensively around Edithburgh on Yorke Peninsula.

(c) <u>Late Cainozoic continental deposits</u>

Inland from the Pliocene coast (fig.5) rejuvenated stream activity at this time led to extensive erosional stripping of older deposits, and an advanced stage was reached in establishing new erosional equilibria. The Willunga and Pt. Noarlunga tectonic valleys became choked with erosional products from higher levels, and a new base-level of erosion was established which represents the second epidode of Fenner and Johnstone's "double peneplanation" hypothesis (Fenner 1931).

With the more complete retreat of the seas at the conclusion of Pliocene times, terrestrial deposition returned in all the equivalent land areas of today. Thick alluvial clays were laid down widely, and attained 200 to 300 feet maximum thickness in the Adelaide Plains. Late in Pleistocene times a rejuvenation of "block" uplift of the Mt. Lofty Ranges initiated the formation of gravel outwash fans which subsequently coalesced in the near escarpment zones, but gravelly creek lines from them extend fully across the plains to the sea. By continuing block movements, gravel creek deposits have been stranded high on the eastern range escarpment foothills in several situations, such as near the mouth of the Brown Hill Creek (RL. c. 525 feet or approx. ± 100 ft. above present valley level RL, approx 400 ft), and on the hill slopes (observable in a railway cutting) north of Hallet Cove. (RL. 1000ft approx.)

More recently the sea has had limited access to the lower Adelaide Plains area on at least two occasions to be followed by extensive retreats. During one of these recessions the sea floor was exposed for many miles beyond the present coastal limits; travertinised crust on the buried shell beds have been probed miles to sea particularly on the western side of the Gulf opposite Pt. Vincent.

VI GEOPHYSICAL INFORMATION

A number of geophysical surveys have been carried out in the vicinity of Gulf St. Vincent, principally by the Geophysical section of the South Australian Mines Department, and more recently also by Geosurveys (Australia) Limited.

Published reports are available concerning earlier gravity surveys by C. Kerr-Grant of the Mines Department (Kerr-Grant 1952 and Miles 1952). These cover the head of the Gulf, an d the immediate Adelaide Metropolitan area (fig.8). The surveys have since been tied together in reconnaissance detail, so that there is coverage of the whole of the Adelaide Plains area (yet unpublished).

Seismic surveys have also been undertaken in the area by the Mines Department along several selected E-W traverses at intervals north from about the level of Salisbury. Geoseismic (Australia) Ltd. has since completed a traverse along the Adelaide metropolitan beaches (fig.7) and an incomplete cross traverse near Dry Creek.

1. Gravity Data (fig.8).

Surveys carried out at the head of St. Vincent Gulf (Kerr-Grant 1951) were successful in delineating a general pattern of block faulting that was interpreted to fit the known and predicted structure of the Inkerman-Balaklava and Whitwarta coal field areas. Two faults that were previously inferred in geological field mapping were revealed as zones of steeper gravity gradients. These are the Mt. Templeton and Owen faults respectively. The Whitwarta coal field is preserved in the down thrown area between the two, and the Inkerman field lies on the back of the Mt. Templeton block. The interpreted fault pattern by Kerr Grant in the Inkerman area is possibly unnecessarily complex. The gravity pattern is complicated by a buried bedrock ridge in Upper Proterozoic A.B.C. sandstone that trends south from Mt. Templeton and which was presumably that encountered in Balaklava No.2 coal bore. It would seem reasonable to place an east-down fault margining this buried ridge on its east, and as the southward and plunging extension of the Mt. Templeton fault.

Subsequent gravity surveys (Mines Department; unpublished) have provided information making possible the projection of the Mt. Templeton fault in a general S.S.E. to south direction to near Wild Horse Plains before swinging abruptly W.S.W. out under the Gulf. Its presumed course beyond the coast is marked reasonably accurately by bottom topography on Admiralty hydrographic charts. The fault eventually links into the more or less north-south Orontes Bank (submarine) fault (Sprigg 1953).

The Owen fault plunges beneath the plains cover opposite the township of Owen, but is readily traced by the Bouger gravity contours to beyond Lewiston, at which situation it is trending more or less due south and arching slightly as if to link off with the tectonic coast line extending south from Marino Rocks.

In the Adelaide region, (Miles 1951) the gravity surveys have similarly delineated the principal structural features quite successfully. The major faults are again loci of steep gravity gradients, enabling the tracing of the faults in their plunge beneath alluvial cover. The major Bouger gravity anomaly extending west of the Para fault escarpment is of the order of 100 milligals and corresponds with the well known zone of deep Tertiary sedimentation, and a fault down throw to more than 2,500 feet opposite the city of Adelaide. The surveys have not been extended onto Le Fevre Peninsula under which a deeper section has been previously predicted by the writer to account for changes in coastal configuration at Point Malcolm. The course of the Para fault in its plunge beneath the plains has been interpreted from these data and from water bore information, and is incorporated on the Adelaide 1 mile geological sheet. (Sprigg Whittle and Campana 1951). The fault bifurcates as it swings more south-westerly and meets the coastal zone in splinter formation. Only the southern leg has been sufficiently active in recent times to noticeably affect coastal configuration. It meets the coast beneath Somerton, and presumably controls the southern limit of the local sub-fossil (West Beach) mangrove embayment.

2. Seismic evidence (fig.9)

Seismic E-W cross sections have been completed by the Mines Department at intervals north of Adelaide through Waterloo corner, Mallala and Balaklava. These have generally verified and amplified the gravity pictures. Final interpretations are not yet available.

Traverses recently completed by Geoseismic (Australia) Ltd. along the metropolitan beach have revealed an unexpectedly deep potential sedimentary section (Fig.9). A particularly strong and continuous group of reflections at a maximum of about 563 milliseconds (under West Beach) are interpreted to be representative of the lower marine Tertiary. An indicated velocity of 7,000 feet per second to the depth this would place the base of the marine section at about 2,000 feet which is in keeping with the available geological information.

