1909.

WESTERN AUSTRALIA.

ANNUAL PROGRESS REPORT

OF THE

GEOLOGICAL SURVEY

FOR THE

YEAR 1908.

WITH THREE MAPS.

PERTH:
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1909.

TABLE OF CONTENTS.

ANNUAL PROGRESS REPORT OF THE GEOLOGICAL SURVEY FOR THE YEAR 1908.

The Secretary for Mines.

Geological Survey Office,
Perth, 26th January, 1909.

SIR,

I have the honour to submit, for the information of the Hon. Minister for Mines, the following report upon the work executed by the various officers of this Department during the year 1908.

THE STAFF.

The work of the Department has been carried out by 10 officers of the permanent staff and three temporary officers, made up as follows:—

Field Staff—Three Geologists and one Topographical Surveyor.

Office Staff—Two Draftsmen, one Clerk, and one Palæontologist (temporary).

Laboratory Staff—One Mineralogist and Assayer, and four Assistants, two of whom are temporary.

FIELD WORK.

H. P. WOODWARD, Assistant Government Geologist.—In the latter portion of January I was engaged upon the completion of the re-survey of the Greenbushes Tinfield, a full report upon which, accompanied by a Geological and Contour Map, has been issued as Bulletin No. 32.

Early in the month of February I was despatched to Kalgoorlie with instructions to make an examination of the lower levels of the principal mines of the Boulder Belt with the object of framing a cable for the information of the Agent General, the full text of my report being as follows:—

The Lodes at the bottom levels of the Boulder Belt, East Coolgardie Goldfield.

"In response to your instructions of January 20th I visited Kalgoorlie, where I inspected the Great Boulder, Ivanhoe, and Golden Horseshoe of the Western Group, and the Associated, Great Boulder Perseverance, and Kalgurli of the Eastern.

"*The Western Group.*—The lodes of this group have a definite fissure character, the ore body being of a highly siliceous nature, distinct and easily recognisable from the country, which latter carries no appreciable gold values.

"No movement appears to have taken place at the time of the opening of the primary fissures, since no striation or polishing is apparent upon the lode walls, which are of a more or less ragged character. Subsequently, however, considerable disruption has taken place both along the ore channel and across it. The former of these are noticed as polished walls in the lode matter itself, generally crossing it from wall to wall at a long angle to the south-eastward with apparently a throw to the southward. These minor faults are apt, in places, when considerable movement has taken place, to cause the lode to assume the character of a series of lenses.

"The lodes are also intersected by a series of thrust faults, the planes of which dip to the westward. These are most common in the Ivanhoe mine, where they have displaced the lode sometimes as much as 40 feet on the hade. These faults are apparently of the swing character, that is, they have a much greater throw at one end than at the other, their origin being in all probability due to a main disturbance in an east and west direction situated to the northward of this belt.

"The ore bodies in these mines vary very considerably in size, being from two to 40 feet in width, and in values from one dwt. to many ounces, whilst up to the present they have yielded about one ounce of gold for every ton of stone treated; but the ore reserves are estimated upon a basis of 14dwts, which should yield a very handsome profit upon the present low rate of working costs, these being more than covered by the treatment of stone of half this value.

"In the lower levels of these mines the ore bodies present as permanent a character as they do in those above, whilst the values at the 2,200 feet level in the Great Boulder (which is the deepest mine upon the field) are higher than any since the zone of secondary enrichment in the upper levels was worked.

"In the Ivanhoe 1670ft. level also greatly improved values are met with, whilst at the 1,650ft. level in the Golden Horseshoe at the point where the lode has been only crosscut it is 10 feet in width and assays 11dwts., this being a poor point evidently, and doubtless much higher values will be cut after driving upon the lode.

"It is impossible to state the size of the lodes at the bottom levels of these mines, since only 5ft. levels have been driven upon their courses; therefore the published statement of the values of the lode at the bottom level in the Great Boulder mine is misleading so far that it does not make it explicit that this width is only the width of the drive and not of the lode, which has not yet been determined by crosscutting or stripping.

"From a careful study of the character of the lode and the ore values at the various levels in these mines, the conclusion is arrived at that no secondary enrichment has taken place below the 1,200ft. level; therefore from this point downwards it may be considered as a primary sulphide zone associated with tellurides and free gold, the values fluctuating as in all ore bodies; but since the lodes maintain their size, character, and average values—whilst in two out of the three mines under review higher values than hitherto met with in this zone have been encountered at the bottom levels—the only natural inference to be drawn is that these reefs are the result of open fissures enriched from below, and in consequence there need not be the very slightest apprehension of their sudden determination or impoverishment, their downward limit being

governed by their source, and the extent to which they can be profitably worked depending solely upon economical conditions.

"*The Eastern Group.*—The lodes of this group differ materially not only from those of the western group but from all others in this State, in that they lack the characteristic commonly attributed to ore deposits, viz., definition.

"The gold is contained in a zone of considerable width, the rocks of which have been foliated by shearing strains, the direction of the schistosity being in a more or less north and south direction. In this zone, the whole of which carries gold in greater or less quantities, are lenticular or pipe-like portions of greater enrichment called lode formations, which bodies, although often of considerable size and richness, lack visible definition, their extent only being determined by the value of the ore by assay.

"These mines upon the whole have yielded richer stone than those of the western group, but owing to their character cannot be so economically handled, since more dead work has to be done of a prospecting character in order to discover the next lens when the limits of the one have been determined; but owing to the nature of the rocks it is easier to mine and treat than the more siliceous ore met with in the Boulder belt.

"The bodies of ore worked in this zone exceed those of the other class in width, in places reaching a measurement of 60 feet, but the longitudinal and vertical extent of the individual shoots is naturally more limited owing to their lenticular character.

"The greatest depth to which these have been worked so far is about 1,700 feet in the Associated, and so far as can be judged from the nature and character of the country and the value of the ore, there appears to be no reason why numbers of these rich shoots should not still be met with at greater depths, and since in the western zone their average permanent values are apparently met with below the 1,000ft. level, if all ore reserves situated above this level are eliminated from estimate, the result will prove conclusively that these mines carry large quantities of profitable ore to the deepest levels to which they have as yet been opened."

———

Upon February 24th the Government Geologist left for England with the object of representing the Mining Industry of this State at the Franco-British Exhibition in London when I was appointed Acting Government Geologist, which position I continue to hold.

At the commencement of March I visited Collie with the object of reporting upon what was supposed to be the discovery of a new coalfield, but which I found to be only the extension of the known basin in a north-easterly direction. This area was mapped in and the following report submitted:—

Prospecting for Coal at Collie.

"As instructed, Mr. H. W. B. Talbot, Topographical Surveyor, proceeded to the Collie Coalfield with the object of tracing and mapping the outcrops of crystalline rock upon the north-western side of the Collie basin, which work occupied him about one week. Upon the completion of this I visited Collie and was enabled, under his guidance, to make a rapid survey of this portion of the basin.

"Upon the plan herewith the outcrop of the crystalline rocks has been laid down as a solid black line, whilst the probable connection between it and the existing survey as shown upon Dr. Jack's map is indicated by dots, whilst Dr. Jack's coal basin also is shown as solid.

"The area as now defined will be found to be almost identical with that laid down by myself and published upon a sketch map in the *ad interim* report of the Department of Mines in 1894, and is undoubtedly a portion of the Collie basin.

"The beds passed through in the Nos. 2 and 3 shafts and bores are said to dip one in 24 to the north-west. If this is the case an anticlinal fold exists between this portion of the field and that being mined where the dip is uniformly to the south-east, and this would account for the non-success of the No. 1 diamond drill bore and also for certain reported isolated outcrops of granite to the south-east of these new workings, which were taken to indicate the edge of the basin.

"So far the seams reported are too small to be payable, whilst the analysis of the coal, although good, being only obtained from a sample weighing three-quarters of an ounce, is unreliable.

"There is of course nothing to indicate that the larger seams of the series exist below these, and in fact the character of the coal would rather lead one to the conclusion that we have here the lower series of high-class small seams met with at West Collie (21-Mile Siding) and below the large seams in the deep bores, but owing to the faulted character of the field and the irregularity in size of the seams it is of course possible that seams of workable size may exist at a greater depth, the solution of which question can only be arrived at by boring.

"The applicants for assistance are not possessed of a suitable plant for boring to a greater depth than that at present attained, and I am doubtful whether they would be able to manage a calix in a satisfactory manner, so that these facts must be taken into consideration before granting this subsidy. Realising this, the prospectors would be content if the Government would put down a bore departmentally, and this I consider would give by far the most satisfaction to all concerned.

"In any case if the subsidy is granted it must be looked upon as lost money, for even should it be proved that a workable coal seam exists at a greater depth it is extremely doubtful whether the necessary capital can be raised to open another pit in order to enter into the already overdone competition, since the combined output of Collie is really only sufficient to keep one pit running profitably."

