

1917.
—
WESTERN AUSTRALIA.

GEOLOGICAL SURVEY.

BULLETIN No. 74.

MISCELLANEOUS REPORTS.

SERIES V., Nos. 61-70.

ISSUED UNDER THE AUTHORITY OF
THE HON. R. T. ROBINSON, K.C., M.L.A., MINISTER FOR MINES.

WITH ELEVEN FIGURES AND EIGHT PLATES.



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1917.

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GEOLOGICAL SURVEY OF WESTERN AUSTRALIA.

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PREFATORY NOTE.

This volume makes the fifth addition to the series of Miscellaneous Reports which deal chiefly with the applied side of geology. The articles are, as usual, issued without being grouped, either according to localities or subjects.

The last collection of miscellaneous reports was contained in Bulletin 64.

A handwritten signature in cursive script, reading "Alib Wairland". The signature is written in dark ink and is positioned above the printed name "GOVERNMENT GEOLOGIST."

GOVERNMENT GEOLOGIST.

Geological Survey Office,
Perth, 28th March, 1917.

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MISCELLANEOUS REPORTS.

SERIES V.

61.—THE PHOSPHATIC DEPOSITS OF WESTERN AUSTRALIA.

By H. P. WOODWARD.

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INTRODUCTORY.

Phosphatic deposits occur in four forms in Western Australia, viz., guano, both live and dead, upon the coastal hills and fringing islands; ferruginous phosphatised wood and coprolite beds of the Dandarragan district; amblygonite near Coolgardie; and cave guano deposits elsewhere.

Up to the present time the only deposits worked upon a commercial scale are the Island and Coastal Guanos, but of these all the material of sufficiently high grade for the manufacture of super-phosphate has, as far as our present knowledge extends, been worked out; therefore the rock employed in the manufacture of this fertiliser at our local works has to be imported.

Up to the end of 1904 (after which year the export of guano was prohibited) 118,530 tons were raised, of which 105,754 tons, by ship's register (40 cubic feet), were shipped, the value placed upon it was £338,732, of which amount the Government received in the

way of royalty, special license fees and rent, £53,658. These figures clearly only represent a portion of the total quantity raised, since in the first place large quantities would appear to have been removed without the knowledge of the Government, and in the second, as guano raised for local consumption paid no royalty, a record was not always kept of this; while further, it will be noticed that in the returns supplied by the Customs the quantity exported is 18,268 tons less than that recorded by the Lands Department, which was responsible for issuing licenses and collecting the royalty.

What led up to the discovery of these deposits is not definitely known, but it was in all probability due to the American whalers who fished the Western Australian coast some 60 and 70 years ago; the reason for this surmise being that the earliest shipment on record went to the United States, while prior to these it was discovered that a very considerable quantity had been shipped to the same destination without the cognisance of the Government. In more recent years the bulk of the trade was with Germany and Belgium, and to a more limited extent with New Zealand, Victoria, Tasmania, and Mauritius.

The earliest official record extant of a shipment of guano is three tons in 1847, followed by further small parcels in 1855, 1865, and 1872; but no record exists of the locality from which these were obtained, while the labour involved in tracing the destination of these shipments would not be repaid by the information disclosed.

From the year 1876 onwards a pretty regular export trade appears to have been carried on, but although this guano was obtained from all the islands between the Ashmore Shoals and the Abroholos Islands, records are far from perfect. From the Ashmore Shoals, Browse Island, Jones Island (the latter being near Admiralty Gulf), and numerous other islands upon the north coast, much larger quantities of guano were probably raised than ever paid royalty, since as recently as 1885 it was reported to the Government that two ships and eight barques were seen loading at Browse Island, on which no return was furnished.

Large quantities of high-class guano must have been exported from Browse Island, as is evidenced by the fact that it is the only locality credited with deposits of this description in Western Australia in either British, American, German, or Colonial publications.

Messrs. J. and W. Bateman would appear to have chartered vessels which removed guano from the Lacepedes, Montebello, Barrow Island, etc., for a number of years prior to 1890, for they stated this fact in a letter addressed to the Government in support of their application to be granted the exclusive rights to work certain islands. No record of these, however, exists, and the present firm is now unable to furnish any particulars.

It would appear that Mr. F. L. von Bibra obtained the sole right to remove live guano from Shark's Bay, where he carried on a

considerable business between the years 1880 and 1888, when some trouble arising between him and other persons who claimed the right to remove dead guano, the Government's attention was drawn to the fact that he had not so far furnished returns of the quantity removed, since he only supplied the local market, in which case no royalty was chargeable. As he had, therefore, the monopoly to work a large area without contributing anything to the revenue in return, it was decided to renew his concession upon a rental basis. Whether the deposits were exhausted, or the rent was too heavy, does not transpire, but the working of them appears to have ceased from this date.

It may be mentioned here that the term "live" guano was applied to fresh unaltered bird droppings, whilst "dead" guano was the limestone which had become converted in part, or wholly, into tri-calcic phosphate, due to the percolation of the soluble phosphates from the bird droppings. It is a very noticeable fact that nearly all the guano raised was exported, while the small portion consumed locally would in all probability prove (could we ascertain the fact) to have consisted almost entirely of live guano.

The fine-ground rock phosphate does not appeal to the average farmer in this State owing to the fact that it is slower in its action than superphosphate, which, sown with the wheat, gives its maximum result the first year. Ground phosphate rock is, however, of great value in wet districts, hence the demand for this material in Europe, America, Victoria, Tasmania, and New Zealand, since it decomposes rapidly in a soil rich in humus or peat.

There is no doubt whatever that if ground phosphate rock or Abrolhos guano was applied in fair quantity to the wet lands situated in the south-western portion of this State it would pay the farmer better in the long run than the continual dressing with superphosphate as at present practised, for it would not only act as a fertiliser for the immediate requirements of the crop without increasing the acidity of the soil, but it would build up the land to something like a good standard grade, since at the present time there is little land under cultivation in this State which is not deficient in phosphorus.

In this connection the following facts may be of interest. The analysis of 150 soil samples made by the Government Agricultural Chemist gives an average percentage of .041 of P_2O_5 . These samples were mostly confined to the South-West, while the writer is indebted to the Mt. Lyell Chemical Company for the results of 26 soil samples which average .038 P_2O_5 . If these are compared with the recognised standard of a good soil, which is .150 of P_2O_5 , it will be seen at once how deficient in this most necessary ingredient these soils are.

As previously mentioned, so far as our knowledge goes, the bulk of the rock phosphate of a sufficiently high grade to manufacture "super" has been worked out, but still there remains a vast

quantity of lower grade material which, if ground, would be admirably suitable for application to the farming lands situated in the wetter portion of this State.

This material, in addition to the phosphoric oxide, contains a small proportion of nitrogen, which adds to its value, while the main impurity is carbonate of lime, which substance is also badly needed in the majority of our soils.

INDIVIDUAL DEPOSITS.

JONES, LESUEUR, AND STEWART ISLANDS, AND BLACK HAWK REEF.

These islands, which lie between Lat. 13deg. 42min. and 13deg. 45min. and Long. 125deg. 59min. and 127deg. 42min. are situated on the extreme north coast, appear to have been worked in the early days of the Colony, but no record exists until the year 1884, when the Government estimated the deposits to consist of 50,000 tons of guano containing 80 per cent. of tri-calcic phosphate, which, at 1s. 9d. per unit, was worth £7 per ton. Upon the strength of this an exclusive license was issued to Messrs. Beaver & Co., of Melbourne, to remove guano for a period of five years on a basis of 13s. per ton royalty. This firm removed 2,577 tons and paid £1,675 1s. royalty and then abandoned their concession, stating that since the balance contained 35 per cent. of carbonate of lime it was valueless for their purpose.

BROWSE ISLAND DEPOSIT.

This island, which is situated about 100 miles off the north coast on Lat. 14deg. and Long. 123deg. 40min., has received the credit all over the world of being a great producer of rock phosphate, consequently it is highly probable that considerable quantities were removed before the Colonial Government became cognisant of the fact, for it was not until the year 1873 that any mention of it exists in the official records. In this year negotiations were opened by an Adelaide syndicate known later as the Browse Island Guano Co., to work this deposit, but no finality was arrived at until 1876, when an agreement was entered into for a period of 10 years by which the Company should pay a yearly rent of £50 with a 2s. 6d. per ton royalty on all guano removed above 400 tons.

The Government appear to have had very great trouble in obtaining statements from the Company, as no direct supervision was exercised; they were therefore entirely dependent upon the honour of the Company, about which apparently there were some doubts, since no returns were furnished for the years 1880, 1881, 1883, and 1885, while during the last-mentioned year the master of a passing schooner reported that he had seen two ships and eight barques busily engaged loading; the return, therefore, of 23,177 tons, upon which a royalty of £3,158 was paid, is probably far below the actual amount removed.

LACEPEDES GUANO DEPOSITS.

The Lacepedes is a small group of islands situated upon the North-West Coast about 30 miles to the westward of Beagle Bay, Long. 122deg. E. and Lat. 17deg. S.

It is not known what led to the discovery of these guano deposits, but it is probably due to the whalers who at one time frequented this coast. These would probably visit the islands in order to boil blubber and obtain water and fuel supplies, so as not to be troubled with the natives on the mainland; and it is possible in the event of an unsuccessful fishing season that they would load up a cargo of guano.

Somewhere about the beginning of 1876 the Government became aware that a regular export trade of considerable dimensions was being carried on; they therefore despatched Messrs. Geddes and Roberts to the scene of action with authority to seize any ships removing guano without license.

At the time of their arrival the "Forcade la Roquette" happened to be taking in a cargo upon behalf of a Mr. Lord, an American citizen, residing in Melbourne; they therefore seized the vessel and conveyed it to Fremantle. Mr. Lord then placed the matter in the hands of the American Consul, who made a claim for compensation from the Government on the grounds that the Governor had no jurisdiction over the Lacepede Islands, as they were not included in his commission. However, after certified copies of the map attached to the Commission were forwarded to the Consul no further action was taken.¹ As the result of this experience the Government decided to appoint a resident Commissioner, in which capacity Mr. Richard Wynne was despatched. Upon his arrival his first duty was to make a detailed survey of the islands and to estimate the extent of the remaining deposits, which he put down as 60,000 tons distributed as follows:—5,000 tons on the easternmost island, 40,000 tons on the main island, and 15,000 on the westernmost island. Upon receipt of this report the Government decided to make a charge of a royalty of 10s. per ton on ship's register, calculated upon a basis of 40 cubic feet; this it was estimated would really only equal 7s. 6d. per ton.

The royalty on this basis during the first year of supervision yielded a revenue amounting to £1,242. In the following year this increased to £6,898, and would have considerably exceeded this amount had not an unforeseen disaster occurred through the visitation of a "Willy Willy" (cyclonic storm), which wrecked six vessels while engaged in loading, and caused the loss of six lives, while in the following year £9,721 was paid.

In 1878 the Government decided that it would be far more satisfactory and economical to grant a lease of the sole rights to remove the guano to one firm, who would then be able to build a

¹ Parliamentary Papers, 1876.

jetty and lay down a tram line, which would greatly facilitate the process of loading, which had up to this time been carried on by means of boats.

With this object tenders for the removal of 40,000 tons were called for on a royalty basis of not less than 10s. per ton on ship's register, while a deposit of £2,000 was to be lodged with the Government until the completion of the contract.¹

The successful tenderers were Messrs. Mockford, McDonald & Co., who despatched vessels from Melbourne laden with the requisite plant and material to commence operations, but after these were landed and erected the discovery was made that the deposit had been completely worked out; therefore nothing remained but to dismantle their plant and re-embark.

Messrs. Mockford, McDonald & Co. then instituted proceedings against the Government, the claim assuming the character of a Petition of Right, and was for about £40,000. The matter, after hanging on for a number of years (1882 to 1888), was eventually brought on for trial before a special jury on the 3rd August, 1888. As the jury's verdict was considered inadequate by the applicants, a Rule Nisi was obtained to show cause why the verdict should not be set aside and for a new trial on the grounds of the inadequacy of the damages and the perversity of the Judge's directions; but the application to make the rule was allowed to lapse. On 31st July, 1888, the sum of £9,783 6s. 11d. was paid over by the Government in full settlement of all claims for damages and costs.

It seems incomprehensible how it came about that tenders were invited for the removal of 40,000 tons when the deposit was practically worked out; but looking carefully into the matter one can only come to the conclusion that the original estimate was formed on a faulty basis, while allowance was not subsequently made for the fact that the 37,226 tons removed were calculated upon a 40 cubic feet to the ton basis, which in reality represented 49,634 tons, thus only leaving 7,000 tons upon a 40 cubic feet basis, presuming that Mr. Wynne's original estimate of 60,000 tons was a correct one. It is also difficult to understand how it was that Mr. Wynne, who resided on the islands, did not point out to the Government that the deposits were practically exhausted before allowing them to arrange this contract.

The Government record a total of £18,611 in royalties from the working of this deposit, but since they had to pay Mockford, McDonald & Co. £9,783 besides their own costs and general expenses with regard to the management of the islands, it will be seen that the revenue was not seriously benefited from this source.

There is absolutely no record of the grade of this material, but since the average value placed upon that exported was £4 14s. 6d., it must have been of very good quality.

¹ Parliamentary Paper, No. 14, 1878.

In 1890 three applications were lodged with the Government for a lease of the Lacepede Islands covering the sole right to remove guano for a period of five years, the lessee to pay a royalty of 10s. per ton on ship's register and to ship not less than 1,000 tons per annum. The applicants were Messrs. Beaver & Co., of Melbourne, who had been carrying on a trade in guano from this coast for several years; Messrs. J. & W. Bateman, of Fremantle, who had been working deposits upon Barrow and other islands; and Messrs. Broadhurst & McNeil, of Geraldton and London, who had been leasing the Abrolhos Islands for a number of years.

This latter firm secured the lease and deposited £250 with the Government, but owing to the unfortunate loss of the "Electra" at Dongara they were unable to ship the quantity agreed during the year. Early in 1891 Mr. F. C. Broadhurst visited these islands and reported as follows:—

"We regret to say that after a prolonged examination we find them (guano deposits on the islands) all but worthless. On the portion marked green on your plan of Middle Island, there are some small quantities of high-class phosphate, but the total of this could not exceed some few score tons. The whole of the parts coloured yellow on Middle Island are either plain sea sand or else guano so much interspersed with shelly sand as to render it valueless, or very nearly so. Of this yellow portion we took 22 fair samples representative of its whole area, the highest analysis of which but reached 43·66 per cent. of phosphate of lime, and the carbonate of lime is excessive (a fatal objection). As regards West Island, there are a few hundred of tons on this, but thickly mixed with small coral, which renders it of no commercial value also. We also examined the two smaller islands of the group, and they are sea sand. We must therefore abandon the Island."

The deposit of £250 was therefore forfeited.

It seems strange that people, on both this and the previous occasion, should have been anxious to obtain a lease of these islands and to lodge a deposit before making an inspection.

PHOSPHATIC DEPOSITS OF THE HOUTMAN'S ABROLHOS.

This group of islands lies off the west coast, about 50 miles from Geraldton, between Long. 113deg. and 114deg. E., and Lat. 28deg. and 29deg. S. They are disposed in four groups, which taken in order from north to south are named the North, Wallabi, Eastern, and Pelsart Groups.

They were discovered by the Dutch East Indiamen, who, when sailing from the Cape of Good Hope to Java upon the Great Circle system of navigation, picked up the coast somewhere about this latitude; consequently this group of low-lying islands, many being little more than reefs, were a constant source of danger if encountered after dark or in hazy weather.

As in the case of the other islands there is no record relative to the discovery of these guano deposits, but since they do not appear to have been worked until those on the other islands farther

up the coast were exhausted, the natural inference is that they were not of such a high value.

The first shipment of which there is any record was of 64 tons, in 1878; but the deposits do not appear to have been regularly and systematically worked until Messrs. Broadhurst and McNeil obtained a lease of these islands in 1885.

Through lack of experience they shipped several cargoes, which only yielded from 30 to 40 per cent. tri-calcic phosphate; consequently becoming financially involved, their business was taken over by Messrs. J. & W. Bateman for a period of three years, 1886 to 1888, during which time 5,900 tons (40 cubic feet), valued at £4 10s. a ton, were shipped to Europe, most going to Hamburg, but a portion to Antwerp. The conditions were at first that the cargoes should not contain less than 70 per cent. of tri-calcic phosphate, but this was subsequently reduced to 68 per cent. It is supposed that this was used in the manufacture of superphosphate, since it was stipulated that the material should not contain more than 2 per cent. of iron; a reduction in price was also made if much limestone was present, while no increased value was allowed for water or citric soluble phosphates. The price was 1s. 3d. per unit of $\text{Ca}_3\text{P}_2\text{O}_8$, determined after boiling in concentrated nitric acid for 15 minutes.

Shortly after this date the lease of these islands was taken over by Mr. F. C. Broadhurst, who worked them continuously until 1904, from which date the export of phosphates was prohibited.

In the year 1897 Mr. W. Saville Kent, who had been engaged in this State reporting upon the fisheries, in a book called "The Naturalist in Australia," gave the following description of these islands:—

"With the exception of the Wallaby Group, which contains plutonic rocks¹ corresponding in character with those of the mainland, and having an elevation of some thirty or forty feet, the largest residue is entirely of coral formation, while reefs of considerable extent also encircle the Wallaby series. Their composition, as manifested, more particularly in the islands of the Eastern and Pelsart Groups, consist of hard coral limestone conglomerate, undermined and weathered on its exposed aspects into low over-hanging cliffs and promontories, often of the most fantastic shape, which frequently show embedded in their eroded surfaces but slightly altered corolla of the Madreporidæ, of which they are principally composed From time immemorial, as testified to by deep guano deposits, Houtman's Abrolhos has been the home or breeding centre of countless hosts of sea birds, which still resort thither in enormous quantities in the breeding season On account of the vast accumulation of guano resulting from the sea birds having so long made the Abrolhos their head-quarters, this island group possesses a considerable commercial value."

¹ This statement was apparently made upon hear-say evidence, since it does not appear from the full text of his work that Mr. Kent visited this group. This point was referred to Prof. W. J. Dakin, D.Sc., etc. Director of the Percy Sladen Expedition to the Abrolhos Islands who makes the following statement:—"It is difficult to understand what particular rocks Kent refers to, but in any case his statement appears to be incorrect. We saw no trace of such rocks on the Wallaby Islands, and it seems unlikely that in the numerous traverses made across them such rocks could have escaped our notice."

In August, 1897, Mr. Surveyor Wells was despatched from Geraldton to the Abrolhos Islands for the purpose of officially estimating the quantity of guano still available on the ground.¹ This officer visited ten islands of the Eastern group and on four of them, viz., Rat, Third, Beacon, and Wooded Islands, found guano, varying from four inches to 27 inches in thickness, extending over an area of 11.72 acres; this he estimated at 13,944 tons, samples of which averaged 57.43 per cent. of tri-calcic phosphate. Of the fourteen islands of the Pelsart Group, nine were found to contain guano, viz. Pelsart, Gun, and seven small islands adjacent. The deposit varied from 7 to 13 inches in thickness over an area of 59.37 acres, and was estimated at 48,468 tons, and averaged 63.47 per cent. of tri-calcic phosphate.

Of the Wallaby Group, 18 islands were examined, but only four, namely West Wallaby, Pelican, North and South Pigeon Islands, contained guano, from about 4 to 17 inches in thickness, over an area of 34.75 acres, estimated at 38,088 tons, averaging 57.42 per cent. of tri-calcic phosphate. Many of the smaller islands also contained a limited amount, but not in sufficient quantity to be worth surveying.

While engaged upon this work he took 23 samples. One-half of each was sent to Mr. John Hughes, of London, and the other half to Mr. S. S. Dougall, the Chemist to the Agricultural Department. These samples, Mr. Wells states, were taken in accordance with the Chemist's instructions, but judging from the results it does not seem possible that the division of the samples could have been properly made, otherwise there would not have been such a considerable discrepancy in the phosphate of lime.

The average of the 23 samples is as follows:—

	Sand.	Moisture.	Phosphate of Lime.
Hughes ..	2.43	7.62	56.20
Dougall ..	2.82	6.16	62.65

Later on 17 samples were analysed by the Government Analyst, as follows:—

Sand.	Moisture.	Phosphate of Lime.
2.59 ..	5.85 ..	61.34

Mr. Hughes reports as follows:—

"You will observe there is a considerable variation in the composition, the percentage of phosphate of lime varying from 46.28 in No. 19 to 72.14 per cent. in No. 11, while the carbonate of lime varies from 2.04 in No. 20 to 10.79 in No. 16."

The agricultural value of Abrolhos guano is now well recognised, and depends upon its richness in phosphate of lime, which, though not soluble in water, is, I find, gradually dissolved by vegetable acids, such as citric acid: consequently on rich vegetable or peaty soils this guano can be used as it is with advantage as manure for root crops, also upon grass land deficient in lime, and where the quality of the herbage is coarse and rank, and therefore not at present of much use either, for cattle.

The effect of this guano on such grass land will be found very beneficial, as it will improve and increase the growth of the fine grasses.

As regards the white sample, marked gypsum, No. 18, I am of opinion that this is a specially valuable deposit, containing nearly a quarter of the total phosphate of lime in a form readily soluble in water, and I have therefore, specially indicated this fact in the analysis, as follows:—

Water (lost at 212°F)	..	..	..	16.03
Organic Matter and Combined Water	..	..	..	17.30
Phosphoric Acid, Water Soluble	..	..	..	5.20
Phosphoric Acid, insoluble in water	..	..	..	20.75
Lime	..	..	..	29.98
Sulphuric Acid	..	..	..	6.22
Alkalies, Magnesia	..	..	..	4.37
Sand	..	..	..	15
				100.00

Equal to soluble Phosphate 11.35 and insoluble Phosphate 45.30."

In 1903 an agreement was entered into between Mr. F. C. Broadhurst and the Government, whereby the former was to supply the latter with 2,000 to 3,500 tons of guano per annum for a period of five years, the standard of which was to be not inferior to the following analysis:—

Water (lost at 212deg. F.)	..	..	9.60
Organic matter and combined water	..	..	18.80
Phosphoric Oxide	..	..	26.65
Lime	..	..	34.66
Carbonic Oxide	..	..	1.10
Oxide of Iron, Alumina, Alkaline Mag-			
nesia	..	..	7.73
Sand	..	..	1.46
			100.00

Equal to Phosphate of Lime 58.17 per cent., and not to exceed Carbonate of Lime 2.50 per cent.

This agreement was never carried out, as Mr. Broadhurst, upon going more closely into the matter, found that he could not supply this quantity of a higher standard than 50 per cent. of phosphate of lime.

After 1904 the export of phosphates was prohibited, when, after many attempts to get it revoked, Mr. Broadhurst forfeited his lease to the islands, which was then taken on by Messrs. Fallowfield & Co., of Geraldton, upon a royalty basis of 10s. per ton on ship's register for each 40 cubic feet raised.

An analysis published in the *Journal of Agriculture* (Western Australia) in March, 1907, gives the following:—

	Per cent.
Nitrogen	1.06
P ₂ O ₅ Citrate soluble	4.57
P ₂ O ₅ Acid soluble	22.38

Equal to 58.8 per cent. phosphate of lime.

In 1916, however, this guano was sold with a guarantee of—
Per cent.

Nitrogen	.. .. .	0.75
P ₂ O ₅ Citrate soluble	.. .. .	5.00
P ₂ O ₅ Acid soluble	.. .. .	14.00

Or equal to 41.5 per cent. phosphate of lime.

PHOSPHATIC DEPOSITS OF THE RECHERCHE ARCHIPELAGO.

This archipelago consists of a scattered belt of islands which fringe the south coast between Fanny's Cove and Israelite Bay, or more precisely between 121deg. 30min. and 124deg. 10min. E. Long.

It is unknown at what date the first discovery of these phosphatic deposits was made, but the attention of the Government appears to have been directed to them by Captain James Sale in 1904, when he forwarded four samples for analysis. This work was carried out in the Survey Laboratory and showed a result of 80.80, 68.86, 78.78, and 85.40 per cent. of tri-calcic phosphate, and with only about .25 per cent. of sand. Seven samples sent in at a later date assayed only 17 per cent. of tri-calcic phosphate and 9.5 per cent. of sand; while the two highest samples collected by the present writer, out of a large number only yielded 59.37, and 73.50 per cent. of tricalcic phosphate, and 23.50 per cent. of insoluble matter. It is therefore very apparent that the first four samples did not come from these islands, being most probably foreign samples used for comparison and forwarded for analysis in error.

The great advancement made in this State in agriculture during recent years created so large a demand for phosphatic fertilisers that rock phosphates were eagerly sought after, which fact, coupled with the discovery of a fine deposit of this character in South Australia, caused Mr. Chaplin, who was Director of Agriculture in 1907, to form a syndicate, who obtained the exclusive right to prospect the islands of this archipelago for a certain period, at the expiration of which they would have the first right of selection. After Mr. Chaplin severed his connection with the Government he superintended this work in person, but owing to the loss of their boat and plant, due to a severe storm, and there being no more capital available, the syndicate applied for and obtained financial assistance from the Government. Mr. Chaplin then abandoned the management, but prospecting was continued for about 12 months on the various islands, and when a final selection was made of Christmas Island, one of the Eastern Group, situated about 20 miles off the coast near Israelite Bay, in the early part of 1908 the present writer was instructed by the Government to make an exhaustive examination and survey, the full report of which appeared in the Annual Departmental Report for that year.

Christmas Island is about one mile in length, while in width it varies from half a mile at the ends to one quarter of a mile in

the centre. The fundamental rock is granite, two bare barren bosses of which (one at either end) rise to an elevation of 500 feet, while the centre portion, which is about 100 feet above the sea-level, is covered by a deposit of phosphate of lime and sand varying in thickness from a few inches to 15 feet, the average thickness being two feet of sand covering two feet of phosphate rock.

Thirty-eight trial holes have been sunk upon this area, which were carefully sampled and yielded an average value of 27 per cent. of tri-calcic phosphate and proved the existence of 102,400 cubic yards. The sampling was done by making a cut down each of the four sides of these pits, the broken-down material being collected on a sampling sheet. This was then roughly sifted to exclude that portion of the sand that could be removed by screening, after which the sample was broken down, mixed, and quartered until sufficiently reduced, when it was bagged and sealed.

This mode of sampling was adopted, as it was considered that it would most nearly approach that of the actual working of the deposit, but it may be mentioned that had it been so desired, samples of a much higher grade could have been obtained by picking out the solid stone quite free from sand; two samples taken in this manner yielded 59.37 and 73.50 per cent. of tri-calcic phosphate.

A number of the other islands carry similar deposits, but they have not so far been extensively prospected.

The high-grade portions of these deposits are not sufficiently extensive to be remuneratively worked with the object of manufacturing superphosphate, since higher grade rock can be more cheaply imported, but there is not the slightest doubt but that they will eventually be utilised for application as raw ground phosphates.

PHOSPHATE DEPOSITS AT DANDARRAGAN.

Dandarragan is situated about 20 miles to the westward of Moora, which town is on the Midland Railway line 108 miles north of Perth.

This deposit appears to have first attracted notice in 1906, when the greenish appearance of the ferruginous rock was mistaken for an indication of copper, but which upon examination proved to be due to the presence of dufrenite, an iron phosphate.

Subsequent investigation by Mr. W. D. Campbell, Assistant Geologist, revealed the fact that the phosphatising of the sandstone was due to the presence of coprolite beds,¹ which he found interbedded with ferruginous sandstones and chalk for a distance of 22 miles.

The weathered surface of this rock upon sampling proved to contain from 0.54 to 2.10 per cent. of phosphoric oxide, the wood and coprolite beds from 15.32 to 39.34 per cent., and the ferruginous

¹ Except for a single shark's tooth, the supposed bones of these beds have been proved by the Mineralogist and Chemist to be fragments of phosphatised wood. *Vide* Journ. Nat. Hist. Soc. W.A. IV.

sandstones, which consisted largely of dufrenite and vivianite, 7.25 to 15.13 per cent.

The coprolite beds average something like three feet in thickness, and the underlying ferruginous sandstone, which has been more or less phosphatised, is at least seven feet in thickness.

The primary forms in which the phosphorus occurred in the beds were probably the calcium phosphates of raw or digested bones. These have to some extent been carried in solution by rain water into the underlying ferruginous sandstones, where they have interacted with the iron oxides producing the more stable iron phosphate, dufrenite.

A full report on this deposit, with a map, will be found in Bulletin No. 26 (*q.v.*).

Mr. H. Rowley, analytical chemist, of Perth, who has been identified with this deposit ever since its discovery, has for some time past been conducting a series of experiments with the object of rendering the phosphate of iron and alumina cheaply water or citric soluble.

CAVE DEPOSITS.