A thickness of Lower Tertiary continental sands greater than the 680 (+) feet encountered in the Oaklands bore (which is situated over the more elevated Para block) is expected in this more negative zone, and should be of the order of 1,000 (+) feet. A discontinuous reflection at about 800 milliseconds would appear to fit this, putting the inferred base of the Continental Tertiary section at about 3,200 feet. The next major reflection event is at 1,100 milliseconds, and is an alternate "pick" for the base of the Tertiary. On the basis, and allowing 8,000 feet per second vertical velocity for this section, the break comes at about 4,400 feet. It may however, represent an older Mesozoic section.

The next deeper persistent reflection event lies about 1,530 microseconds. The vertical velocity for this deeper interval is 9,000 feet per second representing a section of about 2,500 feet. At its deepest development this event would lie at approximately 6,900 feet. Several reflections lie beyond this limit, and some nearest the Para fault extend to 1,676 microseconds which is estimated as an additional 650 feet taking the recorded "maximum" thickness to about 7,500 feet in the zone. There is, however, no certain indication that bedrock has been attained at this depth.

Seismologist Mr. R. Dennison has directed considerable attention to detecting possible multiple reflections that might account for the considerable sedimentary thickness that have been indicated. However, the detailed time measurements and velocity increase with depth, and other standard check proceeding do not accord with these possibilities.

The Seismic section by (Dennison 1960 fig.9) indicates that the two Para splinter faults both dislocate the marine Tertiary section and have a combined throw of about 350 feet in this plane. The base of the presumed Marine Tertiary is shown to be one of gentle unconformity, and a stronger unconformity accords with the next deeper major event at about 4,100 feet. (Maximum figure). To what extent the beds to this latter depth are all Tertiary is debatable, but more probably the section from about 3,000 feet to 4,100 may be Upper Cretaceous (c.f. Winton equivalents), in view of comparable findings at Pt. Campbell along the south coast in western Victoria. Below these latter in Victoria, a several degree unconformity separates the underlying (?) lower Cretaceous section and has possible equivalence in the present area.

VII <u>STRUCTURAL GEOLOGY</u>

The broad structural setting of the Mt. Lofty Ranges, St. Vincent Gulf basin as a zone of intense thrusting and overturning in early Palaeozoic times is well established by detailed mapping. (figs. 1, 8 and 11). The major thrust zones (with associated imbricate faults) impinge on the St. Vincent Gulf graben principally from about Titree Gully (N.E. of Adelaide) around to Cape Cassini and Western River on the north coast of Kangaroo Island. The zone is arcuate, and has developed as a result being caught between the resistant Westralian shield, and movements in the developing Kanmantoo (eu-) geosyncline of epi-Lower Cambrian and later times. (Fig.1). Although the principal thrust zone is believed to be aligned about the general south eastern coast of the Gulf, thrusting has extended also onto Northern Yorke Peninsula from Rocky Point to Kulpara (Horwitz 1959).

More extreme thrusting appears to have been concentrated in a zone from about Echunga to Rapid Bay from where the zone passes under the sea. It is directly opposite this zone that the modern St. Vincent Gulf has its deepest expression (21 fathoms), and where the ten fathom contour hugs the coastline most closely (Fig.8).

Little is known of the structural evolution of the area during Middle and Late Palaeozoic times. Possible intrusion of Devonian granites about the eastern borders of the Kanmantoo zone suggest a degree of orogeny during that period, and that the area may have been mountainous. This latter possibility is supported by the existence of deep transverse (E.S.E.-W.N.W.) relict valleys through the ancient Mt. Lofty Ranges in Permian times that were sufficiently deep to funnel the great continental glaciers originating in the direction of Tasmania. Even allowing for subsequent prolonged, and deep, Mesozoic early Tertiary peneplanation, and base levelling, these fossil valleys still exceed

2,000 feet in relative depth. They remain largely choked with glacial debris to the local plateau and pre-Tertiary peneplain levels, (e.g. Hindmarsh Valley). Elsewhere in outcrop these Permian sediments appear to lie subhorizontally and have suffered no obvious diastrophism. (Note. This would restrict any presumed late Palaeozoic orogeny to pre-Permian times - probably Devonian).

No Mesozoic sediments have been located in outcrop or in drilling in the area, but they are suspected at depth beneath the gulf graben.

1. (?) Cretaceous Structure.

The metropolitan beach seismic traverse (see earlier section) and geological reasoning is inclining strongly to an appreciation that the St. Vincent Gulf graben may have been actively sinking also during late Mesozoic times.

At this time geosynclinal activity bordering the east Australian coast in the Brisbane-Maryborough region directed pressures against the continent from the east and north-east. Inland, the Great Artesian Basin was being gently deformed during late Cretaceous and early Tertiary times, and had developed en-echelon fold patterns evidencing principal "south east block - south west" fault movements at depth (Sprigg, 1959).

Whether these movements were transmitted through to the south coast is debatable, but seismic evidence now indicates that pronounced late Mesozoic thrusting was taking place in the deeper zones of the Gambier Sunklands (Kanawinka fault) in sediments that appear to correlate with the Cretaceous of Port Campbell, and elsewhere in Western Victoria. In these areas, graben development, and extension, was undoubtedly progressing actively. Deep marine troughs had formed in the forefront of the Kanawinka "thrust", and comparable downwarping beneath Pt. Campbell harboured deposition of thick sections of marine black shales. Presumably such forces would also be directed against, and channelled into, other tectonic belts in the general south coast region of this portion of the continent, such as the Gulf region near Adelaide.