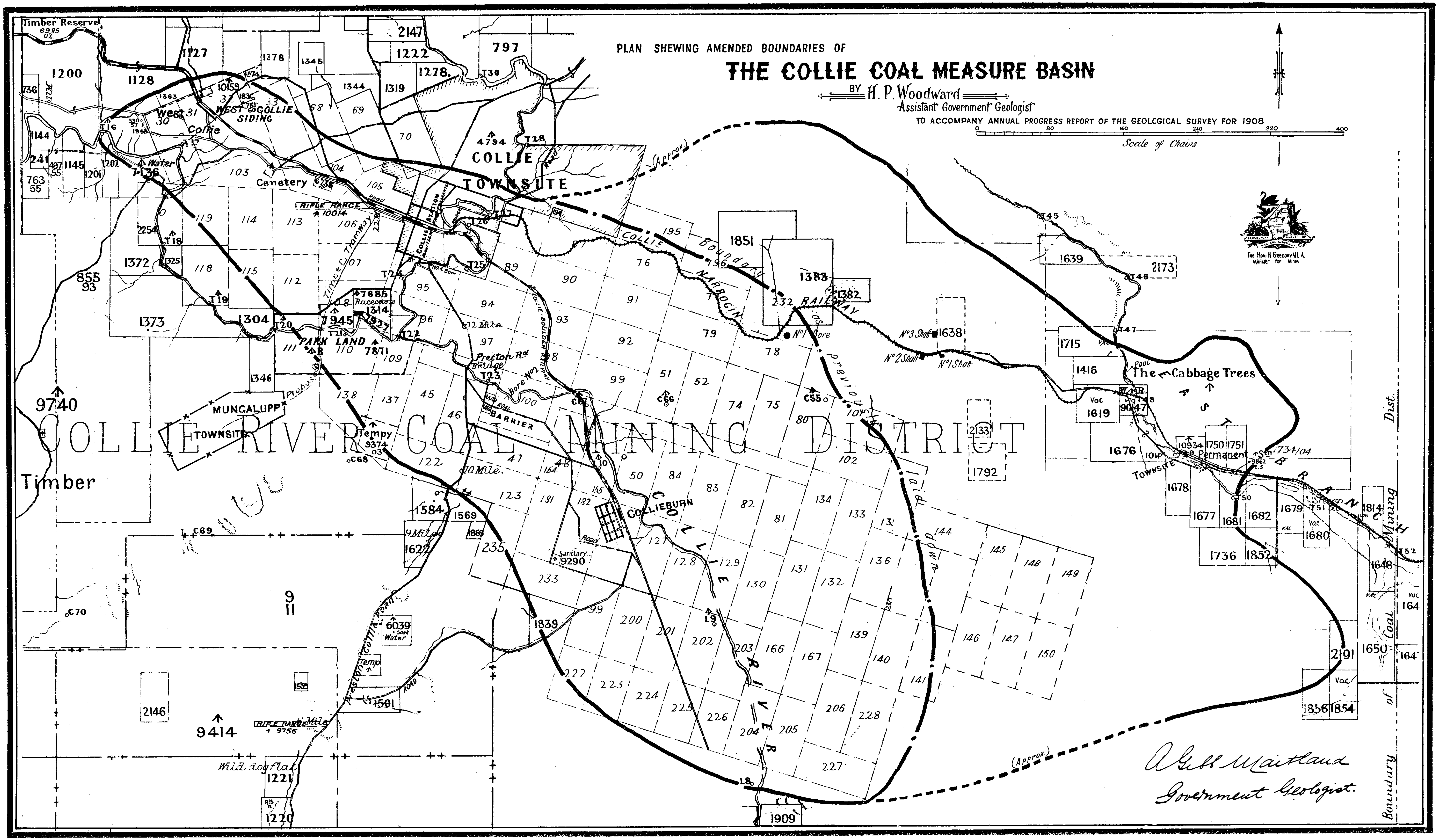
———

About the end of March, at the request of the Hon. Minister for Agriculture, I was despatched to Christmas Island, which is situated about 30 miles off the South Coast, near Israelite Bay, with the object of reporting upon the extent and value of certain phosphatic deposits:—

Phosphate Deposits of Christmas Island.

Christmas Island is a member of the Eastern Group of the Archipelago of the Recherché, which consists of a scattered belt of islands lying along the southern coast between Fanny Cove and Israelite Bay, or more correctly between 121deg. 30min. and 124deg. 10min. E. Long.

This Island, which lies about 20 miles in a south-easterly direction from Israelite Bay, is about one mile in length and averages about a quarter of a mile in width but spreads out at either end where bold,



H J Pether Government Lithographer Perth W A

bare, dome-shaped granite masses rise to an elevation of about 500 feet above the sea level.

The central or isthmus-like portion which connects these two is comparatively low, attaining its greatest elevation to the seaward (east), where it presents a perpendicular granite cliff face of about 100 feet to the ocean swell.

There is a general fall of the surface to the westward where the limestone cliffs never exceed 30 feet in height, whilst about the centre of this side a sandy beach extends for a length of about 13 chains.

This island forms a conspicuous object, presenting the appearance of two isolated peaks each of which rises abruptly from the sea and is visible for a distance of about 30 miles.

A few chains from the south-western part of the island is another called New Year Island, which is a low bare granite mass, the two being so grouped as to form a land-locked harbour protected from all quarters but the north-west, which is in the direction of the mainland.

So far no fresh water has been discovered upon this island, but it is highly probable that a supply of fair quality can be obtained by sinking to a moderate depth in the sandy hollow near the camp. Firewood is scarce since the only vegetation consists of scrub of small size, whilst there is absolutely no timber.

The granite rocks which form the foundation of this island are of a highly igneous character, thus differing considerably from many of those met with in the south-western district which may possibly be of metamorphic origin. They present a bold, bare, polished surface upon which the foothold is very insecure, often having the appearance of colossal ruins or obelisks.

The inclined polished surfaces exhibit a complex structure of dark-coloured biotite granite and gneiss or schists, the foliations of which are much plicated, and appear to represent the primary rocks of this group since fragments and masses of them are often met with entangled in the magmas of porphyritic granite which appears to have been intruded at a subsequent period.

These porphyritic granites are of a pale flesh colour, the ground mass being composed of quartz, felspar, and mica (muscovite), whilst scattered here and there throughout the whole are large crystals of orthoclase felspars which vary in size from one-half to an inch in length.

Radiating from these porphyritic masses are dyke-like extensions in which the character of the rock changes rapidly into pegmatite, whilst further still from the primary magma these pass almost imperceptibly into quartz veins which occasionally contain a little felspar or mica in the form of large crystals, the latter being mostly biotite.

Intersecting the entire series are numerous narrow veins of highly basic fine-grained greenstones which contain magnetite in such large proportions that even the thinnest microscopic sections are almost opaque.

Overlying these granite rocks are a series of limestones and sandstones which were apparently deposited by the action of waves and wind since the lower members of the series contain boulders of granite cemented together by a dark-coloured shelly limestone.

Overlying this shell limestone are a series of cream-coloured limestones very similar to those met with along the south-western coast, followed by a fine-grained sand rock (often ferruginous) upon the top of which is an irregular deposit of travertine limestone which either occurs in the form of layers or nodules often mixed with dark-coloured sandy soil.

Two sections of this limestone have proved to be phosphatic, viz., the basal beds of shelly limestone which have been converted into rock phosphate and the surface travertine.

In considering the first of these the reason for the presence of phosphoric oxide in considerable quantity is difficult to account for since there is nothing in the character of the rock to indicate bone structure, whilst one would imagine that a beach composed of loose shelly gravel would not be selected by birds for a camping ground and nesting place. The fact remains, however, that the carbonate of lime which originally formed the shell fragments has been largely transformed into phosphate of lime. The only possible solution being that at some remote period these beds formed cave bottoms in the cliff face in which large deposits of guano accumulated, the soluble phosphates in which gradually acted upon the shelly matter whilst preserving its structure.

The overlying creamy limestones and sandstones are almost destitute of phosphoric oxide, and since any organic structure that may have existed has been entirely destroyed by meteoric agencies their origin is obscure, but in all probability they resulted from blown sands and shelly matter.

Upon the other hand the presence of travertine can be easily accounted for by the action of capillary attraction in drawing upwards ground waters which have dissolved portions of the carbonate of lime contained in the underlying sands; these, upon nearing the surface during dry warm weather, have evaporated, leaving behind their burden of lime at first as a thin film which has been added to from year to year until a layer of often considerable thickness has been formed, or when in the first instance the deposition has taken place around a particle which has been increased by the addition of thin coats periodically, thus forming nodules which sometimes attain considerable size.

Overlying the travertine deposits is a layer which varies considerably in thickness of soil of a dark colour, rich in organic matter, upon which the salt bush and other vegetation flourish and in which numerous penguins and mutton birds burrow and nest.

This travertine limestone is, as a rule, phosphatic, but its value varies very considerably, ranging from brown resinous-like veins or coatings of almost pure tricalcic phosphate down to a hard white vitreous limestone containing scarcely a trace.

The phosphorization of the limestone has apparently taken place directly from the contact of descending solutions containing soluble phosphates derived from the excrement of sea fowls, the stronger phosphoric oxide having replaced an equivalent of the weaker carbonic oxide, thus forming an insoluble phosphate of lime.

This chemical change has naturally not taken place by any means to a uniform degree over the entire area, the zone of highest value being for the most part confined to those localities where there is a sufficient cover of soil to allow the birds to burrow, whilst those portions where the travertine outcrops at the surface usually contain little phosphoric oxide.

This phosphorized travertine covers a total area of 153,600 square yards and has an average thickness of about two feet, and therefore amounts to 102,400 cubic yards, whilst the average thickness of overburden of sand or soil is two feet.

A considerable number of shallow holes have been sunk upon this area, the majority of which were carefully sampled, the positions of which are shown upon the plan.

These samples were taken in such a manner as to nearly approach that which would be employed in working these deposits upon a large scale, viz., stripping the overburden and screening the limestone to get rid of sand and earth; therefore the results obtained do not represent the actual value of the clean limestone,* since a certain quantity of sand and soil adhering to the stone was included.

The area covered by the limestone may be roughly divided into three, the first of which is situated at the north and includes a belt upon the cliff tops extending southward towards the camp. In the section it will be noticed that the values in phosphoric oxide are uniformly low and it in consequence may be excluded from any calculations.

The second area, which may be called the central, is situated in a dip near the centre of the island, and it has been very thoroughly prospected; this I estimate to contain 15,483 cubic yards of an average value of 13.50 per cent. phosphoric oxide worth about 34s. per ton.

The southern, or third, area has been very little prospected, but what has been done recently is of a most promising character, for not only are the values good but the deposit is of greater thickness. I estimate that there are 36,300 cubic yards in this section, whilst as far as tested it contains an average of 11.50 per cent. of phosphoric oxide, which would make it worth 29s. per ton; this is probably considerably under its true value since all the trial shafts have been sunk upon the edge of the area.

