SOUTH AUSTRALIA

DEPARTMENT OF MINES.

Geological Survey of South Australia.

BULLETIN No. 2.

The Possibilities of the Discovery of Petroleum on Kangaroo Island and the Western Coast of Eyre's Peninsula.

By L. KEITH WARD, B.A., B.E. Government Geologist.

Issued under the authority of
The Honorable RICHARD BUTLER, M.P., Minister of Mines.

ADELAIDE:
R. E. E. ROGERS, GOVERNMENT PRINTER, NORTH TERRACE.

1913.

HPRM 2018D037681

SOUTH AUSTRALIA.

DEPARTMENT OF MINES.

Geological Survey of South Australia.

BULLETIN No. 2.

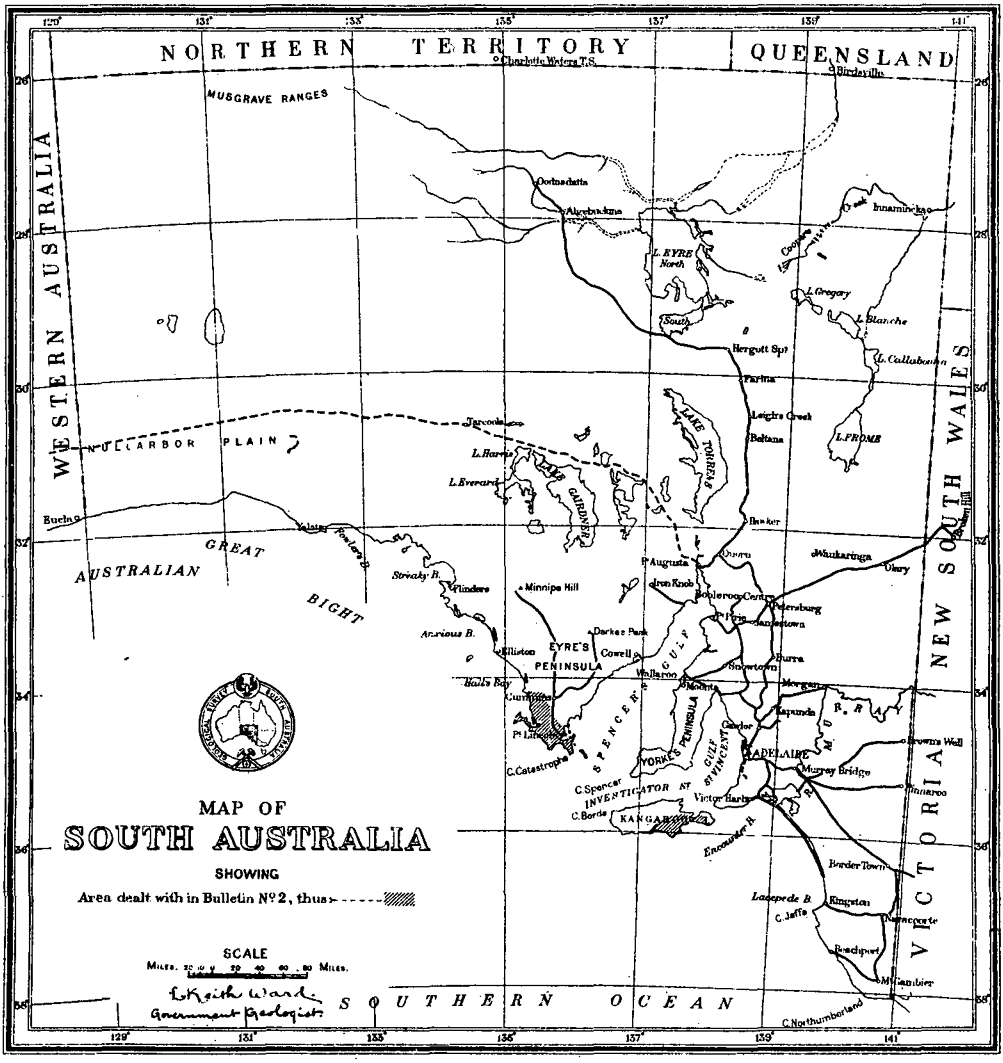
The Possibilities of the Discovery of Petroleum on Kangaroo Island and the Western Coast of Eyre's Peninsula.

By L. KEITH WARD, B.A., B.E. Government Geologist.

Issued under the authority of
The Honorable RICHARD BUTLER, M.P., Minister of Mines.

ADELAIDE:
R. E. E. ROGERS, GOVERNMENT PRINTER, NORTH TERRACE.

1913.



A. VAUGHAN, GOVERNMENT PHOTOLITHOGRAPHER, ADELAIDE.

TABLE OF CONTENTS.

MAPS.

LETTER OF TRANSMITTAL.

Geological Survey Office,
Adelaide,
January 24th, 1913.

Sir—I have the honour to submit to you a report upon the possibilities of the discovery of petroleum in certain parts of South Australia, in which it has been recently stated that signs of the presence of mineral oil have been detected

The question is one in which considerable public interest has been shown.

In preparing this report I have embodied the results of the work of other investigators with my own. I am particularly indebted to Mr. W. A. Hargreaves, the Government Analyst of South Australia, for his detailed chemical investigation of various materials which have been considered to have a bearing upon the question at issue.

I have the honour to be, Sir,

Your obedient servant,

L. KEITH WARD, *Government Geologist.*

The Honorable Richard Butler,
Minister of Mines.

Submitted for approval to print as a Bulletin of the Geological Survey of South Australia.

Approved,

R. BUTLER, *Minister of Mines.*

REPORT

ON THE

Possibilities of the Discovery of Petroleum on Kangaroo Island and the Western Coast of Eyre's Peninsula.

I.—INTRODUCTION.

In accordance with instructions the writer visited the two areas with which this bulletin deals. The visit to Kangaroo Island extended over the period August 3rd to August 22nd, and that to Western Eyre's Peninsula over the period October 15th to October 20th, 1912.

In both areas a rapid geological reconnaissance was made of the particular portions of the districts in which discoveries had been made of materials which led to the belief in the presence of mineral oil. From the following pages it will be seen that the data acquired during this work of reconnaissance are not such as to warrant a more detailed investigation of any portion of the districts visited with the special object of selecting sites for boring operations.

The work carried out by the writer is, however, when added to that of Mr. H. Y. L. Brown, the late Government Geologist, and of other unofficial investigators, of a sufficiently detailed character to afford an accurate conception of those general structural features which are of primary importance for the discussion of the oil-bearing possibilities of any district.

The areas thus examined comprise some 200 square miles on Kangaroo Island, occupying that portion of the southern coast which lies between Vivonne Bay on the west and Hog Bay (or Wilson) River on the east. Within these limits and for a distance of from two to 10 miles from the southern shore line a large number of applications for search licences were recently received by the Department of Mines.

The portion of Eyre's Peninsula which was examined lies in the hundreds of Ulipa and Warrow. The area here taken up under search licences is that which surrounds Lake Greenly. A little to the southward, in the hundred of Sleaford, other areas have been taken up under search licences. The total area thus occupied on Eyre's Peninsula is 50 square miles.

The importance that would be attached to any authentic discovery of workable petroleum deposits in the State rendered another geological investigation of these districts desirable, in order that the sites of recent prospecting operations and reported discoveries might be visited and examined.

During the course of his investigations the writer gathered a number of samples for investigation. Many of these have been examined with minute care by Mr. W. A. Hargreaves, Government Analyst, and the results of his tests have been embodied in this bulletin.

In the preparation of the maps accompanying this bulletin the writer has not hesitated to embody the data acquired by his predecessor, Mr. H. Y. L. Brown, amplifying or amending pre-existing maps by means of information gathered during the recent visits.

II.—HISTORY OF PROSPECTING OPERATIONS FOR PETROLEUM ON KANGAROO ISLAND AND EYRE'S PENINSULA.

As far back in the history of South Australia as 1844, Mr. Inspector Tolmer knew of the presence of fragments of asphaltum on the beaches of the southern coast of Kangaroo Island, and states in his " Reminiscences " that this material was at that time in use for boat building.*

At a much later date some boring was done at Vivonne Bay, and at a point a little to the west of the mouth of the Hog Bay River, without any successful results.

In 1871 coal leases of 10,000 acres each were granted at False Cape and Flour Cask Bay, but no work appears to have been done upon them.

From this point onwards interest in the possibilities of Kangaroo Island as a productive source of petroleum has been from time to time revived. The interest attaching to the discoveries of asphaltum has at no period in the past been so great as it is now, since the competition for sources of oil fuel is now keener than ever before.

Nevertheless, it must be admitted that the burden of prospecting has been borne by very few individuals, and that practically no search is being made at the present time, although so many search licences have been taken out.

These remarks are of general application also to the western coast of Eyre's Peninsula. At the part of the coast recently visited by the writer a large block of asphaltum was found some 40 years ago by Mr. Burns, now deceased. The sons of the late Mr. Burns have informed the writer that their father was firmly convinced that the asphaltum found by him occurred *in situ*, and that it was actually oozing out of the rocks at that time. The writer's visit to the locality was made in company with Mr. R. J. Burns.

Some small amount of prospecting has been done by the Messrs. Burns and others, but no discoveries bearing on the question of petroleum have been made, save on the actual sea beaches.

III.—PREVIOUS LITERATURE.

From time to time geologists have visited Kangaroo Island and have written reports upon the results of their observations. The portion of Eyre's Peninsula dealt with in this bulletin has been visited and geologically mapped by Mr. H. Y. L. Brown, but no description of the geological features has been published.

The late Professor Ralph Tate read a paper before the Royal Society of South Australia in 1883, in which he makes mention of the pitch or asphaltum on the southern beaches.† Professor Tate expressed his opinion that " all " the circumstances conspire to prove that the substance is a waif upon " these shores."