The recently completed seismic traverse along the Adelaide beaches indicated an "unexpectedly" deep potential sedimentary section beneath the Tertiary. The basal surface to the marine Tertiary (at about 2,000 feet) in this zone is shown to be one of unconformity; faulting (interpreted) within the underlying sediments generally do not appear to carry through except in the Para fault zone. The underlying early Tertiary and presumed Mesozoic sediments lie sub-horizontally, and are reasonably continuously bedded as far as reflections are concerned. Mr. Dennison's interpreted seismic section reveals that progressively deeper sediments were subjected to successively greater tectonic disturbance. This would be in accord with the geological structural history of south eastern Australia in late Cretaceous times. The epierogenic movements that allowed the seas entry to the Central-eastern Australian continent late in Blythesdale (Early Cretaceous) times, and which excluded the again at the end of the Tambo interval, possibly correlate broadly with the episodic movements in these Gulf areas to be inferred from the new seismic evidence. A geological interpretation of the seismic section (fig.9) is provided in this light, having in mind that the reported marine Cretaceous at Port Campbell in southwestern Victoria, (above the 5-10 degree unconformity at about 5,700 feet) is probably Winton in age, and that the underlying (?) Cretaceous may be Rolling Downs equivalents.

Structurally these interpretations require that a deep fault must cross the metropolitan coast line obliquely immediately south of Glenelg. It would link up with the "tectonic" coast line extending south from Marino, and presumably to the north it would continue with the Owens fault, last evidenced by gravity beneath about Lewiston. Until more is known of this fault it will be referred to herein as the "Coastal fault" in view of its probably considerable influence on local coastal configuration for much of post Palaeozoic geological time. In its greater (arcuate) development, the fault is presumably also coextensive with the Cygnet River fault (and escarpment) on Kangaroo Island, and in which case it would aggregate more than 200 miles in length. This "coastal fault" is undoubtedly a major, and geologically ancient, structural feature. On Kangaroo Island, in its present day expression, it separates strongly folded and metamorphosed Proterozoic and Cambrian strata from flat-lying and unaltered Cambrian which occur on the northern (inner) side of this arcuate trend. The latter flat-lying beds of Cape Cassini and elsewhere along the north coast of the island, however, are strongly reversed faulted (imbricate fault zones) and recall comparable thrust tendencies on northern Yorke Peninsula.

Relatively deep water accompanies the general down thrown side of this projected trend skirting Fleurieu Peninsula towards Adelaide. On Kangaroo Island the Kingscote "platform" occupies this down thrown situation, and at Cape Cassini a further down-throw is evident as a narrow splinter remaining slightly above sea level. Both the north coast of Kangaroo Island and the west coast of Fleurieu Peninsula are typically "tectonic" coasts. They represent a major structural and topographic breaks, complete with truncated valleys and plunging sea floor contours. Opposite Port Noarlunga, an anachronous narrow and resistant reef in Tertiary limestones extending almost N-S for more than a mile, a short distance out to sea may be related in some way to this fault zone. ? Pos Q. related

2. <u>Tertiary Structure</u>.

The structural pattern evident in block faulting that has been active during Tertiary times, is summarised in figs. 10 and 12. The continuing and differential movement of these blocks has been referred to in detail in previous sections, and has been extensively described also by Fenner (1931), Sprigg (1952) and others. The pattern follows earlier Palaeozoic fold trends in the southern Mt. Lofty Ranges, and broadly the block faults of the eastern Ranges, escarpment display an en echelon relation. They diverge southwards from the zone of the principal anticlincorial fold axis, and in turn swing more southwesterly into the zone of the "coastal fault".

At the onset of Tertiary time, differences in elevation of the various fault blocks margining the Mt. Lofty Ranges were undoubtedly considerable. Five to six hundred feet or more of early Tertiary continental beds blanketted the more negative portions of the down-tilted fault blocks near Adelaide, but in the ranges region, bedrock outcropped extensively. The principal tectonic valleys formed by relative backward tilting of the individual range frontal fault blocks were then in evidence, and when the early Tertiary seas first flooded into these areas, it was via and over these low-lying zones. At no time did the Tertiary sea completely inundate the ancient Mt. Lofty Ranges, although the oligocene - Miocene seas flooded into valley floors that are now elevated many hundreds of feet above sea level, as at Hindmarsh Tiers, and Myponga (C.720 feet). On the other hand marine Tertiary deposits now extend to almost 2,000 feet below sea level beneath the Adelaide Plains coast, and probably considerably deeper beneath the Gulf. There is no doubt that all the major block faults now active were active during Tertiary and earlier times. The deeper graben blocks were probably "negative" to the extent of being below sea level during the whole of Tertiary time, whereas, those involving the central ridge of the Ranges were probably never completely inundated. Intermediate blocks have undoubtedly experienced varying histories of marine advance and retreat as the differential movements have progressed. These trends can be recognised in the accompanying text-figure (5.).

Maximum "Tertiary" block faulting culminated in late Pliocene times, but not always were the Tertiary beds ruptured. At Sellicks Beach, for example, Dr. Glaessner considers that Tertiary limestones were only monoclinally dragged even though they stand on end, and are locally overturned (Howchin 1911). Whether this is the case the faults were clearly active within Cambrian-Proterozoic "bedrock", in all areas. The extent to which the Tertiary beds were dragged or dislocated can only be resolved in most areas by detailed drilling. The presence or absence of actual faulting, however, is of importance in oil exploration in considering the development of traps.

At Sellicks Beach rather characteristic slump-folding in the Tertiary beds has occurred adjacent to the main zone of dragging. A small anticline perhaps 100 yards across, and with about 50 feet amplitude has developed a short distance seaward.

Across the broad back of the principal fault blocks, sediments remain generally subhorizontal. There is an element of tilting eastwards or southwards towards the next higher block.