The rock phosphates on the shore returned the highest percentage of phosphoric oxide, but since it outcrops for only a short distance the extent of this deposit cannot be estimated, but it probably covers a considerable area beneath the southern section last mentioned. A rough estimate of the outcrop gives about 1,000 cubic yards in sight of an average value in phosphoric oxide of 23.64 per cent., worth about £3 per ton.

* Analyses of four picked samples, by the Mineralogist and Assayer :—

No. 765—Resin-like substance in rock, Xmas Island .. .. Phosphoric oxide, P_2O_5 32.03% ; Calcium Phosphate, $Ca_3P_2O_8$, 69·92%

No. 767—G. S. M. 8136 .. .. Phosphoric oxide, P_2O_5 33.67% ; Calcium Phosphate, $Ca_3P_2O_8$, 73.50%

No. 768—G. S. M. 8137 .. .. Phosphoric oxide, P_2O_5 29.67% ; Calcium Phosphate, $Ca_3P_2O_8$, 64.77% encloses large crystals of felspar.

No. 769—G. S. M. 8138 .. .. Phosphoric oxide, P_2O_5 27.20% ; Calcium Phosphate, $Ca_3P_2O_8$, 59.37%

The following is a list of the samples with the section of the formation exposed in each hole and the locality symbol for reference to the map, the analyses having been made by the Government Analyst :—

	Section.	P_2O_5= value	$CaO_3(PO_4)_2$.	CO_2=	Carb. Lime.
1A.	6in. Sand with little limestone rubble	..	..	..	..
	12in. Rubbly limestone with sand	10.62	23.18	6.49	14.85
	48in. Sand rock	..	..	..	..
2A.	18in. Sand and soil	..	..	..	..
	15in. Rubbly limestone	9.00	19.65	16.70	37.95
3A.	18in. Sand and soil	..	..	..	..
	15in. Calcareous sandstone	6.01	13.12	25.18	57.22
	Sand rock	..	..	..	..
4A.	12in. Sand	..	..	..	..
	8in. Rubbly limestone	9.94	21.70	19.75	44.88
	Hard limestone	..	..	..	..
5A.	13in. Sand	..	..	..	..
	12in. Limestone	12.02	26.24	14.18	32.22
	Sand rock	..	..	..	..
6A.	Trench West End—				
	6in. Sand	..	..	..	..
	18in. Rubbly limestone	21.36	46.62	2.86	6.49
	Hard limestone	..	..	..	..
	Trench East End—				
	3in. Sand	..	..	..	..
	6in. Rubbly limestone	21.36	46.62	2.86	6.49
7A.	East End—				
	36in. Sand	..	..	..	..
	24in. Ferruginous limestone	14.41	31.46	15.22	34.59
	Sand rock	..	..	..	..
7A.	West End				
	36in. Sand	..	..	..	..
	18in. Limestone	23.58	51.47	3.47	7.88
	Sand rock	..	..	..	..
8A.	18in. Limestone rubble	15.89	34.71	9.11	20.70
	Sand rock	..	..	..	..
9A.	7in. Soil	..	..	..	..
	18in. Limestone	4.92	10.74	21.13	48.02
	Sand rock	..	..	..	..
10A.	6in. Soil and rubble	..	..	..	..
	12in. Limestone	3.17	6.92	27.95	63.52
	Sandy limestone	..	..	..	..
11A.	15in. Ferruginous calcareous sandstone	8.69	18.97	0.63	1.40
	Sand rock	..	..	..	..
12A.	12in. Rubbly limestone and soil	3.00	6.55	26.62	60.50
	Sand rock	..	..	..	..
13A.	18in. Limestone rubble and sand	3.33	7.27	7.60	17 27
	48in. Yellow sand	..	..	..	..

PLAN SHEWING PHOSPHATE DEPOSITS ON CHRISTMAS ISLAND RECHERCHE ARCHIPELAGO EASTERN GROUP

Scale of Chains 0 7 14

BY H. P. Woodward
Assistant Government Geologist.

TO ACCOMPANY ANNUAL PROGRESS REPORT OF THE GEOLOGICAL SURVEY FOR 1908

GRANITE HILL ABOUT 500 ft HIGH

GRANITE

GRANITE CLIFFS ABOUT 100 ft HIGH

LIMESTONE

GUANO CAVE

GUANO CAVE

GUANO CAVE

CAMP

ROCK PHOSPHATES 21

ROCK PHOSPHATES 21

NEW YEAR Is

GRANITE

GRANITE

GRANITE HILL ABOUT 500 ft HIGH

GEOLOGICAL SURVEY OF WESTERN AUSTRALIA

The Hon. H. Gregory M.L.A.
Minister for Mines.

A. P. H. Whitland
Government Geologist.

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

LIST OF SAMPLES—*continued*.

Section.	P_2O_5 = value.	$CaO_3(PO_4)_2$.	CO_2 =	Carb. Lime.
1B. Limestone outcrop (General)	5.43	11.85	28.75	65.34
2B. 12in. Sand	..	..	..	..
6in. Sand and rubble	..	..	..	..
12in. Limestone	5.22	11.39	25.90	58.86
Sand rock	..	..	..	..
3B. 5in. Sand	..	..	..	..
12in. Limestone	5.06	11.05	24.12	54.81
4B. 17in. Limestone and soil	..	..	..	..
6in. Hard limestone	6.23	13.60	23.69	53.84
Sand rock	..	..	..	..
6B. 36in. Sand	..	..	..	..
18in. Sand and rubble	19.55	42.66	2.25	5.11
6in. Limestone				
Sand rock	..	..	..	..
7B. 42in. Rubbly limestone	12.86	28.07	0.73	1.66
Sand	..	..	..	..
8B. 12in. Sand	..	..	..	..
6in. Ferruginous limestone and sand	8.68	18.95	0.87	1.97
Ferruginous sandstone	..	..	..	..
9B. 24in. Sand	..	..	..	..
42in. Ferruginous sandy soil with nodules	6.37	13.90	0.35	0.79
Ferruginous sandstone and grit	..	..	..	..
A. 18in. Sand	..	..	..	..
30in. Limestone	3.23	7.05	23.50	53.41
Sand rock	..	..	..	..
B. 48in. Sand	..	..	..	..
12in. Limestone	11.56	25.24	14.63	33.25
C. 36in. Sand	..	..	..	..
24in. Limestone	19.30	42.13	8.04	18.27
Sand rock	..	..	..	..
D. 60in. Sand	..	..	..	..
18in. Limestone	17.01	37.13	8.68	19.72
E. 48in. Sand	..	..	..	..
18in. Rubbly limestone	16.27	35.52	8.85	20.11
12in. Limestone				
Hard limestone	..	..	..	..
G. 36in. Sand	..	..	..	..
G. 18in. Rubble and soil	12.97	28.23	5.33	12.11
12in. Soil				
12in. Limestone				
Sand	..	..	..	..
H. 36in. Sand	..	..	..	..
24in. Rubble and soil	11.81	25.78	10.15	23.06
12in. Limestone				
Sand rock	..	..	..	..
I. 9in. Sand	..	..	..	..
12in. Limestone	9.73	21.24	17.13	38.93
Sand rock	..	..	..	..
J. 42in. Sand	..	..	..	..
42in. Sandy limestone	9.23	20.17	16.57	37.66
K. 48in. Sand	..	..	..	..
30in. Limestone	9.75	21.28	23.66	53.77
L. 36in. Sand	..	..	..	..
36in. Rubble and sand	18.90	41.26	0.41	0.93
M. 6in. Sand	..	..	..	..
18in. Limestone	9.17	20.02	21.20	48.18
Sand rock	..	..	..	..
N. 12in. Sand	..	..	..	..
54in. Limestone	*12.51	..	..	..
Sand rock	..	..	..	..
N3. 3in. Sand	..	..	..	..
42in. Limestone	15.46	33.74	0.70	1.59
21 Shell rock phosphate	23.64	51.61	3.55	8.07
31 General sample, from camp to guano caves (cliff)	1.28	2.82	30.50	69.32
36 General sample, cliff south of camp	7.79	17.01	20.88	47.45
42 Rock phosphates, roof of guano caves	†1.38	..	..	..

* = 27.22 Tricalcic phosphate.
† = 3.01 Tricalcic phosphate.

PHOSPHATIC FERTILISERS.

(By E. S. Simpson, Mineralogist and Assayer.)

Of the many substances necessary to insure the healthy and vigorous growth of those plants upon which man depends so much for food and other supplies, there are only four which are not very generally present in all soils in abundant quantities. These four are water, phosphorus, nitrogen, and potash; the absence of the first of which in sufficient quantities necessitates some form of irrigation, the absence of one or more of the last three, some form of artificial fertilisation. This latter process consists in the addition to the soil of small quantities of substances containing a large proportion of the desired element. These fertilisers are largely of mineral origin, and derived from a source where the desired element is abundant and only partly or not at all utilised. Thus coal beds contain nitrogen which is not of any value to plant life until during the preparation of gas it is converted into ammonia compounds rich in available nitrogen. Potash fertilisers are derived mainly from

beds of potash salts buried at considerable depths in the ground in Germany. Phosphorus is derived from very many sources, both organic (bones, guano, etc), and inorganic (Thomas's phosphate, etc.).

The phosphorus in many of these fertilisers has a long and interesting history which will be considered after a statement of the main varieties of phosphatic material used as a source of fertilisers.

CLASS A.—*Primary minerals*—

Apatite,
Amblygonite, etc.,
Iron Phosphates.

CLASS B.—*Animal concentrations*—

Bones, new and fossil,
Guano,
Bat guano,
Coprolite (in part).

CLASS C.—*Secondary minerals, the phosphorus in which was originally derived from materials of Class B*—

Rock phosphate (lime phosphate),
Aluminium phosphate,
Iron phosphates,
Copralite (in part).

CLASS D.—*Manufactured products*—

Superphosphate,
Thomas's phosphate,
Precipitated phosphate,
Bone ash.