Mr. H. Y. L. Brown issued on December 13th, 1898, an official report upon the geology of Kangaroo Island‡ in which he definitely expressed his " opinion " that the occurrence of asphalt and similar substances on the coast is purely " accidental, and that they have been washed up from the sea or deposited by " human agency, and that there is not the slightest evidence of their having " been derived from local subterranean sources."

This report contains the only systematic account of the geology of the whole of the Island.

---

* " Reminiscences," 1882, p. 320.

† " The Botany of Kangaroo Island." Transactions and Proceedings and Report Royal Society of S. Australia, vol. VI., p.p. 128-129.

‡ " Kangaroo Island." Report by the Government Geologist, Dec. 13th, 1898.

At later dates Mr. Walter Howchin twice visited Kangaroo Island and has ecorded results of his observations in two papers, which appear in the "Transactions of the Royal Society of South Australia."*

In the later paper Mr. Howchin discusses at length the conclusions to which he was drawn by the examination of that part of the Island in which discoveries of asphaltum and fossil resins have been made. He offers three possible explanations of the occurrence of the asphaltum, viz.—(1) That the bituminous material has been derived from a natural bed locally developed. (2) That it has been distributed by the agency of man. (3) That the fragments are sea-borne and far-travelled.

In his discussion of these suggested sources Mr. Howchin evidently attaches little weight to the two first mentioned, and appears inclined to the opinion so definitely stated by Professor Tate and Mr. H. Y. L. Brown.

The nature of the rubber-like material known as "coorongite" has been the subject of considerable discussion, and a special list of references to published reports dealing with it is furnished in a later chapter.

IV.—GEOLOGY.

(*a*) The Geological Structure of Kangaroo Island.

The following account of the geological features is entirely restricted to the description and discussion of the formations represented in the southern and south-eastern parts of Kangaroo Island and the elucidation of the structure and inter-relationship of these formations.

(1) *The Primary Rocks.*

The rock-types which have been recognised in the Mount Lofty Ranges are visible on Kangaroo Island, which is undoubtedly the severed southern terminal of these ranges. The age of the rocks has not been determined from the evidence of the exposures on the island itself, but it is reasonable to suppose that the evidences of age afforded by mainland exposures are applicable to this geographical outlier of the Mount Lofty Ranges. Lithological resemblances with both the Cambrian and Pre-Cambrian formations of South Australia have been noted; and it is highly probable that rocks of both ages are represented on Kangaroo Island.

These primary rocks, constituting the backbone of the island, are for the most part altered sediments of variable grain. They are, where surface exposures permit the examination of the unweathered rocks, slates, quartzites, and quartz-mica schists. Long exposures to superficial weathering has resulted in the general degradation of these rocks and the masking of the formations with a superficial mantle of decomposition products. The soil overlying these rocks contains angular fragments of their harder portions—usually ironstained quartzite. And at some points a nodular and loosely aggregated ferruginous laterite has been formed.

The harder quartzites, however, make fairly prominent outcrops at a few points, and in a few road cuttings the undisintegrated rock masses have been reached. From these latter exposures and the reefs which are visible at various points along the southern coast line it may be seen that the general strike of these old sediments is in a north-easterly direction (N.30°E. to N.45°E.), and that the dip is to the south-east at angles varying between 45° and 80°.

---

* (*a*) "Notes on the Geology of Kangaroo Island, with Special Reference to Evidences of Extinct Glacial Action." Transac. Roy. Soc. S.A., vol. XXIII., part ii., p.p. 198-207.

(*b*) "Further Notes on the Geology of Kangaroo Island." Transac. Roy. Soc. S.A., vol. XXVII., part i., p.p. 75-90.

At a few places narrow veins of quartz, having a width of a few inches only, traverse the quartzites.

At Point Ellen, on the southern side of Vivonne Bay, numerous intrusive dykes of tourmaline-bearing granite and pegmatite have intersected the sediments and produced in them a notable degree of metamorphism. The granite itself shows no specially characteristic features, but the pegmatite dykes show a marked tendency to develop very large crystals of the constituent minerals. Garnet is noticeably abundant at one place.

The dykes have on the whole an east-and-west course, but numerous cross dykes occur. The result of the intrusion of so many dykes of a pegmatitic character has been the conversion of the older sediments into crystalline rocks, which exhibit the features of gneisses. A certain schistosity has been developed and lenses of quartz or felspar, or of both together are visible in the metamorphosed sediments which are traversed by the network of dykes.

An outcrop of granite, probably identical with that of Point Ellen, is reported to exist at Cape Gantheaume.

The old rocks, both sedimentary and igneous, are for the most part concealed by a cover of much younger sedimentary deposits, which are described below. It is, however, most important in the present connection to note that the covering is neither of considerable thickness nor perfectly continuous along the shore line. The most significant features of the geological map of the southern portion of Kangaroo Island are the outcrops of the ancient rocks at the capes and promontories. These outcrops do not rise to any notable height above sea-level, and most of them appear at the foot of the cliffs which fringe the shore and form jutting reefs, which extend for short distances out to sea.

In addition to the outcrops at Point Ellen and Cape Gantheaume, to which reference has been made above, there are exposures of the ancient primary rocks at Point Tinline and at a distance of from two to three miles to the west of the mouth of the Hog Bay River. At both the latter places the rocks outcropping are dense quartzites. Similar rocks are shown on Mr. H. Y. L. Brown's geological map outcropping at False Cape.

These outcrops, when considered together with the more extensive developments of similar rocks in the interior of the island, show conclusively that the shallow sedimentary deposits which occupy so large an area in the south-eastern part of Kangaroo Island rest upon a gently sloping shelf, the denser and more durable portions of which are actually above sea-level on the coast line.

(2) *The Upper Tertiary to Recent Sediments.*

Lying in approximately horizontal beds upon these ancient foundations is a series of sediments showing some variation in the state of aggregation of the component parts. The greater part of the formation consists of loosely-aggregated calcareous sand with which are associated certain marly beds.

At the surface over a considerable proportion of the area covered by this calcareous sand formation a crust of travertine limestone has been generated. This consolidated crust is traversed by many cracks, and here and there sink-holes occur. These openings permit the rainwater to escape rapidly into the underlying porous beds, and surface channels are neither well-defined nor continuous in the greater part of this terrain.

The argillaceous material which contributes to the bulk of the formation is neither abundant nor regularly distributed. This fact is of great importance in the consideration of the possibilities of the storage of petroleum in the rocks.

Numerous sections are available for examination along the sea cliffs. These show beyond all doubt that there are no continuous argillaceous beds and that the consolidated limestone forms only a small fraction of the bulk of

the deposit. In addition to the travertine capping there are various concretionary forms, most of which are pipe-like or root-like, traversing the comminuted shell fragments of which the sands are largely composed. These concretions stand out in relief on the cliff faces through the removal by weathering of the loose sand in which they have been formed.

At the base of the formation is a curious compact limestone containing dark-colored and irregularly shaped concretions of limestone. The rock when broken has the appearance of a breccia. Its manner of formation can be seen at the present time at various places. The dark concretions are partly dissolved at the surface by weathering agencies, and become buried in the drifting calcareous sand, which becomes consolidated round them.

The cliff sections of the layers of calcareous sand at the sea shore show that false bedding is a prominent feature of many parts of the formation. The high angle of inclination of the diagonally-bedded strata is strongly suggestive of an æolian origin.

Where the ancient bed rock is visible it is quite plain that this calcareous sand formation constitutes the whole of the cover which conceals the primary rocks between the inland exposures and the reefs on the shore line.

The age of the sands and travertine cannot be quite definitely determined as regards the lower beds, for no well-preserved fossils have been obtained from it. The component shell fragments are not such as admit of the recognition of species. The upper beds of the formation, however, in the vicinity of Murray's Lagoon, carry abundant remains of *Coxiella badgerensis* —a Recent brackish water gastropod*.

From this evidence it would appear that at least the greater part of the coastal sands and limestone is of Upper Tertiary to Recent age—probably the latter.

It should perhaps be noted that the Eocene limestone, which is so widely distributed along the southern coastal part of Australia, has not been observed to underlie these sands and limestone at any place along the southern coast of Kangaroo Island. The limestone of Eocene age has been observed at Kingscote† on the northern side of the island, and again at Cape Willoughby‡.

No positive knowledge exists of its occurrence beneath the Upper Tertiary to Recent sands and limestone within the limits of the area examined by the writer.

The description of these late sediments would be incomplete without a brief mention of the saline deposits enclosed within the limits of the terrain. The majority of the lakes carry water, which is brackish to salt in quality. Those that are very shallow dry up altogether in the summer season and the precipitated salt is harvested and sold.

The principal producing lake is at sea-level and is separated from the ocean at Flour Cask Bay by a ridge of sand dunes. It is quite possible that this separation has only taken place within a very recent period by the growth of the coastal dunes. Immediately to the eastward of Pelican Lagoon in the hundred of Dudley there is another salt lake, which has been worked for its salt content and which has been severed from Pelican Lagoon by sand drifts. The formation of travertine from the calcareous sand has converted the loosely aggregated drift material into a compact rock. Again, Pelican Lagoon itself

* For the determination of this fossil the writer is indebted to Dr. J. C. Verco of Adelaide.

† *Vide* H. Y. L. Brown. Report cit. supra, p. 2, and W. Howchin. Transac. Roy. Soc. S.A., vol. XXIII., part ii., p.p. 198, 199.