VIII <u>OIL AND GAS POSSIBILITIES</u>

Thick marine Cambrian sections occurring about the margins, and presumably more extensively beneath, St. Vincent Gulf offer considerable promise in the search for oil and gas. The possibility of a much deeper marine Tertiary section beneath the Gulf also has considerable appeal, but the recent indication by seismic means that a possible considerable additional thickness of Cretaceous sediments may also be present in this region has excited and considerably increased speculation as to the area's potential. This latter discovery has necessitated a complete re-assessment of the regional geology of the area, as one of continuing deep and dominantly marine sedimentation throughout much of Palaeozoic and later geological time.

Prior to 1956 this area had not been considered very seriously in the search for oil. In 1956, however, when traces of oil (ozokerites) were discovered by Santos Limited in Cambrian limestones 200 miles north along the western border of ranges at Wilkatana, interest was directed to such potential also in this southern area where thick Cambrian sections were known to be similarly well-developed. Traces of oil were subsequently reported by the Mines Department in drilling on Yorke Peninsula (Minlaton) but for a number of reasons the prospects did not appear to be particularly attractive.

With the establishment of a potential 6,500 (+) foot section of presumed Mesozoic - Tertiary sediments beyond the principal "graben" (coastal) fault west of Adelaide, many new and attractive possibilities have presented themselves. With the discovery comes the need for a reappraisal of the history of the graben since earlier Cambrian times. The St. Vincent Gulf zone now appears to have been a persistantly negative zone, favouring extensive marine deposition throughout much of geological time. Along with this, a tendency to being extensively landlocked, or separated from the open ocean by shoals ~~has~~ may have from time to time will have restricted marine circulation, producing the environment of the barred embayment. This is of particular interest in oil exploration.

A deep sedimentary section is now recognised for the area much of which is marine and has been deposited under reducing conditions. For this reason, and in view of the complex history of the graben, and its relatively unstable environment, a suitable association of fine-grained source rocks, and of coarser grained reservoir rock, may confidently be predicted. Structurally the region has experienced many episodes of deformation to cause extensive folding, faulting and warping that will have developed a wide variety of structural and stratigraphic traps suitable for the accumulation of oil and gas.

1. Potential Source Beds

Cambrian (?) Cretaceous and middle Tertiary sediments offer the most promising potential for marine source beds in the area. The graben setting, with its long and complicated history, is a promising environment for thick marine accumulations much of which would have been deposited under reducing conditions (restricted circulation) and presumably would be particularly favourable to the generation of hydrocarbons.

Marine black shales, marls and limestones have been recorded in several situations in the local sedimentary column, in spite of the virtual absenne of deep drilling in the area.

Fossiliferous marine Cambrian limestones and shaley limestones on Yorke Peninsula have produced "showings" of oil and odours of petroliferous gas. The beds are dark grey to black in colour, and presumably include potential source material. Comparable limestones outcropping to the south of Adelaide, at Sellicks Hill, are blue-grey to dark grey in colour, and are overlain by thick marine black shales. These shales have a relatively high organic content and they bleach deeply on exposure.

Cambrian sections are nowhere complete in outcrop about the Gulf (which they practically surround), but despite this, thicknesses aggregating 7,500 feet or more have been measured, and the sequence may be much more extensive. Presumably the beds are preserved most extensively within the down-folded and faulted gulf-graben, and are not available for surface inspection.

Foraminifera have been located in buried Permian sections of Yorke Peninsula (Ludbrook 1957), but there is still no suggestion that a suitable marine environment was present at that time for development of source-beds.

The marine Tertiary section occurring about the Gulf is well known for its dark grey to almost black, and normally richly fossiliferous (Blanche Point) marls. (Usually bleached greyish or whitish in outcrop). Glaessner has referred (personal communication) to potential source bed material recovered from about this horizon in a Government water bore put down along the South Road west of Adelaide during the mid-1940s.

Broadly the Tertiary marine section is considered to lie too shallowly beneath the land areas to excite interest as potential source beds (maximum depth about 2,000 feet in the beach zone). However, as these beds thicken seaward, and deepen in the central graben zone, more suitable conditions may well be attained. "Showings" of oil have been alleged from only one well hole in the Adelaide plains, but this is not surprising in view of the virtual absence of holes beyond several hundred feet deep in the whole basin area. The single "showing" was recorded from Hallions bore on Section Q., Hd. of Pt. Gawler about 30 miles north-north-west of Adelaide (Appendix A). The showings were allegedly encountered at 504½ and 603 feet respectively, along with an artesian flow of 13½ ounce brine. The association with strong brine is significant, particularly as it occurred within dark-coloured fossiliferous marine marls.

Generally the water bores in the lower Adelaide Plains have explored only the highly permeable Pliocene-marine sands, and the Oligo-Miocene bryozoal limestones in their shallower developments. These sections have been extensively flooded by fresh water drive from intake zones along the elevated foothills zones associated with the principal faults ~~zones~~. Any oil entering them would be expected to be flushed northward or westward. These sediments are ~~capped~~ sealed by several hundred feet of Pleistocene clays.

2. <u>Reservoir Storage Potential</u>

Within the lower Cambrian, limestones are considered to be of principal interest as potential reservoir rock, whereas in younger sediments (Permian ?Cretaceous and Tertiary) sands offer more promising potential.

Limestone porosity in the Lower Cambrian results from dolomitization and weathering. The latter will occur adjacent to surfaces of erosional unconformity. Both types are difficult to predict, and are likely to offer limited potential.

The base of the Cambrian on Kangaroo Island presumably extends beneath the Gulf as a surface of erosional unconformity within the Cambrian. Conglomerates and sands at this general level would undoubtedly offer considerable porosity and be of interest.

Permian sands ~~generally probably~~ do not greatly appeal as potential reservoir media, even though they overlie thick Cambrian sections on southern Yorke Peninsula. Generally the glacigene sands are noticeably lenticular, discontinuous and clayey; thicknesses of boulder clay in more basal sections would act rather as barriers to restrict migration from underlying strata, presenting more in the nature of seals or capping to underlying source or reservoir beds.