The ultimate source of all the phosphorus in these substances is those small amounts of apatite and other phosphates present in the rocks forming the crust of the earth. As the rocks weather these have been and are still being absorbed by vegetation; these again are food for animals which concentrate the phosphorus in the bones. Such bones being indigestible (*e.g.*, fish bones), form a considerable proportion of the excreta of birds, reptiles, bats, etc., giving rise to deposits of guano, bat guano, and coprolite. Rain water acting on such deposits carries part of the phosphorus in solution down on to the surface of the underlying rocks where chemical interaction takes place with the formation of one of the many forms of "rock phosphate" according to the nature of the original rock—lime phosphate rock when limestone, aluminium phosphate rock when aluminous lava or granite, iron phosphate rock when ironstone or ferruginous lava. The Coprolite of this class is also formed by precipitation from water of dissolved phosphate of lime.

The relative value of phosphatic material depends upon its solubility in water, in dilute carbonic acid, and in saline solutions, since it is only when dissolved in the water of the soils that it can be absorbed by the plant. The naturally occurring material, with the exception of guano, bat guano, and bone, are almost wholly insoluble and only when finely ground do they show any appreciable effect on vegetation, and that effect is spread over a long period of time owing to the slowness of solution. They have, therefore, to be subjected to certain processes with a view of increasing their solubilities. In this connection the solubility of the chief compounds occurring in the crude and manufactured fertilisers must be considered. These are:—

Tricalcium phosphate.—Practically insoluble in water, dilute carbonic acid and saline solutions. It is the chief constituent of apatite, bone, bone-ash, coprolite, and lime-rock phosphate. Occurs to some extent in guano.

Dicalcium phosphate.—Practically insoluble in water, but readily attacked by dilute carbonic acid or many saline solutions. Occurs in guano, bone, bone-dust (desiccated bone, etc.), and forms main constituent of "Precipitated phosphate." Forms slowly in superphosphate when stored.

Monocalcium phosphate.—Readily soluble in water. Chief constituent of superphosphate.

Basic lime phosphate.—Practically insoluble in water, but attacked by carbonic acid and saline solutions. This is the important constituent of "Thomas's phosphate" or "Slag phosphate."

Aluminium phosphate is practically insoluble. It occurs in many rock phosphates both by itself and in conjunction with iron phosphates and tricalcium phosphate. In superphosphate made from aluminous calcium phosphates more or less of it occurs, especially with the lapse of time.

Iron phosphates of several varieties are known, all insoluble. They occur in phosphatic iron ores from which Thomas's phosphate is prepared, in many rock phosphates and in superphosphate in a similar way to aluminium phosphate.

The important constituent of all these compounds is the compound of phosphorus and oxygen known as phosphoric oxide, or more commonly, but incorrectly, phosphoric acid.

This constituent has three different market values, according to its solubility. Recent Perth rates were per unit (one per cent.) per ton:—

	s.	d.
Water soluble	5	2
Citrate soluble*	3	10
Insoluble	2	7

Owing to the low price of the insoluble phosphoric oxide and its slow action on vegetation it is very desirable that most crude phosphatic material should be treated so as to convert the common insoluble form into the form soluble in water or saline solutions.

The most important of these manufactured fertilisers rich in water soluble phosphoric oxide is "Superphosphate." This substance is prepared by the action of sulphuric acid on a high grade natural calcium phosphate, the final product consisting mainly of a mixture of monocalcium phosphate (soluble in water) and gypsum. In this process approximately equal weights of acid and rock are mixed together and nothing removed by washing so that the resultant superphosphate contains a percentage of phosphoric oxide just half of that in the original rock. For this reason, if for no other, it is necessary to have a high grade raw material, the lowest limit to produce a saleable "super" being about 25 per cent. phosphoric oxide. Superphosphate can only be made from a lime phosphate material, and not from an iron or aluminium phosphate. Small proportions of the oxides of iron and aluminium up to 2 or 3 per cent. do not appreciably affect the value of a rock phosphate but above that point they decrease its value for the making of superphosphate since the manufactured product is found to develop with lapse of time insoluble phosphates of these metals. A little calcium

* *i.e.* Soluble in saline solutions.

carbonate in the rock is advantageous as it renders the final product drier and more granular, but beyond 10 per cent. is a decided disadvantage as it consumes a large proportion of acid which would otherwise be usefully employed in converting insoluble into soluble phosphate. Other metallic compounds readily attacked by sulphuric acid, such as magnesium carbonate, clay, etc., are objectionable constituents of rock for the same reason. Except that it lowers the general grade of the fertilisers, insoluble matter such as sand is no drawback to the crude rock.

Pure tricalcic phosphate when treated with the requisite amount of chamber acid will yield a superphosphate carrying 25 per cent. of phosphoric oxide. A good commercial superphosphate will contain from 15 to 20 per cent. of phosphoric oxide, necessitating 30 to 40 per cent. in the crude rock employed.

It is evident from what has been stated above that much crude phosphatic material is unsuited for conversion into superphosphate. Such material is utilised in one of three ways:—

(1.) Very fine grinding is resorted to, and the crushed material used as a fertiliser without further treatment.

(2.) Iron ores containing appreciable amounts of phosphorus are smelted to form a pig iron rich in phosphorus, which in the process of conversion into steel yields Thomas's phosphate slag, which only needs fine grinding to be available for fertilising. Deposits of iron and aluminium phosphates or of low-grade calcium phosphates could be utilised in this way by smelting with iron ores.

(3.) Similar crude material and phosphatic byeproducts from other industries have in Europe been utilised by dissolving in acid and forming "Precipitated phosphate" by the addition of black ash from the alkali furnaces.

THE COMMERCIAL ASPECT OF PHOSPHATES AND SUPERS.

(Being an extract from a pamphlet published by Dr. Charles Chewings).

The thickness or depth of strata, its horizontal extension, accessibility, and conveniences for winning the rock, taken together with the percentage of tricalcic phosphate it carries (not less than 50 per cent. to 60 per cent.), and its freedom from an excess of the oxides of iron and aluminium, taken together are the points to be considered in determining the value of a phosphate rock deposit. The usual method of testing the value is to put bore-holes down over the area 100 feet apart, and if the results warrant it to then sink pits 10ft. by 5ft. at intervals 500 feet apart. Fifteen feet is the greatest depth boreholes are sunk on South Carolina, when, if no phosphate is encountered, other localities are tested. The value of a phosphate rock depends very largely on its suitability for making superphosphates therefrom. In the manufacture of superphosphates the phosphate is first ground to a fine powder; then mixed with sulphuric acid. The acid dissolves the phosphate, and two parts of the lime (which are combined with the phosphoric acid in the tricalcic form) are first set free and then combine with the sulphuric acid, making a hydrous and water-soluble phosphate, called a superphosphate, and a sulphate of lime, or gypsum. The reaction may be shown thus:—

Tricalcic phosphate. Sulphuric acid. Gypsum.

$$3CaO, P_2O_5 + 2(H_2O, SO_3) = 2(CaO, SO_3) +$$

Monocalcic phosphate.

$$CaO, 2H_2O, P_2O_5$$

There is also what is known as a "dicalcic" or "reverted" form that is insoluble in water, but readily soluble in ammonium citrate, as well as "available" to the roots of plants ($2CaO, H_2O, P_2O_5$). There is a tendency in nature for the monocalcic form to revert to the dicalcic form, and again for the dicalcic to revert to the tricalcic. It is said that when a superphosphate contains too much iron and alumina the tendency to revert is much accentuated, and for this reason they are regarded as deleterious ingredients.

The sulphuric acid molecules' action on the constituent molecules in an ordinary phosphate rock is clearly shown in the following equations, given by Wyatt:—

Tricalcic phosphate $Ca_3P_2O_8 + 2H_2SO_4 = 2Ca\,SO_4 + Ca\,H_4P_2O_8$.

Calcium carbonate $CaCO_3 + H_2SO_4 = CaSO_4 + CO_2 + H_2O$.

Aluminium phosphate $(Al\,PO_4)_2 + 3H_2SO_4 = Al_2\,(SO_4)_3 + (H_3PO_4)_2$.

Phosphate of iron $(Fe\,PO_4)_2 + 3H_2SO_4 = Fe_2\,(SO_4)_3 + (H_3PO_4)_2$.

Magnesium carbonate $Mg\,CO_3 + H_2SO_4 = Mg\,SO_4 + CO_2 + H_2O$.

Fluoride of calcium $Ca\,F_2 + H_2SO_4 = Ca\,SO_4 + 2HF$.

In the preparation of superphosphate the percentage of phosphoric acid per ton of rock is reduced, roughly, by one-half, but the tonnage in superphosphate therefrom is about doubled by the sulphuric acid, water, etc., that is added in the making.

Superphosphates made from rock phosphate that carries a large quantity of iron and alumina have a tendency to revert, or become insoluble again; therefore the unit percentage of tricalcic phosphate is worth less in rock containing a good deal of these than rock containing only a little. Calcium fluoride in excess also reduces the value of a rock phosphate as it uses up too much acid; it forms sulphate of lime (gypsum) and adds weight, to the detriment of the superphosphate. Siliceous matter is a useless, harmless ingredient, adding unnecessary weight.

Phosphates carrying too much carbonate of lime are not good for making superphosphates, as they absorb too much acid. Some water must be added to form gypsum in the preparation of superphosphate. Some phosphates carry too little carbonate of lime. Tricalcic phosphate contains 45.81 parts by weight of phosphoric acid, and 54.19 of calcic oxide. Iron, alumina, and magnesia may partially replace the lime in the raw rock, but the phosphate is always deteriorated thereby, particularly when iron and alumina are the replacing constituents. Wyatt states that next to insufficiency of phosphoric acid itself, a lack of *carbonate* of lime (not lime) is the most serious defect in a phosphate. The defect is augmented in the presence of iron and alumina in any form. By blending, the happy quantity of carbonate of lime can often be effected. Finely-powdered chalk will do, or any other source of cheap carbonate of lime. This method of drying (viz., by adding lime) is to be preferred to any roasting process: how could it (says Wyatt) when we know that the monocalcic or water-

soluble phosphate of lime cannot exist in any other form than the hydrated state? Iron and alumina are not so obstructive if carbonate of lime is present in proper quantity. Calcining the rock before treating is harmful. Free lime retards the drying action, and, of course, calcium produces free lime by driving off the carbonic acid (treating carbonates with acids also releases the carbon dioxide); hence it follows that a phosphate rock from which super. is to be made should be completely chemically analysed, and not only the percentage of tricalcic phosphate and of iron and alumina determined. Phosphates from different localities are often mixed to get a good rock for high-grade super. Finest grinding of the material is absolutely essential.