In the numerous caves which occur in the coastal limestone hills between Perth and Geraldton there are often extensive deposits of guano resulting from the excrement of birds, bats, and beasts which inhabit them. These are often of high quality since, besides phosphate, they often contain a large percentage of organic nitrates which are readily assimilated by plant life. This material, therefore, produces the most surprising results upon vegetation, but since the deposits are very limited in extent they are only of value locally. In many caverns in other portions of the State, limited quantities of phosphatic material are met with, but these are too small and too far from the market to be of any commercial value. A full report upon some of these caverns will be seen in the Annual Report for 1907, and in Bulletin No. 48 (*q.v.*).

MINERAL PHOSPHATES.

The only form in which a mineral phosphate has been found in any quantity in this State is as Amblygonite, which occurs near Coolgardie, but so far this mineral, which is a fluophosphate of aluminium and lithium, has not yet been found in sufficient quantities to warrant exploitation on a commercial scale. A full report on this subject will be found in the Annual Report of the Department of Mines for the year 1911.

GENERAL.

From the above-mentioned details, it will be gathered that the majority of the Phosphate Deposits of this State consist of the phosphatised limestone, due to the excreta of sea-birds upon the rock surfaces.

These, particularly upon the north-west coastal islands, were of considerable extent and of high quality, but since they were removed prior to their value being recognised by the local farmer, the bulk of that which now remains is too low in phosphates to be of use for the manufacture of superphosphate. Could this, however, be supplied to the farmer for use upon peaty soils in the wet areas in a sufficiently finely divided state and at a low price, it would be of far greater permanent value than the continuous application of acid phosphate, which, being strongly acid, by its continuous use causes the soil to deteriorate, unless an abundance of carbonate of lime is present to counteract the acidity and fix the phosphorus. A great loss of phosphoric acid is also experienced after the application of "super" in a humid climate where the soil is deficient in carbonate of lime either by the leaching of the water soluble phosphates, or their conversion into insoluble phosphates of iron and alumina; while the excess of free sulphuric acid present in this class of manure acts as a solvent of any small quantities of carbonate of lime and magnesia, or phosphate of lime that may be present in the soil, thus allowing the latter to be in part leached or be transformed into insoluble phosphates. If, therefore, acid phosphates are continually applied to this class of land, the whole of the carbonate of lime present in the soil will be converted into sulphate (gypsum), thereby destroying the only substances which have the power to retain the phosphorus in the soil in a form in which it is available for plant food, thus in time rendering it more acid and deficient in phosphate than prior to the application.

Upon the other hand, if phosphorus in the tri-calcic form is applied, this, if in a finely divided state, is slowly liberated by the action of organic acids generated in the soil, but the quantity so rendered soluble is little liable to be leached, since it is only liberated as required by the vegetation; therefore, if added in this form in larger quantities than are required by the crop, the land will gradually be enriched in this element. As all phosphate rock contains small quantities of carbonate of lime, applications in this form also act as a neutraliser of soil acid.

The objection to the use of rock phosphate is, of course, its much slower action, it taking as much as five years to obtain the maximum result unless large quantities of organic matter are present; this, of course, means waiting, whilst the money expended is not yielding its full return; therefore this method can only be adopted at the present high price by those farmers whose means are adequate. If, however, it is desired that a crop shall be immediately taken off the land so treated, this can be done by the use of a small quantity of super, which not only supplies phosphorus in a water soluble form, but also renders a portion of that contained in the ground rock immediately available also.

PRODUCTION OF GUANO IN WESTERN AUSTRALIA (1847-1904).

Year.	Guano Raised. *	Used locally. *	Exported. *	Revenue Collected. *	Exported. †	Value.
	tons. cwt.	tons.	tons. cwt.	£ s. d.	tons cwt.	£ s. d.
1847	..	..	..	..	3	† 18 0 0
1855	..	..	..	..	25	125 0 0
1865	..	..	..	..	35	175 0 0
1872	..	..	..	..	52	197 0 0
1876	2,537	..	2,537	1,437 10 0	735	367 10 0
1877	15,054	..	15,054	7,752 6 8	1,212	6,060 0 0
1878	22,676	..	22,676	14,020 19 7	13,129	66,095 0 0
1879	8,602	..	8,602	2,562 12 3	12,041	54,184 0 0
1880	..	..	..	208 15 0	1,330	6,650 0 0
1881	..	..	..	278 15 0	..	..
1882	2,690	..	2,690	194 0 0	..	..
1883	724	..	724	520 0 0	456	2,964 0 0
1884	3,683	18	3,665	2,287 7 9	1,163	7,559 10 0
1885	922	233	689	312 4 4	528	3,432 0 0
1886	10,072	100	9,972	2,697 16 4	10,157 10	66,023 15 0
1887	3,360	229	3,131	2,035 3 0	3,158	20,527 0 0
1888	3,586	449	3,137	1,851 11 0	3,110	12,440 0 0
1889	3,583	188	3,395	1,697 10 0	3,395	8,488 0 0
1890	4,038	125	3,913	1,956 10 0	3,913	9,783 0 0
1891	6,225	508	5,717	2,858 10 0	6,251	15,628 0 0
1892	2,569	777	1,792	1,355 13 4	2,508	4,389 0 0
1893	3,297	157	3,140	1,579 0 0	4,030	7,052 0 0
1894	2,736	218	2,518	969 10 0	2,239	3,919 0 0
1895	1,459	356	1,103	544 0 0	100	200 0 0
1896	1,618	1,168	450	191 5 0	1,660	4,506 0 0
1897	1,897	1,205	692	335 11 6	1,496 5	3,250 0 0
1898	3,604	857	2,747	1,278 4 11	3,950	9,386 0 0
1899	3,092	542	2,550	1,236 5 1	2,045 10	5,165 0 0
1900	1,103	300	803	1,094 8 0	2,902	7,527 0 0
1901	1,692 4	595	1,097 4	466 4 9	1,099	2,742 0 0
1902	1,930	1,130	800	914 2 0	2,400	4,800 0 0
1903	2,668	1,568	1,100	425 19 4	952	2,034 0 0
1904	2,848	1,437	1,411	705 10 0	1,411	4,636 0 0
Total	118,530 4	12,160	105,754 4	53,658 4 10	87,486 5	338,732 15 0

*. Information obtained from Annual Reports and Files of Lands and Surveys Department.
† Information from Statistical Review.

After the year 1904 the exportation of guano was prohibited; the following table, showing the production of guano since that date which has been locally consumed, is taken from figures supplied in the Statistical Register:—

PRODUCTION OF GUANO, 1905-1916.

Year.	Quantity.	Value.
	Tons.	£
1905-1906	 532	..
1907	 2,015	6,045
1908	 2,009	4,932
1909	 1,700	3,500
1910	 950	2,375
1911	 1,853	4,724
1912	 1,282	3,205
1913	 1,720	3,440
1914	 1,583	3,957
1915	 353	1,069
Total	 13,997	£32,247

One shilling per ton was paid upon this by way of royalty.

The shipments which took place prior to 1883 would appear, as far as can be ascertained, to have gone to the United States of America, but subsequently to that date when Messrs. J. & W. Bateman took over the business of Messrs. Broadhurst & McNeil, the bulk appears to have been sent to Hamburg and Antwerp. It is only since 1901 that an official record has been kept of the destination to which guano was despatched, which is as follows:—

TABLE SHOWING THE DESTINATION OF GUANO EXPORTED, 1901-1903.

Year.	Country.	Quantity.	Value.
		Tons.	£
1901	United Kingdom	60	150
	Victoria	728	1,820
	Tasmania	311	772
1902	Victoria	1,600	3,200
	New Zealand	800	1,600
1903	Tasmania	142	353
	New Zealand	810	1,681

LOCALITIES FROM WHICH GUANO HAS BEEN OBTAINED.

Locality.	Period.	Tonnage.	Royalty and Rent.		
			£	s.	d.
Jones, Lesueur & Stewart Islands and Black Hawk Reef ..	1884	2,577	1,675	0	0
Browse Island	1876-1886	23,177	3,158	0	0
Lacepede Islands	1876-1879	37,226	18,611	0	0
Bedout Island	1877-1882	69	38	0	0
Turtle Island	1880-1882	*	3	0	0
East Forestier	1882	*	1	0	0
Dampier Archipelago	1880-1882	*	250	0	0
Barrow Island	1880-1881	*	100	0	0
Montebello Island	1880-1881	*	30	0	0
Trimouille and Hermite	1882	*	15	0	0
Beagle Island	1877	30	15	0	0
Bernier Island	1882	*	15	0	0
Dorrie Island	1882	*	8	0	0
Dirk Hartog Island	1880-1882	*	105	0	0
Faure Island	1880-1882	*	6	0	0
Salutation Island	1882	*	2	0	0
Augustus Island	1881-1882	*	37	10	0
Abrolhos Island	1883-1915	56,025	†		
Carnac Island	1880	*	5	0	0
Undefined Islands	1876-1878	868	483	0	0

* No returns of tonnage raised, as it was consumed locally.

† The tonnage is only approximate, while Royalty and Rent has not been computed as a whole.

IMPORTATION OF PRINCIPAL PHOSPHATIC MANURES.

Year.	Bone Dust.		Rock Phosphate.		Superphosphate.	
	Quantity.	Value.	Quantity.	Value.	Quantity.	Value.
1905	tons. cwt.	£	tons. cwt.	£	tons. cwt.	£
1906	2,218 9	11,286	..	..	8,479 18	21,178
1907	3,369 15	17,629	..	..	8,629 15	20,475
1908	2,569 16	13,946	..	..	9,479 17	30,689
1909	2,259 8	12,264	..	..	15,009 13	50,344
1910	2,833 17	15,260	..	..	14,124 19	50,820
1911	2,966 8	15,786	13,200 0	29,920	19,191 13	100,221
1912	1,585 0	9,106	20,823 9	42,238	15,825 3	49,553
1913	2,850 19	16,871	23,367 0	45,977	8,290 10	25,291
Six months ending June, 1914	2,405 7	14,930	15,256 18	30,713	856 12	3,255
1914	869 14	5,661	27,970 5	60,711	4,208 2	14,533
1914-15	1,761 2	10,607	24,895 14	54,563	14,015 19	48,940
1915-16	1,976 18	11,502	38,465 10	98,543	..	..
Total	27,666 13	154,848	163,978 16	362,665	181,112 1	415,299

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ACT AND REGULATIONS GOVERNING THE WORKING OF GUANO DEPOSITS.

SPECIAL LEASES.

Section one hundred and fifty-two of the Land Act of 1898 as amended by the Land Act Amendment Acts of 1902 and 1906.

On receiving applications in the form or to the effect of the Twenty-eighth Schedule, the Governor may grant leases of any Crown Lands for any area not exceeding (except in the case of leases for guano or other manure, or for the collection and manufacture of salt) twenty-five acres, for a term not exceeding twenty-one years from the date thereof, at a yearly rental of not less than two pounds and a payment by the lessee of the cost of survey, for any of the following purposes (that is to say):—

- (1.) For obtaining and removing therefrom guano or other manure

.....
 Provided that in all cases where it is proposed to grant a lease for a longer term than ten years, notice of the application for such lease and of the purpose and term for which it is proposed to be granted shall be published in four consecutive ordinary numbers of the *Gazette*, the first publication being at least one month before the grant of such lease.

Every application under this section shall be accompanied by a deposit of a moiety of the first year's rent.

REGULATIONS.

His Excellency the Governor in Executive Council has been pleased to approve of the following Regulations respecting the removal of Guano existing upon Islands or Coasts within the territorial limits of Western Australia, and to repeal all former Regulations.

MINISTER MAY ISSUE LICENSES.

1. The Minister for Lands may, at his discretion, license the Master of any vessel to collect and remove guano. The license shall be deemed to be under the Act 40 Victoria, No. IX. (This Act provides Penalties for removing guano without license.)

CLASSES AND FORMS OF LICENSES.

2. A license to remove guano shall be either *General*, *Special*, or *Exclusive*, according to the forms annexed.

GENERAL LICENSE.

3. A *General* License shall apply, save and excepted under these Regulations, and all Coasts and Islands within the territorial limits of the State. It shall only be issued in exceptional cases, to encourage the discovery and utilisation of new deposits of guano. Localities comprised within any previously issued *Exclusive* License, or localities which the Minister for Lands may deem it desirable to reserve, shall be exempted from the operation of a *General* License, and so noted thereon. The localities comprised within any subsequently issued *Exclusive* License, but not until the *Exclusive* License has been exhibited by the holder thereof, or his agent, to the Master of the vessel acting under the *General* License.

SPECIAL LICENSE.

4. A *Special* License shall apply to localities specified and described therein, but shall not exclude the holder of a *General* License, or the holder of any other *Special* License, applicable to the same locality.

EXCLUSIVE LICENSE.

5. An *Exclusive* License shall only be issued to the Master of a vessel the owners and charterers of which are under special agreement with the Government to remove the whole of the guano in a particular locality. An *Exclusive* License shall confer the sole right to guano in the locality specified therein.

LICENSES NOT TRANSFERABLE.

6. A license under these Regulations shall not be transferable, and shall apply only to the vessel named therein, and the voyage therein referred to.

GUANO NOT TO BE EXPORTED.

7. Every license shall be for the removal of guano for use in the State, and not for export, and the Minister for Lands may require the licensee to enter into a bond, with one or more sureties, to duly observe this Regulation.

ROYALTY ON GUANO.

8. A Royalty of one shilling per ton, calculated on the registered tonnage of the vessel, shall be paid to the Minister for Lands or a duly authorised officer, before the issue of any license to collect guano, but this charge may, in the case of an *Exclusive* License, be increased by the Governor in Executive Council.

TERM OF LICENSES NOT TO EXCEED TWELVE MONTHS.

9. Licenses shall be for a period not exceeding 12 months, to be fixed by the Minister for Lands.

MINISTER MAY IMPOSE FURTHER CONDITIONS.

10. Licenses shall be subject to any special conditions and limitations which the Minister for Lands may deem it proper to endorse thereon.

MINISTER FOR LANDS TO SUPERVISE REMOVAL OF GUANO.

11. Guano shall be removed under the direction and supervision of the Minister for Lands, or his agent resident upon the spot. The Minister or his agent may mark off spaces from which only the guano is to be taken, and may order accordingly, and shall prevent waste and unprofitable working of the deposits.

PENALTIES—REVOCATION OF LICENSE.

12. The holders of licenses and their agents are liable to the penalties specified in Act 40 Victoria, No. IX., in respect of any act not duly covered by the terms of their licenses and these Regulations; and the license of any ship infringing the conditions of the license, or of these Regulations, or any order thereunder, shall be held to be revoked or intimation to that effect given to the Master of the ship or his principals by the Minister for Lands or his agent.

GOVERNMENT DO NOT GUARANTEE GUANO.

13. The Government will not be responsible for the quantity or quality of any guano licensed to be removed under these Regulations.

QUESTIONS TO BE DECIDED BY GOVERNOR IN EXECUTIVE COUNCIL.

14. Licenses under these Regulations shall be subject to the conditions that any question or matter in dispute arising between the Government and the holder of a license shall be referred for the decision of the Governor in Executive Council, and that such decision shall be final and binding upon both parties.

Under these Regulations 1s. per ton Royalty is charged while the terms upon which leases are granted is a matter for the Minister's decision in each case.

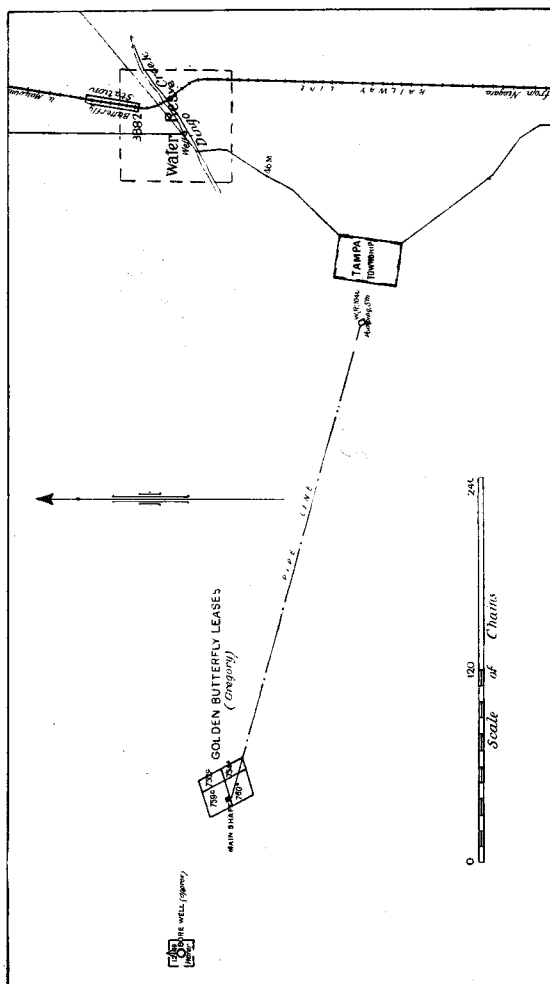
62.—THE GOLDEN BUTTERFLY MINE (BUTTERFLY, TAMPA, NORTH COOLGARDIE GOLDFIELD).

By J. T. JUTSON.

With Figures 1, 2, 3, and 4, and Two Plates I. and II.

The Golden Butterfly Gold Mine is situated about five miles to the west of the Butterfly (late Dingo Creek) railway station, and about 14 miles north-west of Kookynie (see locality plan, Fig. 1). No cut roads communicate direct with the mine, the means of communication being merely by bush tracks.

Fig. 1.



The present leases pertaining to the mine are known as the Gregory or Golden Butterfly leases and are numbered 759g, 760g, 753g, and 754g, respectively.

The mine is equipped with a 10-head mill, with grinding pans, filter press and leaching plant, a rock drill plant consisting of two Butterfly rock-drill machines and two stope hammer drills, and the usual winding and other gear.

The mine water is used in the battery, but is not sufficient. (The present discharge is stated to be 1,800 to 2,000 gallons per day.) It is augmented by that brought from the pumping station four miles to the east. The water in the mine is stated to be almost drinkable, being nearly free from mineral matter. No analysis has, however, yet been made of it.

"Mulga" is practically the only timber in the district, so that when "gum" is required it has to be brought from a considerable distance.

The position of the mine is upon a slight rise on the great arid plateau of Western Australia. In the immediate neighbourhood of the mine the rocks are exposed at the surface. They are mostly of a grey colour when undecomposed, fine-grained, homogeneous, and of a basic-looking character. Two fairly fresh specimens have been examined by the Petrologist (see Appendix); one [$\frac{1}{701}$] from the north drive of the 250ft. level of the mine is referred to a fine-grained slightly quartose diorite, and the other [$\frac{1}{704}$], from the surface 12 chains east of the mine, is described as a medium-grained diorite with subophitic structure and affinities with plutonic amphibolised dolerites. The main rock of the district may therefore be described as a diorite. It is generally massive, but is schistose in places. A schistose rock from the hanging wall of the lode in the winze below the 300ft. level, south of the main shaft [$\frac{1}{698}$], has been described by the Petrologist, who considers there is little doubt that it is an altered phase of the more massive rock [$\frac{1}{701}$], a conclusion towards which the field evidence also points. The strike of the schistosity-planes was noticed in two places on the surface, at one being east and west, and at the other N. 70deg. E. The Butterfly lode strikes about N. 15deg. W., and the quartz reefs noted below strike north-west, west-north-west, and north-east. In the absence of detailed surface examination of a much wider area, it cannot be said that any group of fissures exists having a dominant trend.

A short distance to the south of the mine plant a couple of narrow dykes in the diorite are seen. They consist of a tough, dense, and very fine-grained rock of a felsitic character, but possessing small grains of free quartz. A specimen [$\frac{1}{703}$] has been determined by the Petrologist (see Appendix) as a fine-grained felsitic quartz porphyry. To the south and east of the mine some quartz-

reefs outcrop, but with the exception of a pothole on one, no work has been done on them. Presumably, therefore, they are non-auriferous. Their strikes have been noted above. Laterite is abundant in the district. Omitting laterite and other superficial deposits, the accompanying geological map (Plate I.) shows the geology of the leases.

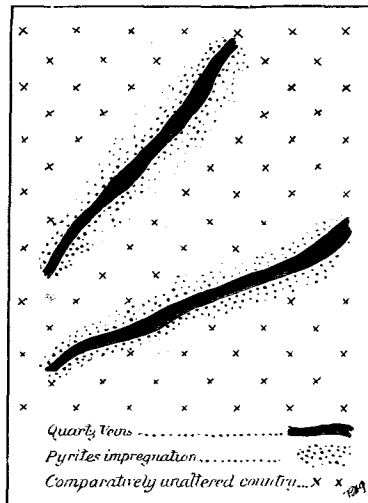
At the time of examination the mine workings comprised an opencut, and a main underlay shaft sunk for about 350 feet (measured on the underlay). There are five main levels, known as the No. 1 (100 feet), the 150 feet, the No. 2 (200 feet), the 250 feet, and the No. 3 (300 feet), these measurements being all on the underlay. In addition there is a short 50ft. level. The bulk of the driving has been north of the main shaft. Thus the lengths of the north drives are as follow:—No. 1 level about 205 feet, 150ft. level about 230 feet, No. 2 level about 270 feet, 250ft. level about 225 feet, and No. 3 level about 50 feet. South of the main shaft the driving is as follows:—No. 1 level about 118 feet, No. 2 level about 110 feet, 250ft. level about 97 feet, and No. 3 level about 95 feet. Numerous winzes and rises have been put in, and below the 300ft. level, in addition to the main shaft, there is a winze to the south, which is connected with the shaft. The accompanying plans (Plate II.) show these underground workings, together with a cross section of the lode, the latter necessarily being somewhat diagrammatic by reason of the difficulty of obtaining accurate data, owing to stoping, etc.

The country consists of diorite similar to that already described from the surface. It is comparatively unweathered almost to the surface, but varies a good deal in its hardness, in some cases being fairly soft and easily broken, and in others very tough and dense. It shows little schistosity, being generally massive, not only on each side of the lode, but in the horses of mullock in the lode. On account of the few crosscuts in the mine little can be seen of the nature of the country away from the lode. No dykes of any kind have been observed in the mine.

The lode is of the type described in Western Australia as a lode-formation, that is, it is, in the main, country which has been fractured, and into which solutions have been introduced, by means of which the original country rock has been largely replaced or penetrated by silica, pyrites, and gold. The various stages of alteration of the country can be clearly seen in the lode, the gradations passing from very slight changes in the original country, through parts largely impregnated with pyrites, into portions where little of the original is left, its place being occupied by quartz, pyrites, and other minerals (see Appendix ($_{699}^1$)). This applies, to the sulphide ore, the pyrites in the oxidised ore having been decomposed. On each side of some quartz veinlets, the country has

been strongly impregnated with pyrites, while farther away it is practically free from this mineral (Fig. 2).

Fig. 2.



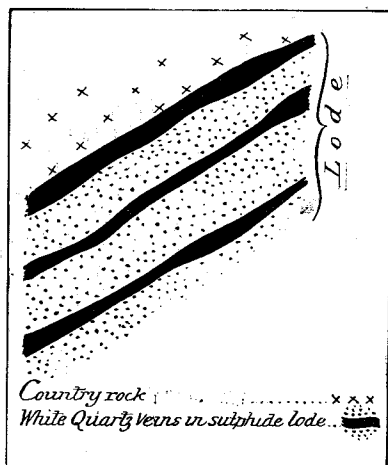
Sketch showing impregnation of country rock by pyrites along quartz veins, Golden Butterfly Mine.

Running through the lode in various directions, but usually in the case of the more prominent ones parallel to the general trend of the lode, are numerous quartz veins and veinlets from one-sixteenth of an inch to 10 or 12 inches thick. These are, as a rule, of white quartz containing little pyrites, and they appear to be of later origin than the solutions which altered the country into a lode, as there are always sharp junctions between the two, and the white quartz veins cut through the ordinary lode (Fig. 3). This idea is strengthened by the section disclosed in the winze below the 300ft. level, south of the main shaft. Here the original lode appears to have been brecciated, and the spaces between the fragments to have been filled by the deposition of the white quartz (Fig. 4), the latter in this case clearly being of later origin than the ordinary lodestuff. The fragments vary in size from one to 18 inches. Some of the small ones are quite rounded, and their sides are in places slightly embayed, so that it is possible that in addition to the white quartz filling the spaces it has also partly replaced some of the original lode; but this at present is merely a suggestion. These white quartz veins are regarded by the mine management as of low values, without, however, any separate assays having been made; but values generally have been found to be poor in their vicinity.

In the brecciated portion of the lode just mentioned a bluish-white quartz occurs. This is part of the main lode material, and it

is penetrated by thin veins of the white quartz. Small calcite veins were noticed in one place. No tourmaline has been observed.

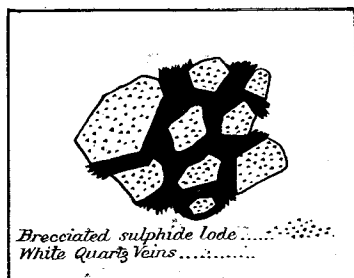
Fig. 3.



Section showing quartz veins in sulphide lode in winze from 300 feet level, South of Main Shaft, Golden Butterfly Mine.

The oxidised ore is usually of a brown colour, is generally rather hard, and is traversed frequently by quartz veins and veinlets. Only in one or two places was the oxidised lode observed to be reduced to a soft white clay, often characteristic of oxidised lode-formations. Pseudomorphs after pyrites occur, and in places these have been

Fig. 4.



Section of sulphide lode in winze from 300 feet level, South of Main Shaft, showing brecciated lode with white quartz veins cementing together, Golden Butterfly Mine.

removed, leaving small cavities, which give the lode material a finely cavernous appearance. In portions the apparent remains of unreplaced mineral constituents of the original country may be noticed. Confirmation of the origin of the lode is supplied by microscopical examination (see $\frac{1}{702}$ of Appendix, which is a specimen of the lode from the north drive of the 250ft. level).

The level of the ground water is about 200 feet on the underlay (about 110 feet vertically), but this does not form the dividing line between the oxidised and sulphide ore. Much of the former occurs between the 200ft. and 300ft. levels, and although along the latter level, and down the winze sunk therefrom, sulphide ore probably predominates, yet oxidised ore occurs. What little can be seen in the roof of the main shaft below the 300ft. level, of the lode, is apparently mostly oxidised ore.

Although the hanging wall is in places rather strongly marked, this cannot be said of the walls as a whole; but an indefiniteness of walls is often characteristic of lode-formations by reason of the mode of origin of the latter. The ore body, however, is yet fairly sharply marked off from the country.

The strike of the lode is about N. 10deg. to 15deg. W. as a rule. In the different levels it varies from this, sometimes more and sometimes less to the west of north, but it is usually west of north. The lode dips flatly to the east, the average dip being between 30deg. and 35deg. The thickness of the lode varies considerably, and it is difficult to give an average of the whole. Its most common width would probably be about six or eight feet, but it frequently runs to 10 and 12 feet, and in places becomes reduced to about four feet; and towards the end of a lens, as at the southern end of the workings, it becomes less than this. On the other hand, what is known as the hanging-wall lode, south of the main shaft, attains in places a thickness of about 20 feet.

With the exception of a small branch lode in the 150ft. level, only one lode has so far been discovered north of the main shaft, but to the south of such shaft, at least between the 200ft. and 300ft. levels, two lodes occur, which are known as the footwall and hanging wall lodes respectively. (A thin lode to the west of the footwall lode at the 300ft. level has also been located, but this need not here be considered). The hanging wall lode is the thicker, reaching about 20 feet in one place, while elsewhere it is of substantial thickness. At the 300ft. level, just south of the main shaft, a lode is at least 15 feet thick. This probably mostly represents the hanging wall lode, but it is possible that the footwall lode is here united with it. The footwall lode varies from about four to 12 feet in thickness. The two lodes probably unite well above the 200ft. level, and are stated to have done so towards the southern end of the workings, but their union has not been proved to the north or downward,

although in the latter direction they probably soon combine. The lodes are separated by a horse of mullock, consisting of the usual country, diorite.

Wherever seen at the southern end of the workings, the lode appears to thin out, but the channel seems to remain. Little work has been done in this direction south of the No. 1 rise south.

The lode is continuous along the drives north of the main shaft, but tends to thinness in places. Thus at the 200ft. and 250ft. levels there is for some yards a contraction to two or three feet, the walls consisting of very hard massive diorite, while the lode here is practically merely schistose altered diorite; the mineralising solutions have apparently almost missed this portion. This schistose diorite commences about 60 feet north of the main shaft at the 200ft. level, but farther north at the 250ft. level. If the two portions are joined, the line connecting them pitches to the north at about the same angle as the small shoot farther north, but whether this is anything more than a coincidence cannot at present be said. At the end of the short north drive at the 300ft. level the lode is only about three feet thick.

The main shaft below the 300ft. level has apparently been sunk below most of the lode. The roof shows some lodestuff, and the lode as seen at the 300ft. level, immediately to the south of the main shaft, appears to be rising so as to pass over the main shaft. Down the winze from the 300ft. level, the lode is well exposed. It is largely sulphide ore, and a thickness of six feet can be seen. The hanging wall forms the roof of the winze, but the footwall was not exposed. This winze has been connected with the main shaft, but neither this connection nor the bottoms of the shaft and winze could be seen on account of some water having accumulated there. Here the lode was said to be 11 or 12 feet thick.