The Cretaceous section, if present in the areas as now predicted, is likely to harbour sand sections along with shale sections. A sand-shale association may well be favoured in the more dynamic graben zone at this time.

In the Tertiary column, porous sands are well-developed at several levels. These tend to be concentrated in the lower ~~basal~~ sections, and also in the marginal zones transitional from the marine into continental facies in the landward sections. The Pliocene beds lying with slight unconformity on the Miocene marine section are essentially sandy, and highly porous and permeable. As with the basal Tertiary sands and gravels, these beds are mostly well sealed by overlying clays and for marls.

Bryozoal limestones present in the Middle Tertiary Port Willunga beds are also highly porous and permeable, and are well-sealed in the deeper basin situations.

By and large the Tertiary sequence is well served for reservoir beds, and an indication of the effective sealing of these beds by interbedded and overlying clays is demonstrated by the presence of connate waters of high salinity within them (c.f. 13½ ounce brine at Pt. Gawler), and by the positive artesian heads in low-lying situations.

3. Traps for Oil and Gas.

A great variety of structural and stratigraphic traps can be predicted for the St. Vincent Gulf sedimentary environment. Lower Cambrian limestones would favour secondary porosity-type traps in the form of irregularly dolomitized zones, or weathered sections, adjacent to erosional unconformities, or in fracture zones. Younger formations on the other hand, would be suited to a much wider range of structural and stratigraphic traps, including those associated with folds, faults, warps, unconformities, sand and limestone pinch-outs, erosional (unconformity) truncations, and any combination of these. These are the normal associations of a tectonically active environment.

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APPENDIX

Report on H.E. Hallion's Boring for Oil on Section O., Hundred of Port Gawler by R.L. Jack.

The site of the bore is to the east of a long, low shelley ridge that marks the sea shore prior to the latest rise of the coast. The ridge traverses a samphire flat, lower on the western side than on the east, and within a foot or two of high tide level. The bore site is unindated by the light floor waters in winter.

The bore had reached a depth of 603 feet and 320 feet of 6" casing is in the hole.

A small flow of strong brine (13 oz.) is escaping, and evidently carries ferrous salts, which oxidise to form iridescent films and scums of oxide.

There is no present evidence of oil, but Mr. Hallion stated that they obtained traces of oil, apparently more volatile than engine oil at 504½ feet and 603 feet. An analysis by the Government Analyst of a sample secured by Mr. Hallion, and another by Hallet, gave traces of oil but an insufficient quantity to determine its type.

A new rope was put on about three weeks before the first oil was seen, and though both the borer and Mr. Hallion did not think it possible, there is the chance that this oil came from the lubricated core of the rope. The bore has passed through parti-coloured sands and clays younger than the fossiliferous Tertiaries, then possibly into the Turritella bed beneath which are the lignitic coal measures which at Clinton and Inkerman rest on the Cambrian bedrock.

(Extracted from Mining Review) 38 (1923).

CROYDON BORE

Hd. Yatala
Elevation 52' above M.S.L.

Recent to Pleistocene

0' - 19'	Brown clayey loam
19' - 45'	Brown clay
45' - 57'	Coarse water worn sand and gravel
57' - 95'	Brown clay
95' - 110'	Clay with nodules of limestone
110' - 212'	Brown clay
212' - 250'	Clay, quartz and gravel
250' - 295'	Brown clay
295' - 315'	Brown clay and quartz gravel
315' - 350'	Brown sandy clay
350' - 378'	Fine quartz sand
378' - 385'	Calcareous sand with lime nodules

Pliocene

385' - 395'	Grey clay
395' - 415'	Fine white calcareous sand with shells
415' - 416'	Hard blue limestone
416' - 450'	Sand and shells
450' - 605'	Dark blue-black silt with shells.

Miocene

605' - 720'	Yellow calcareous fossiliferous sandstone
720' - 790'	Blue clay and limestone with pyrites
790' - 960'	Yellow calcareous fossiliferous sands
960' - 990'	Glauconitic calcareous sand
990' -1760'	Grey fossiliferous sandstone, limestone and clay

Olihocene

1760' - 1904'	Dark sand and clay
1904' - 2034'	Clay
2034' - 2069'	Coarse sand and gravel
2069' - 2242'	Sand and clay

Pre-Cambrian

2242' - 2296'	Sandstone and shale with quartz veins.

PETHICKS BORE : OAKLANDS

Hd.Adelaide - Sec.147
T.D.1002'

0' - 155'	Recent to Pleistocene	
155' - 355'	Miocene	
355' - 1002'	Oligocene?	Logged by K.R. Miles

Log

Recent to Pleistocene

0' - 40'	Clay and gravel
40' - 130'	Clay and gravel
130' - 155'	Yellow clay
155' - 185'	Limestone and sand
185' - 216'	Sand rock and soft yellow rock
216' - 224'	Sand rock and clay
224' - 250'	Sand rock and limestone
250' - 308'	Alternate layers sandstone and clay
308' - 330'	Sandstone and clay
330' - 415'	Black clay
415' - 434'	Hard black sand rock with clay bars
434' - 484'	Soft black rock and clay

Oligocene

484' - 498'	Black mud
498' - 503'	Black clay
503' - 516'	Sand and black clay
516' - 588'	Sand
588' - 610'	Black mud
610' - 640'	Sand
640' - 650'	Stiff black mud
650' - 670'	Coarse sand
670' - 684'	Black mud
684' - 782'	Blue clay
782' - 785'	Brown clay with coarse grit
785' - 820'	Fossilized clay?
820' - 850'	Pipe clay
850' - 851'	Green sand rock
851' - 855'	Green clay
855' - 870'	Stiff brown clay with coarse pieces of rock
870' - 905'	Stiff clay with pyrite nodules
905' - 930'	Chocolate clay
930' - 993'	Clay and sand alternate layers
993' - 1002'	Black mud.