‡ *Vide* W. Howchin Transac. Roy. Soc. S.A., vol. XXVII., part i., p. 83,

has by a similar process become almost a closed basin. With a comparatively insignificant addition of sand to the promontories and islands at its mouth it would be entirely shut off from the American River—an arm of the sea.

The result of the complete evaporation of the water of these saline lakes during the dry season is the deposition of successive layers of gypsum, silt, and salt—the latter being at the top. This succession of evaporation products is in all respects typical of the deposits formed by the isolation and subsequent desiccation of arms of the sea, the saline deposits representing the solids formerly dissolved in the sea-water.

While this explanation may be applicable to the larger lakes at or close to sea-level, it is improbable that the smaller lakes at higher elevations have derived their salt directly from the ocean. In these latter cases the contribution of the ocean is indirect and is effected per medium of the rainfall.

The investigation of underground water supplies by the Geological Survey of South Australia has already established the fact that the dissolved salts present in both the surface and the underground waters of the portions of the State in which run-off is small or non-existent and evaporation is high, are the so-called " cyclic salts."* These salts are precisely those which are held in solution in the sea and which are continually being supplied to the atmosphere during the processes of evaporation, to be brought to earth by every shower of rain. On the earth's surface concentration takes place in the basins of internal drainage and precipitation of the cyclic salts results when supersaturation is attained. The deposition of the precipitated salts must follow the same order as is exhibited by deposits formed by the direct evaporation of sea-water.

There is no reason why the occurrences of salt on Kangaroo Island should not be considered as having an origin similar to the many occurrences in other parts of South Australia.

(3) *The General Structural Features.*

From the foregoing account it appears that Kangaroo Island is essentially a " horst " or residual prominence standing above sea-level, the surrounding land-masses having been faulted down and submerged.

The principal fault-fractures seem to have determined the general outlines of the island, and the surface has been modified by the degradation of the old rocks and the superposition of late cainozoic or recent sediments.

The Admiralty charts show that off the south-eastern part of Kangaroo Island the 10-fathom line is very close to the coast. The 20-fathom line is for the greater part of its length within a mile of the coast, and beyond the 25 fathom contour the shelving of the sea-bottom is more gradual. These phenomena are such as may be produced by block faulting.

The separation of Kangaroo Island from the mainland would seem to have been a result of the extensive crustal fracturing and dislocation which produced Spencer's Gulf and Gulf St. Vincent. It has recently been ascertained that part, at least, of this complex fracturing and dislocation of the crust took place between the Eocene and Pleistocene periods†.

---

* *Vide* R. Lockhart Jack. Geol. Surv. S.A., Bulletin No. 1, p. 21, and F. W. Clarke. The Data of Geochemistry, U.S. Geol. Surv., Bull. 491, p.p. 48-51.

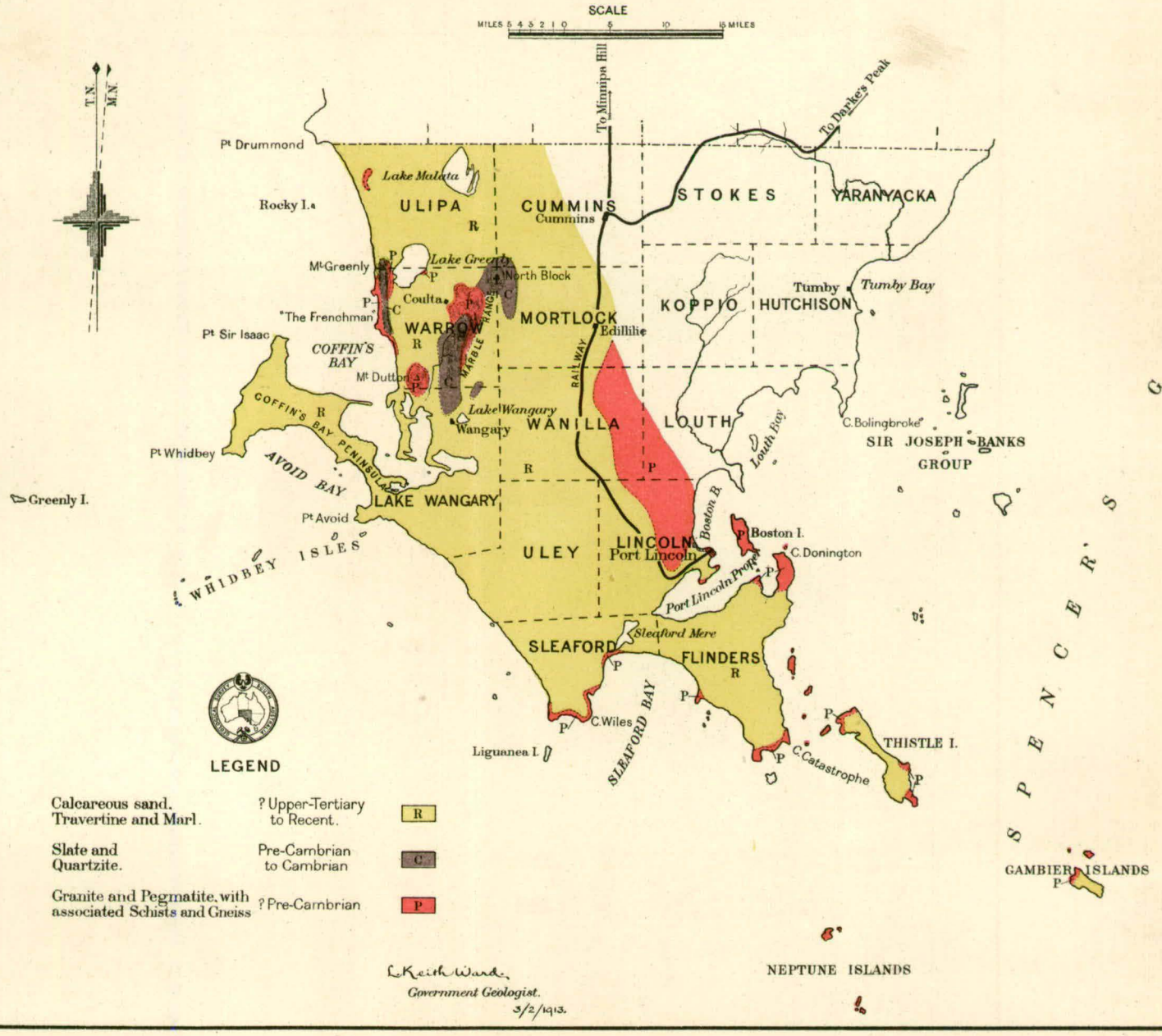
† *Vide* W. Howchin, " Description of a Disturbed Area of Cainozoic Rocks, in South Australia, with Remarks on its Geological Significance." Trans. Roy. Soc. S.A., vol. XXXV., p.p. 47-59.

Plate 2

GEOLOGICAL SKETCH MAP

OF PORTION OF

EYRE'S PENINSULA



LEGEND

Calcareous sand. Travertine and Marl.	? Upper-Tertiary to Recent.	R
Slate and Quartzite.	Pre-Cambrian to Cambrian	C
Granite and Pegmatite, with associated Schists and Gneiss	? Pre-Cambrian	P

L. Keith Ward.
Government Geologist.
3/2/1913.

A. VAUGHAN, GOVERNMENT PHOTOLITHOGRAPHER, ADELAIDE.

(*b*) The Geological Structure of the Western Coast of Eyre's Peninsula.

(1) *The Primary Rocks.*

As on Kangaroo Island there exists on Eyre's Peninsula a fundamental complex of ancient rocks over a large portion of which a thin mantle of very much younger sediments has been spread.

The ancient foundations, however, on the western side of the Peninsula form much more notable outcrops than they do in the south-eastern part of Kangaroo Island.

The Marble Range, Mount Dutton, Mount Greenly, and to a less degree The Frenchman are the most conspicuous prominences which project to a considerable height above the general level of the country covered by the late sediments. They owe their relief to the superior hardness and power of resistance of the component rocks of which they are built. The outlines of these prominences are such as may be produced in highly resistant rock masses by the prolonged erosion of an elevated region.

In addition to the outcrops which constitute these hills and ranges the primary rocks outcrop along the coast to the west of Mount Greenly and The Frenchman, and also to a less extent on the south-eastern shore of Lake Greenly. These facts confirm the belief in the continuity, beneath the recent sediments which cover a large portion of Western Eyre's Peninsula, of the ancient crystalline rocks of the higher parts of the region—a belief which is generated by the recurrence of similar lithological types.

The rock-types comprised in this complex grouping are several. They consist of old sediments, of acidic intrusions of a pegmatitic type and of the highly metamorphosed products of these intrusions.

The ancient sedimentary rocks contribute largely to the bulk of the Marble Range, and form a central core to the interrupted ridge of Mount Greenly and The Frenchman. Quartzites and slates are the rock-types represented.

The quartzite of the Greenly-Frenchman meridional ridge is an exceedingly dense rock with a white or pale-pinkish color. Its dip is to the east at from 45° to 60°. The formation evidently represents a silicified massive bed of sandstone, and it is flanked on both sides by the crystalline rocks described below.

The intrusive pegmatites visible along the shore line to the west of the quartzite ridge mentioned above are identical in appearance with the pegmatite dykes of Point Ellen, Kangaroo Island. They carry notable proportions of schorl and exhibit a marked tendency to differentiate into types consisting of only one or two of the constituent minerals, viz., into rocks composed of quartz, quartz and tourmaline, quartz and muscovite, or quartz and felspar.

These rock-types form a network of intersecting veins or dykes in which no constant orientation can be detected.

Involved in the network of dykes are rocks which show a remarkable variety of characters. Some are quartz-mica schists in which at some places quartz and in others mica is the dominant constituent.