The mine, so far as developed, has been largely stoped out. South of the main shaft the lode has been mostly removed between the surface and the 300ft. level. North of the same shaft the open-cut has removed much, and between the 50ft. and 150ft. levels most of the lode has been taken out. Between the 150ft. and 300ft. levels a strip about 30 feet wide, close to the main shaft, has been stoped, and also the northern half of the lode between the 150ft. and 200ft. levels; all these latter remarks apply to the lode north of the main shaft. Very little stoping has been done above and below the 250ft. level from about 50 or 60 feet north of the main shaft.

From the above particulars it will be seen that a shoot occurs practically the full width of the workings near the surface. It splits north of the main shaft at about the 150ft. level, and the northern portion pitches to the north, but appears to die out between the 200ft. and 250ft. levels. The southern portion continues without any distinct pitch to the 300ft. level (below which only a

winze and the main shaft have been sunk) between No. 1 rise south and a distance about 30 feet north of the main shaft, the principal portion being between the main shaft and such No. 1 rise south. It is evident that this shoot forms a lens of ore of unfortunately short length horizontally.

The gold is said to be very fine, and rarely to be seen in the ore. It is stated to be free as far down as the mine has been worked, in the sulphide ore as well as the oxidised. Values appear to have been better nearer the surface than lower down, but in the main shoot this has probably been somewhat compensated for by the increase in thickness of the lode between the 200ft. and 300ft. levels.

Prior to 1912 the leases produced 59.36 fine ounces of gold from 235 tons. The official returns of the company for the years 1912, 1913, and 1914 show a production of 7,808.27 fine ounces from 31,379.32 tons, giving an average return of 0.25 fine ounce per ton. The low-grade character of the ore is clearly indicated.

The mine has been closed down perhaps only temporarily. With regard to its future prospects, the lode channel appears to be strong and well defined, and it should live to a reasonable mining depth. Even where the lode thins and values become poor, as at the north and south ends of the mine, the channel remains; and in the winze below the 300ft. level the hanging wall is smooth and regular. Concerning the lode itself, it is generally found in Western Australia that lode-formations are persistent in depth, and there appears to be no valid reason why this lode should not continue. It is difficult to say anything definite as regards values. The lode is so low-grade that almost any diminution in values would be sufficient to make it unpayable, and there is no criterion that it will increase in value, unless the country in the lode becomes more completely converted into ore, in which case there is a chance of more gold occurring. On the other hand, as the lode is evidently of a lensy character, there is the possibility that another fairly thick lens of ore may occur below the present one; and its thickness may enable it to be worked profitably. The same remark applies to farther south of the main shaft than at present worked. Values appear to give out to the south, and the lode becomes thin, but as already pointed out, the ore channel exists, and it is quite feasible that another ore body will be found in that direction. The 250ft. level north drive has been unprofitable, but ore may exist below it. Again, there is the possibility of the hanging wall lode being found north of the main shaft. The ore body displayed in the winze below the 300ft. level looks very well, although the values are not high (using this term relatively only. Thus "high" values in this mine, say, 50s. or 60s. per ton, might be "low" in others.)

It may be remarked that while it has been demonstrated that the ore body is a low-grade one, it has by no means been proved that it is worked out. The writer is therefore of opinion (assuming

there are no difficulties in extraction) that, taking the whole of the circumstances into consideration, a further trial might be given to the mine by the deepening of the main shaft to 400 feet or more. Subsidiary to this an attempt might be made to test the ground farther south than yet opened up, either by driving along the 200ft. or 250ft. levels, or perhaps by a series of bores from the surface. The lode lies so flatly that this latter method could be tried without any great depth of boring being required. It must, however, be borne in mind that in view of the low-grade character of the ore, and the futility of expecting to keep always in payable ore, sufficient capital should be provided to enable developmental work to be kept well ahead.

The question of secondary enrichment has not been considered here, as the data are insufficient. The known facts of the mine are, however, in the writer's opinion, sufficient to justify a further trial.

The writer is informed that there is no difficulty in the extraction of the gold from the sulphide ore, but this does not come within his province.

The assay values of the mine (which have been considered in the preparation of this report) have been supplied by the manager, Mr. G. S. Beresford, to whom thanks are due for the same and for facilities for inspection of the mine.

24th October, 1914.

APPENDIX.

PETROLOGICAL NOTES,

By R. A. FARQUHARSON, Petrologist.

$\frac{1}{703}$ (15 chains E.S.E. of Golden Butterfly Mine).—A minutely grained dark-grey felsitic rock showing frequent small clear crystals of quartz and others of felspar. The margins weather to a greyish-white phase. There are a few cracks or irregular joints in the specimens.

S. Occasional phenocrysts of quartz and felspar appear in a fine-grained ground mass consisting of small plates of felspar and quartz, small ragged rods of felspar and a semi-opaque dust in strings and small patches often surrounding the quartz and felspar plates, and consisting of chloritic micaceous scales. Often the latter is yellowish or yellow-green in colour, associated in places both with muscovite scales, epidotic grains and small grains of calcite. With the yellowish-green patches are small grains of black iron ore and an occasional crystals apparently of rutile. The quartz phenocrysts are remarkably euhedral or truncated at alternate corners; slight resorption is noticeable on the margins of some of them, and cracks occasionally occur. The felspar phenocrysts are square, tabular or columnar, all turbid from kaolinisation and often micacisation, sometimes strongly twinned on the albite law, sometimes almost wholly micacised. Determination of the species, especially of the phenocrysts, is difficult, but the rods and plates in the ground appear to be albite. A peculiar feature of the ground is the occurrence of a number of round radially fibrous feldspathic grains resembling spherulites, due to a feldspathic intergrowth. These have no definite arrangement, occurring merely scattered amongst the rods and grains of the ground mass. In some cases, rounded felspar forms appear to be partially platy and partially radial, the latter arrangement resembling a fine albite lamellation.

The rock is a fine-grained felsitic *quartz-porphyry*.

$\frac{1}{704}$ (12 chains E. of Golden Butterfly Mine).—A medium grained dark-green hornblende-felspar rock.

S. The chief constituents are hornblende and felspar, with a lesser amount of black iron ore in ragged plates and grains. The hornblende occurs in ragged columnar aggregates, the columns sometimes small and almost prismatic, sometimes large and almost platy. In all cases there is an absence of crystalline outline. The species is green in colour with pleochroism from green to greenish-yellow; incipient chloritisation is not uncommon, resulting in a weakening of birefringence. The aggregates are loose, the intervals being occupied by roughly columnar and platy felspar, in amount almost equal to that of the coloured constituent. The felspar columns and platy columns and plates are generally slightly turbid from kaolinisation—sometimes from slight micacisation; are coarsely twinned, sometimes on the karlsbad, sometimes on the albite law. Some of the plates do not exhibit twinning. In some places there is an interpenetration of several crystals. Cracks are occas-

ionally noticeable as well as a slight bending of the lamellæ. Owing to the paucity of definite albite twins, and the turbidity, determination of the species is difficult, but from such measurements as have been made, the species is in part at least rather acid, the angles agreeing apparently in places with albite ($10^{\circ}/11^{\circ}$). The structure is referred to the sub-ophitic. The felspar has a stronger tendency to crystalline outline than the hornblende, and frequently exhibits a coarse plexal character, with the hornblende partially moulding the forms. The structure resembles that of some coarse dolerites. A little quartz occurs in occasional grains and a few veinlets. Some grains of epidote are observable associated with chlorite or in fine granular form with felspar. The iron ore is fairly common in large ragged plates bluish in incident light, and referred to magnetite (? titaniferous). In some of the plates there is the striated appearance of ilmenite, suggesting that the ore may be a residual product after alteration of augite to chloritised hornblende. Some needles of apatite are present. In the general structure, the rock resembles a coarse dolerite in which the augite has given place to hornblende, though the character of the felspar appears more acid than in dolerite. It is probable, however, that a basic species such as labradorite is present.

The rock is put down as a fresh medium-grained *diorite* with sub-ophitic structure and affinities with plutonic amphibolised dolerites.

$\frac{1}{701}$ (N. drive, 250ft. level, Golden Butterfly Mine).—In hand, rather similar to $\frac{1}{704}$, but of finer grain and somewhat jointed, and with pyrites on the joint surfaces.

S. In general, similar to $\frac{1}{704}$, but the hornblende is in more ragged and more fibrous aggregates and strings; the individual forms of the aggregates are also smaller. The felspar is mostly in ragged platy forms, and exhibits a greater absence of twinning than in $\frac{1}{704}$. Moreover, in many of the felspars, small prisms and scales of greenish chloritic hornblende are enclosed, and minute needles of hornblende penetrate the margin of both the felspar and quartz plates. Small quartz plates are more frequent than in $\frac{1}{704}$. Though there are occasional columnar felspars with partially idiomorphic outline, in general there is little suggestion of ophitic structure; and the ragged nature of the hornblende, the extent to which the felspar plates enclose chloritised hornblende scales and needles, and the rounded platy characters of the felspar give an ill-defined structure to the rock. Apatite needles, iron ore and epidote occur as before. There is little doubt that the rock is a facies of $\frac{1}{704}$, but a facies decidedly more dioritic than $\frac{1}{704}$.

It is referred to as a fine-grained slightly *quartzose diorite*.

$\frac{1}{698}$ (Winze from 300ft. level S. of main shaft; hanging wall of lode).—Dark-green rather weathered sheared greenstone with chloritic sheen on the shear surfaces.

S. Slide consists of numerous chloritic scales and loose scaly aggregates and numerous grains of calcite punctuated by black aggregates of iron ore grains, of which most preserve some remnant of crystal form, all obscuring a basis which is seen to consist of felspar plates and a few irregular quartz plates. The iron ore (magnetite or ilmenite) is in forms suggesting that it is a decomposition product of a pre-existing ferro-magnesian, doubtless augite or hornblende. The calcite grains—mostly very small—are very numerous, associated with minute chlorite scales. The felspar forms are very indefinite, obscured by chlorite scales and carbonate grains as well as sometimes by micaceous scales. Structure is also indefinite—there is some platy columnar structure in the altered felspar, resembling that of $\frac{1}{704}$ —but there is little doubt that the rock is an altered phase of $\frac{1}{704}$, sheared and considerably weathered.

$\frac{1}{700}$ (About 300ft. level).—A dark-green rock identical with $\frac{1}{693}$ but traversed by quartz veins, on each side of which the rock is very heavily charged with pyrites, producing a kind of bleaching of the green rock.

S. Rock identical with $\frac{1}{700}$; but in proximity to the quartz veins the black iron ore has been converted by sulphide solutions into pyrites, while probably the chlorite itself has lost its iron, which has also been converted to pyrites.

$\frac{1}{699}$ (ore from winze from 300ft. level, south of main shaft).

A phenomenon similar to that in $\frac{1}{700}$ has occurred in the case of this specimen. Remains of iron ore are still to be seen, but most of the forms have been partially or wholly converted to pyrites, while the main mass of the slide is occupied by large plates of a carbonate (calcite), and numerous platy and columnar turbid twinned feldspars which are frequently themselves partially carbonated. There are occasional bands of quartz and quartz mosaic.

The rock in hand is greyish in colour, of medium to fine grain, with several white quartz veinlets producing the appearance of banding, and heavily pyritised material between the bands. Since in some cases there is no pyritisation of the surrounding material in proximity to the quartz veins, it is probable that the lode alteration of the rock (carbonation and pyritisation) took place prior to the introduction of these veinlets. On the other hand, some of the veins are bordered by a heavy deposit of pyrites, so that there may be two sets of quartz veinlets in the lode.

$\frac{1}{702}$ (N. drive, 250ft. level).—A somewhat coarse-grained, very much weathered ferruginous rock consisting of blackish iron-stained crystals separated by yellowish or reddish-white feldspar. Resembles a heavily oxidised, iron-stained, coarse amphibolite.

S. Consists of large turbid columnar and platy crystals of feldspar, irregular platy crystals of quartz, scaly particles of yellowish and greenish chlorite, and many irregular platy crystals of bluish-black iron ore, surrounded by heavily stained yellowish or brownish chloritic and feldspathic material. Veinlets of yellow epidote appear; the feldspar plates, some of which are twinned, are partly kaolinised, partly micacised. Yellowish scaly chloritic patches and streaks are common, but they are mostly iron-stained.

The structure is undoubtedly platy as in plutonic rocks but otherwise obscured by alteration.

There is little doubt, however, that the rock was originally a *feldspar-quartz-hornblende rock*, probably identical with $\frac{1}{700}$. A small amount of a kaolinised feldspar-quartz intergrowth is present.

63.—GOLD DEPOSIT AT FIELDS' FIND (THE PATCH), DUKETON, MOUNT MARGARET GOLDFIELD,

By C. S. HONMAN.
(With a Sketch Plan, Plate III.)

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INTRODUCTION.

Field's Find was discovered some three or four years ago, when alluvial gold was first found around a "boody hole." A rush followed, and some rich claims were pegged. Over 1,000 ozs. of alluvial gold was won off the patch, but it is believed that altogether 2,000 ozs. would be nearer the actual figure.

Further prospecting revealed alluvial gold to the north, on rising ground above the original workings. An acre of ground was dry-blown here; subsequently still further north two more alluvial patches of about an acre each were worked. The original workings cover an area of about 12 acres.

On the line of these alluvial patches a number of shafts have been sunk, and some rich patches of gold were obtained here and there, apparently close to a schist footwall and associated with iron-stone lodes resting on the supposed footwall. Most of these patches were struck at about 40 feet below the surface.

Altogether between 30 and 40 such patches were obtained, all disconnected, and owing to the decomposed nature of the country apparently occurring anywhere and in all kinds of country, consequently a method of blind stabbing has had to be resorted to. The largest patch yielded 250 ozs. of gold, and others 200 ozs., 170 ozs., 75 ozs., down to 50, 40 and 35 ozs., and as small as 2 ozs.

TOPOGRAPHY.

The find is situated roughly three miles west of Duketon Town-site, and occurs on slightly undulating country. Between Duketon and "The Patch" the ground is almost level. To the south-west there appears to be a fall towards the head of Borodale Creek. To the north-west the country rises gradually towards Inji Jingi or Mason Hill. There is rising ground to the south-east. The main alluvial workings occur in a depression which falls to the south-west.

GENERAL GEOLOGY.

Owing to the hurried nature of my visit no time was available for any geological mapping of the surrounding country, but the rocks appeared to be composed of decomposed greenstone schists for miles around. Isolated and narrow bands of what appeared to be granite schists were noted here and there, but owing to the decomposed leached nature of the country these might be crushed porphyries which can be definitely recognised a few miles west of "the Patch."

On the find itself two kinds of rocks are represented:—

- (1) Decomposed schist, probably derived from an Amphibolite schist.
- (2) Decomposed massive intrusive, probably derived from a fine-grained Dolerite.

On the west of the intrusive rock the schists are either more acid or very much leached, but at no great distance west the obviously basic schists occur again.

The schists all strike roughly N. and S., and dip from 40deg. to 50deg. to the west. The massive rock is an intrusive dyke cutting across the schist at an acute angle on a bearing of 25deg. W. of north, and has an average width of about 100 feet. The dyke dips to the west at a steep angle varying from almost vertical to 75deg.

Along the eastern contact of the dyke and the schist a "sliken-side" or greasy head occurs, with vertical groovings, giving it the appearance of a contact fault. This is borne out by the behaviour of quartz leaders coming in on to the contact. When the leaders come in from the schists and dip towards the contact they seem to be dragged into the contact, while leaders coming from the dyke and also dipping towards the contact are broken short and apparently dragged upwards along the contact or greasy head. Leaders in the fault zone are also crushed and granulated. It therefore appears that the dyke has slipped downward from the footwall or schist country, or the contact is a plane of normal faulting (see cross section of figure on plan).

At the surface it is impossible to recognise the existence of the dyke without scraping off the loam, and then it is extremely difficult to distinguish it from the schist on account of the cement covering.

For 20 feet below the surface, owing to the extreme alteration of the rocks, it is impossible to see the contact, and the schist cannot be definitely distinguished from the dyke above that depth, except for bands of ironstone occurring along the planes of foliation and dipping with the schists towards the contact.

In the southernmost lease, known as the Gravel Pit, the alteration of the rocks is more extreme. The surface rock here has been almost changed into a laterite capped with cement, and along the contact of the dyke and schist large pockets of ironstone gravel or (laterite) have been formed by the concentration of the ferruginous constituents of the rock into nodules. At first sight these pockets of gravel appear to be of alluvial origin, but they are undoubtedly an extreme form of alteration of the country rock in the neighbourhood of the contact fault.

Along the contact wall the line of the cement which caps the rocks at the surface has been leached out, forming a rugged channel which extends down from the surface for some distance. The "boody hole" from which the first gold on the find was specked was probably formed by a similar leaching of surface line from the western contact of the dyke.

The quartz leaders in the dyke are short and narrow and more like gash veins. They were probably formed by the filling of shrinkage cracks on the margin of the dyke. These quartz leaders generally strike north and south and dip 45deg. east, towards the contact. The quartz leaders coming in from the footwall side, on the other hand, are generally parallel with the contact and dip, the same as the schists.

ECONOMIC GEOLOGY.

The occurrence of the gold on the find appears to be undoubtedly associated with a contact fault, which is represented by the "slickenside" or greasy head that divides the schist from the massive greenstone. Patches of gold occur when a quartz leader from the dyke or massive greenstone abuts against the greasy head. When a patch occurs the gold impregnates the country about the greasy head, and along the course of the leader and on the hanging-wall side of the head. Leafy gold can also be seen along the face of the greasy head. At the time of my visit no one was actually working out a good patch, but Messrs. Brennan, Duke, and Hogan were working a couple of small patches, and from these some estimate could be made of the nature of the gold occurrence.

The quartz leaders in the massive greenstone in most cases strike N. and S. and dip 45deg. east, and between the leaders and parallel to them there is a slight incipient foliation. The gold solutions appear to have ascended along the greasy head and to have deposited their gold contents in the shrinkage fissures in the massive rock. There are cases in which patches have been found in the

massive rock away from the greasy head, but wherever pointed out they were associated with a quartz leader and were probably fed by the quartz leader from the greasy head.

The quartz leaders are very narrow, and are not continuous, but occur in small gashes, which may account for the occurrence of gold in patches and not as a continuous shoot.

Supposing the quartz leaders were continuous, then their line of intersection with the greasy head would pitch about 20 deg. south, if the greasy head is taken as striking 25deg. W. of N. and dipping 80deg. west and the leaders as striking N. and S. and dipping 45deg. to the east. Hence it is probable that along the greasy head a series of patches may occur pitching to the south at 20deg., but apparently with big blank spaces between them. It is possible, however, that in places where the patches are fairly close that values will lead from patch to patch and probably provide lode material between the patches of sufficient value to pay to crush at a battery. With the absence of anything else to go on, the contact fault or greasy head should take the place of an "indicator" to the next patch when the last has been worked out.

The contact fault should extend down to a great depth, and there is no reason why the vertical distribution of the patches should be any different from their horizontal distribution at about 40ft. level all along the line.

To the east there are some large blows of quartz, the dip of which cannot be discerned on the surface, but which is probably the same as the schists. If the blows live to hit the contact there is a possibility that they may carry gold there.

The greasy head often carries a narrow quartz vein apparently connected with leaders coming from the schist wall.

THE LEASES.

The North Block G.M.L. 1937T (Messrs. Dwyer Bros.).—On this lease six prospecting shafts have been sunk. At the south end the deepest is down 67 feet in hanging wall country and is sunk below the water level, which is about 63 feet. At 61 feet, drives north and south follow the hanging wall side of the greasy head. At 50 feet a patch has been worked east of the shaft.

At the north end of the lease one shaft is down in hanging wall country, but no gold had been located below the surface. Crossing the northern boundary there is a dry-blown patch covering about an acre of ground, on which claims yielding 30ozs. of gold were worked. The richest gold was got just above the contact fault.

Just outside the northern boundary on the same alluvial patch there are three prospecting shafts, one in hanging wall country and two in footwall country.

About four chains north of the same boundary there is another small dry-blown patch. This has been prospected by sinking six shafts in the patch, two in hanging wall country and four in foot-wall country. The two countries can be easily distinguished on the dumps, but in the neighbourhood of the contact they are very much altered, and it is difficult to locate the contact. No results were obtained from these underground workings, though some nice reefs were exposed in the schist dipping towards the contact.

At the south end of the lease from about 20 feet north of the water shaft a 200-oz. patch was obtained at a depth of 35 feet, and also other patches south of the water shaft.

G.M.L. 2018 (Messrs. Dwyer & Macallum).—On this six prospecting shafts have been sunk, three in footwall and three in hanging wall country. The party is at present working from two shafts in the middle of the lease from where they obtained a patch from the hanging wall country and close to the contact. They are now driving south on the contact at 50 feet. The kaolin in the neighbourhood of where they got a patch shows fine gold distributed through it.

G.M.L. 1938T (Messrs. Clarke & Cox); now held on tribute by Messrs. Brennan, Duke & Hogan.—This party was working at the north end of the lease, and had struck two small patches at 40 feet on the contact fault. One patch contained about 35ozs. The gold was coarse around the leader, and fine where it impregnated ironstone and kaolin. They were driving north and south on the contact.

At the south end of this lease a considerable amount of work has been done, and a patch yielding 250ozs. was obtained here. Also a block of ground between leader coming in from the south and the contact had been worked out. The ground between the quartz leader and the contact is apparently gold-bearing. The leader has been worked for 70 feet from the contact.

South of where the above leader cuts the contact the dyke appears to take a slight turn to the east. It is possible that the dyke has been fractured or slightly twisted, causing the leaders to penetrate to the opposite side of the dyke and possibly the gold had been carried across to the western contact and southwards along the western contact. This may account for the poor results obtained from prospecting the eastern contact in the south block, or Gravel Pit.

The South Block, G.M.L. 1917T (Messrs. Field & Fox); locally known as the Gravel Pit.—A great deal of work has been done all along the contact at about 40 feet, but with very discouraging results. Any prospects that have been obtained have been from the contact. All the workings in this lease are on the alluvial patch, and the richest gold from the alluvial was obtained from 100 to 150 feet west of the underground workings on the eastern contact. The line

of strike of the richest gold is roughly parallel with the eastern contact and across the "boody" hole from which the original gold was specked. I am of the opinion that in this lease the western contact of the dyke will prove to be the chief gold carrier, and would suggest prospecting near the "boody" hole, which is about 100 feet west of the eastern contact.

Outside the southern boundary there are three shafts, two of which are sunk in footwall country and the western one in hanging wall country. The contact has been driven on for 100 feet at 40 feet from surface, but without result, but the drive has not kept to the front all the way. At one place on the contact a series of vugs were encountered extending from the surface. It is probable that the "boody" hole is the opening of a similar line of vugs on the western or opposite contact of the dyke.

RECOMMENDATIONS FOR FUTURE PROSPECTING.

The patches have so far all been got at about 40 feet from the surface, and in almost all cases the shafts from which they have been got have been sunk in footwall country. These shafts were sunk vertically until the country was sufficiently undecomposed to give a schist footwall, which, dipping less steeply than the contact, when sunk on took the shaft up against the contact, and often along a promising looking ironstone lode.

If a patch were struck on the contact the ironstone lode has been regarded as the gold carrier, whereas really it is only a zone in the schist impregnated with iron, dipping with the schist and abutting against hanging wall country.

The plane of schist being taken as footwall, a rise put up along the ironstone would lead into footwall country and leave the plane on which the patches occur at the back of the rise. Hence it follows that if the contact fault is the true plane of the patches, then by following it upwards there should be 40 feet of backs practically unprospected.

In sinking there should be no difficulty because the hanging wall of massive greenstone would be easily recognised and is bounded by the greasy head, or zone of greasy heads. In places there may be two or three parallel heads and branch heads, but they should never be far from the contact and one (the principal gold carrier) will be more distinct than the others.

In rising the difficulty is that the contact fault or greasy head is not so distinct near the surface, and the rise is apt to follow the foliation of the schist which goes into the footwall country, and most of the ironstone leaders are parallel with the schists.

The ironstone in schist has, in my opinion, nothing to do with the gold except that the ironstone formations happen to generally

follow the quartz leaders into the schists. The ironstone formations are merely concentrations of iron due to the leaching of the country, and generally where ironstone is formed large masses of kaolin and pug are left around it.

In Messrs. Clarke and Cox's workings the gold could be seen in both the kaolin or pug and the ironstone, and on either wall of the greasy head.

It is therefore evident that the ironstone and pug is apt to mask the true structure which is responsible for the gold occurrence.

Below 40 feet this alteration, which is due to the action of atmospheric waters, will be less intense and the structure plainer.

The western contact of the dyke has so far not been prospected below the surface, and very little on the surface. This contact should be well worth trying, as the same conditions should occur there except that the dyke instead of the schists will be footwall, and the schists hanging wall. The difficulties on the west side of the dyke will probably be greater, because the schists will be dipping down and away from the contact and will probably carry quartz leaders and ironstone formations, which would be tempting to follow.

The rich alluvial gold from "the Patch" has probably come from the western contact, because the ground around the boody hole does not appear to have been subjected to any water action, since there is only a thin coating of alluvial (a few inches), and any sudden rush of water would have been carried away in the deep ground (two or three feet) on the north and south side of the alluvial workings.

In the deep ground the rich claims were lower down than the western contact, but here, apparently, a sudden rush of water occurred, probably caused by a severe thunderstorm, as I am told that the gold was distributed through the wash from top to bottom.

If the rich gold had come from the eastern contact, the rich alluvial should be very close to that contact, especially as the contact is dipping west.

I would therefore recommend:—

- (1) On all leases to follow the contact-fault or "greasy head," using it as an "indicator."
- (2) In the northern leases rise up on the contact fault from convenient places in levels driven on the contact.
- (3) In south block, sink on as conveniently close to the boody hole as possible, find contact and drive on it.
- (4) If on a series of good patches, prospect for further patches as if they were pitching south at 20deg.

SUMMARY.

(1) A fine-grained basic dyke striking 25deg. west of Magnetic North and dipping 90deg. to 75deg. west, cutting at an acute angle across greenstone schists which strike north and strike and dip 40deg. to 50deg. west, occurs.

(2) The gold occurrence is composed of a series of patches of gold associated with quartz veins in shrinkage cracks that abut against a contact fault occurring on the eastern wall of the dyke.

(3) The gold is never far from the contact fault except where carried into country by a quartz leader.

(4) The patches occur mostly in the hanging wall of the contact fault or indicator.

(5) The contact fault is represented by a greasy head or slickenside which is probably the carrier of the gold solutions which have impregnated the shrinkage veins in the dyke.

(6) The western contact is probably the chief ore-bearing zone at the southern end of the line.

(7) The vertical distribution of the patches should not differ from their horizontal distribution.

8th June, 1916.

64.—INVESTIGATION INTO THE CAUSE OF THE MINERALISATION OF THE "SEVEN-MILE" SWAMP AT GRASSMERE, NEAR ALBANY, SOUTH-WEST DIVISION.

By H. P. WOODWARD.

(With a Map, Plate IV.)

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INTRODUCTORY.

This investigation was undertaken at the request of certain settlers who claim that the drainage as carried out by the Government has not only been ineffective, but has in reality caused considerable damage to their lands by causing the deposition of certain injurious matter upon them, *i.e.*, by the flooding of their lands by storm water brought down from the hills by a drain which is said, contained injurious mineral matter.

EVOLUTION OF TOPOGRAPHY.

With the object of making the subject of this report as clear as possible, it will be necessary in the first instance to consider the physiographical changes that have taken place in this, and during recent geological times.

The area under review embraces that narrow strip of coastal country which runs in an east and west direction from Princess Royal Harbour, off King George's Sound, to Torbay Inlet.

It consists of a low-lying valley about one and a half miles in width and 10 miles in length, bounded on the south by a coastal range composed of granite masses and ancient consolidated calcareous sand dunes which rise fairly abruptly from the flats to an elevation of from 500 to 700 feet. On the rock side of the valley the

land rises more gradually, the surface of the slope being for the most part covered by sand and iron lateritic gravels with occasional outcrops of granite interspersed between small swampy basins.

A number of bores have been put down from time to time in this valley with the object of proving supposed coal or oil deposits, but in every instance these, after passing through beds of drift sand, ferruginous sandstones (coffee rock), and in some instances seams of brown coal of poor quality, encountered crystalline rocks at depths varying from 50 to 150 feet. This proves it to be a narrow granitic trough which at one time probably formed a shallow strait connecting King George's Sound with the sea at Torbay.

This strait appears in the course of time to have silted up with material brought down by the numerous streams which drain the country to the northward, assisted by the direct wash-off from the coastal hills to the southward, and to a certain extent by sand drifts wind-driven over these hills.