Hundred Dublin
Section 97.
T.D.583'

0' -	1'	Dark loam
1' -	15'	Yellow clay with limestone
15' -	35'	Reddish sandy clay
35' -	36'	Water cut
36' -	58'	Varigated sandy clay
58' -	59'6"	Brown sand and gravel
59'6" -	90'	Varigated clay
90' -	105'6"	Red and white sandy clay
105'6" -	120'	Yellow clay
120' -	125'	Yellow sand
125' -	128'6"	White sandy clay
128'6" -	132'6"	Sandstone boulders and sand
132'6" -	134'	White clay
134' -	160'	Course brown limestone
160' -	178'	Brown marl marine fossils
178' -	184'	Hard dark grey limestone
184' -	220'	Bluish marl with marine fossils
220' -	223'	Hard dark grey limestone
223' -	234'	Bluish marl marine fossils
234' -	236'6"	Hard dark grey limestone
236'6" -	241'	Bluish marl marine fossils
241' -	245'	Hard dark grey limestone
245' -	310'	Dark blue clayey silt marine fossils
310' -	311'	Water cut
311' -	320'	Sand stained green with chlorite, marine fossils
320' -	335'	Drift sand
335' -	348'	Light bluish clay
348' -	370'	Clay slate
370' -	373'	Drift sand
373' -	376'	Decomposed clay slate
376' -	408'	Bluish calcareous rock, slightly crystalline
408' -	432'6"	Light blue clay
432'6" -	583'2"	Hard bluish calcareous rock.

Hundred of Grace

Section 17
T.D. 654'

Recent to Pleistocene

0' - 5'	Not logged
5' - 45'	Clay
45' - 50'	Sand and water
50' - 60'	Clay

Miocene

60' - 66'	Sands and stronger supply water
66' - 210'	Clay with alternate sand beds, water cuts
210' - 260'	Sandstone rock with hard and soft bars

Oligocene

260' - 528'	Black mud with black sand lense
528' - 580'	White clay
580' - 595'	Yellow clay with yellow sand
595' - 627'	Reddish clay
627' - 628'	Sand
628' - 629'	Hard bar of rock
629' - 630'	About 3" of coal, burnt with bright crackling flame.
630' - 633'	Hard bar of rock, water cut to within 30' of surface
633' - 651'	Bedrock) Brownish grey limestone
651' - 654'	")

INKERMAN BALAKLAVA COAL BORE

Hd. Inkerman Sec. 363
Bore 31 (1A Govt.)

PLEISTOCENE TO RECENT

0 - 5'	Cream buff massive to nodular travertine.
5' - 15'	Red fine sandy clay with whitish travertine lenses.
15' - 23'	Red sandy clay.
22' - 23'	Grey argillaceous sand with red, brown, and yellow mottlings (drive tube sample).
23' - 30'	Red argillaceous sand coarse grain size.
30' - 31'	Red mottled grey argillaceous sand. (Drive tube sample).
31' - 35'	Red clayey sand, coarse grained.
35' - 40'	Red sandy clay.
40' - 41'	Beige grey clay with fine red streaks and mottlings.
41' - 50'	No sample.
50' - 51'	Grey clay with red, brown and purple stainings.
57' - 80'	Light yellow grey clayey silt or sandy clay with yellowish mottlings and some ironstone nodules at top - also grey argillaceous silt with rhythmic iron deposition - yellow and light red stainings - Degree of staining and iron content also, proportions of clay and sand vary through-out thickness, otherwise little sign of change if environment.

PORT WILLUNGA BEDS

80' - 85'	Buff to yellow medium to coarse grained quartz sand with some gravel; sand well rounded.
85' - 87'	White microcrystalline limestone, not obviously fossiliferous.
87' - 90'	Light yellowish brown fine grained sand.
90' - 95'	Brown grey coarse grained sand or sandstone, cemented by lime into nodules.
95' - 100'	Brown fine to coarse grained sand or sandstone cemented by lime.
100' - 112'	Yellow to yellow-brown fine grained calcareous sand - non fossiliferous, somewhat micaceous.

BLANCHE POINT MARL EQUIVALENT

112' - 119'	Yellow brown calcareous fossiliferous sand or very poorly consolidated sandstone - Fossils comminated and fragmentary. Quartz grains are coarse cemented by ferruginous calcareous paste - Sparse macro fossils.
119' - 129'	Yellow brown fine clayey sand - quite plastic - becoming greenish towards bottom. Greenish grey clay laminations come in at 124. At bottom black to very dark brown clay comes in and also streaky red bands part to bedding.

NORTH MASLIN SANDS

129' - 137'	Greenish grey carbonaceous sand with linticular clay streaking. Sand very fine to fine grained quartzose.
137' - 180'	Grey brown humified fine grained micaceous sand, some lignitic fragments at bottom.
180' - 183'	Black lignitic sand or sandy lignite.
183' - 185'	Black and brown impure lignite with micaceous sandy layers.
185' - 186'	Black and brown carbonaceous sand.
186' - 209'	Dark grey brown humified fine grained sand.
209' - 209'	Black lignitic sand.
209' - 211'	Black and brown impure lignite.
211' - 215'	Dark grey brown humified medium grained sand, some coarse to very coarse quartz grains.
215' - 242'	Black to dark brown sand with black clay lenses or pellets and lignite fragments. Black due to humic acids.
242' - 271'	Black to brown lignite - plant leaves and stems observable.
271' - 279'	Black and brown lignite.
279' - 282'	Black to brown lignitic clayey fine quartz sand.
282' - 310'	Black to brownish buff micaceous carbonaceous sand (fine grained).
310' - 312'	Green micaceous clay (may be misplaced sample).
312' - 313'	Grey micaceous fine grained sand.
313' - 315'	Greenish grey micaceous fine grained argillaceous sand - quite compact.
315' - 320'	Black to brown carbonaceous clayey fine grained sand.
320	Bottom of bore.