The factor for converting phosphoric anhydride (P_2O_5) into phosphate of lime is 2.18; consequently $2.26 \times 2.18 = 4.92$ phosphate of lime.

For traders the following form may be found useful in buying:—"The unit per ton of $Ca_3P_2O_8$ not to be less than ( ) and contain not more than ( ) per cent. of Fe and Al, calculated as oxides, on the dry basis. Every unit of these oxides, singly or combined, in excess of maximum shall be deemed to neutralise two units of the phosphate of lime, and such excess shall, therefore, be deducted from the total phosphate of lime if found in the results of chemical analysis."

In commerce phosphoric anhydride (P_2O_5) is misleadingly referred to as phosphoric acid. Laboratory tests show that the phosphoric acid in bone, while insoluble in water, may be partly dissolved at a certain temperature by a neutral solution of ammonium citrate. This medium is used to determine what is called "available" in other phosphatic products. The rate of solubility in this medium is measured by the method of preparation of the bone and its fineness, the phosphate in a raw bone-meal of the same fineness showing rather a lower rate of solubility than the phosphates in steamed bone. The phosphate in finest steamed bone is much more soluble than that of the coarser grades. This measure of the rate of solubility of bone, while not, perhaps, showing the exact rate at which the plants may obtain it, is a fairly safe guide in its use for most crops, as compared with those mineral phosphates which are not perceptibly soluble in this medium. The range of solubility in different kinds and grades of bone is from 20 per cent. to 75 per cent., and the average of a large number show that about 30 per cent. is soluble in citrate of ammonia, which would be called "available" if found in mixed fertilisers, and probably can be as safely depended upon as the "available" shown in other products.

Soluble Superphosphate means the percentage of tricalcic phosphate which has been dissolved, and *not* the percentage of monocalcic phosphate. In analysis terms: monocalcic phosphate of 17.3 per cent. is equal to tricalcic phosphate rendered "soluble," 27.2 per cent.; this means that it would require 27.2 per cent. tricalcic phosphate to furnish 17.3 per cent. of soluble phosphate. The former is called "soluble phosphate," and such a super. as the above would be described as containing 27.2 per cent. of soluble phosphate. In commercial transactions in mineral phosphates the "total available" only is regarded, the contents of insoluble being ignored.

Marketable superphosphate usually contains from 32 per cent. to 35 per cent. of bone phosphate, which contains some 17 per cent. of phosphoric acid, the phosphoric acid being in an "available" form. Bone ash superphosphates contain on the average about 16 per cent. of total available phosphoric acid. South Carolina rock superphosphates contain 12 to 14 per cent. of total available, of which 1 per cent. to 3 per cent. is dicalcic or reverted. The sum of the soluble and reverted forms is called the "total available."

Florida superphosphates, from the pebble rock, often contain 16 per cent. or 17 per cent. of total available, with varying percentages of reverted and insoluble.

Tennessee superphosphates run up to 16 per cent. to 18 per cent. of "total available" and the concentrated or "double superphosphates" may contain as high as 45 per cent. of "available," practically all of which is soluble. It will thus be seen that bone phosphate (raw) of 60 per cent. and upwards will, when treated, produce a superphosphate containing a 30 per cent. and upwards bone phosphate, the half of which should be soluble in water, and the other half in ammonium citrate. The phosphoric acid contents of a 60 per cent. (or any other percentage) raw rock may be ascertained by multiplying the 60 per cent. by 46 per cent., that being the proportion of phosphoric acid in bone phosphate.

The phosphates mentioned above, with the exception of Thomas's phosphate, constitute what are known as "raw materials." As a rule they are not used directly on the land, but are first subjected to chemical treatment to render the phosphoric acid constituent more soluble and assimilable by the plant. In the raw state, even if ground very fine, the bone phosphate is insoluble in water, and the phosphoric acid is not so readily available to the plant as when "treated," on account of the slow rate of decay of the raw material. The finer the grinding of course the more rapid the decay, and this is the method adopted with phosphates that do not lend themselves readily to the manufacture of superphosphates, *e.g.,* when they have an excess of impurities such as alumina or iron, or the percentage of phosphoric acid is too low. Natural bones contain on an average about 20 per cent. of phosphoric acid (if good), which is equivalent to 43.60 per cent. of bone phosphate, but in certain cases 60 per cent. Ground bones are more readily attacked by the natural solvents—air, water, and solvent substances in the soil—than the mineral phosphates, but if the bones are "treated" the phosphoric acid contents become immediately available.

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Early in June I proceeded to the Phillips River Goldfield to conduct a Geological Survey of the Ravensthorpe, Mt. Desmond, and Kundip mining centres, which were mapped in and the mines examined. A full report upon this, accompanied by a Geologically-coloured and Contour map will appear shortly as Bulletin No. 35, which is now in the printer's hands.

I also visited Wagin to examine some workings for gold upon private property, but since the assays of the samples taken did not prove the existence of that metal, no report was prepared. Owing to the absence of the Government Geologist my time has been very largely occupied upon official matters, and therefore only 101 days have been spent in the field during the year.

W. D. CAMPBELL, Assistant Geologist.—In the early portion of the year this officer continued his survey of the Irwin River coal district and the preparation of plans, sections, and Part I. of the report; an interim report, with photographs of the glacial beds met with there, was also prepared in advance of the main report.

In May he proceeded to Derby with Mr. Surveyor Ellis and inspected and reported upon the Yampi Iron Ore deposits, Mr. Hadley's mission cutter being engaged specially for that purpose. The report submitted on his return is as follows:—

Yampi Sound Iron Ore Deposits.

"The locality at Yampi Sound where leases Nos. 128 to 132 have been taken up on iron ore deposits is an island known to the aboriginals in the neighbourhood as Koolan. On the south side there is a navigable passage from three-quarters to one-eighth of a mile wide, the narrow part being at the eastern end. The island is about eight miles long and one mile wide, and has a series of mountainous ridges in the direction of its greatest length, composed of highly inclined metamorphic rocks consisting chiefly of sandstones, quartzites, and schists; these have been upturned and their denuded edges have a strike of about 118 degrees and underlay about 50 degrees southerly. The iron lodes appear to be interbedded with these rocks, and their outcrops are very conspicuous along the high ridge skirting the south side of the island and other ridges near the north side. The ore has not become hydrous but retains a black metallic lustre, characteristic of magnetite, but does not uniformly exhibit magnetic properties.

The ore appears to have been first discovered here in the early pearling times, probably about thirty years ago, but it was re-investigated last year by Mr. Percy Kean of the Australian Prospecting Association of Charters Towers, Queensland, which company supplies the Mount Morgan Gold Mines with iron ore for flux purposes. Mr. Kean has now taken up leases with the idea of exporting the ore.

At the west end of the westernmost lease, No. 130, the lode forms the south slope of the ridge from its summit about 350 feet in altitude to its base at the water's edge. Easterly from here a quartzite ridge intervenes between it and the water, but the outcrop is exposed all along the side of the ridge in this direction and for 200 feet in altitude on its side. This lode outcrops more or less continuously through the one and a half miles intervening between leases Nos. 131 and 132, where the general character of occurrence is similar to No. 130.

Eastward of lease 132 there is a break in the country, the position of the ferruginous outcrop as it reappears several chains distant being more to the southward, where it occurs in two or more beds which underlay to the northward at about 40 degrees, as do also the accompanying strata, but the lay of the quartzite ridge remains unaltered. The explanation of this may be that there is a fold of the strata, leases Nos. 128 and 129 occupying the upper part of the fold.

In the three western leases the lode appears to vary from four to fifty feet in width, whilst in places another smaller one can be seen about fifty feet distant on the north side. The ore in the main lode has numerous cross jointing, dipping 66 degrees to the westward; this will have to be taken advantage of in quarrying, for its hardness and toughness preclude promiscuous drilling.

In the lode body there are occasional bars and patches of vesicular iron ore, whilst sheets of this material appear to also accompany it in places. Towards the foot of the cliff in the westerly leases there are grey micaceous slates, and on the opposite side of the shallow bay there are siliceous and ochreous beds.

All across the island there is a succession of sandstone beds underlying southerly. About three-quarters of a mile north of lease No. 131 there is a small steep-sided bay, near which a line of iron ore outcrops; it must be about forty feet thick and separates easterly into two divergent beds which follow a nearly parallel course about twenty chains apart; the northernmost continues for a distance of nearly a mile but the southern one extends considerably farther; both underlay south and appear to range from five to twenty-five feet in width. I would suggest the desirability of reserving these ore beds on the northern side of the island, temporarily at least, and so preserve it from export.

About half a mile from the eastern extremity of the island there are several rocky islands which appear to consist principally of iron ore, but they were not inspected. Cockatoo Island, about two miles west of the opposite end of the island, appears to have a similar southerly underlay to that of Koolan, whilst there are also some smaller outlying islands of a dark brown colour, which may denote the presence of iron ore.

Most of the iron lodes lie so conformably with the strata that they have the appearance of being contemporaneous with them, but this theory is not supported by the divergent ones on the north side of the island, which possess the general characteristics of fissure veins. The lodes generally appear to closely resemble the celebrated magnetite beds of Lapland and Sweden. The siliceous strata overlying the ore exhibit, in places, a ripple-marked surface and also irregular markings which may have been formed by shrinkage cracks or may possibly even be fossilized organic remains. [8424.]