This latter is evidenced by a series of sand ridges which traverse the valley at right angles, thus cutting it up into the series of swamp basins of which it is now composed.

This ancient strait is now represented by a series of salt-water inlets, freshwater lakes or lagoons, and swamps which commence at the eastern end with Princess Royal Harbour which is a comparatively shallow inlet open to King George's Sound. Into this basin the swampy country for a distance of three miles to the westward and known as the Robinson Estate is drained, no engineering difficulty being experienced owing to the fact that the distance is insignificant and the elevation of the surface sufficiently above high water to obtain a fair fall in the drains. Upon the western edge of this area the main valley is crossed by the largest of the sand ridges before referred to, which forms the divide or water parting between it and the low-lying area to the westward in which, still taking them in the order from east to west, lies the "Six Mile" swamp, which is again divided from the "Seven Mile" swamp by a sand spit.

The "Six Mile" swamp, besides the run off from the surrounding hills and numerous springs at the base of the coastal hills, originally received the water brought down by the "Six Mile" creek, and, when filled, overflowed at the lower points of the spit into the "Seven Mile" swamp, which latter not only received this water but also that brought down by the "Seven Mile" Creek. Upon the western margin of the "Seven Mile" Swamp there is a sand bar over the lowest parts of which the natural drainage flowed, partly into Lake Grassmere, but mainly down a natural swampy valley which lies between this lake and the coastal hills, and eventually into the south-eastern area of Torbay Inlet.

Lake Grassmere is a fine sheet of fresh water which is fed by the Marbalup Brook. It lies upon the northern side of the main valley, and the water level in it stands at some few feet above that

of the saltwater of the inlet from which it was divided by a sand bank over which it discharged in time of flood.

The Torbay Inlet, which is salt, consists of two deep basins connected by a narrow neck some half-mile in length, the easternmost of which extends in the form of a salt creek for a distance of a mile in an easterly direction when it bifurcates, one branch running for a short distance to the northward being apparently the old course of the Marbalup Brook, and one to the eastward into the swampy valley before referred to which lies between Lake Grassmere and the coastal hills.

The western basin of Torbay Inlet, after receiving the entire drainage of the main valley referred to above, supplemented by that from the swampy country which lies between the coastal hills and the main plateau for a distance of four miles to the westward, discharges into the ocean by a channel some half-mile in length cut through the coastal hills.

The embouchure of this channel is closed for a considerable portion of the year by a sand bar thrown up by the sea, consequently all drainage and flood waters are impounded within these basins until such time as it rises sufficiently high to overflow it, or until an opening is artificially formed, when the scour cuts and keeps open a deep channel until the level of the enclosed sheet is reduced to that of the ocean, which latter then begins to re-build the bar.

The portion of the main valley which drains in a westerly direction is a little over six miles in length and, as previously stated, is of little elevation, a considerable area being only two feet above high water level (this of course is exclusive of those deep basins which are permanently filled with water), consequently, prior to the inauguration of a drainage system all these low-lying portions were flooded during a considerable portion of the year, or in some instances for longer periods when the flood waters failed to cut the bar.

ARTIFICIAL DRAINAGE OF THE AREA.

After reading the above it will be apparent that the drainage of the low-lying area with a rainfall of somewhere about 40 inches presents a fairly difficult problem, for given only a fall of two feet above high-water mark in the lower portions of the area and of only six feet in the same above dead low water, it will be seen that the greatest possible fall obtained from the eastern portion of this basin (which is six miles from the outlet) cannot exceed one foot in the mile.

This difficulty is further augmented by the trouble experienced in keeping the outlet open to the ocean, which may cause the water level inside the inlet to rise to a level exceeding that of ordinary high water, while further, an extra high tide accompanied by strong westerly gales may bank up the water from the inlet into the drains at its eastern end, thus causing flooding.

The drainage of this area was in the first instance undertaken by the Lands and Survey Department, and a main drain constructed along the north side of the "Seven Mile" Swamp, then southerly between it and Grassmere, and thence down the valley between the lake and the coastal hills, and so into the eastern branch of the inlet.

At a later date this district was proclaimed a drainage area when it came under the Water Supply Department, which changed the system by constructing a drain which diverted the water of the "Six Mile" creek from the swamp of that name and conveyed it directly into the main drain, while the entire volume of water thus conveyed was discharged direct into Grassmere instead of being conveyed round it by the old drain. A new discharge was then put into Grassmere at its south-west corner, which lowered the general level of that lake by some 18 inches or two feet. Under this changed system the old drain which followed down along the eastern and southern sides of Grassmere was devoted exclusively to the drainage of the "Seven Mile" swamp, although the old overflow from the lake into it was not closed.

From the above it will be seen that the larger volume of fresh water brought down by the "Seven Mile" creek was diverted from its natural course over the swamp of the same name, and that also the overflow of the "Six Mile" swamp and creek, which was fresh, was also cut off, the result being that so far as the "Seven Mile" swamp was concerned it received no fresh water other than the actual rainfall within the basin, and a limited amount of drainage from the coastal hills.

Having in the first place roughly traversed the topography of the entire basin as it existed prior to the initiation of a drainage system, and in the second place by the alteration made in the direction of the drainage by artificial means, the following portion of this report will be confined exclusively to the causes, effect, and suggested remedies for the overcoming of the disastrous condition which prevails in the lowest lying area of the "Seven Mile" swamp and along the course of the old drain which connects it with the inlet.

EFFECT OF THE DRAINAGE UPON THE "SEVEN MILE" SWAMP AND LAND BELOW IT.

It is claimed, and there are no grounds for doubt, that during the early years that this swamp land was cultivated the soil was very productive; now, however, the lower lying portions have become so highly saturated with mineral solutions as to render it perfectly infertile.

It is further contended that this state of affairs dated back to the first year of the completion of the new drainage system when, owing to an excessive rainfall, so large a volume of water was brought down by the newly excavated drains and the Marbalup

brook into Grassmere that the level of that lake was so materially raised as to cause it to discharge by its old outlet under what is known as the "Humpty-back" bridge, into the old drain which, presumably being choked, the water backed up in the ditches and thus flooded the "Seven Mile" swamp.

As the newly constructed drain connecting the "Six Mile" with the "Seven Mile" creek had been largely excavated through what is locally known as "Coffee rock" (ferruginous grit), the water brought down by this drain contained a considerable quantity of oxide of iron in suspension; and since the point at which the main drain discharged into Grassmere was not far distant from that at which the lake connected with the old drain, a considerable portion of this water would flow back in this direction, the consequence being that a large precipitation of this ferruginous matter took place upon this swamp, thus leaving a red-brown incrustation after the subsidence, and this it is claimed was the primary cause of the damage.

In order to avoid the recurrence of this, the old outlet from the lake into the drain was closed by filling it in at the point at which the "Humpty-back" bridge formerly crossed it.

From this date onward the infertility of this area has, it is stated, materially increased; it is therefore claimed that the flood is solely responsible for bringing about this condition of things by bringing down mineral solutions of a poisonous character which has utterly ruined large tracts of this area.

With the object of solving this problem a careful examination of the area in question has been made, all available evidence obtainable collected, and samples of soil and water analysed and reported on by the Mineralogist and Chemist, whose report is appended.

From the report it will be seen that the whole source of the trouble can be directly attributed to the decomposition of pyrite which is present in soil and subsoil of the swamp itself in considerable quantity; but in order to determine whether or no the water brought down from the higher land which lies to the northward would assist in producing a detrimental effect, a sample of water was obtained from the drain and tested, but this proved to be perfectly innocuous.

It therefore becomes clear that the flooding of this area in no way contributed to the poisoning of the land, while the phenomenon can be quite simply accounted for by the oxidation of the iron pyrites contained in the soil itself. Pyrites in its natural state is perfectly innocuous and remains so so long as it is kept from coming in contact with the air or any oxidising substance, and this fact accounts for its presence in much larger quantities in the subsoil as compared with that in the soil itself, as the former being situated below the water level is naturally protected from the air. The decomposition of pyrites is, however, brought about by either, or more rapidly by both, of the following conditions: firstly, by the drainage

of the land which permits the access of the air into the soil, and secondly, by cultivation, which opens up the soil, thus exposing the pyrites to the atmosphere.

In the course of decomposition pyrite forms sulphate of iron which is commercially known as copperas, or green vitriol, and free sulphuric acid, either of which substances in considerable quantity renders the soil unsuitable for the support of vegetation.

Having arrived at the conclusion that the source of the trouble can be clearly traced to the soil itself, the next point which naturally requires elucidation is, why for a considerable number of years should it have been possible to have grown fine crops on this land while during the last few years, or since the flooding, it has proved to be sterile?

In considering this aspect of the question it must be remembered that in its natural condition the entire drainage of the country lying to the north and east flooded over the "Seven Mile" swamp, therefore when this area was first drained and cultivated this large volume of fresh water travelling in a westerly direction would carry away each year large quantities of the acid solutions. After the construction of the first drain which cut off the water of the "Seven Mile" creek a certain amount of this scouring out would cease, but still it did not seem to have affected the fertility of the land to any considerable extent until the whole system was completed, after which date, however, no fresh water other than the direct rainfall was available for the removal of the injurious salts. The flooding which took place in the same year that the drainage system was completed would, since it entered the drains by their normal out-flow, have driven back the accumulated acid solutions instead of washing them out had the flow taken its original direction.

As previously stated, this flood left large deposits of iron oxide over the surface after the water receded which, taken in conjunction with the fact from this date onward the land became infertile, naturally led the persons whose land was injured to assume that this was the primary cause of the damage, as this was the only visible one. The fact is, however, merely a coincidence, since the flood immediately followed the completion of the drain which diverted the direction of the natural flow of the surface water. The present condition of the "Seven Mile" swamp is, that it is an isolated basin the lowest portions of which are only two feet above high water and six feet above low, situated at a distance of six miles from an outlet to the sea which is closed for a considerable portion of the year.

The rainfall, although considerable, is responsible for adding little more than that which actually falls upon the area when, after allowing for evaporation, it naturally follows that only a comparatively limited quantity would be carried off by the drains, while

the water remaining in them after the main rainfall period is passed becomes a very concentrated mineral solution.

The water discharged from this swamp would, therefore, contain a very large percentage of mineral matter, and since the drain which carries it off is the old one which was cut by the Lands Department along the swampy valley which lies between Grassmere and the coastal hills, this naturally becomes filled with these acid solutions since it does not receive any portion of the fresh water from the main drain; consequently when the water level of the inlet rises after the first heavy rains, this water is forced back and floods the low-lying areas, thus rendering these also infertile.

SUMMARY.

(1) The poisonous mineral solutions in the soil of the "Seven Mile" swamp are due to the oxidation of the iron pyrite in the soil itself owing to this mineral being brought in contact with the air by drainage and cultivation.

(2) So long as a large volume of fresh water traversed the swamp the injurious solutions were removed as rapidly as formed, but that this removal ceased to a considerable extent when the course of the natural drainage was diverted.

(3) The cause of the damage to the swamp-land lying in the valley between Grassmere and the coastal hills is due to their flooding by the acid solutions drained from the "Seven Mile" swamp.

REMEDIES.

There are only two remedies for the prevailing condition of this, namely, drainage and limeing—the former of which, coming within the province of the engineer controlling the drainage areas, will not be dealt with in other than a series of suggestions the feasibility of which must be left for those qualified to deal with them.

1. If means could be devised whereby an outlet to the sea could be kept permanently open, with flood-gates to prevent the inflow of high tides, a fair natural drainage of this area might be obtained.

2. If a series of high level channels were constructed into which the mineral water in the low level ditches could be pumped by wind or other power similar to the system adopted in the Fenlands of England and Holland.

3. If a main canal was cut south across the swamp from the point at which the "Seven Mile" creek crosses the railway line, from which smaller drains were cut in a westerly direction in a similar manner to an irrigation system, the fresh water traversing these would in the course of its passage drive before it and thus wash the injurious solutions from this area.

4. Limeing without drainage would be impracticable, since the quantity of this basic mineral required to neutralise the acid in the soil waters would be so great that the cost would make it prohibitive.

Mr. Simpson recommends the application of burnt lime in the first place, followed by ground limestone in the second. Either of these would, however, be costly unless permission was obtained to remove stone from the adjoining Crown lands, when kilns and a small crushing plant could be erected which would materially reduce the cost and thus allow of a liberal application, say of two tons to the acre, as a first dressing of burnt lime, and subsequently one ton of limestone annually until the acid in the land was overcome, after which the yearly dressing would have to be governed by conditions.

5. It must further be remembered that the trouble is due to the presence of the acid and acid salts, therefore the application of acid phosphates such as "Super" are only adding to the trouble; therefore it would be advisable to substitute this by any of the following: Thomas' Basic Slag, Bone Dust, Abrolhos Guano or Ground Rock Phosphate; the latter for preference, since it is guaranteed to contain 84 per cent. of phosphate of lime, and in consequence would go from two to three times as far as the others, while the free sulphuric acid in the soil would render the phosphoric oxide available, in fact convert it into super.

CONCLUSION.

This acid poison after drainage of lands is of quite common occurrence, in fact is to be expected; but since in the majority of cases the natural character of the country lends itself to the artificial drainage, these injurious solutions can be removed as rapidly as they are formed, consequently no injurious effects are experienced. Here, however, the natural gradient of the surface and other causes stand in the way of a simple drainage system, and reduce it to a more or less complicated engineering problem, which, however, there is little doubt will be overcome.

APPENDIX.

SOIL AND WATER FROM GRASSMERE DISTRICT.

I have made a preliminary examination of the soils and water from the Grassmere District, collected by Inspector Vaughan. The soils are said to have been previously fertile, but to have recently become barren.

The water proves to be strongly acid and to contain in solution abundant sulphates and chlorides of aluminum, iron, lime, magnesium and alkalis. Such water, even in small quantities, would have a fatal effect upon any vegetation to which it had access. On exposure to air it would slowly deposit a rusty iron compound such as that referred to by Mr. Vaughan.

All three soils are peaty swamp soils, strongly acid in reaction. Those from the sides and bottom of the drain are impregnated with pyrites and much soluble salts (sulphates and chlorides) of aluminum, lime and magnesium. That from the top appears to be free from pyrites and to contain much smaller quantities of soluble salts. Such strongly acid and saline soil could not possibly support vegetation of any kind.

The *cause* of the trouble is that the soil in these swamps, like those in the neighbourhood of Perth, contain a considerable quantity of finely divided pyrites (sulphide of iron) below the level to which air penetrates into the soil under normal undrained conditions, say two feet down. When the water level is lowered by drainage the pyrites is subjected to the action of the air, which converts it into a mixture of iron sulphate and sulphuric acid, both of which are completely destructive to vegetation.

The remedies are:—

- (1.) To ensure rapid removal of the water from the soil and surrounding drains and to refrain from returning to the ground any water from the drains ;
- (2.) To dress the surface of the soil heavily with burnt lime at first and with ground limestone later ;
- (3.) To use basic fertilisers and never acid ones such as superphosphate.

EDWARD S. SIMPSON.
Mineralogist and Chemist.

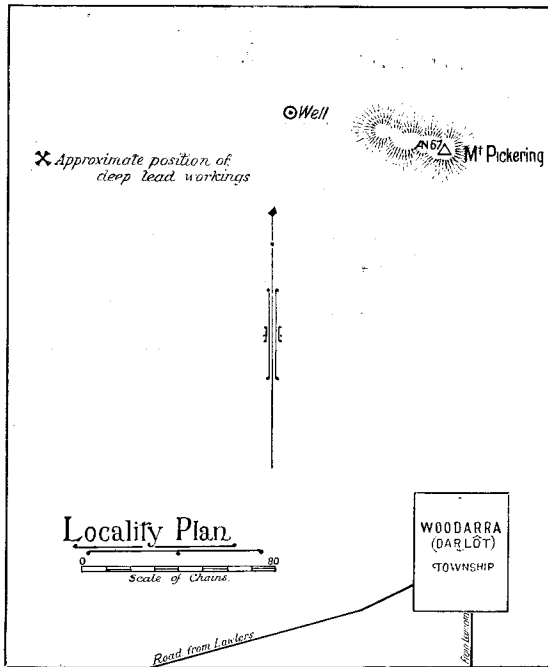
65.—THE DEEP LEAD AT DARLOT^A—EAST MURCHISON GOLDFIELD.

By J. T. JUTSON.

(With three Figures, 5, 6, and 7)

The workings pertaining to this deep lead are situated about three miles to the north-west of Darlot (Woodarra), on Prospecting Area 647, which is held by the Darlot Deep Lead Syndicate (Metzke and party) (Fig. 5). The country is quite flat in the immediate

Fig. 5.



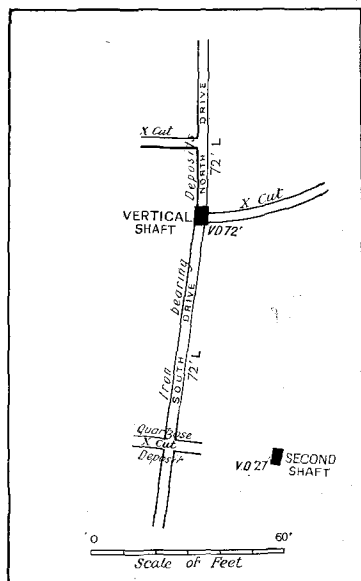
Locality Plan showing approximate position of Darlot
Deep Lead Workings.

vicinity of the workings, but some ridges and hills occur, rather short distances away, part of the drainage of which passes on to the flat. This flat is covered by detrital laterite and clay, and there

are no outcrops of any rocks, but from the nature of the surface material, the chief rock appears to be greenstone. Granite was stated to occur in various directions from the prospecting area, but none occurred (it was said) nearer than about five miles.

The workings on this prospecting area at the time of my visit are shown on the accompanying plan (Fig. 6).¹ They consist of

Fig. 6.



Sketch Plan of the Workings P.A. 647,
Darlot Deep Lead.

a main vertical shaft 72 feet deep, from which all the "driving" and "cross-cutting" have at present been done. From the bottom of the shaft there is a drive (the "north drive") north for 50 feet. At 19 feet from the shaft, a crosscut west has been made for 18 feet. From the shaft a curving crosscut east has been made for 38 feet. South from the shaft there is a drive (the "south drive") for 95 feet. At 68 feet from the shaft a crosscut west for 10 feet and a crosscut east for eight feet have been put in from this drive.

At a distance of 74 feet in a direction about S. 18deg. E. from the main shaft another vertical shaft was being sunk, and had reached a depth of 27 feet. It is the intention of the owners to continue this shaft to the bottom of the wash, and then to connect with the east crosscut from the south drive of the main shaft. That

¹ This plan is based on that prepared by Mr. H. Colbran, Inspector of Mines, with some slight additions, bringing the work done up to the 28th September, 1913 (the date of the present writer's inspection).

having been done it is then proposed to take out about 40 or 50 tons of the wash for the purpose of a trial crushing. The reason for sinking the second shaft and making the proposed connection, is that the water in the south drive and crosscuts makes the work of extraction and haulage too difficult. It is believed that the sinking of the second shaft will much facilitate this work.

The drives and crosscuts are only about 4 feet or 4 feet 6 inches high, and about 3 feet broad. They have been timbered to some extent, this being absolutely necessary on account of the "greasy" nature of the ground.

The low height and small width of the drives and crosscuts, combined with the fact that the water was at times knee-deep, made the examination of the ground difficult.

As far as could be seen descending the main shaft on a rope, the material through which this shaft had been cut consisted near the surface of several feet of detrital laterite, arranged in nearly horizontal layers and cemented by oxide of iron. Below this there were iron-stained clays, with bands and irregular patches of iron-stone pebbles, and near the bottom a few small quartz fragments were seen. The whole of the material may be described as "wash," in the sense that it has not resulted from the decomposition of rock *in situ*, but there is little evidence of much transport of any of the component parts, and this despite the fact that many of the iron-stone pebbles are rounded; for such rounding (for some pebbles at least) is probably due to concretionary action before the pebbles reached their present positions.

Along the north drive, the west crosscut from that drive, the crosscut east from the main shaft, and the south drive for more than 50 feet, the material is much alike. It is undoubtedly of detrital origin and consists principally of iron-stained clay with ironstone pebbles from one quarter of an inch to three or four inches in diameter and frequently rounded, such rounding being partly due to attrition, and partly to concretionary action. Scattered through these deposits is an occasional fragment of quartz, sometimes angular and sometimes well rounded. The writer was informed that these iron-bearing deposits, as they may be termed, carried traces of gold, but were regarded as unpayable. Throughout the portions just described, no undoubted bedrock could be seen. The iron-bearing deposits practically occupy the whole height of the drives and crosscuts, but in places a white clay, almost free from coarse detritus, could be seen above.

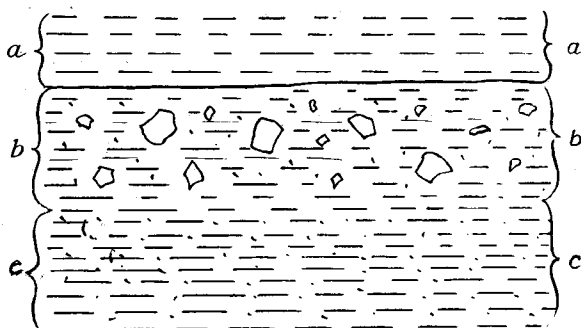
In the east and west crosscuts of the south drive, and in the latter south of the crosscuts and for about 12 feet north of the crosscuts, the wash is different from that hitherto described. Three distinct bands can be seen (Fig. 7). On a level with the roof of the workings a white very "puggy" clay occurs, which appears to contain scarcely any grains or fragments of quartz, ironstone, or

other material, being practically homogeneous, with numerous small irregular planes, which are smoothed and striated, and which thus prove that considerable local movement must have taken place in

Fig. 7.

DARLOT DEEP LEAD

Section . of auriferous wash 4^{ft} 6 in thick in east cross-cut of south drive 68 ft from main shaft :—



Bed Rock

- (a) Non auriferous wash, composed of white clay almost free from grains or fragments of quartz, ironstone, or other detrital matter
- (b) Auriferous wash, composed of white clay with numerous angular and subangular fragments of quartz, and some of ironstone. The fragments vary in size from a grain to 3 or 4 inches in diameter
- (c) Auriferous wash, composed of white clay, and chiefly grains of quartz. Few large detrital fragments.

Section of Auriferous Wash, 4ft. 6in. thick, in East Cross-cut of South Drive, P.A. 647, Darlot Deep Lead.

the mass.¹ It was stated that this material practically carried no gold. Below this, and separated by a sharp line was similar white clay, but mixed with it was an abundance of fragmental quartz. These fragments varied in size from flattish pieces about four inches

¹ This is also shown by the fact that some of the soft earthy pebbles of the coarse wash have been planed and striated.

in diameter to grains about the size of a pin's head. Both the small grains and fragments up to about one and a-half inches in size were common. The large pieces of quartz were generally quite angular, but at times were slightly rounded at the corners. The small grains were also angular, but the most numerous pieces (from a quarter-inch to about one and a-half inches in size) were often sub-angular, and partly rounded. Here and there an extremely rounded small pebble occurred, and a fair number of similar ones (which had been picked out from time to time by the owners) were shown to the writer. Taken as a whole, however, the fragments were angular and sub-angular. They showed some evidence of attrition, but the majority of the fragments must have travelled but a comparatively short distance. The extremely rounded forms may be regarded as forming a small minority of the whole, and the contrast between these and the more numerous fragments is so great that it is quite possible that these very rounded pebbles belong to a pre-existing gravel deposit, and have since been incorporated with the more modern deposits of the present deep lead.² In the wash were also some rounded ironstone nodules from a quarter-inch to two inches in diameter. Some of these are probably of concretionary origin before inclusion in the deposit. There were also some few rounded soft pebbles of a decomposed rock, apparently a greenstone.

This coarse-grained deposit would average between two and two and a-half feet in thickness. It passed irregularly and gradually into an underlying deposit, which is generally from 18 inches to two feet in thickness (so far as seen, and this is probably correct, but neither its lower margin nor the bedrock was visible on account of the water, and of the floor being covered with wash from the walls of the drives and crosscuts). This last-mentioned deposit consists of the same "puggy" white clay, with the larger fragments of quartz and ironstone generally absent, but small quartz grains were fairly numerous. Both the coarse and the fine wash were stated to carry gold, but the fine wash was regarded as being the richer.

Going north along the south drive from the crosscuts the white quartzose wash appeared to gradually pass into the iron-bearing deposits already described, at a distance of about 12 feet from the crosscuts. Going south the coarse band loses its identity, and is apparently dying out, but the fine band is maintained, although the gold was said to be becoming scarcer. The coarse material also appears to be dwindling in the west crosscut.

No cross-bedding or stratification bands (other than the coarse and fine ones mentioned) were noticed in the quartzose deposits. As far as could be observed, they appeared to have a slight fall to the south-west, but this is not too certain.

In the south drive, near the junction of the crosscuts, two granitic boulders, somewhat rounded, and being about 9 and 5 inches

² If this be so, some of the gold may also be of similar origin.

respectively in length, were noticed on the floor of the drive. The writer was informed that they occurred at the bottom of the wash, and presumably, on the bedrock. This granitic rock [13295] has been examined by the Petrologist, who describes it as a very felspathic facies of a fine-grained granite or porphyrite, with actinolite, and deficient in quartz. The occurrence of these boulders is curious, as no granite is seen on the surface for some miles around. It is evident that granite, perhaps as a dyke, must be close to the surface in the neighbourhood of the deep lead; and it may be largely responsible for the small quartz grains and the kaolinic-looking clay forming such a feature of the detrital deposits.

Another interesting point is that, in the south drive, south of the crosscuts, a "bar" of hard rock, about three inches in width, was stated to cross the drive, and to project above the decomposed bedrock for about a foot in height. This "bar" was unable to be seen, but a specimen of it was handed to the writer. If it occur as stated, it is probably a small dyke, which has resisted erosion more than the adjacent rocks. It also shows that the bedrock has been reached.

This rock [13297] has also been examined by the Petrologist, who points out that, although quartz is conspicuously absent, there is a close resemblance to [13295] and suggests that they may be genetically connected, [13295] being slightly more acid than [13297]. The latter, he states, has some similarities to the non-porphyrific phases of the albite-porphyrates, and it may therefore be regarded as a felspathic facies of a granite with actinolitic hornblende, or as a very felspathic phase of an amphibolite; more probably the former.

The field and microscopic evidence therefore suggests that [13297] is a small dyke cutting through the bedrock of the lead, and that the boulders of [13295] are probably derived from a different phase of the same or another similar dyke.

Several dishes of the quartzose deposit were washed and mostly gave fair prospects of gold, the latter being coarse as well as fine. Several quartz fragments containing free gold were shown to the writer, and they were reported to have come from the quartzose deposit.

The second shaft that was being sunk contained material generally similar to that of the main shaft, but no quartz fragments were noticed. Irregular bands and patches of gypsum occur.

A few yards to the east of the shafts mentioned are several old shafts (now inaccessible) which were apparently sunk to work the deep lead, but from which payable wash had not evidently been obtained. The material thrown out was much akin to that which has been described above as the iron-bearing deposits.

Taking all the facts into consideration, it may be stated that a true auriferous detrital deposit occurs, which in accordance with the usage in Western Australia may be described as a deep lead.

The extent, thickness and direction (except possibly to the southwest as to direction) cannot be given, as insufficient work has yet been done, and the surface throws absolutely no light on these questions. The old workings and most of the present ones are probably not in payable ground, but the quartzose deposit (which was discovered by careful, economical, underground prospecting) undoubtedly carries some gold, but whether payable or not will probably only be determined satisfactorily after 40 or 50 tons have been crushed, such crushing being advisable in consequence of the heavy wash in places, and the hard nature of some of its components. The prospects appear to be sufficiently good to further prosecute the work, to enable this trial crushing to be made. This further work may also demonstrate whether the quartzose deposit is a mere "pocket" (as to some extent appears probable), or whether it represents a portion of an ancient well defined stream-bed deposit. At present no distinct "gutter" can be said to have been located.

3rd October, 1913.

66.—REPORTED OCCURRENCE OF OIL NEAR WONNERUP —SOUTH-WEST DIVISION.

By E. DE C. CLARKE and H. P. WOODWARD.

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INTRODUCTORY.

May 31st and June 1st and 2nd, 1915, were occupied in travelling to and examining the neighbourhood of Block 687, near Wonnerup, where indications of petroleum were reported to occur.

Block 867 (see Plate V.) is about four miles in an east-south-east direction from Wonnerup Junction, which is six miles from Busselton and 143 miles from Perth. It lies on the Coastal Plain of the South-West, which is described by Messrs. Saint-Smith¹ and Jutson². Where uncultivated, the surrounding district is forest-clad. Bordering on the block, however, is a treeless area of about 1½ square miles, covered only with stunted vegetation. The Abba River, a meandering watercourse, discharging into the Vasse Estuary, should cross the block in a north-westerly direction, but has no defined course in the part with which this report deals.

CHARACTER OF "INDICATIONS."