MINLATON STRATIGRAPHIC BORE NO.1

Section 153. Hd.Ramsay

Drilled by Department of Mines 1956

Permian	
0' - 110'	Post glacial fluvial sands - medium to coarse qtz. grains, sub rounded, some times polished generally more or less facetted. 0' - 45' Red brown sandy clays 45' - 75' Pale buff gritty and clayey sand 75' -100' Yellow coarse gritty sand with facetted pebbles of granite, gneiss and sandstone. 100' -110' Pinkish brown medium quartz sand. Worked lithological change.
110' - 500'	Glacial boulder clay. 110' -260' blue grey boulder clay and clayey sand with facetted and worn pebbles of various kinds. 260' -500' chocolate brown gritty boulder clay with facetted pebbles of various kinds.
500' - 535'	Fossiliferous sandy clay stones 500' -530' Dark bluish grey fossiliferous claystones with odd pebbles. 530' -535' grey sandy claystones.
535' - 566'	Deltaic sandy claystones, light brown in colour with a few fossils and small amount of sand a few pebbles. Marked lithological change.
566' - 615'	Fluvio glacial sandstone medium to coarse white grading to light brown, incoherent quartz sandstone, calcareous, with pebbles of limestone, and choc. shale 570'-575'. An abundance of heavy minerals mostly garnet and rutile with accessories including chalcopyrite, biotite, epidote agarite, magnetite, zircon and limonite. There is no evidence to suggest other than low temperature conditions of deposition, probably in a deltaic environment. From 0-615' is considered to be Permian in age. Marked lithological change.
615' - 724'	<u>Lower Middle Cambrian</u> Ramsay limestone - dark blue-grey fossiliferous dolomitic limestone.
724' - 1087'6"	<u>Red bed clastics</u> and <u>evaporites</u> 724' - 730' Grey shaley limestone 730' - 750' Grey cryst.limestone and dol.lst. 750' - 770' Grey shaley lst.with interbedded crystalline gypsum after 760' 771' - 809' Purple-choc.laminated calc.shale with thin bands gypsum. 809' - 872' Massive dark grey and blue grey calc. siltstone. 872' - 880' Grey shaley limestone

	880' - 893'	Grey chocolate and purple laminated calcareous shales.
	893' - 1052'6"	Grey and chocolate fine grained laminated sandy shales showing intra-formational breciation and slumping.
	1052'6" - 1087'6"	Grey and chocolate fine grained laminated shales with bands of coarse gritty and sandy material.

1087'6" - 1117' **Upper Lower Cambrian**
Conglomerate - coarse limestone conglomerate with compact chocolate matrix. Conglomerate pebbles are richly fossiliferous. A few horizontal interbedded shale bands near top. Continental conditions.

1117' - 1177' Chocolate to grey laminated shales unfossiliferous with a few interbedded calcareous bands. Bedding near horizontal. Continental conditions.

1177' - 2123' **Lower Cambrian**
Parana Limestone
Calcite abundant in cavities and thin veins. stylolites common after 1380'. Core broken in clays after 1500'.

1177' - 1210'	Grey compact calcareous shales.
1210' - 1254'	Gradual gradation from the above to a grey compact fine grained dolomite.
1254' - 1291'6"	Grey to pink, massive archaeocyathinae, dolomitised limestone abundant fossils.
1291'6" - 1380'	Grey, massive microcrystalline dolomitic limestone.
1380' - 1504'	Light grey and cream microcrystalline dolomitised limestone with occasional fossils.
1504' - 2111'	Dark grey microcrystalline dolomitised limestone with irregular blackish grey carbonaceous dolomitised limestone bands arranged so that the rock looks like a breccia.
2111' - 2123'	Must to light grey microcrystalline dolomitised limestone with irregular black partings.

2123' - 3176' **Lower Cambrian**
Kulpara limestone

2123' - 2593'	Alternating bands of light and dark grey massive microcrystalline dolomitised limestones - porous in places. Stylolites and calcite filled fractures common.

- 3107' - 3126'

2593' - 2597'	Porous dolomitised limestone with partings at 90^0 from core.
2597' - 2613'	Grey massive dolomitised lime-stone lignitic material along bedding planes at 2597'9" -2601'6".
2613' - 2630'	Porous quartzitic dolomitised limestone.
2630' - 2637'	Grey massive dolomitised lime-stone.
2637' - 2662'	Porous quartzite dolomitised limestone.
2662' - 2686'	Massive dolomitised limestone with a few porous zones.
2686' - 2764'	Porous dolomitised limestone occasional massive after 2741'.
2764' - 2778'	Massive dolomitised limestone.
2778' - 3075'	Grey dolomitised limestone generally massive.
3075' - 3107'	White to whitish grey lime-stone with pink bands.
<u>Lower Cambrian</u>	
3107' - 3126'	Elastic dolomitised limestone with iron staining.
3126' - 3131'	Grey calcareous arkosic sand-stone.
3131' - 3134'	Coarse grained dolomitised sandstone, well rounded quartz grains and feldspar with interstitial dolomite.
3134' - 3141'	Mid grey calcareous arkosic sandstone.
3141' - 3174'	Dark grey fine grained, arkosic quartzite limestone.
3174' - 3176'	Dark grey carbonaceous slate.
3176' - 3247'	<u>Round Quartzite</u>. transitional from quartzitic limestone - calcareous quartzite.
3247' - 3255'	Dark grey hard calcareous shale and grey interbedded quartzite.
3255' - 3261'	Grey siliceous limestone with black slightly contorted laminae of shaley material.