In other types a gneissose character is developed and felspar becomes an important constituent. Much of this gneissose rock exhibits *augen* of quartz or of felspar or again of a quartz-felspar aggregate. In a few places specular hæmatite is to be seen.

Such rocks as these thus briefly described are characteristic of zones intruded by aqueo-igneous pegmatites*. It is impossible to furnish a map showing the intrusive material differentiated from the gneisses and schists resulting from the contact metamorphism.

---

* *Vide* C. R. Van Hise, "A Treatise on Metamorphism." U.S. Geol. Surv. Monograph XLVII., p.p. 720-728.

The outstanding feature of interest is the dense quartzitic ridge of Mount Greenly and The Frenchman, in which silicification only has been effected, whereas the pegmatitic and gneissose rocks appear on both sides of the hard siliceous core. It would seem that the quartzite was formed during an early stage of the metamorphism through the cementing influence of siliceous solutions, which probably found an easier channel of ascent along the old sandstone formation than along the beds of finer-grained sediments. The aqueo-igneous intrusion of pegmatitic material was perhaps later and found the compact quartzite incapable of further alteration, but effected profound changes in the other sediments.

(2) *The Recent Sediments.*

The covering which obscures so large a part of the ancient foundations of this region is in almost every particular identical with that described above as occurring on Kangaroo Island.

The formation is composed of horizontally-bedded calcareous sand or sandstone which merges at a few points into marl. The redistributed carbonate of lime forms concretions of various shapes in the mass of the formation, and these concretions are left strewn on the surface as disintegration of the formation proceeds.

Travertine is abundantly developed at the surface at a number of places but the sections exposed along the sea front show that the bulk of the formation is composed of loosely-aggregated sand.

Lake Greenly is a saline lake, at the southern shore of which a deposit of gypsum attains a thickness of as much as 15ft. A sample of exceedingly fine-grained crystalline gypsum, occurring at the north-western corner of section 102 of the hundred of Warrow, has been analysed by Mr. W. S. Chapman and found to contain :

Sulphuric anhydride	44·00
Lime	31·88
Water	20·32
Carbon dioxide	1·19
Silica	0·72
Alumina	0·24
Ferric oxide	0·24
Magnesia	0·12
Soda	0·39
Potash	0·10
Strontia	nil
Chlorine	0·05
Phosphoric anhydride	nil
Organic matter	1·08
	100·33

(3) *The General Structural Features.*

The recent sediments constitute a horizontally-bedded series which lie unconformably upon the tilted ancient rocks. On the seaward side of the Mount Greenly-Frenchman ridge the water falling as rain upon the calcareous sand formation and absorbed thereby finds its way directly to the sea. A large number of brackish-water springs exist at various points along the beach, the water having sunk through the sand as far as the crystalline bed-rock and followed the downward slope of the surface of the latter to the points of emergence on the shore.

On the eastern side of the ridge of ancient rocks the drainage is towards Lake Greenly, which has become salt through the continual evaporation and concentration of the water.

V.—THE DISCOVERIES WHICH HAVE LED TO THE BELIEF IN THE EXISTENCE OF LOCAL ACCUMULATIONS OF PETROLEUM, AND THEIR SIGNIFICANCE.

From time to time a number of different substances have been found in various parts of South Australia, including the areas with which this bulletin is specially concerned, which have led to a hope of the discovery of petroleum in payable amounts. At one time the public attention has been attracted towards one particular substance, such as coorongite, and at another time a different substance has received the greatest amount of attention.

The character common to most of the various substances which have been supposed to indicate the existence of a local oil-field is combustibility. But at periods of intense interest in the question all manner of evidence has been adduced to furnish collateral support.

It is the object of this bulletin to set forth a summary of the nature of these several materials and of their mode of occurrence, and to discuss their significance in regard to the question at issue.

(i.) Asphaltum.

The only substance yet discovered which bears clear and indubitable evidence of derivation from some petroleum-bearing source is a black bitumen, or asphaltum. Discoveries of this material were the immediate causes of the visits of the writer to both districts with which this bulletin deals.

The asphaltum discovered at various times occurs in blocks varying in weight from a few ounces to many pounds. The material is amorphous and the blocks usually possess angular outlines. Some specimens are quite soft and plastic, while others of a harder nature are brittle. In large specimens the external portions are noticeably harder than those centrally situated. Large pieces are traversed by irregular cracks, due to the contraction consequent upon the loss of the more volatile constituents. To this gradual loss of material by volatilization the disintegration into angular fragments is due. Small specimens are often found with their outlines almost completely rounded by attrition on the beaches.

Several samples were submitted to the Government Analyst, who has described the results of his examination and anaylsis thus :

> " *Black Bitumen.*—The bitumen varied in consistency from a soft " pasty semi-solid to a brittle solid having a conchoidal fracture. " The specific gravity of different portions of bitumen were found to " be 1·0041 for the soft pasty portions, 1·017, 1·018, 1·035, 1·036, and " 1·040 for the harder and more brittle parts. The softer parts gave " off a volatile substance similar in smell to gasolene. A piece of " medium density was distilled and yielded 0·6 per cent. of a benzine " product and 11·7 per cent. of an oil of the consistency of kerosene. " The bitumen readily dissolved in chloroform, carbon tetrachloride, " carbon bisulphide, benzene, and xylol. It was less soluble in ether " and petroleum ether. It was not soluble in alcohol, and was not " attacked by dilute hydrochloric acid nor by dilute ammonia. It " was acted on to some extent by strong hot sulphuric acid. It " burned with a smoky flame and gave off an odor similar to that " given by kerosene or mineral oil. In my opinion this bitumen is a " petroleum product."

The specimen from which the lowest specific gravity was recorded in these tests is one recently found at the mouth of the Hog Bay (or Wilson) River, on the southern coast of Kangaroo Island.

Other samples from various portions of the South Australian coast have been examined by Mr. W. S. Chapman, Analyst and Assayer to the School of Mines, who has found the specific gravities to be respectively 1·049, 1·066, and 1·075.

The specific gravity of sea water is, in the Southern Ocean off the coast of South Australia, about 1·0285, according to recent determinations.

Hence it is obvious that the freshest bitumen, before the volatile ingredients have disappeared, is capable of floating on sea water.

Along the whole of the southern coast line of Australia specimens of varying size have from time to time been found. The largest pieces recently discovered were cast up on the southern beaches of Kangaroo Island, which exist at a point about three miles east of Nobby Island and at the mouth of the Hog Bay (or Wilson) River. Other large blocks are reported to have become stranded at West Bay on the western coast, and also at the mouth of Middle River on the northern coast of Kangaroo Island.

The mass of asphaltum discovered many years ago on the western coast of Eyre's Peninsula by Mr. Burns must be taken into account together with the Kangaroo Island discoveries, as also must the very numerous other specimens picked up at various times on the southern coast of the continent.

From the beaches between Cape Otway and Cape Leeuwin specimens of asphaltum have been obtained, and a few discoveries have been made beyond these limits. The writer has personally examined a specimen from Bunbury, on the western coast of Western Australia, and fragments are reported to have been found along this coast as far to the northward as Mandurah, near Fremantle*. They are also occasionally found on the western coast of King Island and other islands in Bass' Strait, and on the north-western coast of Tasmania.

No satisfactory evidence of any other mode of occurrence than that of the stranded blocks on the beaches can be furnished at any locality yet known. There are other occurrences reported, but none has received confirmation by any scientific observer.

It is doubtless true that small fragments have been picked up at various points inland from the beaches, but these appear to have been carried to the places where they have been found by human agency. It does not appear possible, when the purity of the asphaltum is taken into consideration, that the source of the fragments is located within a formation consisting principally of unconsolidated sand.

Various accounts have been given of the existence of asphaltic springs, both near Mount Greenly on the western coast of Eyre's Peninsula and on the southern shores of Kangaroo Island. No such occurrence can at the present time be located, in spite of the fact that the importance of any such phenomenon is now duly appreciated by many residents of the districts concerned. The old residents of Kangaroo Island and Eyre's Peninsula, who are responsible for these statements, are undoubtedly honestly convinced that their interpretation of the facts of occurrence is correct ; but their failure

* Mr. A. Gibb Maitland, Government Geologist of Western Australia, in a recent communication to the writer has kindly furnished the news of this reported discovery.

to convince scientific observers of the genuine character of their claims and the geological features presented by the localities at which these discoveries are said to have been made are more than sufficient to discount the value of the statements made. Two such localities were visited by the writer. That on Kangaroo Island is situated at a distance of a mile and a half to the westward of the mouth of the Hog Bay River. At this place the bed rock outcropping on the shore is an exceedingly dense dark-colored quartzite, and above this foundation are 70ft. to 100ft. of calcareous sand in a state of semicoherent aggregation. A bore has been drilled through these beds of sand, but no information other than that afforded by the cliff sections in the vicinity has been obtained. It is claimed now that the bore was a failure because it stopped at bedrock. The texture of the latter is by no means such that it might be regarded as a possible reservoir of petroleum. The outcrop on the shore has long been wave-beaten and the joint planes have weathered superficially into defined crevices. It seems reasonable to infer that the idea of a supposed asphaltic spring arose from the discovery of a stranded mass of asphaltum which, under the influence of a hot sun at low water, became plastic and gradually adapted itself to the form of a crevice. Such a mass might then appear to be " oozing out of the rock " instead of into it, as would really be the case.

The case of the reported spring on the western coast of Eyre's Peninsula is almost entirely parallel. There the actual spot cannot now be exactly identified, at which the spring is said to have been seen 40 years ago. But the whole shore line is occupied by dense-grained Pre-Cambrian pegmatites and various gneisses and schists resulting from the contact metamorphic effects of the pegmatitic intrusions. These rocks are not suitable for the storage of petroleum. Sand and very loosely aggregated sandstone overlie them, and certainly do not appear to have constituted the formation in which pure asphaltum, free from included sand grains, could be discovered *in situ*.