Pools of good water were found in holes in the iron ore at the top of the cliff in M.L. 128 and upon the lode at the head of the south arm of the above-mentioned cove, at the north side of the island; a spring also was reported by one of the aboriginals accompanying our party, situated in the mangroves in the creek bed west of M.L. 132, near which tracks and camping places of aboriginals were noticed.

The accompanying sketch shows the position of the iron ore deposits in the portions of Koolan Island that were visited, and a list is appended of the mineral specimens obtained here.

On the journey out from and the return to Derby, Sunday, Mermaid, and Long Islands were touched at, the rock being found to consist for the most part of gneissic granite. Whilst at Sunday Island I was shown specimens of tourmaline said to have been found there. Near Water Point at the south side of Yampi Sound there is a dark-coloured schistose rock containing clear particles of quartz. There is every indication that the last terrestrial movement in this district was one of subsidence, which theory is supported by the great scarcity of sandy beaches and the numerous coral

reefs. The channels separating the islands are often over 200 feet deep.

List of Mineral Specimens.

Reg. No.	Description.
8424	Koolan Island, Yampi Sound, South side of M.L. 130, quartzite showing ripple marks.
8425	Do. Quartzite showing markings (organic remains (?)).
8426	Do. Conglomerate composed principally of iron ore.
8427	Do. Iron ore.
8428	Do. Iron ore showing iridescence.
8429	Do. Magnetic iron ore from South side of M.L. 132.
8430	Do. From South side of M.L. 132, sandstone, underlaying iron ore on the North side.
8431	Do. South side of M.L. 129, vesicular iron ore.
8432	Do. Sandstone accompanying iron ore.
8433	Do. Conglomerate.
8434	Do. South side of M.L. 129 at sea level, micaceous schist.
8435	Do. South side of arm of bay, opposite M.L. 128, shaley sandstone,
8436	Do. Ochreous bed.
8437	Do. Sandstone, ½ mile North of M.L. 130.
8438	Do. ¾ mile North of M.L. 131, iron ore.
8440	Sunday Island, North side, gneiss.
8441	Yampi Sound, one mile South of Water Point, dark schistose rock.
8442	Do. One mile South of Water Point, quartz reef in dark schist.

On returning to Derby he proceeded, as soon as pack-horses were available, to the Federal Downs where wolfram had been found, of which he brought some bulk samples to head office, and prepared the following report:—

Wolfram Find near Federal Downs Station, West Kimberley.

"In accordance with instructions I proceeded after my return from Yampi Sound, as soon as horses and equipment were available, to the Wolfram Find with an aboriginal guide. The locality is about 70 miles north-easterly from Derby. At Mount Marmion a day was occupied collecting fossils from a calcareous zone at the base of the hill in the Upper Carboniferous beds; these fossils together with some samples of the limestone bands, which appear likely to afford good cement-making material, will be despatched by dray later on to Perth. The deep bore at the 67-mile on the Derby to Lennard Road was then visited and reported on, and the journey to the wolfram was resumed. The precipitous limestone range which forms the north boundary of the clay and sandstone plain was passed through by the valley at the head of the watercourse which passes near the Hawkstone Peak, when diorite and garnetiferous micaceous and chlorite schist hills appear. These schists contain numerous quartz veins which trend mostly in the direction of their foliation about 275 degrees and dip 80 degrees southerly. The hills are mostly steep, and in one of these about 350 feet high, comprising M.L. 146, the wolfram occurs crystallised out in the quartz veins which range from 3 to 15 inches wide, the wolfram crystals projecting from the side of the vein into the quartz matrix. The ridge of the hill is about a quarter of a mile long in the direction of the quartz veins. The principal patch of wolfram ore is towards the west end of the hill and on the south side.

"Samples were taken from various parts as well as bulk specimens totalling 163lbs. A sample of wolfram and quartz from here was submitted by Mr. J. F. Taylor, the lessee, and the laboratory report dated 9th October, 1907, stated that there was 68.5 per cent. of tungstic oxide.

The show of wolfram is fair and it may be found that the various veins unite at depth. No developmental work however had been done but tools were brought on the ground while I was there by Mr. Armitage, who is Mr. Taylor's representative. The approach to the lease is along the valley-flat right up to the outcrop.

An assay for gold also has been made in the Laboratory and the report states that 'none was found, but some specimens of a green mineral which proves on examination to be scorodite (arsenate of iron). It doubtless results from the weathering of arsenical pyrites, which mineral will probably be found below water level in the wolfram lode.'

"I then proceeded westerly to Mondooma, passing along the same belt of likely mineral country to near Trig. L2 where some promising schistose and pegmatite rock occurs, the latter containing tourmaline, staurolite, and kyanite, the last named being a translucent pale blue mineral which when clear and of good colour is cut as a gem and it is therefore well worth further attention.

"To the westward of Mondooma, the schists with quartz reefs re-appear for about 3 miles; beyond this is an extensive plain with a few scattered granite hills, until the white quartzite mountainous Wyndham Range is approached near Obagooma. This white quartzite is similar to that occurring at Yampi Pass.

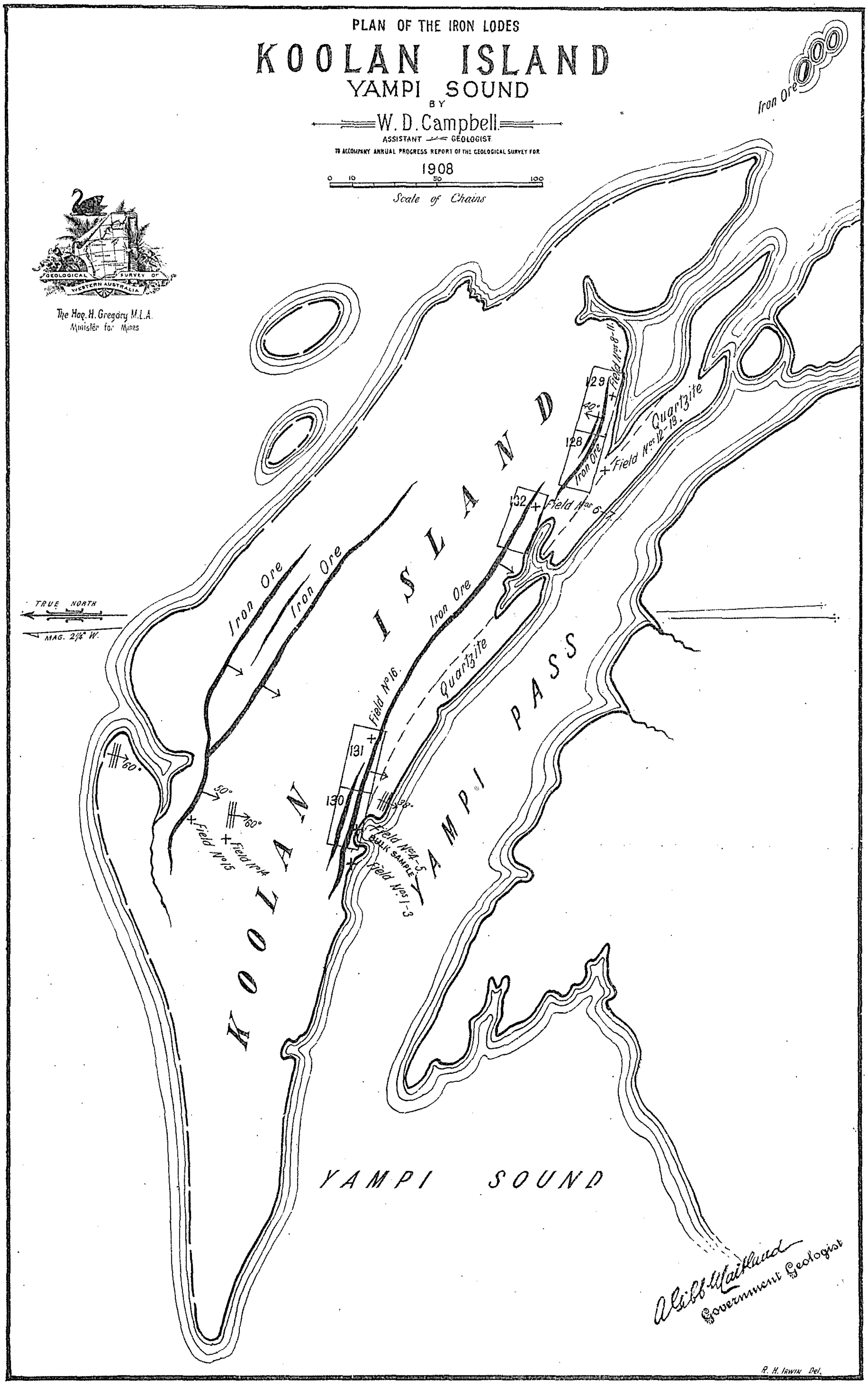
"Several bores have been put down by the pastoralists to depths of 150 feet and more, on the line of springs that occur on the flat plain 10 to 18 miles south from Obagooma, and a copious flow of good artesian water has been obtained."

He next was occupied with preliminary work in connection with re-gauging the Artesian bore discharges, but this was eventually taken over by the Public Works Department, when a progress report was prepared. For facilitating water supply information the boundary of the granite hills was sketched from the Canning River to St. John's Brook south of Donnybrook, a distance of about 120 miles.

Inspections and recommendations were made for mineral reservations on the Oakabella Estate and on proposed mineral resumptions in the Northampton district also on reputed coal measures at Lynton, and reports and inspections on the possibility of artesian water supplies at Cookernup and Capel; also report on coal near Serpentine and on an alleged gold find near Highbury.

Reputed Coal Indications at Lynton, Northampton District.

"I have to report that I visited the Lynton District in company with Mr. J. W. Acton, prospector. I drove out by the Nonga Road and Chearry Well (The Gardens) and saw the square shaft sunk many years ago by Mr. Gregory. It is about the centre of Loc. 2395 and is in friable sandstone with thin ironstone beds. The shaft is nearly filled in now and the dump showed no indications of any other material, but coal is said to have been found in it. I consider the report to be manifestly absurd.