MINLATON TOWNSHIP BORE

Hd.Ramsay Sec.153

0' - 10'		Pale buff sandy marl.
10' - 20'		Red sandy clay, slightly calcareous, ochreous
20' - 34'		Red clayey sand
34' - 45'		Red brown sandy clay
45' - 75'		Pale buff gritty siliceous sand-clayey granite pebble at 65 feet (fluvio glacial sands).
75' - 100'		Yellow gritty sand, med to coarse grained, pebbles
100' - 110'		Pink-brown medium grained siliceous sand
110' - 117'		White-grey gritty sand with pink feld.gne. and some pebbles.
117' - 120'		Pale grey gritty clay.
120' - 126'		Pale blue-grey gritty clay.
126' - 132'		Gritty sand with some pale blue clay.
132' - 140'		Pale blue grey sandy clay.
140' - 160'		Pale grey clay sand with pebbles quartzite & granite.
160' - 170'		Grey pebbly sandy clay - boulder clay.
170' - 190'		Stiff brown clay with pebbles.
190' - 193'		Buff coloured clay with fine sand.
193' - 225'		Grey sandy clay with pebbles.
225' - 250'		Grey clayey sand and grit.
250' - 260'		Grey sandy clay.
260' - 295'		Pale choc.gritty clay - weakly calc.
295' - 300'		Pale choc.sand and grit - calc.
300' - 400'		As above
400' - 501'		Choc.brown gritty and sandy clay with odd pebbles up to ½" diam.
501' - 510'		No sample.
510' - 530'		Dark bluish grey clay shale with odd qtz.pebbles. Well compacted.
530' - 531'		Choc. brown clay shale.
531' - 532'		Dark bluish grey shale.
532' - 533'		Choc. brown sandy shale with pebbles.
533' - 535'		Bluish grey shale.
535' - 543'		Dark greenish grey clay shale with pebbles.
543' - 554'		Pale choc. brown clay shale with odd sandy shale partings and pebbles.
554' - 565'		As above.
565' - 566'		Greenish grey clay shale.
566' - 567'		Highly calc. medium white sand, with some dark coloured gritty inclusions.
567' - 575'		White gritty sand with pebbles of limestone and choc brown shale.
575' - 595½'		Pale brown gritty calc.fine sand with some grit.
595½' - 605'		Pale brown fine calc. sand and grit.

Percussion rig taken off. Diamond rig set up over hole. All above classified as Permian fluvio glacials by N.Ludbrook.
Two diamond drill cores examined by D.King were of red granite and fine grained amphibolites between 1700' and 1900'.

PENINSULA OIL BORE NO.1

(Peezie Swamp)

Hd. Moorowie Sec.121

	0'	-	21'	Limestone, crops out above sand drift
	21'	-	45'	Grey clay, sandy, recent shell fragments, fossil wh.lst.
	45'	-	60'	Grey calcareous clay with white limestone fragments (fossiliferous).
	60'	-	100'	Dark grey argillaceous clay with rounded quartz grains; fragments of calcareous and argillaceous limestone, fossiliferous.
	100'	-	138'	Dark grey argillaceous clay with quartz grains and fossil, frags. (At 138' drill entered tillite? Permo-Camb? P25 Bull 22).
	139'	-	146'	Brownish grey argillaceous clay with ScO2 lst. unfossiliferous.
	146'	-	185'	As above
	185'	-	220'	Light brown grey clay, fragments of granite, dolomite calcareous limestone, cemented and grain quartz.
	220'	-	225'	Brownish grey clay (as above but with fossils, micaceous schist and cu pyrites.
	225'	-	256'	Greyish clay - many sub-angular particles of limestone.
	256'	-	300'	"Washed residue". Dark grey limestone with quartz and shells.
	300'	-	334'	Dark brownish-grey clay, fragments quartz grains and shells.
	334'	-	366'	"Washed residue". ScO2 grains and few shells, limestone fragments.
	366'	-	395'	Dark brownish grey clay with fragments limestone, quartz and shell fragments. (Erratic boulder from 377' consists of unaltered micracline granite).
	395'	-	450'	Dark grey clay with limestone and quartz.
	450'	-	464'	Bluish grey clay with limestone and quartz (small grains).
	464'	-	500'	As above but with less yellowish quartz and mono-clear grains.
	500'	-	510'	Washed material with quartz and dark grey limestone.
	510'	-	565'	Washed material, fine quartz grains, fragments dark grey limestone.
	565'	-	600'	Dark grey clay with fragments dark grey limestone with quartz grains.
	600'	-	630'	Dark grey clay with grey limestone and quartz grains.
	630'	-	650'	Light grey clay with fragments limestone, pink crystalline limestone and quartz.
"Red water"	650'	-	660'	Reddish brown sand with lst.and angular ScO2
tered about	660'	-	663'	Quartzite, gneiss with Cu pyrites and Qtz.veinlets.
	663'	-	670'	Weathered fragments of gneiss.
	670'	-	1132'	Gneiss with quartz veins, mica.schist bands.

KINGSCOTE BORE

Hd.Menzies
Kangaroo Island
T.D.1094' - Abandoned Jan. 1910.

0' - 20'	Limestone
20' - 120'	Sandstone with hard bands
120' - 150'	Blue sandy clay
150' - 192'	Clay various colours
192' - 214'	Clay with boulders
214' - 253'	Sandy clay
253' - 346'	Soft blue shale
346' - 348'	Soft sandstone
348' - 470'	Blue shale with thin layers of sand
470' - 500'	Sandstone
500' - 574'	Sandy shale
574' - 578'	Soft sandstone
578' - 590'	Blue and brown shale
590' - 603'	Soft sandstone
603' - 650'	Sandy shale
650' - 667'	Sandy shale
667' - 669'	Hard rock.
669' - 688'	Conglomerate with pyrites
688' - 759'	Shale with pebbles
759' - 806'	Slaty shale
806' - 857'	Brown shale
857' - 982'	Calcareous shales and pebbles
982' - 1015'	Blue shale with quartz granites
1015' - 1039'	Brown shale
1039' - 1042'	Quartzite
1042' - 1044'	Blue shale
1044' - 1052'	Sandstone with pyrites
1052' - 1094'	Hard slate rock.