The portion of Block 687 from which the most pronounced "indications" are reported, was, until cleared by the owners, covered with the ordinary forest. The surface is almost level with the exception of a low mound, known as "the Bank," which rises about six

1. G.S.W.A. Bull., No. 44., p. 8, *et seq.*
2. G.S.W.A. Bull., No. 61., pp. 41, 171, *et seq.*

feet above the surrounding plain, and, running in a general north-west and south-east direction for about 18 chains, passes gradually at both ends into the general plain (see Plate VI.). There is no evidence that the "Bank" marks an anticline or any other geological feature of importance. About 20 chains away from the farmhouse is another slight elevation occupied by a clump of trees and marking an occurrence of "ironstone" (ferruginous laterite), which also is of no significance for the purpose of this report.

Unfortunately, at the time when the visit of a geologist was requested, the "indications" had been almost entirely dispersed by heavy rains. Iridescent scums were pointed out to the writer on some of the pools occupying the course of the Abba River, near Wonnerup, and also on the wells near the farmhouse. Some were apparently mobile, but did not, when disturbed, give the "rounded, curved or convoluted figures" of undoubted oil films. Others were iron oxide films.

As no promising surface indications were to be seen at the time of the writer's visit, the following summary of the "indications" observed by the owners may be of some interest:—

"Indications" were first noticed about the end of 1910, when, on sinking well No. 1 (see Plate VI.) to a depth of about 11 feet, a strong 'smell of kerosene' was noticed. The water could scarcely be drunk either by man or beast. When a well is first sunk in new ground, the water often improves with baling, but this improvement did not take place in Well No. 1. Sometimes the water would be covered with a sheet of oil so thick that a pint could have easily been collected. Moreover, oily drops, as much as one inch in diameter, would often be seen floating on the water. If touched these drops would break up and form either an iridescent scum or chains of minute globules and at the same time a shower of fine red dust would sink to the bottom.

The best "indications" are seen during the hot weather from December to March. The winter rains almost completely disperse them. However, between July and November of each year oil films occur on all the puddles over the area under discussion.

The absence of trees from the area near Block 687 is thought to be due to the evil influence on plant life of petroleum and accompanying saline exudations.

The writer wishes to make clear that, while he is not responsible for any of the observations in the last three paragraphs, he believes that they were recounted to him in all good faith. It is true that chemical investigations have failed to reveal any trace of petroleum in strata from these wells, but it has frequently happened in many parts of the world that disagreeable tastes and smells in water draining swampy ground have been mistaken for the taste or smell of "kerosene."

are devoid of coal seams, whereas if the same beds are examined in a neighbouring area where barren of oil they will prove to contain coal seams or other traces of vegetable matter.

Plate V. shows the position of certain bores put down some years ago in this district in search of coal. A simplified diagram showing the strata passed through in three of these bores is also given (Fig. 8). It will be seen that in each bore thin seams of coal were cut, but no trace of oil or gas was recorded.

Again, it is known that coal occurs in the Donnybrook Beds further east.¹ It is, therefore, rather unlikely that in or near Block 687 those coal seams which exist unaltered both to the east and to the west will have been changed to petrolaceous substances.

Beds of the same character and probably of the same age occur in the Blackwood River District, and despite a good deal of effort have not been proved to be oil bearing.²

Summarising: geological evidence as to the possibilities of oil occurring in or near Block 687 is, in the absence of outcrops and of bores in the immediate neighbourhood, very scanty. What little there is is unfavourable.

METHOD OF COLLECTING SAMPLES.

The collecting from the most favourable localities of fresh, reliable samples for analysis was undertaken. A new well (No. 4 on Plate VI.) was dug by the owners to a depth of 11 feet; a hole was bored by hand to a further depth of 11 feet. Samples of the material sunk and bored through were taken. A bore was also put down from the bottom of No. 1 well a further 11 feet and the borings kept. The strata passed through are noted on inset Plate VI.³

If oil is sufficiently abundant in these beds to exude in summer time to the extent reported in Section 2, we should expect that the piercing of hitherto untouched strata would, even in winter, liberate a noticeable amount, more particularly as the clay passed through in both bores was well suited to prevent the escape of oil and so would presumably have kept considerable quantities sealed up.

After 12 hours the water which had collected in Well No. 4 showed such a very slight film that no satisfactory sample could have been taken. The owners, however, after allowing the material to accumulate for some days, obtained the sample of water which is reported on below.

Portions of a sample of sand and clay from Well No. 2 had been treated by Mr. M. A. Browne, at Ravensthorpe, and had yielded an appreciable amount of a substance which appeared to be a hydrocarbon. Mr. Browne records, however, that the sample had been moistened with water from No. 1 Well, on which oil was said to have been floating at the time. Through the kindness of Mr.

1. G.S.W.A. Bull. 44., p. 25, *et seq.*
 2. G.S.W.A. Bull. 65.
 3. Scale of inset should be 20ft. to 1in.

Browne the balance of this sample was secured for further examination and is referred to in Mr. Simpson's report as "Browne's Sample."

In conclusion, I wish to record my thanks to the owners of Block 687 for their courtesy and ready help both in giving information and in carrying through the re-sampling of the supposed oil-bearing rocks.

12th July, 1915.

APPENDIX

ON SAMPLES OF SUPPOSED PETROLEUM-BEARING EARTHS
AND WATER FROM WONNERUP.

The samples submitted consisted of five lots of wet sand and sandy clay from shallow depths and a sample of water from a well sunk in the same.

There were no visible indications of petroleum-residues in any of the samples.

Since liquid petroleum consists largely of oils which are volatile in the air at the ordinary ground temperatures reached in the day time in this locality, it is highly improbable that any liquid petroleum should exist in moderately porous earths obtained so near to the surface. Had petroleum at any time however, penetrated into this earth, it would have left behind one or other of those typical non-volatile residuals, paraffin wax or asphaltum. Experiments were therefore made with a view to extracting any such residual and determining its nature and amount. Quantities of earth were taken such that one part per million of asphaltum or paraffin wax might be recognised. Three common solvents were available for extraction, viz., carbon bisulphide, ether, and petroleum spirit. Paraffin wax and liquid petroleum are completely and readily soluble in all three, asphaltum is completely soluble in carbon bisulphide, whilst ether and petroleum spirit dissolve from 40 to 100 per cent. by weight of this substance. At the same time it is to be remembered that all three are powerful organic solvents capable of dissolving many oils, resins and other substances of vegetable and animal origin, such as have been proved to exist in many soils.

For various reasons carbon bisulphide was not used as a solvent, but all five earths were extracted by both ether and petroleum spirit, and the extracts evaporated at room temperatures to recover any dissolved matter. No trace of petroleum or either of its typical residuals was found in any of the five earths. The five samples tested were marked 516c, 517c, 518c, 519c, and "Browne's sample." The last named enclosed in its midst a dirty cork, which may or may not at some time have come in contact with a vegetable or animal oil.

No indication of petroleum or petroleum residues could be detected in the water sample, which, however, was greatly contaminated by dead and dying animal and vegetable matter.

EDWARD S. SIMPSON,
Mineralogist and Chemist.

8th July, 1915.

THE ABBA RIVER OIL PROSPECTING AREA—SOUTH-WEST DIVISION.

This area, which covers 3,000 acres, is situated upon the coastal plain about four miles south-east of Wonnerup and about eight miles east of Busselton.

The coastal plain in this locality is nine miles in width, running in a north-east and south-westerly direction, being bounded on the north-west by the sea and the south-east by the laterite-covered scarp which extends from the Collie River to Cape Naturaliste.

The Abba River takes its rise in the elevated laterite-covered and jarrah-clad country which lies to the south-eastward of this scarp, from which it flows in a well-defined channel for a distance of about three miles, one mile of which is included in the south-eastern corner of the prospecting area.

At this point the river spreads out over a wide flat which, during the rainy season, it mostly covers with a shallow sheet of water; the only portions not so flooded consist of low eminences upon which "black butt" and other timber flourish, while the open flats are destitute of timber but for the most part covered with rush-like growth.

On this level tract of country open flats destitute of vegetation are fairly common, upon the surface of which an incrustation of salt is often present during the dry season, this being apparently due to the evaporation of the salt contained in the run-off water from the hills supplemented by previous accumulations contained in the soil of which these swampy areas are composed.

Upon the northern margin of this area, in which direction the surface of the country gradually falls, the water brought down by the Abba from the hills accumulates in swamps which eventually are drained by a defined channel which discharges into the Vasse Estuary.

Upon Location 687, which is situated at about the centre of this area, the Wilkinson family, who own this property, which is known as Seven Oaks, discovered in sinking a well that the water after being allowed to stand for a short time was covered with an oily substance, which gave rise to the assumption that deposits of mineral oil existed in this locality.

With the object of further testing this question a number of holes were sunk, in all of which when water was struck, which is usually at a depth of about eight feet, what is called by the Wilkinsons the oil phenomena, may be observed.

Upon the area itself no geological features can be observed, since the only rocks visible are clays in the flats, with loamy rises

and occasional outcrops of laterite; while to the south-east the bold scarp of laterite-covered sandstones and shales belonging to the Donnybrook Series rises abruptly from the plain. To the north-west at a distance of about two miles from the coast is a belt of cherty limestone country about one mile in width which is densely timbered, largely with tuart. This limestone is the southern extension of the Marine limestones at Capel, which contain fossils, shells, and corals of existing species. It is, therefore, only natural to assume that these beds are of the same age and were deposited in a shallow sea.

Westward of this limestone belt there is a long valley in which exists a chain of swamps and estuaries into which the drainage of the land to the eastward is discharged, while these estuaries empty themselves into the sea through the Wonnerup Inlet, which is a comparatively narrow gut cut through the line of lofty sand dunes which fringe the coast line. The contentions advanced by the prospectors as evidence of the existence of mineral oil are (a) greasy scum on the surface of the water in the shallow wells and swamps; (b) ebullition of gas which rises in bubbles through the water, and is also observed to rise from the earth subsequently to the annual flooding of the flats, in which case blow holes are left after the surface water has subsided; (c) drumming sound of the ground in certain localities when a horse or cart passes over the surface; (d) the failure of vegetation in patches upon the cultivated land; (e) the occurrence of sandstone in the trial holes sunk; (f) salt patches on the surface of the ground.

Taking these in order, I have arrived at the following conclusions:—

(a) There is undoubtedly an oily substance upon the surface of the water in the wells, that on the swamps I was unable to observe as they were dry. This greasy film is very common on all waters in the swampy areas of the south-west, and is quite distinct from the iron scum as it flows on the surface of water. The rate at which this film covers the surface of the water after being disturbed is regulated by the atmospheric temperature, thus it may take a considerable time to close in the early morning but flows rapidly in the hotter portion of the day.

This film is so thin that even after repeated skimmings the quantity of oil collected is practically inappreciable, while it is stated that if these skimmings are reskimmed and placed in a bottle that the oil evaporates through the cork. This latter I believe to be an error, and would suggest that the oily film attaches itself to the inside surface of the glass and thus vanishes from the surface of the water.

The composition of this oily matter has as yet been undetermined, but I am of the opinion that it is of vegetable origin,

probably exuded from the roots of the rushes, as I have never observed it in any locality where these do not grow.

(b) Ebullitions of gas.—These can be observed if the muddy bottoms of the holes or pools are disturbed. This is quite a common phenomenon, being due to the liberation of sulphuretted hydrogen gas the origin of which is the decomposition of any vegetable matter, and is of very common occurrence in all swamps.

The supposed gas blows could not be observed as the ground was all dry, but the blow holes were distinctly visible; these, however, I attribute to the escape of air held in the soil, which is first covered by flood water and then driven out by the descending water soaking the ground. A similar effect can be readily produced by filling a flower pot with fine dry earth and submerging it in a bucket of water, when the air contained in the soil is driven out with a similar formation of blow holes.

(c) The drumming sound noticed in crossing the surface is very common, being due to a hard crust or layer of rock at or near the surface, beneath which is a dry stratum containing air; this is not to be observed in the rainy season as the interstices in the substratum would then be filled with water.

(d) The failure of crops to grow upon patches on the cultivated land is not necessarily caused by the exudations of mineral oil, but is more probably due to the rise of saline water drawn up by capillary attraction. This action is induced by cultivation and is therefore not observed on the untilld land. It may be mentioned here that all the water encountered in sinking upon this area is saline, and probably contains chloride of magnesia as well as soda; I have not, however, the results of the analysis of the sample collected by Mr. Clarke.

(e) Occurrence of sandstones in the trial holes—This is looked upon as an indication by the prospectors who, in reading up the subject, find that sandstone was invariably one of the rocks met with in all the noted oil fields. The sandstone in question is of a ferruginous character and presents more the appearance of an iron-cemented sand bed similar to the deposits so frequently met with in swamp beds, since all evidence of bedding is wanting.

(f) The presence of salt is also advanced as an indication of the presence of petroleum as this substance has invariably been found in association with it.

From the foregoing it will be noticed that all the so-called indications are of extremely common occurrence in other parts of this State, while the oil, although its true character* has not as yet been determined, is clearly not petroliferous, otherwise horses, which are most particular and possessed of a wonderful sense of smell, would not drink of it.

* NOTE.—On 8th July, 1915, Mr. Simpson did report that there was no indication of petroleum or petroleum residues in the water sample collected by Mr. Clarke.

If, however, for the sake of argument we allow that the oil represents a petroliferous seepage, we must naturally conclude that the impervious cover beds essential to the retention of oil in a subterranean reservoir are absent, therefore boring in search of these would be naturally useless since at best low-grade petroliferous beds could be expected.

In conclusion, I am reluctantly compelled to state that after a careful examination of the area, and after weighing the so-called evidence adduced in support of the existence of petroleum deposits in this locality, I find that all the so-called oil phenomena could be attributed, and in my opinion are, to much simpler causes; therefore, although it is impossible for me to make the statement that oil does not exist in this area, I can safely state that absolutely no indications exist of its presence in this area, which is identical in every way with many thousands of square miles of territory in this State.

23rd March, 1916.

67.—THE CHEMICAL AND PHYSICAL PROPERTIES OF SOME OF THE DONNYBROOK SANDSTONES.

By EDWARD S. SIMPSON.

(With a map, Plate VII., and two figures, Nos. 9 and 10.)

NOTE.—Six samples of sandstone representative of the various quarries at Donnybrook, and from different horizons in the same, were submitted by the Chief Architect for the express purpose of having an investigation made by the Laboratory Staff, with the view of determining their relative durability as building material. The quarries are situated on the Bunbury-Bridgetown Railway line, 132 miles from Perth, and at elevations approximating to 200 feet above sea-level.

A. GIBB MAITLAND,
GOVERNMENT GEOLOGIST.

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Introduction.

During the last fifteen years a number of quarries, all of them as yet comparatively small, have been opened up in various places within a radius of about three miles of the railway station at Donnybrook, where there is a considerable development of almost horizontally bedded sandstones of unknown age.¹ The stone from these quarries has gradually won its way into favour with the metropolitan architects, who now recognise its artistic appearance and practical utility for a large variety of structures. Experience of

1. Only a single very imperfect fossil (mollusc ?) has been obtained from these beds, viz., from the Government Quarry.

its lasting qualities is however limited, owing to the short time during which it has been in use, to the various localities from which the stone has been derived, and to the small development of the quarries from which it has been won. In view, therefore, of the growing importance of the stone as a building material in the city of Perth, and of the large expenditure proposed to be made on a new General Post Office, it was considered advisable to obtain some definite data regarding the strength and probable durability of the various grades of stone obtainable from the different quarries in the Donnybrook area.

In general the workable Donnybrook stone may be described as a felspathic sandstone whose principal binding is kaolin or halloysite. In colour it varies from pure white to deep buff or exceptionally deep pink, the paler coloured stone invariably darkening evenly on exposure to the air. In grain it varies from very fine to moderately coarse. The stone is obtainable in large blocks of even quality, and in those which reach the City current bedding and "sand-balls," *i.e.*, poorly cemented patches, are rarely seen, and flinty patches never. The stone is easily worked by machine or by hand when freshly quarried, but hardens distinctly on exposure to dry air.

Originally six different stones, each in duplicate, were submitted by the Chief Architect as representative of the quarries at Donnybrook, and subsequently a seventh was obtained from the new Government quarry. With them was a "Sydney" sandstone for comparison. From my own experience, however, of Sydney sandstone, I am of opinion that this latter stone did not come from any of the important Pyrmont or other quarries of "Hawkesbury Sandstone" within the boundaries of the New South Wales metropolis, but from some quarry outside that area and nearer to the edge of the basin in which the rock has been deposited. This opinion was shared by a Sydney architect to whom the specimens were submitted. I shall therefore, in order to avoid misconception, refer to this rock as "Hawkesbury" stone, recognising that it is derived from the Hawkesbury Series, but that its exact locality is uncertain.

It will be convenient to state early in this report the relative value I place on the stones for building purposes, and give details subsequently. At the outset, however, it is necessary to draw attention to the fact that no quite satisfactory value can be placed on any sedimentary rock for building purposes without more data than are at present available with regard to these stones, of the highest importance being a crushing test on thoroughly wetted stone, and a comparison of physical properties of portions of the same block before and after actual exposure to the weather for at least twelve months. As Donnybrook stone promises to become the most important building material in Perth, such tests should be carried out as soon as possible by the Government Architectural Branch in conjunction with Geological Survey Laboratory.

The relative building values of the stones submitted, having regard to their strength, durability, and general fitness, are as follows:—

- (1) { Quarry No. 1, Loc. 1244, North Donnybrook.
- (2) { Government Quarry, Res. 2720, North Donnybrook.
- (3) "Hawkesbury," New South Wales.
- (4) Goldfields Quarry, Loc. 535/152, South Donnybrook.
- (5) Quarry No. 3, Loc. 48/1924, North Donnybrook.
- (6) Armstrong's Outcrop.
- (7) Arnott's 1st Quarry, Loc. 48/1991, North Donnybrook.
- (8) Pink Quarry, South Donnybrook. Stone at eight feet.
- (9) Pink Quarry, South Donnybrook. Stone at surface.

Owing to the disappearance in transit of specimens of the best Sydney sandstones from the Pyrmont Quarries with which I had arranged to be supplied, I have been unable to make any close comparison with this greatly used stone. In the absence of specimens it was also impossible to compare in detail the Donnybrook stones with what is usually considered to be the best freestone in Victoria, viz. that from Stawell. Many details regarding the latter are to be found in the *Proceedings of the Royal Society of Victoria*, Vol. XXII., pp. 172-197.

Tests applied.

The strength and durability of a sandstone depend mainly upon three factors:

A. The relative quantity of quartz, a practically indestructible mineral, amongst the sand grains.

B. The relative proportions of grains of various sizes. It is just as essential in a good sandstone as in a good mixture for concrete that there should be sufficient smaller grains of various sizes to fill in the large spaces between the coarse grains.

C. The tenacity and durability of the binding material under the varying conditions of exposure in a building. This is the most important point of all, since though the sand-grains individually may be strong and durable, without a strong and durable cementing material the stone in mass will ultimately approach to the condition of a mere sand without coherence.

In order to elucidate these points the following tests were required:—

(1) *Crushing Test of Dry Stone.*—The utility of this test is obvious, and figures for it were available from the testing plant at the Midland Junction railway workshops.

(2) *Crushing Test of Wet Stone.*—This should be made on duplicates of the same blocks after thorough saturation with water. The surface of a sandstone in the outer walls of a building is frequently, owing to its great porosity, saturated with water to a greater or less depth during the wet season, and in this condition

the stone is still subject to the usual compressive stress due to the superincumbent weight, as well as to the scouring action of rain, wind, and, to some extent, of sand grains and passing traffic. In all sandstones the cementing material consists to a greater or less extent of colloidal minerals of the clay group, which will appreciably soften when wetted and may even pass into a slurry devoid of all cementing power. It is evident, therefore, that a wet crushing test is of great importance in the case of sandstones. No definite figures are, however, available in these cases, and hand compression, which was resorted to, is very unsatisfactory, though the results in the case of the stones from the Pink Quarry were one of the chief causes why they were placed so low in the list on page 77.

(3) *Actual Weathering Tests.*—These would be of the highest value, if carried out under scientific control, over definite periods of time, and under identical conditions, on a series of blocks from the different quarries, each block being cut into a number of similar small masses, with comparison of physical and chemical properties before and after the exposure. No such tests have yet been made, but they should be inaugurated immediately. In the absence of such tests, an examination has been made of buildings in the City whose age is known as well as the source of stone. Such an examination would in any case supplement the scientific tests. A list of the more important structures in which Donnybrook stone has been used is given on page 91.

(4) *Artificial Weathering Tests.*—Many laboratory tests have been devised from time to time which are supposed to indicate in a few hours or a few days the effects of years of weathering. Such tests are all extremely artificial and there is no definite proof that any of them give figures corresponding to the true weather-resisting properties of the stone, except perhaps in regard to frost, a phenomenon which may well be disregarded in Perth, where it is of such rare occurrence and of such slight intensity. None such was therefore applied to these stones.

Long-continued brisk boiling, which might be expected to give some idea of the resistance of the stone to the abraded effects of wind and rain, gave results which were small and inconclusive.

(5) *Size of Grains and Porosity.*—As a rule a stone with an unusually high percentage of coarse grains and but little medium and fine, or one with an overwhelming proportion of very fine and but few grains of medium size, will wear less well than one composed largely of medium-sized grains with due proportion of fine cementing material. The ideal condition would be such a blending of grains of various sizes that all pores are completely obliterated. Such a state is approached in the cases of the stones from the No. 1, Government and Goldfields quarries, but more perfect conditions in this respect would have been indicated by still lower figures for the porosity. As a key to the exact class of stone represented by the

crushing and other tests, the figures for the size of grain are invaluable when dealing with such a stone as sandstone which varies in texture within a small area.

The determination of porosity is important from several points of view, and is often incorrectly estimated. It is usually determined by finding the quantity of water required to fill up all the pores in a unit mass of rock. In this connection it must be remembered that mere immersion of a block of stone in cold water for a few hours or even a few days will not result in driving out all the air from the pores and substituting water for it. In the present case this result was attained by first standing the stone in shallow water and allowing this to be drawn up through the block by capillarity, then completely covering the block with water and alternately heating to boiling and cooling down until no further increase in weight occurred.

The figures obtained are important in determining the relative values of a series of stones for building purposes. A highly porous stone will absorb so much water as to make a building damp along exposed walls; further, it will allow of the free percolation of rain through the outer portions of blocks, thus accelerating disintegration. Again, the greater the pore space the larger must be the surface area of grains left uncemented to their fellows. Finally, the more porous a building stone is, the more rapidly the outer walls of a building in the City become discoloured by dust and smoke. All the Donnybrook stones compare somewhat unfavourably in respect of porosity with Sydney (Pymont), "Hawkesbury," and Stawell stone.

(6) *Chemical and Mineralogical Examination.*—The direct object of this section of the investigation was to determine what proportion of the whole stone is likely to be entirely unaffected by exposure to the natural elements, what proportion will slowly disintegrate, and what proportion will rapidly be affected.

Chemical analysis accompanied by examination under the microscope of rock powder and of thin slices of the rock (*see Appendix*) indicate that quartz, a practically indestructible mineral, forms quite three-quarters or more of the whole rock, occurring in grains of various sizes. Only to a slight extent does secondary silica occur as a cementing material, there being no unusually hard masses of silicified rock such as are present in several of the Victorian sandstones. Associated with the quartz is a fair proportion of felspar of two kinds, both of which are liable to soften, but at an extremely slow rate, on exposure. Of these the lime-soda felspars (oligoclase, etc.) are slightly less stable than the potash felspar (microcline).

The only other constituents in important proportions are kaolin (halloysite ?), limonite, and possibly talc. The first two are the important binding agents, whilst limonite or other iron hydrate is

responsible for the cream or brown colouring. Kaolin and limonite are not liable to chemical change except under the influence of the sulphuric acid found in the atmospheres of busy manufacturing centres. Kaolin would soften appreciably on wetting unless it were well impregnated with secondary silica, a condition approached in the stones from the No. 1 and Government quarries. Carbonates are almost absent, as is also mica.

Two typical stones were selected for complete analysis, viz., No. 10 from the No. 1 Quarry and No. 13 from the No. 3 Quarry. The former is pure white on fresh fracture but slowly turns cream or light brown on exposure. The latter is light buff in colour with deep yellow stripes (secondary iron staining), and deepens only very slightly in colour on exposure. The results of analyses were as follow, analyses of typical Sydney and Victorian building sand stones being quoted for comparison.

TABLE I.
Analyses of Typical Australian Sandstones used for Building Purposes.

	Donnybrook.		Stawell, Victoria.	Egerton, Victoria.	Pymont, N.S.W.
	No. 1 Quarry.	No. 3 Quarry.			
Silica, insoluble ..	86.55	84.53	96.19	90.22	83.55
Silica, soluble (1) ..	1.38	4.73			
Alumina ..	5.83	5.82	1.90	7.56	5.30
Ferric oxide ..	.32	.50	.37	trace	.10
Ferrous oxide ..	.10	.08	.06	Nil	1.37
Manganese oxide ..	Nil	Nil	..	trace	.04
Magnesia ..	.76	.24	.09	trace	.25
Lime ..	.21	.21	trace	trace	.08
Soda ..	.56	.33	.04	.38	.01
Potash... ..	2.58	2.18	.39	.22	.81
Water at 100° ..	.47	.13	.11	.58	.33
Water on ignition ..	1.01	1.28	.48	1.56	1.05
Carbonic acid ..	.02	.01	Nil	Nil	.84
Phosphoric oxide ..	.17	.11	..	..	..
Titanium oxide ..	.14	.30	.10	..	.66
Sulphuric oxide ..	.02	.03	..	..	trace
Organic matter (2) ..	.04	Nil	..	..	trace
	100.16	100.44	99.73	100.52	100.40
Analyst	H. Bowley.	H. Bowley.	P. G. W. Bayly.	H. C. Richards.	J. C. H. Mingaye.

(1.) *I.e.* soluble in Lunge's alkali solution after treating the rock with fuming sulphuric acid.

(2.) Calculated as humus from the carbon determined by wet combustion.

TABLE I.—*continued.*

		Donnybrook.		Stawell, Victoria.	Egerton, Victoria.	Pymont, N.S.W.
		No. 1 Quarry.	No. 3 Quarry.			
<i>Approximate Mineral Composition.</i>						
Quartz..	.. ..	70·85	74·84	92·63	79·27	79·46
Microcline	.. ..	15·05	12·80	2·31	1·28	4·78
Oligoclase and Albite		4·73	2·91	·31	3·20	traces
Kaolin	.. ..	5·43	7·23	3·60	16·94	12·95
Talc ..	.. ..	2·28	·76	..	..	..
Limonite	.. ..	·37	·56	..	..	..
Apatite	.. ..	·37	·27	..	..	..
Ilmenite	.. ..	·21	·17	..	..	..
Doelterite	.. ..	·03	·26	..	..	..
Gypsum	.. ..	·03	·05	..	..	.. (3)
Calcite	.. ..	·04	·02	..	..	2·22
Organic matter	.. ..	·04	<i>Nil</i>	..	..	..
Water ..	.. ..	·47	·13	..	..	..
		100·00	100·00	98·85	100·69	99·41

(3.) Iron carbonate.

In the case of the other stones the chemical and mineralogical examination was restricted to the following five determinations:—

(a) A qualitative determination of the minerals present as shown by the microscope in a thin slice. This showed that all the stones were of the same type of felspathic sandstone.

(b) Total insoluble in fuming sulphuric acid. This represents the total proportion of the stone which may be taken for all practical purposes to be absolutely resistant to any chemical change on exposure to the atmosphere. In every case it was approximately 95 per cent., a figure higher than any Sydney sandstone of which I have data, but approximately the same as in that from Stawell, Victoria.

(c) Carbonic acid. This indicates the proportion of carbonates present. These, in conjunction with clay, form one of the strongest of all binding materials, but not resistant to acid vapours. The Sydney and Hawkesbury stones owe their strength mainly to this combination of clay and carbonates. The Donnybrook stones are practically devoid of carbonates, but in those from the Government and No. 1 Quarries their place is filled by secondary silica, a still stronger and more durable cementing material.

(d) Acid-soluble Alumina.—This gives an indication of the relative proportions of clay; the percentage of the latter being approximately equal to the percentage of soluble alumina multiplied by two and a half.

(e) *Acid-soluble Iron oxide*.—This is a useful binding agent. The presence of iron in a light-coloured stone such as Donnybrook No. 1 or Pymont indicates the certain darkening of the stone on exposure, an important matter from an aesthetic standpoint.

(7) *Colour, Evenness of Appearance, etc.*—These are noteworthy from an aesthetic point of view, and normally should be determined before and after weathering. In the absence of weathering tests, note is made of the amount of iron in the stone, and of any change of colour on gentle heating to about 200deg. C.

Any visible unevenness in grain or texture is a serious drawback, as it will almost certainly lead to uneven weathering.