It thus appears that the discoveries of asphaltum that have been made are referable either directly or indirectly to masses of this material which have become stranded on the shores of southern Australia. While the facts here recorded are not inconsistent with a distribution by the agency of the oceanic currents, it is quite impossible to indicate with any pretension to accuracy the exact source whence the bitumen has drifted.

(ii.) Coorongite.

Appreciable quantities of the rubber-like material known as " coorongite " have recently been found on the western shores of Murray's Lagoon, on Kangaroo Island. The essential identity of this substance with the coorongite of the mainland has been established by the Government Analyst, who has carried out researches on the substance.

Interest in this substance has at different times been very considerable on account of the view expressed by many persons that it is a sign of petroleum deposits below the spots at which it is found. In fact, the coorongite has often been popularly referred to as " solidified oil-cake," as if it were definitely proved to be an inspissation product of petroleum.

Ever since its discovery in the middle of the last century no small amount of scientific interest has been centred in the chemical characters and probable origin of coorongite. A summary of the work of research is here given for the information of those who are interested in the question.

An official investigation was made by the Government Analyst, Mr. W. A. Hargreaves, in June, 1903, of a sample of coorongite from the Coorong, forwarded to him by the Government Geologist for analysis. The Government Analyst furnished the following report :—

"The sample consisted of a dark substance resembling indiarubber, "vegetable fibre, and sand. The vegetable fibre was intimately "associated with the rubbery substance, and presented the appearance "of having either grown through the pre-existing rubber or of having "been surrounded by the rubber when in a more or less fluid condition. "The substance is dark-brown or black in color, burns readily with a "luminous, smoky flame, melts before the flame, and gives off a "characteristic odour which does not in any way suggest petroleum.

"A portion of the sample was submitted to dry distillation in a "copper retort. At a temperature of 170°C. the substance "cracked," "and a distillate was obtained under gradually rising temperature. "The first portion obtained between 170°C. and 250°C. was a dark "liquid oil, and the second, distilling between 250°C. and 350°C. "was a semi-solid oil. The first portion was again distilled in a "glass retort, and yielded a series of oils ranging from a volatile oil "like mineral naphtha obtained at 70°C. to 100°C. to a semi-solid oil "distilling between 300°C. and 310°C. The fractions obtained between "70°C. and 150°C. formed a clear solution with alcoholic potash, "which turned to a milky emulsion with water, with the ultimate "separation of the oil. The fractions distilling between 150°C. and "300°C. were mixed and treated with strong sulphuric acid, with the "object of separating kerosene. Some action, however, took place, "a little sulphurous acid was evolved, and on adding water an emulsion "was formed which required two days to settle out. The oil was there-"fore not kerosene, nor allied to it in character. The portion of the "original distillate obtained between 310°C. and 360°C. was a semi-"solid oil, somewhat like impure vaselene. This was treated with "alcoholic potash, with the following results :—

"Unsaponifiable oil	93·67
"Saponifiable matter	3·62
"Other substances	2·71
	"100·00

"The bromine absorption of the 'unsaponifiable oil' was found to "be approximately 50grms. of bromine per 100grms. of the oil.

"The remainder of the sample sent for analysis was freed from "adhering sand and vegetable fibre as far as possible, and submitted "to analysis with the results shown—

"Moisture and substances volatile at 120°C.	0·8
"Gaseous substances given off in distillation and "small quantity of an aqueous distillate having "an acid reaction	14·0
"Oily distillate	69·2
"Tarry matter and coke (less the mineral matter)	10·1
"Mineral matter (chiefly sand)	5·9
	"100·0

"The 'oily distillate' was redistilled and gave a series of oils of "varying densities from thin mobile oil to semi-solid thick oil, in the "following fractions :—

"(1) 110°C. to 170°C.	6·3	per cent.	by volume.
"(2) 170°C. to 240°C.	27·3	"	"
"(3) 240°C. to 295°C.	25·1	"	"
"(4) 295°C. to 300°C.	27·3	"	"
"(5) Residue and loss	14·0	"	"
	"100·0		

"A number of qualitative tests were made on the several fractions "with the object of determining the nature of the substance, for "example the bromine absorptions and the action of sulphuric acid "were examined. The whole quantity of coorongite submitted for "analysis was too small to permit of the isolation of a large enough "quantity of the separate fractions for thorough examination. The "substance is of such a highly complex nature, as will be evident "from the details furnished above, that a complete examination of it "would occupy a long time, and so be a costly undertaking."

These tests by the Government Analyst are supplementary to others previously made. A paper* by Mr. J. R. Jackson, written in 1872, contains a reference to an analysis of coorongite by Dr. A. J. Bernays, who found it to contain—

Moisture	0·4682
Carbon	64·73
Hydrogen	11·63
Ash	1·79
Fixed carbon	1·005
Oxygen and unestimated	20·3768
	100·0000

On October 9th, 1902, a paper† was read before the Royal Society of Victoria by Mr. Alex. C. Cumming, in which a detailed account of chemical research into the nature of coorongite is set forth. Mr. Cumming found that the material supplied to him was separable into two portions, the one soluble and the other insoluble in carbon bisulphide. The sample tested yielded nearly 24 per cent. of the soluble constituent, and the residue was found to contain from 30 to 40 per cent. of sand and other mineral matter.

The soluble constituent is a clear, yellow, translucent, wax-like solid softening at 35° and quite fluid at 42°. It dissolves readily, in all proportions, in benzine, ether, toluene, chloroform, and carbon bisulphide ; and is insoluble in water, methyl alcohol, and ethyl alcohol. It oxidises readily.

The insoluble constituent resembles cork filings mixed with much sand. Practically all elasticity is lost during the carbon bisulphide treatment. The product is combustible, burning with a white luminous flame and melting before the flame, emitting the same odour, like that of a burning fat, which coorongite itself gives. This constituent, unlike the soluble one, was found to be saponifiable by hot alcoholic caustic potash, a soluble soap being obtained which yielded an insoluble fatty body on treatment with acid.

* Pharmaceutical Journal, 1872, p.p. 763 and 785.

† *Vide* Alex. C. Cumming, "Coorongite, a South Australian Elaterite." Proc. Roy. Soc. Victoria, vol. XV. (new series), part ii., p.p. 134-140.

Some experimental work carried out by Mr. Cumming tends to show that the constituent insoluble in carbon bisulphide may be derived from the soluble one by a natural change involving hydration and oxidation combined. The final conclusion arrived at by Mr. Cumming is that the chemical constitution of the constituents of coorongite favor the idea that it is really related to caoutchouc.

A sample of the coorongite from the north-western shore of Murray's Lagoon, Kangaroo Island, recently collected by the writer was submitted to Mr. Hargreaves, Government Analyst, who reported at follows :—

> "This material was found to be like the rubbery substance found "on the Coorong, and known as coorongite. It was similar in character "to the coorongite reported on by me on July 3rd, 1903. The material "when distilled yielded 10 per cent. of a distillate, consisting chiefly "of water having an acid reaction and a smell of pyroligneous acid, "and 15 per cent. of an oil. The oil was readily attacked by sulphuric "acid, and therefore does not contain paraffin. The coorongite "was not dissolved by chloroform, carbon bisulphide, ether, petroleum "ether, or oil of turpentine, but it was slightly attacked by acetic "anhydride. This evidence is unfavorable to the idea entertained "by some people that coorongite is a petroleum product."

It is to be noted that the sample submitted was externally charred by bush fires, and this fact may account for the insolubility of the substance in carbon bisulphide. In fact, it may be that the constituent soluble in carbon bisulphide has been altered by natural processes into the insoluble constituent, as indicated by the experiments of Mr. Cumming.

The mode of occurrence of the coorongite recently found on Kangaroo Island is identical with that which was discovered many years ago in the vicinity of Salt Creek, a small stream which flows into the Coorong, a narrow coastal lake which extends for a distance of 90 miles in a south-easterly direction from the mouth of the Murray River, and which is separated from Encounter Bay only by a narrow sand-spit, known as Younghusband Peninsula.

The material seen by the writer on Kangaroo Island occurs as a scum left behind at flood-level on the north-western shore of Murray's Lagoon, which is a large shallow lake subject to seasonal variations of level. It is intimately associated with all manner of vegetable debris and has apparently accumulated on the lee shore under the influence of strong winds. The coorongite at this place was found through its combustibility ; for a bush fire kindled by one of the residents continued to burn round the shore of the lagoon long after it had become extinguished in places where the coorongite does not exist.

The mode of occurrence on the mainland near the Coorong is in essential respects the same*.

It therefore appears that the coorongite deposits are of recent date and that they are formed on the surface by processes still in operation at the present time.

Any theory as to the origin of coorongite must needs take into account the mode of occurrence and the intimate association with vegetable matter. Freshwater diatoms have been recognised in it by the Rev. E. O'Meara† and by Mr. D. J. Mahony‡.

---

* *Vide* W. T. Thiselton Dyer, B.Sc., F.L.S., "On a Substance known as Australian Caoutchouc." Journal of Botany, 1872, p.p. 103, 104.

† *Vide* E. O'Meara, "The diatoms in the Australian Caoutchouc." Quart. Journ. Microscop. Science, vol. XIII. (new series), p. 211.

‡ *Vide* Alex. C. Cumming, op. cit. supra, p. 139.

Mr. A. C. Cumming failed to find any phosphoric acid in the samples which he analysed. But Mr. Hargreaves, Government Analyst of South Australia, found traces of phosphoric acid in the sample submitted to him in June, 1903, remarking at that time that "this might be accounted for by the "vegetable matter that is associated with the rubber in the sample."