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

"Mr. Acton then showed me the site where he wished to make a trial boring at the junction of the Whitewater and Hutt Rivers at the crossing of the track from Lynton, opposite the north end of Loc. 1500. There are here massive beds of ferruginous sandstone, which dip to the west about 2 degrees, and these are overlaid by coastal limestone a few chains westerly. I could not find any fossil remains in the beds and the only specimens that Mr. Acton had found proved to be only circular ferruginous concretions. The strata are evidently of Jurassic age and are not likely to contain coal beds."

Cookernup Water Supply.

"I have to report that I visited Cookernup and saw Mr. A. L. Cunnold, the Secretary of the Farmers' Association, who showed me the site suggested by the Association for the test bore; it is on the west side of the Railway adjoining the railway crossing and is Crown land. Mr. Cunnold said that the Association have applied to have this block made a camping reserve for the convenience of settlers out west, so that if any water was struck it would be of public benefit as that obtained by wells is not good, and he represented that if artesian water was obtained at a reasonable depth it would encourage the settlers generally to put down bores. The site is marked on the accompanying litho of the townsite.

"The nearest indication of gneissic rock is one and a quarter miles easterly from the site, and it is probably about 30 feet higher, a steady rise occurring eastward of the township boundary. The strata hereabouts consist of a very stiff clay with ferruginous seams or patches. The probabilities of obtaining artesian water are fair and a supply would be of considerable value to the district. I can therefore commend the proposal."

Capel Water Supply.

"I have to report that I visited Capel and inspected the geological conditions of the site of the proposed bore and also of the locality generally. The site suggested is on the edge of the coastal limestone (8580) and the nearest granite occurs about seventeen miles easterly. The intervening country is flattish for six miles and is composed of clays and argillaceous sandstone, there are then hills of sandstone and clay, capped extensively with ironstone gravel and laterite.

"Basalt has been found to occur in the bed of the Capel River at Boronia Bridge, six miles south-easterly from Capel (8579). There appear to be several reported outcrops of this rock, viz., at Blackwood River, two miles from St. John's Brook and at Black Point on the South Coast; these are all approximately in a due south direction from Bunbury where the basalt can be seen on the sea-coast. There does not however appear to be any probability of this rock occurring at Capel.

The conditions appear to be favourable for obtaining an artesian supply of water here.

In regard to the position of the site, I do not think that there would be any objection as far as the probable flow is concerned if a higher site was chosen, as this one would be only a few feet above the bed of the river."

Proposed Boring for Artesian Water and Coal at Serpentine.

"I have visited the blocks of land numbered 468/72 at Serpentine, referred to by Mr. C. J. R. Le Mesurier in his letter of the 5th August. They are situated three miles south of the Railway Station between the Perth-Bunbury road and the railway line. The foot of the Darling Range is here a quarter of a mile east of the road; this is the boundary of the gneiss rock.

"The ground is flattish and is formed of clayey and sandy strata, with a covering of ironstone gravel and laterite in places. The north end of the blocks is watered by the Two-mile Brook and the south end by the Three-mile Brook, which however do not run throughout the year. There are shallow wells in the neighbourhood having subsoil soakage. I could not hear of any well near that had been sunk to 100 feet, but I have found since that it is situated about three miles to the south.

"The specimens submitted to the Department consist of:—

(*a*) a ferruginous clayey conglomerate,
(*b*) friable grey sandstone, and
(*c*) loose particles from a bed at the bottom of the well.

"These contain a few fragments of lignite about the size of a pin's head and a few larger particles of a ferruginous cement.

"Since returning to Perth, Mr. Le Mesurier has called on me and stated that he has given up the idea of boring here and that he has applied more recently for a prospecting area on Crown lands, two miles south of Keysbrook or four miles further south than the former place.

"I consider both sites to be too near the range for successful sinking for artesian water and the strata to be too porous for the existence of coal seams."

Reported Gold Find near Highbury, Narrogin.

"In accordance with instructions I visited the site of the reported find of gold, five miles south of Highbury, which is on Loc. 5592 belonging to Mr. George Syme and is marked on Lands Department litho, 385/40D, and specimens showing gold are said to have been picked up on the ploughed field but no reef has been found. Two trenches have been made in the direction of 21 degrees (magnetic) about two chains apart; the western one is about 5 chains long and about 1 foot deep with several deeper parts, in decomposed granite sand and ironstone gravel. The eastern one is 2 chains long and about 3 feet deep with a cross trench about 15 feet long; there are here a few blocks of pegmatite apparently from a vein about 9 inches thick. Granite outcrops a few chains to the south, the joints trending 256 degrees. I did not see any auriferous quartz.

"I saw Mr. George Syme on my way back who said he had no specimens as they had all been given away but that he intended to resume prospecting in about 2 months. Police Constable Crowe had a small sample said to have been found here which is a ferruginous quartz showing gold. Although it is not impossible for the samples to have been found in this locality, I can only say that I did not see any similar quartz there.

"I also visited Loc. 2456 about 1½ miles to the north of Syme's, where there is a large white quartz reef about 20 feet wide trending in the direction of 251 degrees, which is about the same as the jointing of the granite, and underlaying about 45 degrees to the east. A sample has been assayed in the Laboratory (L. 1733) but no gold was found."

During the year Mr. Campbell was engaged for 180 days in the field.

C. G. GIBSON, Assistant Geologist.—The following is a summary of the work performed by this officer during the year:—

During January he was at the Head Office employed upon his Bonnievale Report* whilst in the early part of February he revisited the Youanme district with the object of obtaining further information. He returned about the middle of the month and from that time onwards until April 6th he was engaged in the preparation of his report upon Berrigrin and the Black Range District.*

He then proceeded to the Murchison Goldfield making an examination of Errolls, Barrambie, and Gum Creek upon his way to Wiluna in the East Murchison Goldfield,† from which District he returned upon June 23rd, and from that date was engaged upon his report until August 24th when he started for Kanowna in order to examine the country passed over by the Trans-Continental Railway Survey, from which expedition he returned upon December 4th.

During the year Mr. Gibson has been 192 days in the field.

H. W. B. TALBOT, Topographical Surveyor.—This officer returned to Perth from Ravensthorpe, where he had been carrying out a topographical survey, upon January 20th, leaving again on February 17th for Collie with the object of surveying the supposed new coal field which work occupied him until the 23rd, but he returned again with me upon March 4th for two days.

Upon March 30th he left Perth for Ravensthorpe in order to assist me in the preparation of the Geological Map of the district, which work occupied him until June 29th.

After completing the necessary plan drawing he took his annual leave and then started for Wiluna upon August 25th in order to accompany the Canning Expedition in the capacity of geologist, upon which work he is still engaged.

During the year Mr. Talbot has been engaged for 248 days in the field.

L. GLAUERT, Palæontologist.—This officer was temporarily engaged upon July 1st to assist in the arrangement of the Museum, upon which work he was employed until October 1st. During October and a portion of November he was engaged upon the examination of a series of rock specimens collected by myself upon the Phillips River Goldfield, the result of which work is now incorporated with the report by Mr. Simpson, which will be issued as an appendix to Bulletin No. 35.

During the remainder of the year he has devoted his time to the identification, classification, and description of a large series of fossils collected by Mr. Campbell upon the Irwin River Coalfield, which work will be published in a special Palæontological Bulletin now in course of preparation.

THE GEOLOGICAL LABORATORY.

Mr. E. S. Simpson, Mineralogist and Assayer, who controls the laboratory operations, has handed me the following report upon the work carried out under his direction during the year:—

"I have the honour to submit the following report upon the work carried out under my supervision during the year 1908:—

"The accompanying table, prepared upon the same lines as those appearing in the previous annual reports, shows that the routine work of the laboratory is still on the increase. This is especially noticeable in the work done for other Government Departments, principally for the State Batteries Branch. In consequence of the large amount of time taken up by this work it has been found impossible to devote as much attention as is desirable to the detailed examination of the material comprised in the Geological collection with regard to which authoritative information is continually in request both at home and abroad. Such information serves not only to advertise the mineral resources of the State to persons likely to enter upon local industries and enterprises, but is of the greatest assistance to the mining community already settled in the State. In order to free senior professional officers from much clerical and other work incompatible with the salaries paid to them, and in order to facilitate their investigations, it is highly desirable that a cadet and junior clerk should be attached to the staff, and another room added to the laboratory for research work.

In spite of constant interruptions a considerable advance has been made with an investigation into the composition and properties of the coal from the various seams worked at the Collie. This will have a bearing upon the relative liability to spontaneous combustion, relative keeping qualities, etc.

"A beginning has been made with a re-examination of all the bore-waters of the State. This will help to decide whether they become better or worse after long flowing and what is the ultimate source of the water.

"During the earlier portion of the year I still continued to act as a member of the Local Franco-British Exhibition Board and as such, in conjunction with Messrs. King, Maughan, and Göczel completed the collection, cataloguing, and despatching of the mineral exhibit shown by the State. This has won several prizes at the Exhibition, including a Grand Prix, and has been described in eulogistic terms by the scientific and general Press. Every effort will, I trust, be taken to preserve the greater portion of this collection intact, in order that it may be used on future occasions as an advertisment of the mining industry and resources of the State.

"During the year the Executive Council decided that the mineral collections of the Perth Museum and of the Geological Survey should be amalgamated and placed under the control of the Government Geologist. To me was allotted the task of taking over the Museum collection and preparing a combined exhibit in the Mineral Gallery. After three months of almost constant work with the assistance of Messrs. Glauert and Jackson, the greater portion of Western Australian specimens in the Museum have been gone through, weeded out, and all those of value catalogued and incorporated with the Geological Survey collection. They can now be seen in the Mineral Gallery of the Museum, where they constitute a very valuable and instructive exhibit."