Cross-bedding (current bedding) is a serious source of weakness in a sandstone, as are also clay partings. Neither was observed in the specimen blocks of Donnybrook stone, nor, with one exception, in any City buildings, though Mr. H. P. Woodward, who has recently visited Donnybrook, informs me that confused bedding is the cause for rejecting a considerable amount of stone at some of the quarries. The streaky colour scheme not uncommonly seen in blocks from Vincent's and the No. 3 Quarries is not an indication of cross-bedding, but is merely due to irregular distribution of small amounts of iron oxides which in most cases have penetrated into the stone from overlying laterite. It is not parallel to any structural lines of parting or weakness.

Another frequent defect in sandstones is the presence of small pockets of softer, incompletely cemented sand grains, "sand balls." These should be detected by hand and eye during working and not allowed to appear on the outer surface of a building. Though infrequent in Donnybrook stone and not observed at all in any of the specimen blocks submitted, they are to be seen in several blocks of the stone in City buildings.

Visual inspection should disclose if any organic debris is present in sufficient amount to cause local weakness. None was observed in any Donnybrook stone. The "organic matter" shown in the analysis of the stone from the No. 1 Quarry is very evenly distributed through the stone, probably in the form of an organic compound of iron, which is colourless in the natural state but darkens on heating or exposure to the weather.

Results of Tests of Individual Stones.—The accompanying Table II. gives the numerical results of the tests applied to the different stones. The inferences drawn from them and from the inspection of local buildings are given in the following notes.

No. 1 Quarry (Alexander's).—North end of Loc. 1244, North Donnybrook. The stone from this quarry is pure white in colour when fresh, and finer in grain than any other in the series examined.

Moderate heating (200deg. C.) changes the colour to dark grey, and exposure to the air even under cover produces a decided cream tinge on the surface in about twelve months. An inspection of the buildings in which it has been used shows that it somewhat rapidly darkens to a light to medium brown colour on exposure, giving a very agreeable appearance of age to the structures. The specimen blocks show no cross-bedding, sand balls, or unevenness in grain, though this latter is marked in some few blocks in local buildings. It is composed mainly of quartz grains with about one-quarter the amount of felspar grains, the cementing material being clay with a little secondary silica, a strong combination when in sufficient quantity, as appears to be the case with this stone. The figures given by the crushing test (490-542 tons per square foot) place it amongst the best freestones the world over. The chief defect of this stone is its porosity, which is double that of average Sydney stone, and three times that of typical Stawell stone. Its absorption of water is, however, well within the limit laid down for best building brick (10-12 per cent.), and so far as I have been able to ascertain it has not caused dampness in the buildings in which it has been used, nor has it led to a noticeable amount of surface fretting. This stone is entirely devoid of those extremely hard patches of secondary silica which are the chief drawback to the use of Stawell stone. It carves well, taking a fine edge, and is capable of any sort of finish short of a polished surface.

An inspection of the Art Gallery and Technical School indicates that all originally sound blocks have maintained their sharp outlines and the surface is everywhere in a sound, hard, even condition. Some blocks in both buildings were evidently originally faulty from the presence of "sand balls" or confused bedding and should never have been put into the face of the buildings.

All things considered, this is an excellent stone for building purposes, though slightly expensive to work, a natural result of its superior hardness and durability. Attempts are being made to put on the market grindstones cut from this stone.

No. 2 Quarry (Alexander's).—Near centre of Loc. 1244, North Donnybrook. No specimen blocks from this quarry have been subjected to investigation in the Geological Survey Laboratory. The stone has been used for portions of the Telephone Exchange in Murray Street, Perth, where it can be seen to be a stone closely resembling that from the No. 1 Quarry. It is uniformly fine grained, white on a fresh fracture, but somewhat darkened by exposure. It is a hard stone capable of a fine finish. There are no signs of fretting, and the arrises are still sharp after several years' exposure. Several of the blocks are disfigured by sandballs. In the absence of experimental data, it is inadvisable to express a definite opinion of this stone.

Vincent's Quarry.—South end of Loc. 1244, North Donnybrook. No investigations have been made in this Laboratory of the stone from this quarry, which was one of the first to be opened in the district. The stone from it used in the basement of the Supreme Court, Perth, is much coarser and more irregular in grain than that from No. 1 or No. 2 Quarry. It is fairly hard and shows no signs of deterioration after thirteen years' exposure, but is not capable, apparently, of a very fine finish. The chief defect in the fresh stone was its great irregularity of colour, the stone being variously ironstained in streaks and blotches of crude yellow and brown tints. Weathering has darkened the background and obliterated this effect to a large extent on the outer walls, though the appearance is still not very pleasing except perhaps under the arcade on the south front, where the stone now has a rich yellow ground with lines of deeper yellow not unlike wood graining.

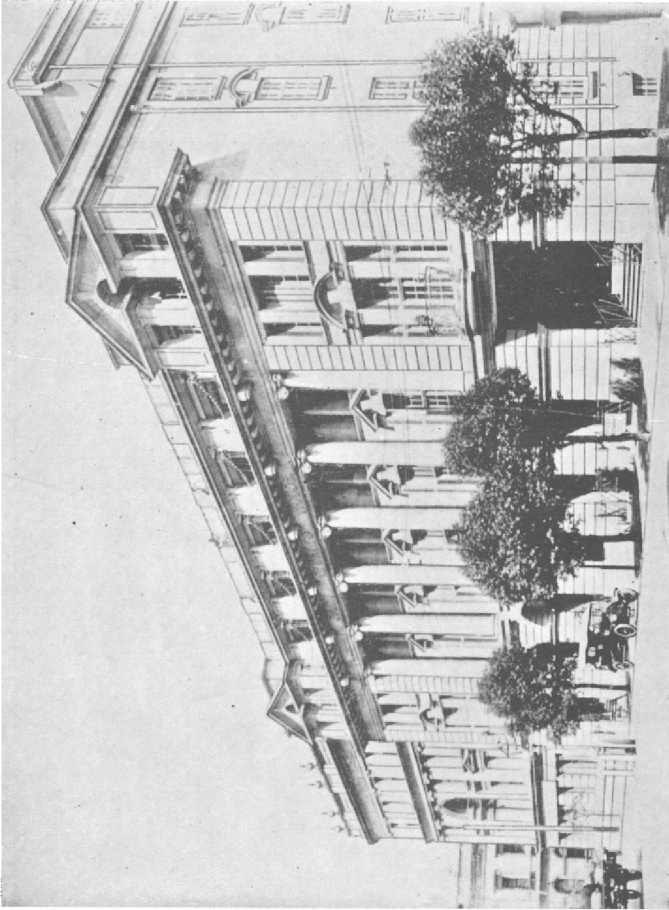
Government Quarry (Arnott's No. 2).—Reserve 2720, North Donnybrook. This quarry is furnishing the stone now being used in the upper portions of the east front of the new General Post Office, Perth. It is a stone similar in appearance and equal in quality to that derived from the No. 1 Quarry. It is mostly pure white in colour with rarely creamy or light brown inconspicuous blotches or stains. On exposure the white stone will doubtless darken somewhat in colour since, like the No. 1 Quarry stone, it contains iron compounds and darkens distinctly on heating to 200deg. C. The grain is very fine and even, and the stone as a whole is dense, tough, and hard. It works excellently by machine or by hand, and is well suited for fine carving. The Chief Architect informs me that it is singularly free from sandballs, and personal inspection shows its freedom from quartzitic patches or other appreciable variations in texture. The grains are quartz with a fair amount of felspar, whilst the binding material is essentially kaolin with traces of secondary silica. Crushing tests have given results equal to those of the stone from No. 1 Quarry, viz., 418 to 597 tons per square foot.

No. 3 Quarry.—North-east corner of Loc. 48/1924, North Donnybrook. The specimen stone from this quarry is distinctly inferior to those from the No. 1, Government, and Goldfields Quarries, having a much lower compressive strength, and much greater porosity. It is somewhat fine grained, and consists mainly of quartz grains with some felspar grains and a clay cement. The uneven iron-staining of the new rock is a slight disadvantage. This stone is moderately soft and in consequence works easily.

Stone from this quarry has been extensively used in Perth, and in the Police Courts has undergone exposure for twelve years. At present in this building all arrises above the reach of heavy traffic are quite sharp and unbroken, nor is there any sign of surface fretting, or of flaking or splitting. Even close to the pavement

in a busy street the arrises are but little chipped or worn. Despite its high porosity, no signs of damp are to be discovered inside the building. This is evidently a very satisfactory building stone. It does not apparently darken greatly on exposure. Further, either the quarry yields but few faulty blocks, or these have been kept out of the building by careful inspection during erection. Two of the

Fig. 9.

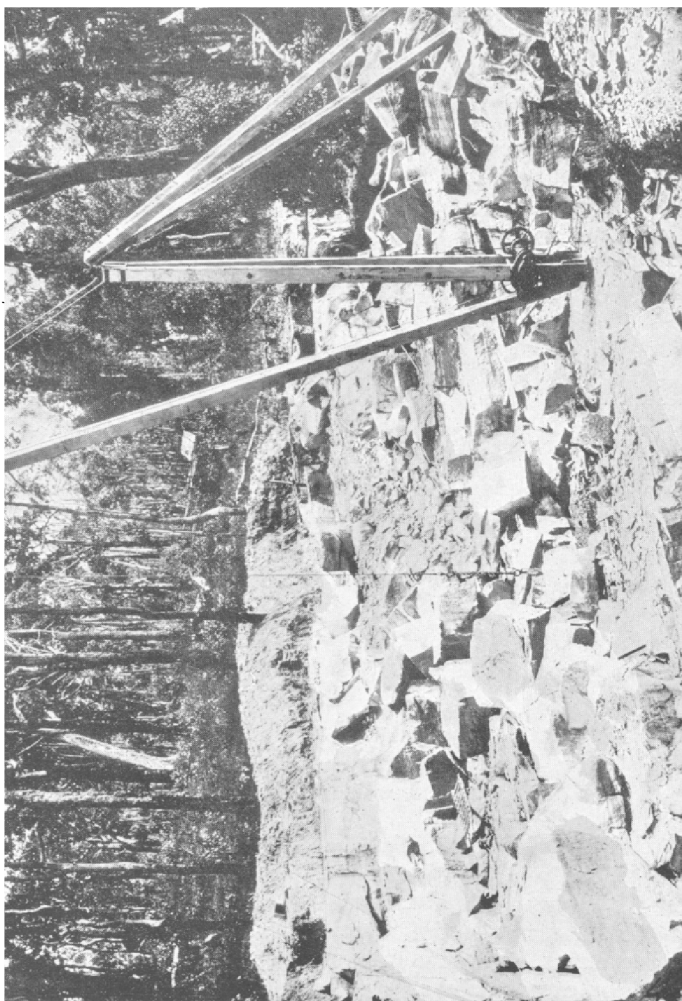


St. George's House, Perth. Facade of stone from No. 3 Quarry, North Donnybrook.

largest buildings in Perth, viz. the Australian Mutual Provident Society's offices and St. George's House (Millars' Timber and Trading Co.), were built of this stone. Sand balls are not uncommon in the stone used in the latter, and in both small circular dark brown iron-stains have developed on exposure; they are, however, inconspicuous except on close scrutiny.

Armstrong's Outcrop.—South-west corner of Loc. 1518, North Donnybrook. This yields a medium-grained stone of pleasing creamy colour with white mottling. It bears considerable resemblance in grain, porosity, etc., to the stone from No. 3 Quarry, with which it compares favourably when dry. Tests show, however, that it loses seriously in coherence when wetted. Wet crushing tests of it are badly needed. This stone has not been used in any building in Perth, so that exact data with regard to its durability are wanting. On purely laboratory figures I am inclined to consider it to be inferior to those previously described, and unsuited for important public buildings.

Fig. 10.



Goldfields Quarry, South Donnybrook.

Arnott's No. 1 Quarry.—North-east corner of Loc. 48/1991, North Donnybrook. This small quarry yielded stone of very irregular grain and coloration. A small quantity has been used in one part of the basement of the new General Post Office on the south side, where it is seen to be a light-coloured stone with irregular iron-staining and uneven and confused texture, such as might be caused by violent eddies in the current during the deposition of the sand grains.

Goldfields Quarry.—West side of Crendon Road, on old Gold Mining Lease 66, South Donnybrook. This stone is the heaviest and coarsest grained of the series, and is also less porous than that from any other Donnybrook quarry. It is from deep to light buff in colour, and is devoid of cross-bedding or irregularity in grain. The grains are mainly quartz with a little felspar, the cementing material being clay with a little secondary silica. It is somewhat inferior in crushing strength to the stone from the No. 1 and Government Quarries, but I am of opinion that it would not be much, if at all, inferior to these in durability. It would doubtless be cheaper to dress, though incapable of yielding such sharp outlines as the other two mentioned.

One of the few places in which this has been used is in the lower portion of the facade of the Government Stores Office. An examination of this, which has been exposed for about six years, shows so far no sign of any defects other than a few apparently original ones in isolated blocks. Some of the stones in this building are plainly finer grained than the average. In view of its superior density and lower porosity, this stone is worthy of further application in local buildings devoid of fine detail.

Pink Quarry.—North of Loc. 48/1316, South Donnybrook. Two different classes of stone were submitted from this quarry, one from the surface, the other from a depth of eight feet. The latter when freshly quarried possesses a very handsome appearance, being of a rich pink colour which is evenly distributed. This colour, being due to fully oxidised compounds, is likely to be permanent over a long period of time. Small black blotches due to a local concentration of oxide of iron present a marked blemish when close to the eye, but at a slight distance are invisible, and would have no effect upon the general appearance of a building. Similar blotches have developed in stone from No. 3 Quarry (*vide supra*). Unfortunately, though possessing a moderately high compressive strength when dry, on soaking with water it loses the greater part of its coherence. This condemns it completely for outside work in a building of any importance. Owing to its beauty it might well be given a trial in some small building where its failure would not cause any serious loss.

The stone from the surface resembles the previous stone in colour, but is distinctly bedded, with large variation in the grain in the different thin layers (*vide* figures in Table II.). Like that from a depth of eight feet, it loses most of its coherence on wetting, and must be looked upon as valueless for outside work.

Original, 19th March, 1915.

Revised, 30th December, 1916.

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DONNYBROOK SANDSTONES.

TABLE II.
Results of Laboratory Tests.

G.S.L. No.	Mark.	Quarry.	Colour of fresh fracture.	Sp. Gr.	Weight per cub. ft. lbs.	Porosity.		Compressive Strength. Tons per sq. ft.	Size of Grain.					Analysis.			
						Water absorbed per cent. of weight.	Pore Space per cent. of volume.		Over 30 mesh.	Over 60 mesh.	Over 90 mesh.	Under 90 mesh.	Relative Coarse- ness (3).	Total Insol- uble.	Soluble Alumina.	Soluble Iron Oxide.	Carbon dioxide.
6802	4	Goldfields ..	Deep buff ..	2.31	144	5.9	13.63	385	6.8	56.3	24.2	12.7	414	94.04	2.33	1.79	0.01
6803	5	Goldfields ..	Light buff ..	2.28	142	6.7	15.28	344	1.2	46.0	39.6	13.2	370	95.07	2.85	0.50	0.02
6804	8	No. 1 ..	White ..	2.21	138	7.8	17.24	494	Nil	4.5	34.2	61.3	186	94.86	2.91	0.35	Nil
6805	10	No. 1 ..	White ..	2.25	140	7.2	16.20	542	Nil	1.5	38.1	60.4	182	95.25	2.53	0.38	0.01
6806	12	No. 3 ..	Buff with deep yellow bands	2.07	129	11.1	22.98	228	..	..	..	..	..	..	..	..	..
6807	13	No. 3 ..	Buff with deep yellow bands	2.12	132	10.5	22.26	206	1.9	36.2	35.2	26.7	327	94.52	3.26	0.59	0.02
6808	14	Pink (Top) ..	Deep pink ..	2.15	134	F.P. (1)10.9 C.P. (2)10.3	23.43	263	Nil	4.4	44.6	51.0	207	..	..	..	..
6809	16	Pink (Top) ..	Deep pink ..	2.15	134		22.15	280	0.7	20.2	44.9	34.2	274	..	..	..	..
6810	17	Pink (8ft.) ..	Deep pink ..	2.12	132	10.8	23.22	259	Nil	1.4	46.9	51.7	199	94.76	2.36	0.98	0.01
6811	18	Pink (8ft.) ..	Deep pink ..	2.18	136	10.5	22.26	259	..	..	..	..	..	..	..	..	..
6812	20	Armstrong's ..	Deep pink ..	2.10	131	10.4	22.67	249	0.2	25.4	45.3	29.1	293	94.77	2.22	1.9	0.03
			Pale pinky buff with white mottling			10.5	22.05	220	..	..	..	..	..	..	..	..	..
6813	22	Armstrong's ..	Pale pinky buff with white mottling	2.17	135	9.1	19.75	268	trace	33.0	41.8	25.2	316	93.57	3.94	0.43	0.01
187	23	Government ..	White ..	2.19	136	6.9	15.11	418-597	trace	18.1	43.6	38.3	260	94.88	3.35	0.35	Nil
6814	2	Hawkesbury, N.S.W.	Buff with numerous black specks	2.49	155	3.2	7.97	472	..	..	..	..	..	..	..	..	..
6815	3	Hawkesbury, N.S.W.	Buff with numerous black specks	2.46	153	4.4	10.82	402	1.5	50.5	30.0	18.0	371	87.71	5.54	2.68	0.90
..	25	Pymont, N.S.W. ..	White or light buff ..	2.30	144	3.65	8.40	473	..	..	..	..	..	(4) 85.45	(5) 7.60	2.12	1.09
..	26	Stawell, Victoria ..	White ..	2.37	148	2.38	5.64	723-1128	..	..	..	..	..	(4) 96.19	(5) 1.90	0.44	Nil

(1) Fine grained portion. (2) Coarse grained portion. (3) An empirical figure obtained by multiplying the percentage of grains over 30 mesh by 7; that over 60 mesh by 5; that over 90 mesh by 3; and that under 90 mesh by 1. The figure for the coarsest possible stone would thus be 700, for the finest possible, 100. (4) Total silica. (5) Total alumina.

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TABLE III.

Principal Structures in which Donnybrook Stone has been used.

Quarry.	Town.	Building.	Date completed.
No. 1 ..	Fremantle ..	Railway Station ..	..
Do. ..	do. ..	Customs House ..	1908
Do. ..	do. ..	St. John's Church, Tower and Spire	..
Do. ..	Perth ..	Art Gallery ..	1908
Do. ..	do. ..	Technical School..	1910
Do. ..	Midland ..	Court House ..	1907
Do. ..	Bunbury ..	Court House ..	1907
No. 2 ..	Perth ..	Telephone Exchange ..	1913
No. 3 ..	Fremantle ..	Technical School..	..
Do. ..	Perth ..	Police Courts ..	1905
Do. ..	do. ..	Haynes, Robinson, and Cox's	1906
Do. ..	do. ..	Public Health Department	1911
Do. ..	do. ..	Parliament House, Central portion, west front	..
Do. ..	do. ..	Public Library ..	1913
Do. ..	do. ..	St. George's House ..	1914
Do. ..	do. ..	A.M.P. Buildings ..	1914
Do. ..	do. ..	Dalgety's ..	1915
Do. ..	do. ..	Levi Green's ..	..
Do. ..	East Guildford	Chapel of S.S. Mary and George	1914
Do. ..	Collie ..	Court House ..	1913
Goldfields ..	Perth ..	Government Stores ..	1911
Do. ..	do. ..	Government Analyst's Office	1904
Vincent's ..	Perth ..	Supreme Court ..	1903
Do. ..	Claremont ..	Training College ..	1902
Government..	Perth ..	New General Post Office	Under construction.

APPENDIX I.

 PETROLOGICAL EXAMINATION OF SIX SAMPLES OF BUILDING STONES FROM
 DONNYBROOK.

BY R. A. FARQUHARSON.

The difficulty in sectioning these having been overcome, examination of the slides has given the following results:—

The rocks are all essentially similar in structure, composition, and physical character. The mineral composition is in brief: quartz, felspar, kaolin and some iron staining. No pyritic ore, and no mica was observed. In general character they are all somewhat incoherent and friable felspathic sandstones or grits, the compactness of which is more due to pressure than to the presence of cementing material such as secondary quartz or iron oxides. The cementing material is in very small part secondary quartz and in part (in some of the specimens) oxide of iron, but both are but poorly developed. The majority is of an argillaceous (kaolinic) nature.

As building stones the samples will be easily dressed and in spite of the argillaceous nature of the cement and the comparative absence of resiliification should, under normal conditions, wear reasonably well, though not so well as resiliified sandstones.

Following are descriptions of the samples:—

[13934] (S2456) No. 10.—No 1 Quarry. A very fine-grained white gritty rock, slightly friable, but more compact than the rest of the specimens.

In section, the minerals are quartz grains and felspar grains, rounded and angular with very little cementing material. The latter appears in places to be secondary quartz, but most of the material between the grains—and there is very little of it—is opaque, granular and white, with argillaceous (kaolinic) characters. Some of the quartz grains are cracked and enclose indeterminable hair-like inclusions, while some irregular extinction is noticeable in them.

The rock is a partially compacted *Felspathic Sandstone* of somewhat friable nature, and of very fine grain.

[13933] (S2454) No. 13.—No 3 Quarry. A slightly coarse gritty rock banded alternately yellowish-brown and yellowish-white and somewhat friable.

The rock is again composed of rounded and angular quartz grains and felspar grains, with a yellowish-brown clayey cement. The felspar is in places microcline, in places too much kaolinised for determination. No secondary silicification was observed. The banding is due to limonitic staining.

The rock is a friable banded *Felspathic Sandstone* or *Grit*.

[13931] (S2452) No. 22.—Armstrong's Outcrop. A fine-grained, pinkish, granular rock quite friable and hence easily dressed, but liable to fretting, and consisting of quartz grains and minute white particles with occasional reddish spots.

In section, the bulk of the rock is made up of small rounded, as well as more or less angular quartz grains—occasionally showing strain shadows—less common grains of felspar which are frequently kaolinised to complete turbidity and which include microcline and orthoclase as well as twinned plagioclase, and occasional small dusty red patches of material that is probably iron-stained kaolin.

Cementing material is present only in small amount as a thin film between the quartz grains, and appears to be of argillaceous (kaolinic) nature.

Secondary silica as cement is very poorly if at all developed. In consequence, there is some slight lack of coherence in the rock and its friability is noticeable.

The rock is a fine-grained *Felspathic Sandstone*, formed by compacting of grains of quartz and kaolinised felspar by pressure without the production of much secondary silica as a cement, or the introduction of such binding material as oxides of iron.

[13935] (S2457) No. 5.—Goldfields Quarry. A slightly coarser-grained yellowish, and somewhat friable gritty rock, very similar to the above.

The composition is the same as in No. 22, *i.e.*, rounded and angular quartz grains and occasional kaolinised felspar grains with cementing material as before. The structure, however, is again rather loose and incoherent. Iron staining is almost entirely absent.

The rock is a *Felspathic Sandstone* or *Grit*.

[13932] (S2455) No. 16.—Pink Quarry. A fine-grained, reddish-pink, granular, gritty, and friable rock, with grains of quartz, whitish specks, and reddish grains.

In section there are small quartz grains mostly, but subsidiary kaolinised felspar grains and slight iron staining are also visible. Cementing material is again not conspicuous, but there appears to be a slight development of secondary silica between some of the quartz grains. The structure of the rock is again somewhat loose and incoherent, due to the comparative lack of development of cementing material.

The rock is a somewhat friable felspathic sandstone in which the coherence is due in part to compacting by pressure, in part to secondary silicification, and in part to an argillaceous (kaolinic) cement.

[13930] (S2451) No. 18.—Pink Quarry. In all respects is essentially similar to No. 16, with slightly deeper iron staining.

10th November, 1914.

68.—THE KENDENUP GRAPHITE DEPOSITS—SOUTH-WEST DIVISION.

By H. P. WOODWARD and T. BLATCHFORD.

(With two Figures.)

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HISTORICAL.

Although the existence of these deposits has been known for over 50 years, and that at least upon three occasions attempts have been made to work them, owing to the low grade of the material discovered they were each time abandoned after a short trial. In 1903 a syndicate was formed to further test them, when the work carried out revealed the presence of some much higher grade ore, but owing to the fact that funds were difficult to obtain little mining development of a systematic character has been executed, although work in a more or less desultory manner has been conducted for a period of years.

SITUATION.

The area in which these deposits exist is situated close to the Great Southern Railway line at a distance of 290 miles from Perth and 50 miles from Albany, the nearest port of shipment.

PHYSIOGRAPHIC GEOLOGY.

The deposits are situated on the banks of the Kalgan River, which at this point follow an east and west course along a valley, which is about 500 feet above the sea-level. This valley lies between

the Stirling Range to the northward and the Mt. Barker-Porongorup Range to the southward. The surface level rises gradually along the course traversed by the railway line some 450 feet in a northerly direction to Tenterden, which is 14 miles distant, and 300 feet southward to Mt. Barker, which is eight miles away.

The Stirling Range is a bold mountain mass which runs in an east and west direction for a distance of about 40 miles, and in it the main peaks attain an elevation of close on 4,000 feet. This range consists of stratified rocks (mostly quartzite), the geological age of which has not as yet been determined owing to the absence of organic remains and other difficulties of correlation. It would at one time appear to have formed a portion of a chain of mountains which extended from Phillips River on the east, at least as far as the Gordon River, though, in latter portion the rocks are, however, of a more highly metamorphic character.

On the south side of the Kalgan valley there is a distant change in the character of the rocks. These form a broad strip along the south coast from Cape Riche to Point d'Entrecasteaux, and also makes its appearance westward of the Darling fault at Cape Leeuwin.

In this valley, which lies between the two range lines, beds which contain marine fossils referable to the Tertiary Period are met with a few miles to the eastward of the railway line and extend from that point to Cape Riche, thus proving that at no very remote period it was submerged.

From the foregoing it will be apparent that this valley has been formed by marine and fluvatile agencies along a shear zone which exists at the contact of the igneous and metamorphic rocks, and that this is of probably considerable extent, which, being the case, further graphite deposits may be discovered along it in both an east and west direction, while those situated on the Donnelly River and at Big Brook, which lie due west, may also prove to be situated in the same zone.

So far as can at present be determined from the meagre evidence afforded by the highly weathered and altered rock specimens available, it appears that the rock formations in which this valley has been cut are composed of highly metamorphosed and sheared ancient sediments which have been tilted at a high angle, and further, that the graphite deposits which always occur in a bed-like form result from the crystallisation of beds rich in carbonaceous matter.

GENERAL.

Graphite in commercial quantities was first found on Plantagenet Location No. 27, at a spot about a mile distant from the Kendenup Homestead, and on the south side of the Kalgan River.

Since this discovery traces of the mineral have been found on Location No. 12, to the east of the Great Southern Railway, between the 48- and 49-mile posts, the mileage being that from the port of Albany.

Also, traces have been reported to the west at Mollyalup Lake, but such were not located by the writer, though there seems no reason to doubt that traces were found in this locality. The geology of the area is difficult to translate, as the surface is for the most part covered over with recent superficial deposits, and outcrops of the underlying rocks are rare, and do not exist at all to the south of the Kalgan River. North of the river granite outcrops, and it would appear that the river marks the junction of granite and sedimentary rocks, with the graphite occurring in the latter rock. Unfortunately, the nature of these sedimentary rocks could not in any instance be investigated with accuracy, as it is doubtful whether the unaltered forms outcrop at all, and in the mine workings the weathering extends below the deepest level yet reached and, in consequence, masks the characteristics necessary for definite classification.