Very discordant opinions have been expressed as to the origin of coorongite, and it appears doubtful whether any finality will be attained without a considerable amount of research. The writer would suggest, in view of what has been said above with respect to the apparent alteration by oxidation of portion of the substance of coorongite, that an effort be made to secure the freshest possible samples for investigation, and that this material be submitted to searching chemical and microscopical examination.

Observations should be made of the dates at which accumulations of the material take place§.

On the basis of existing knowledge it is impossible to state that any genetic connection between coorongite and petroleum has been proved, although some of the distillation products from each may be identical. That is to say, although by heating coorongite volatile substances similar to those derived from petroleum may be produced, it does not follow that coorongite is itself a derivative of petroleum.

Dealing with the question of origin in his report of 1903, the Government Analyst, Mr. W. A. Hargreaves, stated—

> "The substances we obtained by the destructive distillation of "coorongite present the characters of hydrocarbon or mineral oils, "having a peculiar odour somewhat like shale or peat products. The "acid reaction of the watery distillate indicates an origin from peat "lignite or other vegetable matter. The bromine absorptions distin- "guish the oils from those derived from American petroleum, and show "an analogy with oils from peat or shale. From the foregoing it will "be evident that the subject is a complex one and does not permit of "a ready solution. Sufficient information is not yet available to "determine the exact nature of coorongite. The conclusions I draw "are that coorongite is apparently a more or less oxidised product of "some pre-existing hydrocarbon, but whether this is derived from "petroleum or not is still an open question, though the balance of "evidence so far is against this view."

It has been suggested that coorongite might serve for the same purposes as those for which rubber is used, and experiments have shown that a mixture of coorongite with rubber may be readily vulcanized. But the supply of coorongite is not sufficiently large to render it of commercial value for such purposes. The deposits on both the mainland and Kangaroo Island are, as far as known, quite superficial, and there would be considerable difficulty in collecting a few tons of the material from both sources.

The following is a bibliography of coorongite which, though probably far from complete, may be of use when further researches are being undertaken :—

1862. Phipson, T. L. Geologist, vol. v., p. 141.
1866. "The Register," Adelaide, May 8th.
1866–7. Ulrich, G. H. F. Official Record of Intercolonial Exhibition, p.p. 91 and 168.
1869. "The Observer," Adelaide, July 3rd.
1871. "The Observer," Adelaide, April 17th, September 1st and 20th.

§ A paragraph was printed in *The Advertiser*, Adelaide, on October 5th, 1912, stating that a 'scum' recently appeared on Murray's Lagoon, Kangaroo Island, near the site of the recent discovery of coorongite. (The nature of this scum is not known.—L.K.W.

1872. "Journal of Botany," p.p. 103–106, 338–339.
"The Pharmaceutical Journal and Transactions," p.p. 763 and 785.
"Baird's Annual Record of Science and Industry," p. 134.
"Der Naturforscher," V. No. 23, p. 186.
(?) "Quarterly Journal of Microscopical Science." Vol. XIII., New Series, p. 211.
1874. "The S.A. Chronicle and Weekly Mail," February 21st.
1877. Morris, G. C. Proc. Acad. Nat. Sciences, Philadelphia, p. 131.
1889. David, T. W. E. Proc. Linnaean Soc. N.S.W. Vol. IV., Series 2nd, p.p. 491–494.
1899. Transac. Roy. Soc. S.A. Vol. XXIII., Part II., p. 295.
1902. "The Argus," Melbourne, June 23rd.
Cumming, Alex. C. Proc. Roy. Soc. Vic. Vol. XV. (New Series), Part ii., p.p. 134–140.
1903. "The Age," Melbourne, July 27th.
Memoirs Geol. Surv. N.S.W., No. 3, p. 109.
1908. "Record of the Mines of South Australia," p.p. 350, 351.

(iii.) Fœtid Limestone.

During the visit of the writer to Kangaroo Island an extensive development of an odouriferous limestone was discovered round the south-eastern shore of Murray's Lagoon and extending back from the lake for some distance. The limestone with which the fœtid smell is associated is of Recent age, as has been definitely determined by the remains of *Coxiella badgerensis* in it. The peculiar odour attracted no small amount of attention from those interested in the question of petroleum indications. Samples were taken by the writer and submitted to the Government Analyst, who reported—

> "The sample was of a creamy-white color in the mass with dark-
> "colored superficial patches. When freshly broken the limestone
> "gave off a peculiar odour which was more pronounced in the dark
> "parts. The sample, when treated with hydrochloric acid, gave off
> "a small quantity of sulphuretted hydrogen. The rock was found to
> "contain a small quantity of nitrogenous matter equivalent to 0·05
> "per cent. of nitrogen. No petroleum extract was obtained by treating
> "the rock with chloroform. When submitted to dry distillation
> "it gave 3·9 per cent. of distillate consisting chiefly of water having an
> "alkaline reaction, and a minute quantity of an oily substance, which
> "had a peculiar ammoniacal odour. When distilled with steam
> "no oily substance whatever was obtained. I found nothing in
> "connection with this limestone that suggested petroleum. The
> "organic matter in the rock is, in my opinion, of vegetable or animal
> "origin."

The occurrence of a fœtid limestone is not uncommon and it is not to be regarded as a phenomenon to which great importance should be attached in the search for petroleum. It is true that sulphuretted hydrogen is given off from some oil deposits*, but this gas is more often produced by the decomposition of organic matter.

In the case under discussion the odour is almost wholly restricted to the superficial crust of the limestone, which crust is usually of a grey or brownish color. The amount of gas present is not great, and the samples submitted to the Government Analyst for examination contained the odouriferous portions chipped from the face of the outcrops. It should be noted that there is not known to be any gas-spring, but that the gas observed is occluded in the limestone and set free only when the surface is broken.

---

* *Vide* E. H. Cunningham Craig, "Oil Finding," 1912, p. 108.

The area in which the fœtid limestone has been found is in part submerged beneath the waters of Murray's Lagoon in wet seasons, but a similar odour is emitted by some of the limestone which stands above the level of the flood waters. It is probable that the fœtid limestone extends beyond the limits which are shown on the sketch map accompanying this report.

The odour appears to the writer to be due to the absorption of the gases arising from decomposing vegetable matter either embedded in the rock or resting upon it.

(iv.) Dark-colored Limestone.

At a number of places along the coast line in both of the areas with which this bulletin deals there are to be found subangular pieces of black or brown limestone embedded in a cement of white or cream-colored carbonate of lime. The dark portions of the limestone weather more slowly than the matrix and stand out in relief upon the weathered surfaces of the rock, many of them possessing a smooth shining surface.

Fragments of this dark-colored limestone were collected on Kangaroo Island from various points between Vivonne Bay and the Hog Bay River, and were submitted for chemical examination to the Government Analyst, who reported as follows :—

> "This limestone contained carbonate of lime, sulphides, some "iron and little more than traces of carbonaceous matter. The "carbonaceous matter was not attacked by hydrochloric acid, sul- "phuric acid, aqua regia or ammonia. It was not soluble in chloro- "form, but was destroyed by ignition. It yielded carbon dioxide "when strongly heated with copper oxide. It is not bitumen, and, "in my opinion, it is not a petroleum product."

These chemical results entirely confirm the tests previously recorded by Mr. W. Howchin†, and fail to support the contention that the dark limestone owes its color to bituminous material.

(v.) Kerosene Shale.

A large block of the so-called "kerosene shale," identical in appearance with that which has been worked at various places in New South Wales, was recently found on a beach near The Frenchman, Eyre's Peninsula.

Another block of this material was brought to the office of the Geological Survey of South Australia earlier in the year 1912, having been found on the shore at the head of the Bight.

This "kerosene shale" in many characteristics and in mode of occurrence resembles cannel coal‡, and is not associated with petroleum deposits§. Hitherto no such material has been discovered *in situ* in South Australia, nor have there been found rocks of Permo-carboniferous age similar to those constituting the portion of the coal measures in which kerosene shale is found in New South Wales.

These facts, when considered together with the mode of occurrence of the recently found block of shale, do not suggest that such a discovery is of any value as an indication of subterranean supplies of mineral oil on Eyre's Peninsula. On the other hand it is known that much of the high-grade shale has been exported from New South Wales, and it is not unreasonable to suppose that the stranded blocks picked up on the South Australian coast were jettisoned from vessels freighted with kerosene shale.

---

† Transac. Roy. Soc. S.A., vol. XXVII., part i., p. 87.

‡ Memoirs of the Geol. Surv. of N.S.W., No. 3. "The Kerosene Shale Deposits of New South Wales," by J. E. Carne, F.G.S.

§ Ibidem, p.p. 102-106.

(vi.) Various Other Materials.

(*a*) On the eve of the writer's departure from Kangaroo Island a small quantity of granular material, having a brownish-purple color, was given to him. It was obtained among Brecknell's Sandhills, which lie to the south of Murray's Lagoon. The substance was examined by the Government Analyst, who reported—

> "This material was easily crushed between the fingers to a loose "sand, consisting of quartz, carbonate of lime, and carbonaceous "particles. The material gave off a small quantity of sulphuretted "hydrogen when treated with acids. The carbonaceous matter "was slightly attacked by acid, was insoluble in chloroform and "could be easily burnt. It was attacked by dilute ammonia and "was charred by cold strong sulphuric acid. It is, therefore, not "bitumen, and it does not suggest a petroleum product. It is probably "of vegetable origin."

The mode of occurrence of the substance is unknown to the writer. From the same place some small fragments of a black material possessing a low density were obtained. These also were tested and found to consist of charcoal.