From this report it will be seen that although nominally the laboratory of this Department, the great bulk of the work performed is for others and the general public. This is due to the fact that, firstly, all the referee work of the Battery Department is carried out in our laboratory, and secondly, the liberal manner in which this Department treats the prospector, by making free assays and determinations. The demand for these two have now attained such considerable proportions that the limited staff are quite unable to cope with it, and in consequence a large amount of departmental work of a research character has to be

* Bulletin No. 31. † Bulletin No. 34.

left undone since Mr. Simpson finds it impossible to personally undertake it. The time has therefore arrived when it has become imperative that the services of a highly qualified chemist should be secured who could devote the whole of his time to the requirements of this Department under the supervision of Mr. Simpson. Such an addition would not in reality be an increase of our staff since in the initial stages we had the undivided services of Mr. Simpson who with his one assistant were able to devote practically their entire time to such chemical investigations as were required by the Department, whilst at the present both he himself and his four assistants are fully occupied upon outside work.

The Batteries Department is even in a better position than we are, for by agreement they pay one assistant who devotes his entire time to their work which has now assumed such considerable proportions that he is unable to manage it single-handed, for although the total number of assays is given as 1,094, since these are check or umpire samples they have to be done in either duplicate or triplicate, which is really raising the total number of assays made to something like 2,000.

MISCELLANEOUS MINERAL NOTES.

Several interesting minerals have been noted during the year.

Olivenite (basic arsenate of copper), in fibrous veins and in earthy crusts and masses in oxidised ore from Alice Mary Copper Mine, Kundip.

Erythrite (hydrous arsenate of cobalt), in crystals covering faces of cracks in ore from Cave Hill G.M., Waverley; Alice Mary C.M., Kundip; and Carlow Castle C.M., Roebourne.

Native Sulphur.—A soft yellowish sandstone from Dongara possessing a very sulphurous smell was found to contain:—

Sulphur, free .. .. 14.24 per cent.
Sulphur as gypsum .. 0.39 per cent.

Vermiculite, Bulong.—A rich green foliated mineral, perfectly transparent in moderately thin sheets was found to approximate to Jefferisite in composition and to possess a remarkable capacity for exfoliating when heated.

Scorodite (hydrous arsenate of iron).—Pale green porous masses in surface portion of quartz vein carrying wolfram at Federal Downs Station, West Kimberley.

Allanite (silicate iron aluminium calcium and cerium metals).—Black isotropic masses in pegmatite from Fraser's Range.

Fergusonite (tantalate and niobate of yttrium, cerium, and uranium), and *Euxenite* (tantalate, niobate and titanate of yttrium, cerium, and uranium).—Angular fragments from alluvial material at Cooglegong. These minerals have been described in detail in a paper presented to the Australian Association for the Advancement of Science.

Talc (hydrated silicate of magnesium).—A deposit of this mineral has been opened up at Mt. Taylor. It is of excellent quality, well suited for the production of talc powder for all industrial uses."

Table showing Routine Work of the Geological Survey Laboratory during 1908.

	Public.		Official.			Total.
	Pay.	Free.	Geological Survey.	Batteries.	Other Departments.	
Total samples dealt with	97	364	302	1,076	330	2,169
Assays for gold	72	148	55	1,076	213	1,564
Assays for silver	6	50	8	13	22	99
Assays for copper	11	45	9	1	6	72
Assays for tin	4	21	6	...	9	40
Assays for lead	...	15	2	...	7	24
Assays for iron	...	2	1	...	...	3
Assays for nickel	...	2	...	...	...	2
Assays for cobalt	...	3	...	...	...	3
Assays for aluminium	...	2	...	...	...	2
Assays for manganese	...	2	...	...	...	2
Assays for chromium	...	1	...	...	...	1
Assays for thorium	...	1	...	...	1	2
Assays for tantalum	...	...	6	...	1	7
Assays for bismuth	...	1	...	...	1	2
Assays for lime	1	...	...	...	...	1
Assays for phosphoric oxide	...	37	7	...	8	52
Assays for sulphur	...	1	1	...	...	2
Analyses complete	1	4	40	...	5	50
Analyses proximate	5	2	5	...	1	13
Analyses partial	1	2	3	...	2	8
Determination of rocks and minerals	5	188	170	...	82	445
Petrographical descriptions	...	...	49	...	...	49
Calorific valuations	13	2	5	...	...	20
Valuations of gold specimens	...	2	1	...	12	15
Miscellaneous	1	6	3	4	12	26
	120	537	371	1,094	382	2,504

THE GEOLOGICAL MUSEUM.

Prior to 1908 two independent State Geological Collections had been on exhibition in Perth, the one in the Museum and Art Gallery, which included the specimens gathered by the previous Government Geologists, and the other in that portion of the same building occupied by the Geological Survey Department.

This duplication entailed extra expense and was not of so great a value for educational and mining purposes as a united collection would be, therefore the Executive Council decided early in the year to combine these two as a National Geological Collection to be housed in the Museum and Art Gallery, under the arrangement and custody of the Government Geologist. Upon the completion of the New Art Gallery therefore the collection in the Museum was transferred to this Department, the old back gallery being placed at our disposal for its arrangement and exhibition, whilst our collection was removed from the room above our offices, the latter being handed over to the Museum Authorities for a Water Colour Gallery and Lecture Theatre.

The two collections were then incorporated and arranged under the supervision and direction of Mr. Simpson, Mineralogist and Assayer to this Department, assisted by Messrs. Glauert and Jackson. The main scheme of arrangement adopted is first a division of the collection into three groups representing specimens belonging to this State, the Commonwealth, and Foreign, then each of these into Minerals, fossils and rocks, whilst the minerals, rocks, etc., of this State are further grouped under the districts from which they were obtained, thus Western Australian gold specimens are shown in the cases starting from the South-east corner of the Gallery, commencing with those from Kimberley followed by those from Pilbara, and so on. These occupy most of the cases upon the eastern side and are followed by the other metallic ores such as lead, copper, tin, iron, etc., which are carried round into the cases at the north-west corner. The next cases upon the west side contain the non-metallic products of this State, after which the balance of the cases on this side are occupied by the Commonwealth and Foreign specimens.

Down the centre of the Gallery is a double line of cases which at the north end contain the fossils, followed by the rock and rock-forming minerals, these being grouped under districts, whilst at the back of each case in an upright frame the geological maps of the district from which they were obtained will be exhibited.

A technical collection is also in the course of preparation but it will be impossible to exhibit this until further accommodation is provided.

At the present time a considerable number of blank spaces will be observed in the show-cases, these have been intentionally left for the specimens at present in London at the Franco-British Exhibition, upon the return of which it will form a very fine collection.

The collection has now assumed the considerable proportions of 9,967 registered specimens (exclusive of the London Exhibit), out of which number 1,290 have so far been taken over from the Museum Authorities and registered. Included in this number are 448 registrations of fossils which, having as yet not been determined, are given one number; therefore when these are worked out the total will be very considerably increased.

The collection also contains 1,004 microscopic rock slides which have been increased to the extent of 160 during the past year.

The combination of the collections has most certainly been a move in the right direction, but of course like all radical changes there are many little issues to be settled before the arrangement can be considered as entirely satisfactory. So far it has been mutually agreed between the Museum Authorities and the Survey that the former keep the Gallery clean and police it whilst the latter relieve the former of the work of arrangement, determination, etc., which occupies pretty well one assistant's time. The point however which has as yet not been settled is out of what vote is the purchase of specimens, etc., to come; if out of the Museum vote a portion of this should be allocated for this purpose and be placed at the disposal of the Government Geologist, whilst upon the other hand if it is to be paid out of this Department's vote an additional sum will have to be set down for that purpose.

GENERAL.

Besides the numerous special reports for various Government Departments, 59 have been written upon applications for the alienation of lands reserved for mining purposes, 8 upon subsidies applied for under the Mining Development Act, and 2 upon Mining upon Private Property.

PUBLICATIONS.

During the year the following official publications have been issued:—

Annual Progress Report for the year 1907.

Bulletin No. 31. Part 1: The Bonnievale and Kunanalling Districts, Coolgardie Goldfield; and Part 2: The Black Range District, East Murchison Goldfield.

Bulletin No. 32. Notes on the Geology of the Greenbushes Tinfield, with special reference to the Deep Leads; a Report upon the Mt. Malcolm Copper Mine, Eulaminna, Mt. Margaret Goldfield; and a Report upon Fraser's Gold Mine, Southern Cross.

Bulletin No. 34. Report upon the Auriferous Deposits situated at Barrambie and Errolls (Cue District) and Gum Creek (Nannine District), Murchison Goldfield, and Wiluna, East Murchison Goldfield.

Whilst :—

Bulletin No. 35. Geological Report upon the Gold and Copper Deposits of the Phillips River Goldfield

is in the printer's hands, and

Bulletin No. 33. Geological Investigations in parts of the Gascoyne, Ashburton, and West Pilbara Goldfields.

is in course of preparation.

LIBRARY.

The collection in the Geological Survey Library now consists of 3,646 volumes, it having been increased during the year by the addition of 484 donations and 52 purchases.

The donations to the library are mostly from the various Geological Surveys, being accompanied by maps of which a considerable number from all parts of the world are now in the possession of the Department.

PROPOSED PROGRAMME OF FIELD WORK FOR 1909.

A re-survey of the Kalgoorlie Mining District, with a report upon the lodes of the Boulder Belt.

A Geological and Topographical Survey of Kanowna, Niagara, and Kookynie.

The completion of the West Pilbara Goldfield, with reports upon the Whim Creek and other Copper Mines.

An examination of the country between Pilbara, Peak Hill, and Meekatharra, with special reports upon the last two mentioned centres.

A general examination of the Murchison Goldfield including the minor centres not already reported upon.

The completion of the examination of the belt of country between the Irwin River and Northampton.

I have, etc.,
HARRY P. WOODWARD,
Acting Government Geologist.

INDEX.

INDEX—*continued.*

By Authority: Fred. Wm. Simpson, Government Printer, Perth.