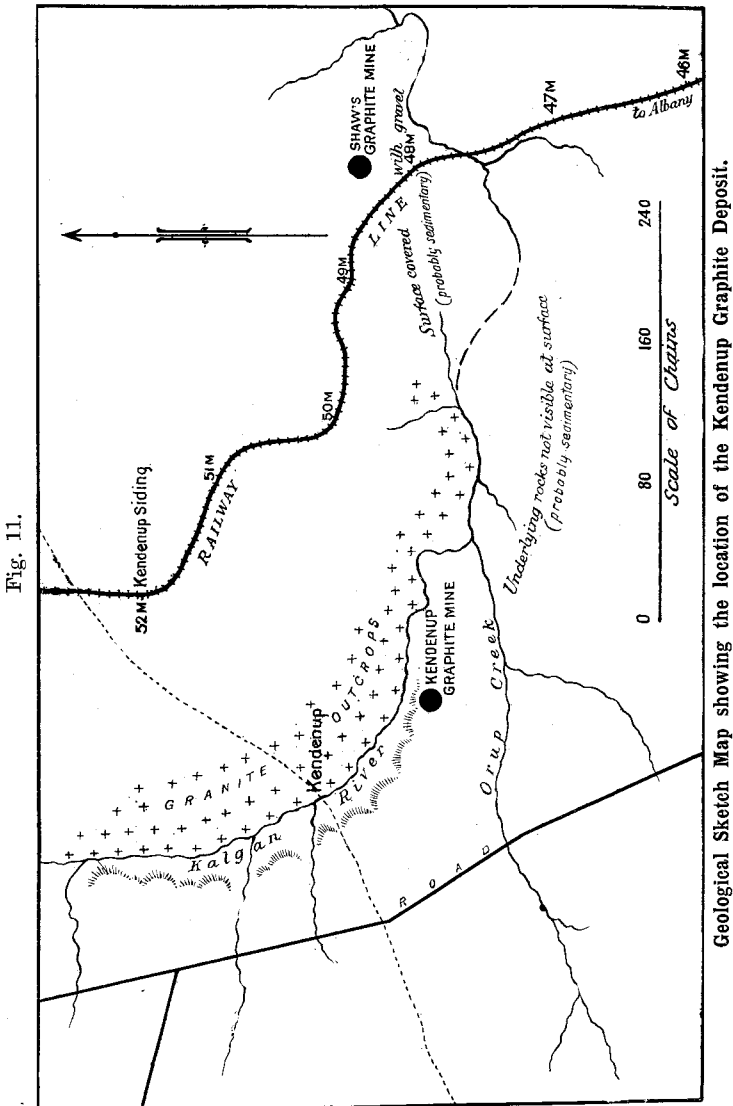
The general features, however, would lead one to suggest a sedimentary origin, and there is every likelihood, in the writer's opinion, that the rocks represent much weathered schists, shales, or allied sedimentary beds.

Kendenup Graphite Mine.—The accompanying plan (Plate VIII.) shows the extent of the workings of this deposit, with the exception of a few minor ones at the surface, since fallen in and inaccessible.

From the main shaft, at a vertical depth of 50 feet, a drive west 20 feet in length passed through soft ground, throughout which were grains of scaly crystalline graphite. A sample taken across the back of the drive, about midway between shaft and end, yielded at the hands of the departmental Chemist 12.10 per cent. graphite.

From the same level a drive was put in eastward for a distance of 38 feet. Towards the end this drive was diverted to the north, and in consequence resolved itself into half-drive and partly crosscut. At the extreme end of the drive a hard siliceous band was encountered, the thickness of which was not determined. A sample of this siliceous rock was submitted to the Petrologist, who, on microscopic inspection, is definite in his decision that the rock represents a much crushed quartzite, throughout which are innumerable small specks of graphite. Felspar is wholly absent, and the quartz veins show stress figures and uniform fracturing, evidences of strains induced in the rock since it was originally formed. From here on the drive was diverted to the east and continued for a distance of 20 feet, the hard band being on the north side of

the drive. This portion of the workings could not be inspected personally owing to the fact that the whole of the drive had caved in and was completely filled.



Starting from the shaft, one can readily see the increase in the graphite contents as the quartzite is approached, until, lying up

against the quartzite itself, extremely rich seams of the mineral are exposed. This is also borne out by a comparison of the rough samples taken, the value in percentage of graphite increasing in direct ratio with proximity to the quartzite band.

The mineral occurs for the most part in isolated scales, the long axes of which appear to run parallel to an indistinct foliation striking approximately east and west, and is fairly uniformly distributed. When the quartzite band previously referred to is approached, these scales are seen to increase in number and occur both in lenses and seams or veins in which the proportion of graphite exceeds that of the gangue, a picked sample yielding as high as 80.54 per cent. of the mineral.

The full extent of this enrichment was hidden from inspection owing to the caving in of the workings, and it is unfortunate for all parties concerned that the mining has been carried on in such an unsystematic manner. With proper mining equipment and at small expense the deposit could easily be developed to a depth of probably 100 feet, for the water is negligible to a vertical depth of 60 feet, and the ground, though heavy in places, is not "difficult" ground.

On the other hand, the deposit gives promise of paying its way from mineral won in development, for there should be considerable quantities of ore available, by hand-picking only, which would yield 60 per cent. graphite contents, a distinctly marketable and profitable product.

Shaw's Mine.—This property is situated almost due east from Kendenup (*vide* plan), and lies about 400 yards east of the 48¼-mile post of the railway line. At the time of my inspection there was practically nothing to be seen except one shaft, which had been sunk to a vertical depth of 25 feet. The rock pierced in this shaft was a much weathered clay in which occurred numerous ironstone nodules. Traces of graphite in the form of minute specks and occasional small nodules indicated the presence of the mineral. A sample from the bottom of the shaft yielded 6.57 per cent. of graphite. The coarse mineral here is more in the form of plates than scales, and not uncommonly it is seen to be very fine in texture too. It does not assume the uniform scaly form of the Kendenup deposit.

Outcrops of the underlying rocks do not occur in the vicinity, and until a greater depth in sinking is attained the nature of the rock will be undeterminable with any degree of accuracy, though in all probability it will be found to be a continuation of the same country as that in which the Kendenup deposit occurs.

The only other place in which graphite was detected was in the mud banks of the Kalgan River, between Kendenup Homestead and the mine of that name.

Here a sample of the ordinary swamp mud was taken, and on drying, distinct grains of the crystalline mineral could be seen when examined under a microscope.

The graphite contents on chemical analysis proved to be 1.57 per cent.

This trace of graphite is important, as it tends to prove the existence of graphite other than in the Kendenup mine, for the spot where the sample was taken was above the mine, and the mineral could not possibly have come from that source unless the lode extended fully half a mile westward. It would be interesting to take samples further up the river to see how far these traces extend and thus, may be, locate their origin.

In addition to the samples of the crude ore, two samples were also taken of the concentrates bagged for shipping.

These yielded 46.63 per cent. and 54.38 per cent. graphite.

The concentration has been carried out in an experimental plant by first putting the ore in small vortex mixers and allowing the whole to flow on to a shaking screen with three compartments: the flow is into the centre compartment. In practice, the fine argillaceous gangue is supposed to pass through the screen, whilst the flaky graphite is supposed to dash out of the centre compartment into the two end ones and thereby form a concentrate. Unfortunately, it appears to have a reverse action, the fine graphite passing through the screen and the gritty gangue remaining on top. Certainly the concentrates do not exceed some of the crude ore in graphite contents. One of the reasons for this apparent mistake is the deceptive appearance of the size of the graphite scales, which appear on first sight to be much larger than they are, whereas probably 90 per cent. will pass a 40 mesh (1,600 holes to a square inch). In developing the mine, the writer would strongly recommend a system of mining whereby the richer or northern side of the lode would be opened out, and until the deposit was exploited sufficiently to warrant a proper concentrating plant, let hand-picking and shipping the crude high-grade ore be resorted to. The deposit should be well worthy of such treatment.

APPENDIX I.

Table of Proximate Analyses of Graphite from the Kendunup Deposits, made in the Geological Survey Laboratory by H. Bowley.

G.S.L. No.	9248.	9249.	9250.	9251.	9252.
Mark	1	2	3	4	5
Moisture	2.99	2.26	.49	3.63	2.96
Volatile matter *	9.63	2.40	1.49	4.55	3.94
Graphite	6.57	36.58	80.54	18.22	46.24
Ash	80.81	58.76	17.48	73.60	46.86
Total	100.00	100.00	100.00	100.00	100.00
Colour of Ash	Brown.	Light Brown.	Buff.	Brown.	Light Brown.
Fusibility of Ash †	Infusible.	Infusible.	Infusible.	Infusible.	Semi-fused.

G.S.L. No.	9253.	9254.	9255.	9256.	9257.
Mark	6	7	8	9	10
Moisture	4.24	3.26	2.68	3.88	8.66
Volatile matter *	2.11	12.59	3.83	4.74	13.82
Graphite	26.86	12.10	54.38	46.63	1.57
Ash	66.79	72.05	39.11	44.75	75.95
Total	100.00	100.00	100.00	100.00	100.00
Colour of Ash	Brown.	Brown.	Brown.	Brown.	Light Brown.
Fusibility of Ash	Semi-fused.	Infusible.	Infusible.	Infusible.	Infusible.

* Mostly water.

† On ignition by an air-coal gas blast in a platinum crucible.
2nd August, 1916.

DESCRIPTION.

No.		Per cent. Graphite.
1	Taken from bottom of Shaw's Shaft	6·57
2	Taken at east end of drive six feet from face, across back of drive	36·58
3	Picked sample from one of the veins	80·54
4	Sample across back of drive about 15 feet from face	18·22
5	Bore-hole slightly inclined to the North, about six feet deep..	46·24
6	Sample, continuation of No. 5 into North Wall—where broken down	26·86
7	Sample from back of West drive, about 12 feet West of shaft	12·10
8	Shipping sample, 1st grade	54·38
9	Shipping sample, 2nd grade	46·63
10	Sample of alluvial in Kalgan River banks	1·57

APPENDIX II.

PETROLOGICAL NOTES ON THE GRAPHITE ORE AND CHARACTER OF THE FLAKES FROM KENDENUP.

In the low-grade samples the ore is of a dirty reddish colour due to the presence of a considerable amount of disseminated earthy iron oxide. The material has a roughly banded or laminated structure with frequent lenticles or thin bands of quartz and quartzite. The graphite itself occurs in small folia or booklets of aggregated scales as well as in confused scaly masses in the clayey gritty and ferruginous laminated gangue. The graphite laminae or scales are arranged generally with their flat surfaces parallel to the imperfect banding or lamination. Samples have been found which show a diminution in the amount of iron oxide and also of gritty quartz, but the presence of a considerable amount of a canary or greenish-yellow material in small masses, which is referred to nontronite, the hydrous iron silicate. The presence of this mineral suggests that the graphitic deposit has been produced rather by dynamic metamorphism of carbonaceous sediments, than by igneous emanations. A little granular granite is also present. Samples of a fairly high degree of purity up to 80 per cent—show but a low development of grit or earthy iron oxide. The ore in these cases has a laminated schistose or shear structure, with the flakes (or flaky aggregates) elongated along the planes of schistosity. These samples are dark lead-grey in colour and very friable. Interleaved mica was not observed in any sample. The character of the graphite is scaly crystalline, but the size of the scales is very deceptive. The refined product in bulk appears quite coarsely scaly with the individuals about the size of a pin-head or a millimetre in diameter. Examination, however, shows that these apparently large scales are undoubtedly scaly aggregates; the maximum size of scale observed did not much exceed half millimetre in diameter, i.e., about 1/50th of an inch to 1/40 of an inch, whilst the vast majority of the scales varied in size from 1/50th of an inch to mere specks. So far as could be seen, however, all were crystalline, though determination of the crystalline or amorphous character of minute specks is very difficult.

R. A. FARQUHARSON,
Petrologist.

31st August, 1916.

69.—THE GEOLOGY OF THE WATER RESERVE FIND AT LINDEN, NORTH-EAST COOLGARDIE GOLD- FIELD.

(C. S. HONMAN.)

WITH ONE FIGURE.

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SITUATION.

The main open-cut from which the crushing was taken by Messrs. Love & Lowe is situated in the Water Reserve, 25 chains north-east of the tank, and on the east side of the main watercourse leading to the tank. The tank is 128 chains 24° east of south of the Mt. Linden Trigonometrical Station W 8.

GEOLOGY.

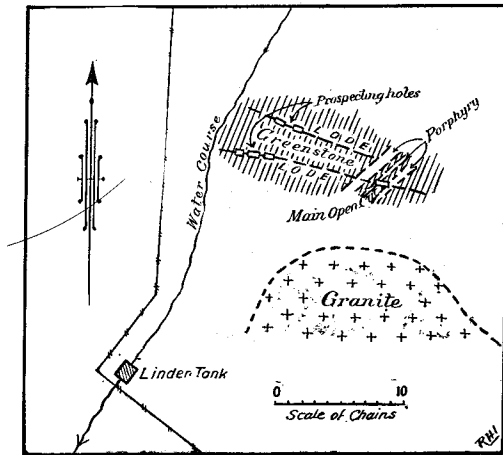
The rocks occurring in the locality are fine-grained greenstones and ferruginous quartzites intruded by granite and porphyry. The greenstones are schistose, even having an incipient schistosity developed where they are more massive. In the vicinity of Love & Lowe's open-cut the greenstone schist strikes 13° east of north, and the porphyry dykes 45° east of north. Massive granite occurs five chains south of the open-cut, and half a mile to the east a large granite belt abuts the greenstone. Numerous porphyry dykes intrude the greenstones in the vicinity. The greenstone is probably a transmuted doleritic basalt. Evidence of volcanic origin occurs in many places, such as distinct vesicular structure and presence of interbedded agglomerate schists. One band of the agglomerate schist occurs west of the open-cut.

MINING GEOLOGY.

The gold occurs in a "lode formation" which resembles those at Kalgoorlie, possessing the most important characteristics of such, viz. :—

- (1) Indefinite walls. Limits of the "lode formation" only determinable by the dish prospects.
- (2) Presence of "greasy heads" or planes of parting in lode. The best gold values are associated with these heads.
- (3) The strike of the lode formation crosses the strike of the country.
- (4) Extensive impregnations by carbonates.

Fig. 12.



Geological Sketch Plan of Workings in the Water Supply Reserve, Linden.

The "lode formation" strikes between 70° and 80° west of north and almost at right angles to the greenstones, which are frequently cut by porphyry dykes. The lode apparently persists through the porphyry, as gold occurs in the porphyry on the line of strike of the lode. The experience at Kalgoorlie is that lodes are impoverished where they occur in porphyry.

The "lode formation" is practically vertical, being associated with "planes of parting" or "greasy heads" in proximity to which small quartz veinlets occur.

A crushing taken out from an average width of three feet gave a return of 1 oz. per ton from a parcel of 30 tons. Considering the unoxidised nature of the country this is most favourable, since the gold is probably all primary.

The "lode formation" cannot be followed on the surface except by dish prospects. The cap of the lode does not differ in appearance from the surrounding country rock. When opened up, the only other indication apart from dish prospects is the "greasy heads."

Nine chains distant from the open-cut on a bearing of 282° , and on the strike of the lode, a similar formation has been opened up having the same strike. There is no indication of the presence of the lode on the surface between these two points, except that gold prospects have been obtained at intervals on the line of strike.

Three chains east of the main lode a similar formation has been opened up striking parallel, but on this not much work has been done.

All the work has been done on the central prospecting area held by Messrs. Love & Lowe.

In conclusion, I am of opinion that this find is an important discovery, and that no hindrance should be put in the way of its being thoroughly prospected for two main reasons:—

- (1) Resemblance to the "lode formation" of Kalgoorlie.
- (2) Occurrence in a promising mining centre, Linden, and in a district in which similar geological conditions are wide-spread.

The experience is that this type of lode lives to the greatest depth that mining has attained in Western Australia.

It must be borne in mind that the find is totally undeveloped, and that the lode may be greatly interfered with by porphyry dykes, and possibly by granite at depth.

13th December, 1916.

70.—THE CLAY DEPOSIT AT NEWLANDS, SOUTH-WEST DIVISION.

H. P. WOODWARD.

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LOCALITY.

This deposit is exposed in a cutting upon the Bunbury-Bridgetown railway line about one mile due north of the Newlands Railway Station, the exact locality being on the boundary of locations Nos. 6 and 7 of the Preston Agricultural Area. The cutting referred to is situated at the top of a steep gradient about 22 chains in length and 36 feet deep at its centre.

CHARACTER.

The rock exposed in this cutting consists for the most part of a gritty clay, but near the centre of the cutting a kaolinitic clay shale deposit is exposed beneath it for a length of five chains, rising in the section to a height of 12 feet.

This shale is divided from the sandy clay by a lateritic layer which often contains pebbles of rock and quartz fragments clearly representing an old surface, while from this downwards numerous iron-stained veins penetrate the white shale, colouring a considerable portion of it a deep hue.

The present surface of the ground is also covered by a lateritic deposit which gradually passes into sandstone to the westward, while to the eastward at a distance from 10 to 20 chains the granitic rocks outcrop.

This shale deposit clearly belongs to the Donnybrook Series, as the beds are identical in character with those met with in the working beneath the sandstone on the Donnybrook Goldfield.

The deposit is described as a kaolinitic clay shale owing to the fact that its weathered faces on drying present the characteristic

cleavage, this is lost, however, directly it become wet, when it becomes massive and highly plastic.

The light-coloured portions of this shale, which predominate, dry a dead-white and it has been used locally for white-wash, very similar to china clay, while the red portions become lighter in colour in drying.

EXTENT AND THICKNESS OF THE DEPOSIT.

Owing to the fact that outcrops of this deposit do not occur it is impossible to make any definite statement upon this point, but judging from the fact that it underlies the sandstone series near Donnybrook it is highly probable that it does so in this locality, and should this prove to be the case it will, of course, be met with beneath the sandstone to the westward. To the eastward it cannot extend far owing to the presence of the granite in that direction, while near this outcrop it is highly probable that it has been removed to a considerable depth by the action of an ancient water-course, evidence of the existence of which is furnished by the detrital matter which is exposed overlying it in the cutting section.

To the northward the surface falls steeply into a fairly deep valley which has been cut through the granite at a distance of some 10 chains from the cutting, while to the southward the surface also falls towards the Capel River at Newlands.

As previously stated, a thickness of 12 feet is exposed in the deepest part of the cutting, while a small bore hole put down at this point proved it to extend for a further depth of six feet, the total thickness of the bed is, however, not proved, since this was not penetrated.

INFERENCE.

The impression created from an extensive study of the surrounding district is that the railway line follows the direction of an ancient valley cut by stream action either at or close to the contact line of the granite with the Donnybrook Series, and at this particular point the deepest portion of this old valley lies on the eastern side of the cutting close to the granite outcrop. In which direction this old river flowed has not yet been determined, but it would appear that at this point the shale deposit was exposed in its bed, or rather upon its western bank in bend of the stream.

Owing to either more recent earth movements or to stream capture, this ancient valley, instead of being occupied by one stream flowing in a definite direction, is now occupied by two, one flowing north into the Violet Brook and one south into the Capel River, while that portion of the valley at which the cutting is situated, and which now forms the water parting of these two streams, has been filled in by the sandy clay and detrital matter exposed in the upper portion of the cutting section.

The red staining of portions of this deposit will probably be found to extend only so far as the shale bed was at one time exposed to atmospheric action, and is directly due to the downward permeation of the ferruginous solutions from its lateritic covering, therefore in the extension of this bed beneath the sandstone to the westward it will most probably be found to be all white.

The object of the inspection was to ascertain whether this deposit was of sufficient extent to warrant the erection of works for the manufacture of roofing tiles, upon which point no definite statement can be made until it has been further tested by boring, since it is clear that only that portion of the bed which is iron-stained will be of any value for making red tiles, but judging from the exposure in the cutting which averages five feet in height by a length of five chains, to which may be added roughly another six feet proved by boring, there is every promise of the existence of ample material here for all requirements for many years to come.

SUITABILITY OF THE MATERIAL FOR TILE MAKING.

Mr. Simpson, the Mineralogist and Chemist, in his report (Appendix I.), speaks in the highest terms of the suitability of the ferruginous portion of this clay for the manufacture of roofing tiles, though only a very small amount of red clay is suited for tile making, and the red and white could not be mixed at all for this purpose. The writer has seen a very fine sample of terra-cotta ware in the form of a water-bottle owned by one of the local residents and manufactured from the red clay, and also a jug of ceramic ware equal in appearance to the Doulton art ware, which latter was manufactured from the white portion of the clay.

Before any definite steps are taken to work this deposit it would be advisable to put down a few shallow bores with a hand drill with the object of not only proving the existence of shale of a similar character, but also the thickness of the over-burden, which latter will be of material importance in selecting the position most suitable for opening up a quarry. One or two deeper bore-holes might also with advantage be put down with the object of ascertaining the thickness of the bed, while the core would furnish a good idea of colour of the mixed clays.

CONCLUSIONS.

1. The red material is admirably suitable for the manufacture of a high-class, durable, and non-porous roofing tile of excellent colour.
2. That so far as can be judged the deposit is of considerable extent.
3. Its position leaves little to be desired, since a siding can easily be constructed into the quarry face; the only drawback will be the railway freight, as it is situated at a distance of 141 miles from Perth.

31st August, 1916.

APPENDIX.

THE CHEMICAL AND PHYSICAL PROPERTIES OF TWO CLAYS
FROM NEWLANDS.

(E. S. SIMPSON.)

The two samples of clay from Newlands, in the Donnybrook District, have been examined with the following results. With these are given the results obtained on the sample of Campbellfield (Victoria) white clay, submitted with them.

Physical Characters.—Both local clays were very plastic and extremely fine grained, and, as far as could be seen from the samples submitted, very uniform in character. One clay was greyish white when wet, dead white when dry; the second was of a brownish red colour. The Victorian was very similar to the white clay from Newlands.

Chemical Composition.—The following are the results of analyses made of these clays:—

	2264.	2265.	2408.
	White clay.	Red clay.	Campbellfield.
Silica, SiO_2	65.45	61.39	70.99
Alumina, Al_2O_3	21.53	18.12	17.88
Iron peroxide, Fe_2O_3	.94	8.74	1.38
Iron protoxide, FeO	.12	.12	nil
Manganese protoxide, MnO	.09	.11	.06
Lime, CaO	nil	trace	.20
Magnesia, MgO	.71	1.00	.94
Soda, Na_2O	.31	.40	.52
Potash, K_2O	1.69	1.98	2.46
Water lost above 100°	7.34	6.38	4.64
Water lost below 100°	1.96	2.16	1.68
Totals	100.14	100.40	100.75

The analyses were made on thoroughly air-dried samples, and show that there is a considerable difference in the composition of the Victorian and local clays, the latter containing more kaolin and less quartz and felspar than the former.

Firing Tests.—Briquettes were made of each clay separately and of a mixture of 90 per cent. of raw 2264 with 10 per cent. of raw 2265, as it was thought the former by itself might not be sufficiently fusible for the manufacture of stoneware, whilst the latter by itself was expected to be too fusible. Also mixtures of 75 per cent. raw 2264 with 25 per cent. burnt ditto, and of 75 of raw 2264 with 25 per cent. of washed Perth sand. (The latter was not a success.) Specimen briquettes after drying in the air and then by steam were fired at temperatures of $1,050^\circ$, $1,250^\circ$, and $1,400^\circ$ (Centigrade), with the following results:—

2264.—NEWLANDS WHITE CLAY.

At $1,050^\circ$.—Temperature too low to yield anything but a porous brick.

At $1,250^\circ$.—Product a grey vitrified brick with a porosity (water absorption by weight) of 1 per cent. Temperature too low to give good stoneware.

At $1,400^\circ$.—Product a light grey well vitrified mass devoid of porosity and of great strength. Burnt at this temperature this clay should yield an excellent drain pipe or other vitrified body, which, judging from the analysis of the raw clay, should take a salt glaze well. The

greatest fault of the clay is the large shrinkage it undergoes in drying and burning, viz.:—

	Wet moulded.	Steam dried.	Burnt.
Mean linear dimensions ..	100	91.9	81.2
Mean volumes	100	77.6	53.6

The shrinkage in diameter of a hollow pipe will, of course, be much less than in a solid briquette.

2265.—NEWLANDS RED CLAY.

At 1,050°.—Yields a good hard porous mass of a pleasing terra cotta colour and smooth surface, suitable for tiles, flower pots, etc. Porosity, 17.1 per cent. Six Marseilles tiles of different brands had porosities ranging from 9.3 to 17.5 per cent., the mean being 13.7 per cent.

At 1,250°.—Gave a very dark red vitrified mass showing signs at the edges of fusion. Porosity, 0.3 per cent. Shrinkage:—

	Wet moulded.	Steam dried.	Burnt.
Mean linear dimensions ..	100	92.1	81.1
Mean volumes	100	78.2	53.3

This clay appears to be unsuited by itself for making stoneware. It might, however, be used as a slip glaze for the white clay, or if the latter be not abundant, in admixture with it for the body of the ware.

NEWLANDS MIXED CLAY (90 per cent. White, 10 per cent. Red).

This gave results similar to those obtained with the white clay. The resulting masses, however, were not as good either in texture or colour as those given by the white clay alone, due possibly to imperfect mixing, neither was the shrinkage any less.

NEWLANDS WHITE—MIXED, BURNT, AND RAW.

This gave a well vitrified mass when burnt at 1,400°. Numerous internal flaws were noted, and were probably due to insufficient grinding of the burnt brick, which was only made to pass a 30-mesh sieve. The shrinkage was reduced to the following figures, viz.:—

	Wet moulded.	Steam dried.	Burnt.
Mean linear dimensions ..	100	92.5	83.6
Mean volumes	100	79.1	58.5

2408.—CAMPBELLFIELD CLAY.

Raw Campbellfield clay burnt at 1,400° gave a mass not quite so well vitrified, and hence neither so impervious nor so strong as the Newlands clayware. The shrinkage was, however, much less.

	Wet moulded.	Steam dried.	Burnt.
Mean linear dimensions ..	100	93.1	87.5
Mean volumes	100	80.7	67.0

Conclusions.—There is considerable difference in composition between the Victorian and Newlands white clays, resulting in differences in behaviour on burning. The Newlands white clay yields a very well vitrified, non-porous, tough but much shrunken ware; the Victorian clay yields a ware less well vitrified, slightly porous, and less tough, but showing much less shrinkage. The shrinkage of the Newlands white clay can be reduced by mixing with a suitable proportion of previously burnt clay, and should, with careful handling, yield an excellent drain pipe or other vitrified ware.

The Newlands red clay is not well suited for making drain pipe or other stoneware, as it might easily be overburnt. It would yield, however, an excellent roofing tile or other similar ware if burnt at a lower temperature (about 1,050° C.).

LIST OF MISCELLANEOUS REPORTS, CHIEFLY ON APPLIED GEOLOGY.

SERIES I.—Nos. 1-8.—Bulletin 26.

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| (1.) Artesian Water in the Northampton and Geraldine Districts. | (6.) Greenough River District. |
| (2.) Northward Extension of the Gascoyne Artesian Area. | (7.) Recent Advances in the Knowledge of the Geology of Western Australia. |
| (3.) Phosphatic Deposits near Dandaraga. | (8.) Prevention of External Corrosion of Goldfields Water Supply Pipes. |
| (4.) Meteorite from the Nuleri District. | 1907. |
| (5.) Occurrence of Oil in Princess Royal Harbour. | |

SERIES II.—Nos. 9-32.—Bulletin 48.

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| (9.) Radium-Uranium Ores from Wodgina. | (22.) Miscellaneous Mineral Notes. |
| (10.) Guano Deposits at Watheroo. | (23.) Boring on Normanby Lease, near Cue-Murchison Goldfield. |
| (11.) Preliminary Notes on Mineral Resources of Southern Cross. | (24.) Boring on Duke of York Lease near Cue, Murchison Goldfield. |
| (12.) Monazite at Cooglegong and Moolyella. | (25.) Proposed Boring at Nannine, Murchison Goldfield. |
| (13.) Country at Heads of Ashburton and Gascoyne Rivers. | (26.) Maori Lass Leases, Southern Cross, Yilgarn Goldfield. |
| (14.) Possibility of obtaining Artesian Water at Moora. | (27.) Diamond Drilling on Violet Lease, Golden Valley, Yilgarn Goldfield. |
| (15.) Kelmscott Clay Deposit. | (28.) Kohinoor South Mines, Stake Well, Murchison Goldfield. |
| (16.) Coals from Collie Fields, with Appendix on Spontaneous Combustion of Coal. | (29.) Diamond Drill Boring on Volunteer Flat, Cue, Murchison Goldfield. |
| (17.) Limestone Deposits at Pinjarra. | (30.) Geological and Physiographical Notes on the Darling Plateau. |
| (18.) Two new Meteorites from Western Australia. | (31.) Rutile at Yulgering. |
| (19.) Gold Discovery near Goodingnow, Yalgoo Goldfield. | (32.) Mount Jackson Centre, Yilgarn Goldfield. |
| (20.) Peculiar Biotite (Anomite) from Ubini. | 1912. |
| (21.) Nemesis Gold Mine, Tuckanarra, Murchison Goldfield. | |

SERIES III.—Nos. 33-51.—Bulletin 59.