(*b*) A brownish substance, with the appearance of a resin, found on the beach in Pennington Bay was also tested by the Government Analyst, whose report states—

> "This substance consisted of rounded light-colored granular particles "in a waxy matrix. It had a specific gravity less than 1·000, and it "floated on water. It was almost wholly soluble in hot rectified spirit. "It burnt readily, melting before the flame to a dark waxy substance. "It yielded practically no ash, and, therefore, contains no mineral "matter. It was readily soluble in ether, benzene, chloroform, carbon "tetrachloride, carbon bisulphide, and more slowly in oil of turpentine. "It was only partly soluble in petroleum ether. When distilled a "small quantity of water having an acid reaction was obtained and "an oil with a terpene-like odour.
>
> "When treated with hot alcoholic potash 90 per cent. of it remained "unattacked. This matter was of a yellow color, very sticky and "resinous in character, and dissolved completely in cold rectified "spirit. It also dissolved in acetic anhydride and gave a reaction "with concentrated sulphuric acid similar to that of an oleo-resin. "The part of the material attacked by the alcoholic potash amounted "to 4 per cent. and gave a 'saponification value' to the whole material "of 21. It was a dark brittle resinous substance, readily soluble in "cold alcohol and had an acid reaction.
>
> "From the foregoing reactions it appears that this substance is "not a petroleum product but is of a resinous character."

Water-worn fragments of resin are widely distributed along the western beaches of Eyre's Peninsula, and have in some cases been confused by local residents with paraffin. Resins do not originate from deposits of mineral oil.

(*c*) It has been stated on more than one occasion that ozokerite has been found on the shores of both Kangaroo Island and the Great Australian Bight. A supposed specimen from the latter locality was tested by the Government Analyst and found to consist of beeswax. No official record of an authentic discovery of ozokerite can be traced.

VI. THE ORIGIN AND MODE OF OCCURRENCE OF PETROLEUM AND ASPHALTUM.

Much controversy has taken place over the origin of petroleum and asphaltum, and it must be confessed that no finality has been attained. The question of origin is of no little interest in the present connection when a conclusion is to be arrived at as to what rocks may be regarded as possible reservoirs of petroleum.

The various theories which have been proposed to account for the generation of the natural hydrocarbons are to be classified as :

I. Theories of inorganic origin.
II. Theories of organic origin.

It is not intended to enter in detail into the discussion of this very complicated question which has exercised the minds of geologists and chemists for very many years. A summary only is given of the essential tenets of the rival theories and references to recent literature on the subject are added.

I. Those geologists and chemists who ascribe an inorganic origin to petroleum hold the opinion that it is generated by the chemical interaction of certain constituents of the earth's mass*. Experimental work has proved that gaseous liquid and solid hydrocarbons may be generated by the reaction of various metallic carbides with water. Hydrocarbons have been recognised among volcanic emanations, and a few occurrences of solid hydrocarbons appear to have originated without organic intervention.

II. On the other hand there are many who hold the view that petroleum is derived from animal or vegetable remains by some process of destructive distillation or of bacterial action†.

In support of both hypotheses much experimental proof has been afforded and it appears probable that the hydrocarbon compounds are produced by both organic and inorganic agencies.

A matter of much greater value in the discussion of what rocks are and what rocks are not favorable for the occurrence of accumulations of petroleum is texture. Whatever may be the origin of the oil it is essential that the texture of the rocks must be favorable in order that appreciable amounts of oil may be stored in them. The commercial supplies of petroleum are almost invariably derived from the sedimentary rocks.

It is now a well-established fact that petroleum has a wide range, both in space and in time. Traces of the gaseous, liquid, and solid hydrocarbons are extremely widespread throughout the earth, although the concentrations of such materials which alone can be regarded as the commercial sources of petroleum are not abundant.

Petroleum has been won from sedimentary rocks of all ages from the Ordovician to the Recent, and it appears that between these observed limits of time the age of the sediments which may serve as reservoirs of petroleum is immaterial. If the inorganic origin of some petroleum deposits be granted it follows that the age of the reservoir rocks is not a matter of importance. Whatever may be the origin of petroleum it certainly follows that the mere fact of the discovery of sediments of a certain age is in itself of no great

* *Vide* Sir Boverton Redwood. "Petroleum and its Products," 1906, vol. I., p.p. 252-254 ; Transactions Inst. Min. & Met., 1911-1912, vol. XXI., p.p. 91-192 ; Geol. Surv. U.S.A. Bulletin 401, and Bulletin 491, p.p. 693-696 ; Proc. Roy. Soc. Queensland, 1912, vol. XXIII., part ii., p.p. 131-137 ; Geol. Surv. Tasmania Bulletin 8, p.p. 94-95.

† Sir Boverton Redwood. "Petroleum and its Products," 1906, vol. I., p.p. 254-261 ; Transactions Inst. Min. & Met., 1911-1912, vol. XXI., p.p. 91-192 ; Geol. Surv. U.S.A. Bulletin 491, p.p. 696-704 ; Geol. Surv. Ohio, Fourth Series, Bulletin 1, p.p. 311-318 ; E. H. Cunningham Craig, "Oil Finding," p.p. 1-24.

significance in the absence of a productive field in the close neighborhood. For in North America alone the productive horizons range between the Ordovician (as in Ohio and Indiana) and the Tertiary (as in California and Texas).

The greater proportion of the petroleum produced in the world at the present time is won from the Tertiary rocks, but the most productive fields in the United States derive the oil from the Palæozoic rocks. From these briefly stated facts it is clear that it is not sufficient to determine the age of the sedimentary rocks to decide whether a supply of petroleum may or may not be anticipated.

The actual rocks in which petroleum is found are almost invariably either sands, sandstones, conglomerates, or limestones, since these rocks alone possess the porosity which is demanded of a natural reservoir.

The gas and oil cannot accumulate and be stored in such a reservoir unless the structural conditions prevent their escape from the petroliferous beds. Thus the majority of the productive oil horizons are found to be sealed by a cover of impervious rocks. Both gas and oil are lighter than water and hence they lie above it in the porous reservoir rock. When a folding of the strata containing the gas and oil takes place, the water sinks into the troughs of the folds, while the gas and oil accumulate in the crests or anticlines. The anticlinal structure is not an absolutely essential condition for the occurrence of valuable oil pools, but it is an exceedingly common one in the productive fields of all parts of the world. In a few localities there are known* to be accumulations of oil under pressure in tilted sediments, which have been prevented from escape by the faulting of the strata, or by the clogging of the pores in the oil-bearing rock at its outcrop with the asphaltic products of inspissation, or by the gradual thinning out of an oil-bearing sandstone.

When thus sealed within these porous rocks the gas and oil in many cases accumulate under a pressure which is sufficient to expel them to the surface through any natural or artificial opening that may be made. The pressure is due to the accumulation of gas or to the column of water associated with the oil and gas, or to both.

Recent researches† tend to show that there is probably some relationship between the distribution of petroleum fields and the major tectonic lines of oil-bearing continents. But this fact lends no support to the hope of discovery of oil on Kangaroo Island, which is, as mentioned above, geologically considered, a fragment of the Australian continent and tectonically related to a region which is not known to contain deposits of petroleum. The same general statement is of application to Eyre's Peninsula.

It has recently been claimed by Dr. G. F. Becker‡ that there is a remarkable coincidence, at least within the confines of the United States of America, between the areas of marked irregularities in the compass declinations and the principal petroleum fields. No isogonic lines can yet be plotted for the State of South Australia on account of the lack of sufficient data, and it is, therefore, not yet possible to state whether signs of local magnetic disturbances are noticeable in the districts with which this bulletin deals.

Asphaltum, bitumen, manjak, or mineral pitch is formed naturally by the alteration of asphaltic petroleum. In fact there is no defined distinction between liquid petroleum and solid asphaltum since numerous substances of intermediate composition exist. The differences which exist between

---

* *Vide* A. Beeby Thompson. "The Relationship of Structure and Petrology to the Occurrence of Petroleum." Transac. Inst. Min. & Met. 1910-1911, vol. XX., p.p. 215-237.

† *Vide* A. M. Finlayson. Transac. Inst. Min. & Met., 1911-1912, vol. XXI., p.p. 168-169.

‡ Geol. Surv. U.S.A. Bulletin 401.

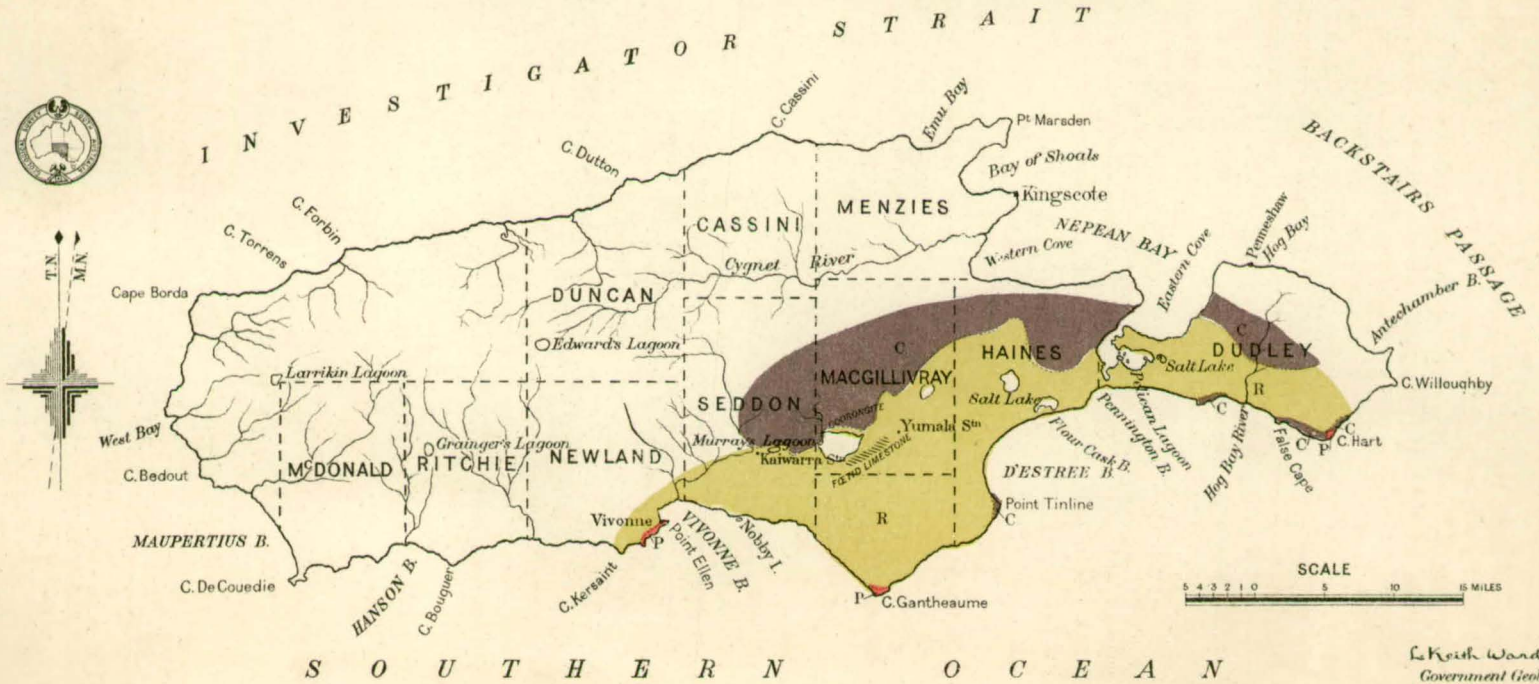
Quæ contra vide W. A. Tarr. Economic Geology, vol. VII., No. 7, 1912, pp. 647—661.

Plate I

GEOLOGICAL SKETCH MAP

OF PORTION OF

KANGAROO ISLAND



L. Keith Ward.
Government Geologist.
3/2/1913.

Calcareous sand, Travertine and Marl.	? Upper-Tertiary to Recent.	R	Slate and Quartzite.	Pre-Cambrian to Cambrian.	C	Pegmatite, with associated Schists and Gneiss.	? Pre-Cambrian.	P

A. VAUGHAN, GOVERNMENT PHOTOLITHOGRAPHER, ADELAIDE.

these varieties depend upon the chemical composition and the relative abundance of the more volatile constituents.

The varieties which approach most nearly to the liquid state are found filling the interstitial pores in sands, sandstones, or limestones. The more solid varieties are found as exudations from such rocks, or filling crevices which traverse the rocks either between or across the bedding-planes§.

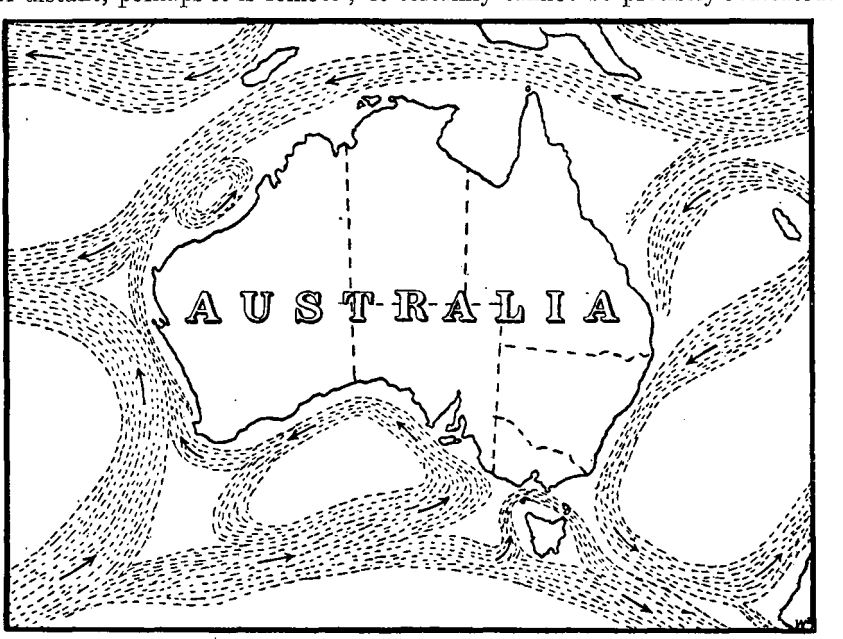
Those occurrences of bituminous material which have been recorded in schistose or igneous rocks are not of commercial importance.

The asphaltum found in both the districts of which this bulletin treats is of remarkable purity and appears to have been derived from some vein of the material. But it is quite impossible in the present state of our knowledge to state where such a vein occurs. It appears only that the unlocated outcrop is submarine, for the reason that the asphaltum is found on the sea beaches.

VII. CONCLUSION.

Of the various discoveries that have been made none is of such a character as to indicate the probable existence of any commercial concentration of any oil-bearing material on either Kangaroo Island or Eyre's Peninsula.

It has been indicated in this report that the asphaltum to which great importance has been attached by the discoveries is cast up on the beaches, and that it is also found widely scattered along the southern coast of Australia. It has been shown also that the freshest material available for examination has such a density that it will float readily in sea water, and that variations in density occur in a single specimen. The writer is therefore of the opinion that this asphaltum has been borne on the oceanic currents from some unknown source to the beaches on which it is picked up. Perhaps this source is not far distant, perhaps it is remote ; it certainly cannot be precisely indicated.



The accompanying map shows at a glance the distribution and trend of the principal currents. The main current of the Southern Ocean follows,

§ Geol. Surv. U.S.A. Mineral Resources of the United States, 1908, part II., Non-metallic Products, p. 708 ; and Twenty-second Ann. Report, 1900, 1901, part I., p.p. 219-452.

as far as known, the fortieth parallel of latitude on an easterly course to a point south of South Australia and there splits. One branch flows northwards and then westwards, forming a large eddy in the Great Australian Bight. Another branch passes through Bass' Strait in an easterly direction.

But the course of these currents, which may well explain the distribution of the asphaltum, is not sufficient to indicate the source of the asphaltum, since no known petroliferous areas can be regarded as the certain contributors of such material to the well-recognised currents.

Whatever may be the actual source of the bitumen it appears to the writer from the evidence now available to be beyond the limits of Kangaroo Island and Eyre's Peninsula. No trace of any rock impregnated with similar material has yet been discovered in either of these portions of the State, nor has any reported discovery of a vein of asphaltum *in situ* been confirmed by any competent authority.

The substance known as " coorongite " certainly is indigenous to Kangaroo Island. But though its exact mode of origin is not yet ascertained, its chemical composition at least suggests, if it does not actually prove, a derivation from vegetable matter. It has at least been proved that a considerable proportion of the ingredients of coorongite exhibit characters that no petroleum products possess. The occurrence of coorongite on Kangaroo Island resembles that of the similar material on the mainland where no successful results have attended prospecting operations for oil.

The fœtid limestone of the shore of Murray's Lagoon and vicinity owes its odour principally to sulphuretted hydrogen and contains only traces of organic matter, but no trace of petroleum or its derivatives has been detected in it after adequate examination. The odour is due, in the opinion of the writer, only to decomposing vegetable (or animal) material absorbed into the mass of a porous rock.

The other substances mentioned above do not call for further separate mention and discussion.

The geological structure of the south-eastern part of Kangaroo Island does not appear to be favorable to the accumulation of valuable concentrations of petroleum. The surface sand, sandstone, and limestone occupy a marginal strip which is continuous along the southern coast between Vivonne Bay and the Hog Bay River. The Cambrian or Pre-Cambrian slate quartzite and granite outcrop at sea-level at various points along this part of the coast; and between such outcrops the greatest depths of overlying sediments are likely to be found.

The structure of the western coast of Eyre's Peninsula is similar.

It has been indicated above that traces of petroleum or bitumen are to be found in many sedimentary rocks, but that concentrations which are brought about only when structural conditions are favorable are rare. The texture and disposition of the rocks which occur in the areas under examination are not, in the opinion of the writer, favorable. The bed rocks seen in both districts are so dense in character that no considerable quantity of petroleum can be expected to be found impregnating their mass. The porous sedimentary covering lying upon the bed rocks is capable, as far as texture is concerned, of impregnation, but does not appear to be capable of retaining any supplies of petroleum that might be introduced. There is a free outlet to the sea in both districts, and the shallow porous sediments rest upon a shelf of impervious rocks which has a seaward slope.

In the absence, therefore, of any satisfactory proof of the presence of either petroleum or any of its derivatives *in situ* within the areas with which this bulletin deals, and from the consideration of the geological structure it does not appear to the writer probable that any boring operations that may be undertaken will meet with success.

The least improbable localities in which discoveries might be made are those in which the greatest depths of sedimentary rocks are to be anticipated, viz., on Kangaroo Island at spots intermediate between the outcrops of the bed rocks on the southern coast. The success of such a bore would be contingent upon the co-existence, below the rocks visible at the surface, of an oil-bearing stratum and of an impervious cover structurally disposed in such a manner as to retain the oil. There is no evidence of the existence of these conditions either separately or in conjunction.

The writer is therefore unable, in the light of what is yet known with regard to the districts of which this bulletin treats, to recommend the expenditure of capital in boring for oil.

L. KEITH WARD, Government Geologist.

Adelaide, January 24th, 1913.