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| (33.) Boring for Coal, Murchison Railway Line. | (43.) Petrographical Notes on specimens from Greenbushes. |
| (34.) Kurnalpi, N.E. Coolgardie Goldfield. | (44.) Golden Ridge G.M., East Coolgardie Goldfield. |
| (35.) Rare Metals and their distribution in W.A. | (45.) Ilgarere Mineral Leases and Humphry's Copper Find. |
| (36.) Ruby Well Centre Peak Hill Goldfield. | (46.) Bremer Range, Country, Dundas Goldfield. |
| (37.) Mikhaburra (Holden's Find), Peak Hill Goldfield. | (47.) W.A. Meteorites. |
| (38.) Mt. Keith District, East Murchison Goldfield. | (48.) Kanowna. |
| (39.) Mt. Magnet, Lennonville, and Boogardie, Murchison Goldfield. | (49.) Narra Tarra Mines, Victoria District. |
| (40.) Yuiin, Yalgoo Goldfield. | (50.) King Sound Tin Mine, West Kimberley. |
| (41.) Woodline Rush, N.E. Coolgardie Goldfield. | (51.) Some Rocks from the Phillips River. |
| (42.) Kapanga Mine, Greenbushes Tinfeld. | 1914. |

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| (52.) Coal Resources of Western Australia. | (57.) On Chloritoid and its Congeners with special reference to the Chloritoid at Yampi Sound. |
| (53.) Mining Geology of Yorilla. | (58.) Geology of Western Australia. |
| (54.) Certain Mining Centres at the South of the Yalgoo Goldfield. | (59.) Mining Fields of Western Australia. |
| (55.) Classification of Kalgoorlie Rocks. | (60.) Geological Observations in the Mulline, Riverina, and Ularring Centres, North Coolgardie Goldfield. |
| (56.) On Concentration Tests of a Tungsten-Molybdenum Ore from Callie Soak, Poona, Murchison Goldfield. | 1915. |

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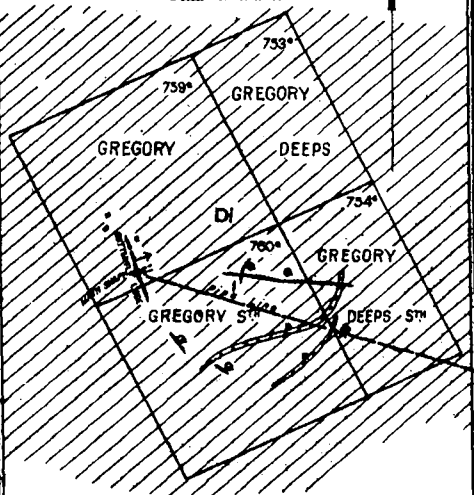
The Hon. R. T. Robinson, K.C. M.L.A.
Minister for Mines

SHALTIM 76 PLATE 1

GEOLOGICAL MAP OF
THE
GOLDEN BUTTERFLY G.M.COS LEASES
TAMPA N. COOLGARDIE G.F.

J. T. Jutson, Field Geologist

Scale of Chains



GRANITE... **Di** ... PELITIC QUARTZ PORPHYRY... ... QUARTZ REEF... ... SHAFTS...

H. J. Pether, Government Lithographer, Perth, W. A.

PLAN AND SECTION OF UNDERGROUND WORKINGS

GOLDEN BUTTERFLY G.M.

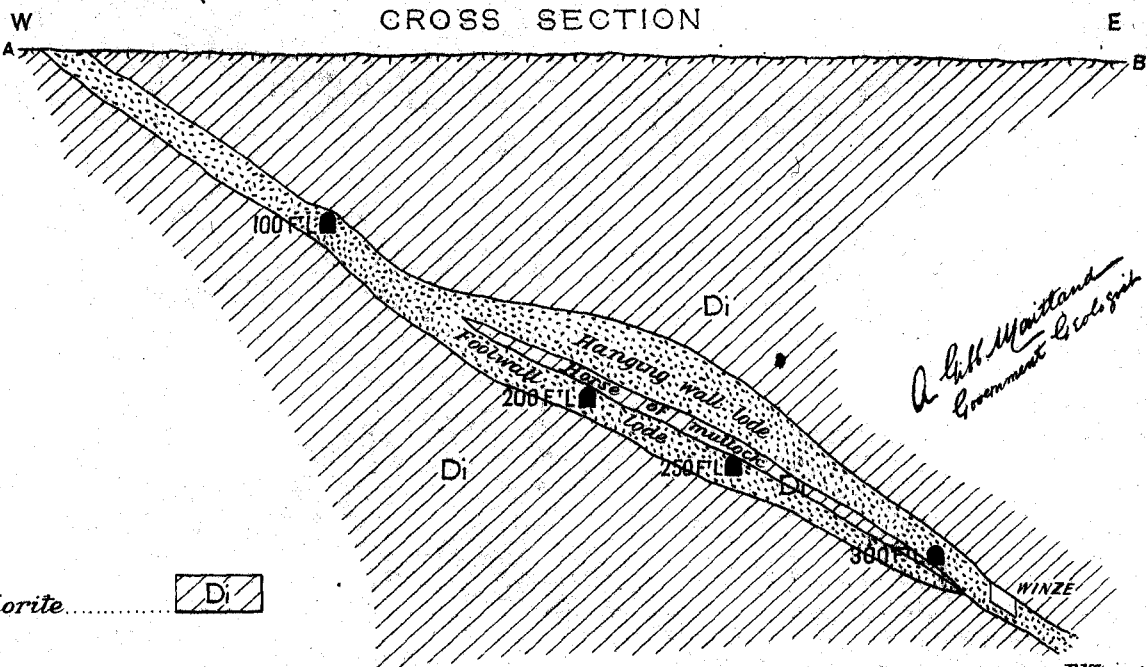
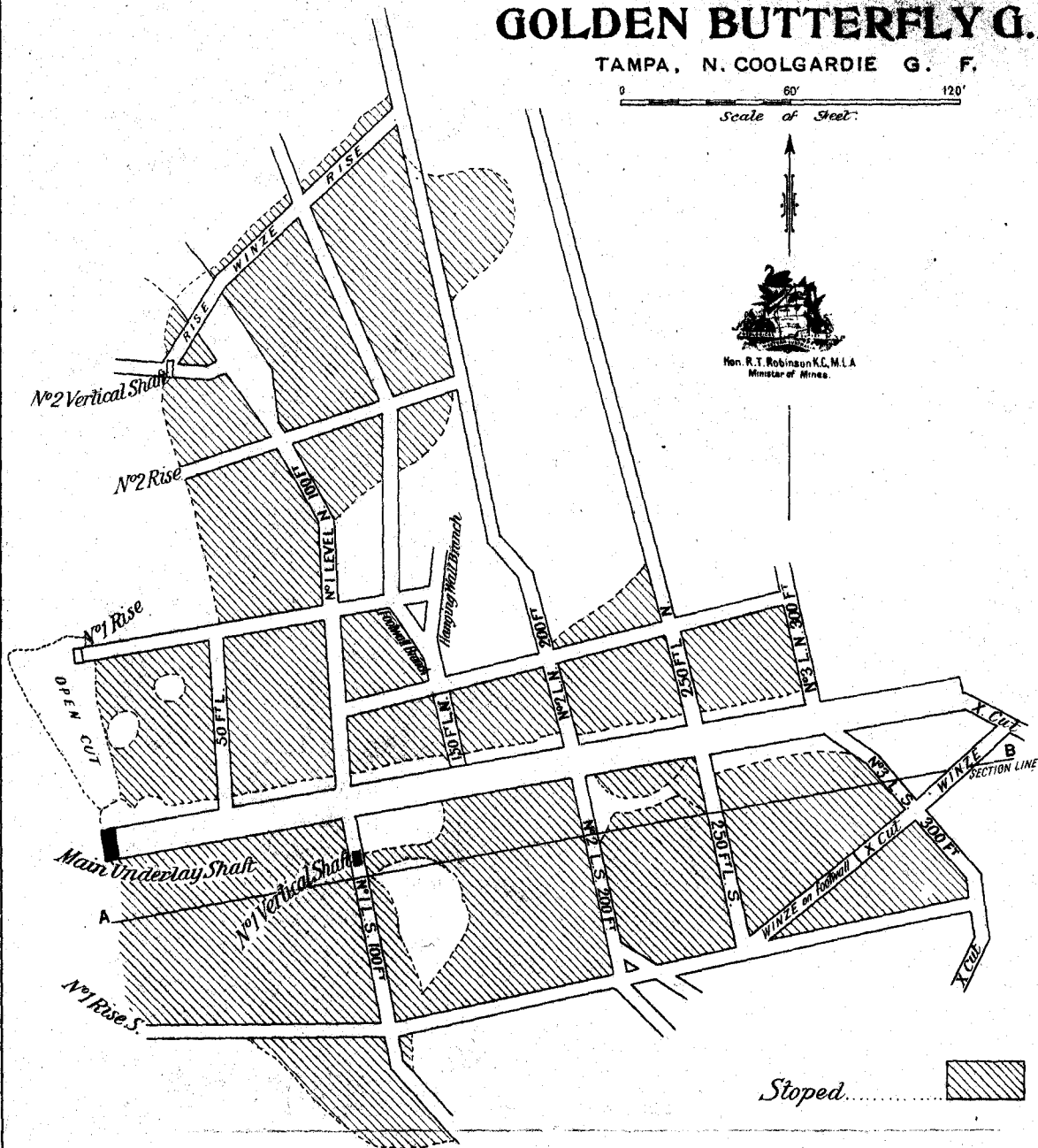
TAMPA, N. COOLGARDIE G. F.

0 60' 120'

Scale of Feet.



Hon. R.T. Robinson K.C., M.L.A.
Minister of Mines.



*A. Lill Waitt and
Government Lithographer*



The Hon. R. T. Robinson M.C., M.L.A.
Minister for Mines

GEOLOGICAL SKETCH PLAN OF LEASES AT FIELDS FIND

DUKETON, MT MARGARET G. F.

BY
C. S. HONMAN, Field Geologist:

0 10 20 30 40 50 60 70 80 90 100

Scale of Chains

Explanation

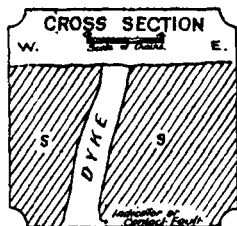
Basic Dyke.....



Schists.....



Dry blown patches.....



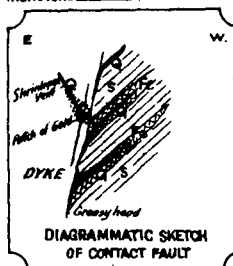
SCHIST



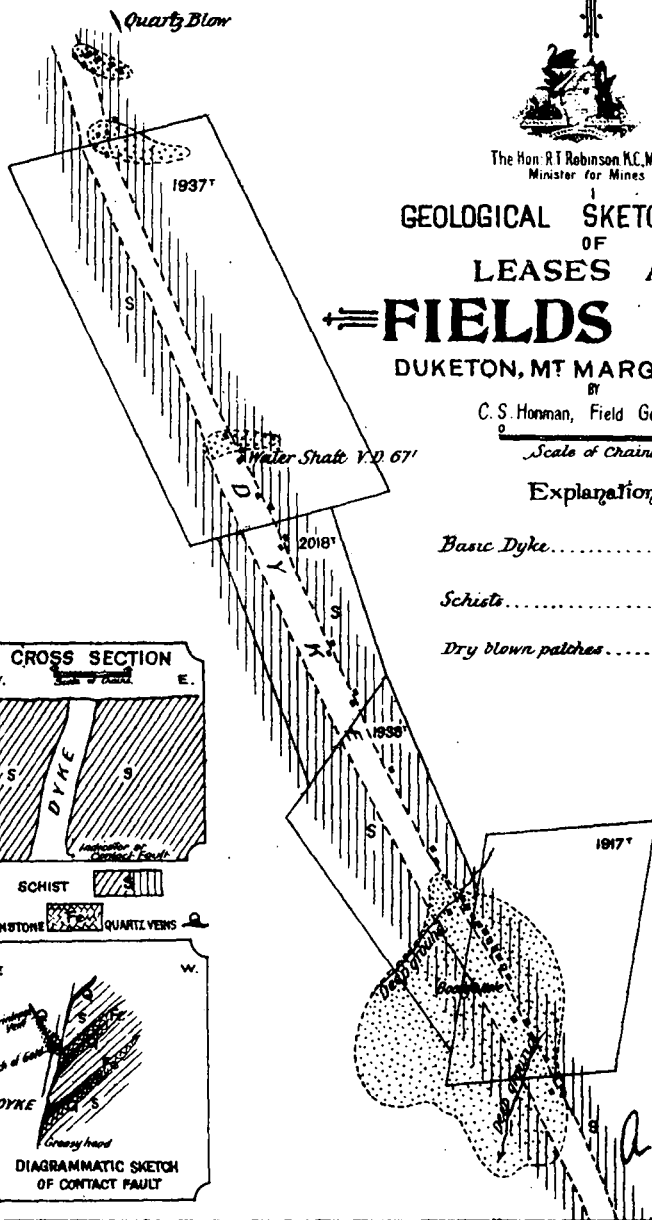
IRONSTONE



QUARTZ VENS



DIAGRAMMATIC SKETCH
OF CONTACT FAULT



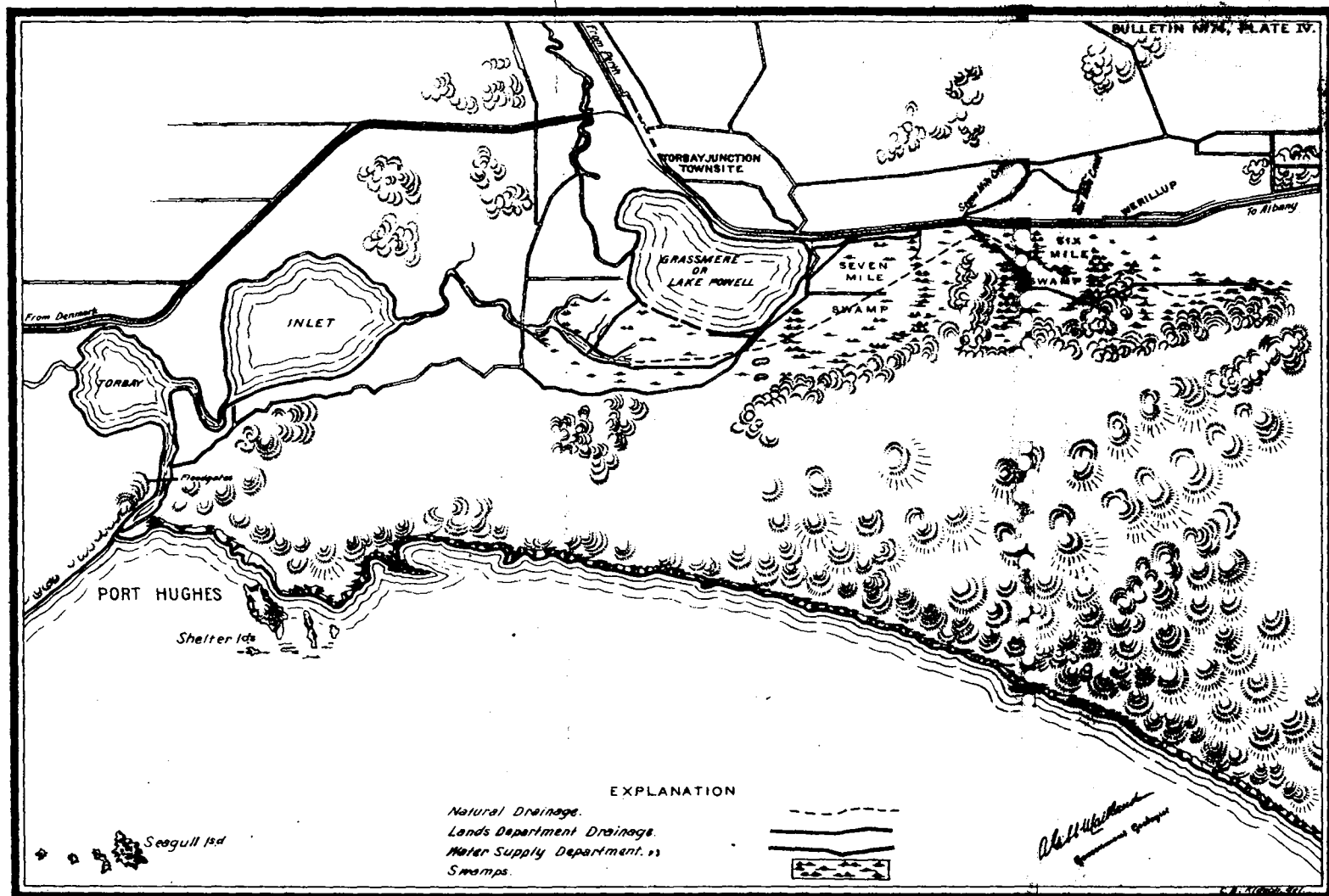


Hon. R. J. Robinson M.L.A.
Minister of Mines

PLAN SHOWING THE SIX & SEVEN MILE SWAMPS GRASSMERE, S.W. DIVISION.

BY
H. P. WOODWARD ASSISTANT GOVERNMENT GEOLOGIST.

0 40 80 120 160
Scale of Chains





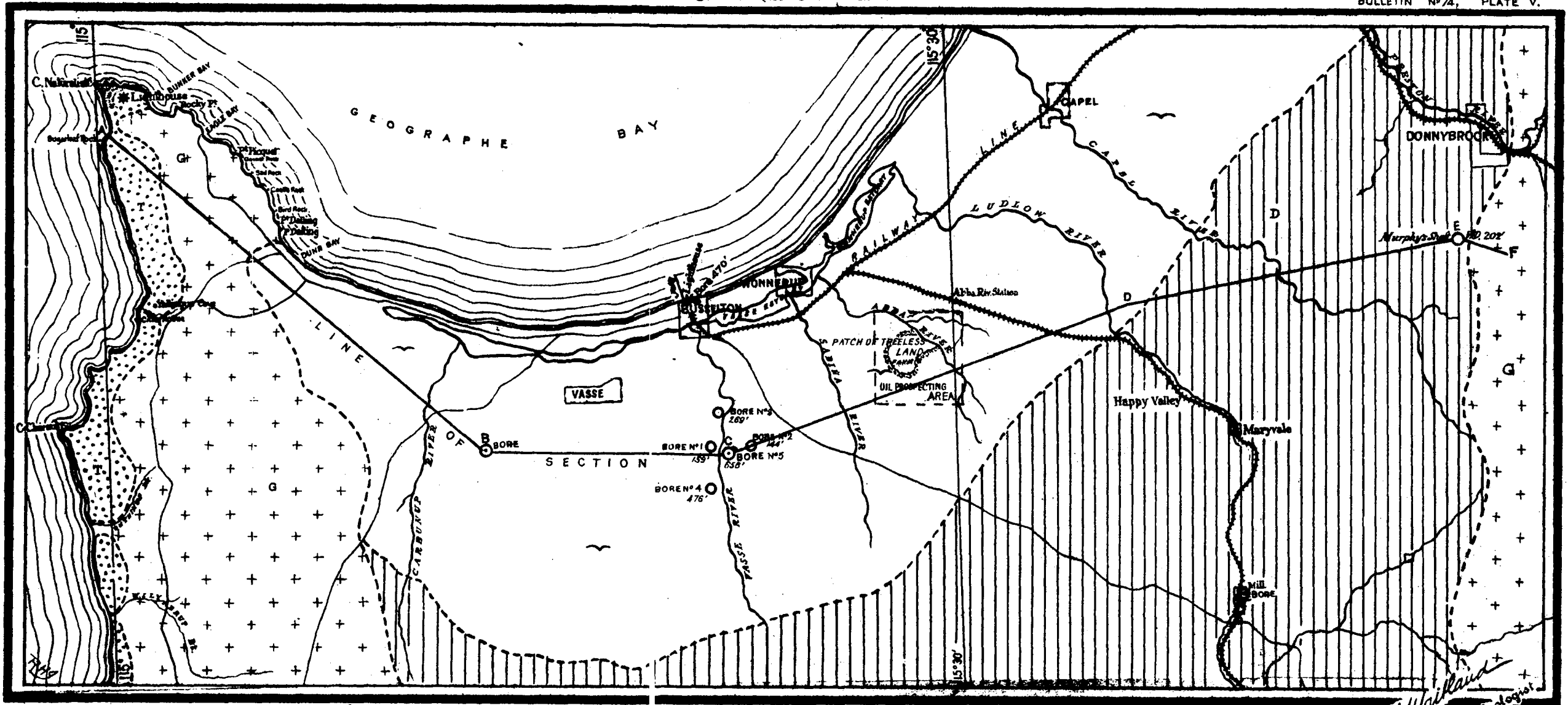
Hon. R. T. Robinson K.C. M.L.A.
Minister of Mines

GEOLOGICAL SKETCH MAP SHOWING THE SITE OF THE ABBA RIVER OIL PROSPECTING AREA

SOUTH WEST DIVISION,
BY H. P. Woodward and E. C. Saint-Smith

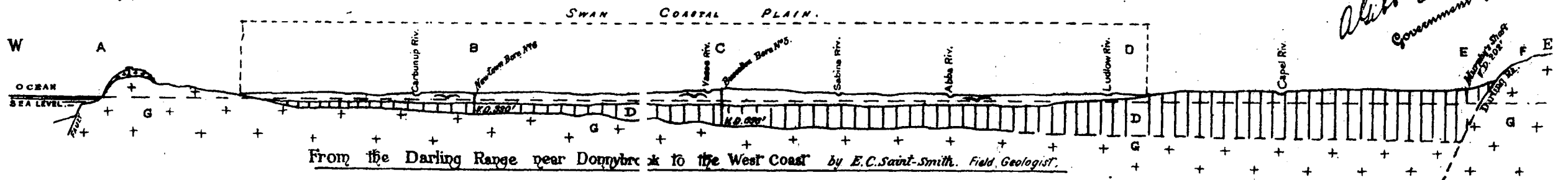
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BULLETIN No 74, PLATE V.



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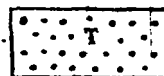
Alfred Wailand
Government Geologist



From the Darling Range near Donnybrook to the West Coast by E. C. Saint-Smith, Field Geologist.

EXPLANATION

CALCAREOUS SANDSTONES...
TERTIARY



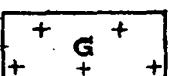
SAND AND LOAM FLATS...
TERTIARY



SANDSTONES & SHALES WITH COAL SEAMS...
DONNYBROOK SERIES,
PERMO CARBONIFEROUS(?)



GNEISSIC GRANITE...
CARLING RANGE SERIES.





Laterite Mound

Hon R.T. Robinson K.C., M.L.A.
Minister of Mines

SKETCH OF PART OF BLOCK 687

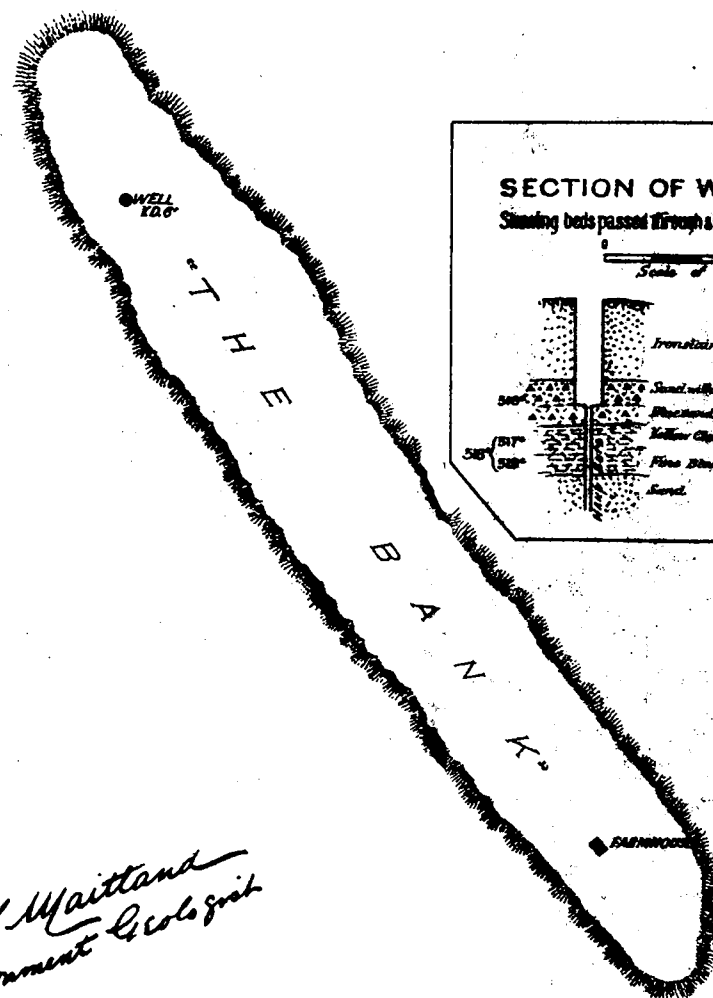
NEAR WONNERUP, STH W. DIVISION.

Showing position of wells in which Mineral Oil is reported to have been seen.

By E. de C. Clarke, Field Geologist

Scale of Feet

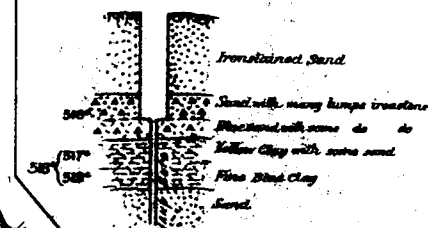
A. Giff Maitland
Government Geologist



SECTION OF WELLS 1 & 4

Showing beds passed through a location of samples 500 to 505

Scale of Feet

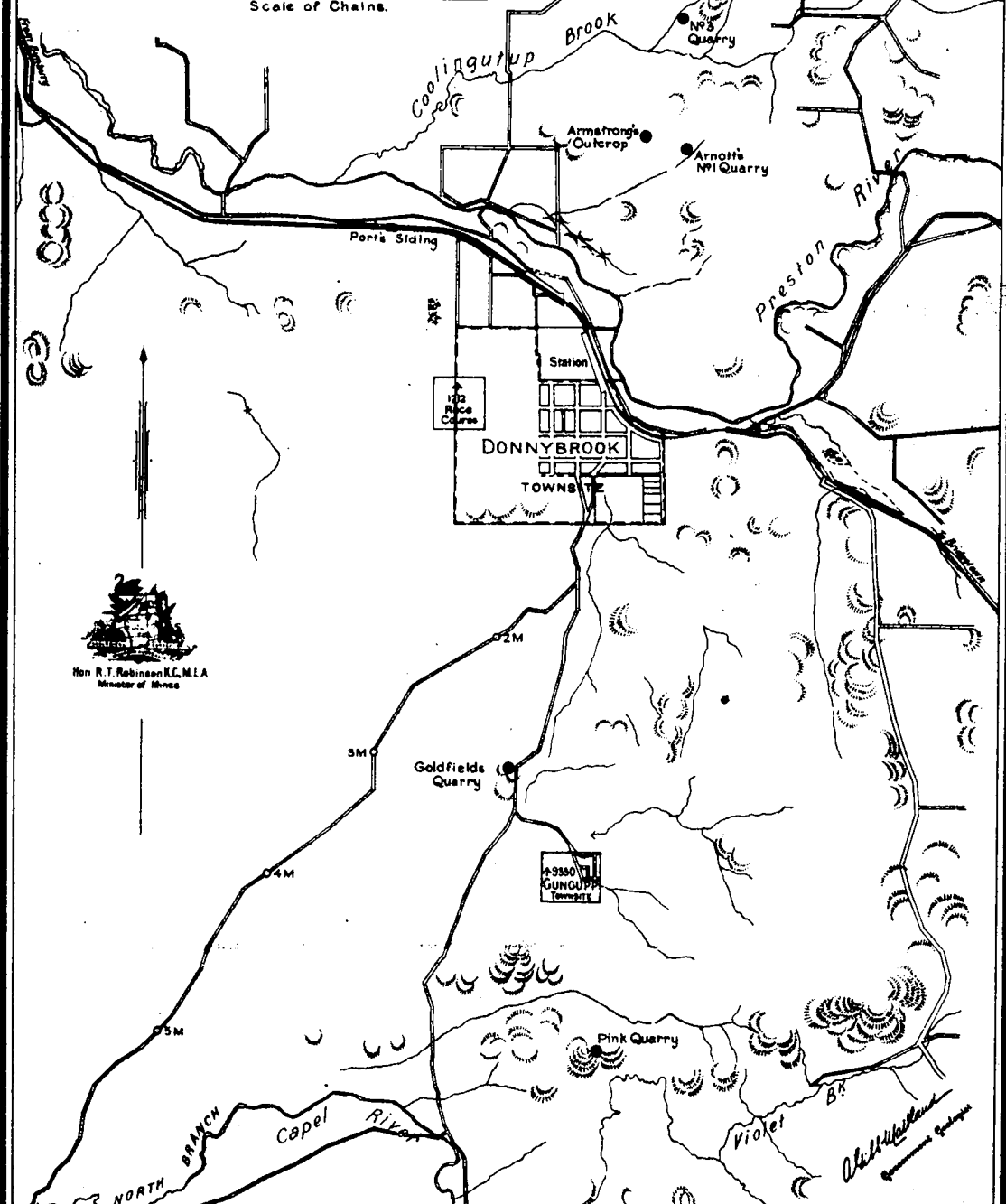


WELLS

R.D. Brown del.

PLAN SHOWING THE SITUATION OF THE SANDSTONE QUARRIES NEAR DANNYBROOK, S.W. DIVISION.

0 40 80 120 160
Scale of Chains.



SKETCH PLAN
OF

THE KENDENUP GRAPHITE MINE

ST^H W. DIVISION.

T. Blatchford, Assistant Geologist.

Showing Main Workings, where samples were taken and results.

0 5' 10'
Scale of Feet.

