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WESTERN AUSTRALIA.

# GEOLOGICAL SURVEY.

## BULLETIN No. 77.

# SOURCES OF INDUSTRIAL POTASH IN WESTERN AUSTRALIA.

BY

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## *WITH TWO APPENDICES.*

1. Examination of Western Australian Seaweeds for Potash and Iodine,

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2. Alunite Deposits at Kanowna,

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# GEOLOGICAL SURVEY OF WESTERN AUSTRALIA.

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# PREFATORY NOTE.

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Prior to war breaking out in 1914 the major portion of the world's potash supplies was derived from Germany.

The demand for potash not diminishing as a natural sequence, supplies have gradually shortened, and to such an extent that at present potash in any quantity is practically unobtainable.

The following report on the sources of industrial potash in Western Australia has been prepared with a twofold object; first, to place before the public such data as may be of use in the development of our local potash-bearing deposits and thus gain supplies for the immediate present, and secondly, if possible, establish the industry to such an extent as to be independent of foreign potash imports for the future.

The present report deals with the subject in all its phases, and embraces descriptions of the uses, manufacture, foreign supplies, and the local occurrences throughout the State as far as they have been examined.

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Geological Survey Office,
Perth, 3rd September, 1918.

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## I. INTRODUCTION.

Potash is one of many mineral products which are absolutely essential to mankind at the present day, its chief use being as a plant food in agriculture, particularly for potatoes, onions, and fruit of all kinds. Such crops left unsupplied with potash for more than one season are liable to be complete failures. In addition potash is used for many industrial purposes, particularly in the manufacture of explosives, as well as of soaps, medicines, photographic supplies, etc.

Prior to the war the world was using about three million tons of potash per annum, and practically the whole of it was coming from Germany. It is very easy to understand how the potash market has been affected by the protraction of hostilities. Local stocks kept agriculturists and manufacturers going fairly well for about 12 months, but immediately thereafter the shortage began to be felt, growing more acute until at present it is almost impossible anywhere outside Germany to obtain as many pounds of potash as previously tons were used. In Australia there is an absolute famine in potash. In the United States crude potassium chloride carrying 50 per cent. potash was quoted at £8 per ton (3s. 3d. per unit) early in 1914. In April, 1918, it was quoted at £70 per ton (28s. per unit). The pre-war rate for crude potash salts in Western Australia was 6s. per unit or £15 per ton for 50 per cent. salt; a very conservative estimate of its present value, if obtainable at all, would be 20s. per unit. This figure has been used as the basis of calculation in the ensuing pages. Turning to fine chemicals, potassium permanganate was less than 1s. per lb. in Perth in 1914. It is now 16s., and in London already 21s. per lb. wholesale.

In view of these facts possible local sources of supply of potash have been under investigation for the past year by the staff of the Geological Survey Laboratory, and the recent discovery in the Laboratory of Alunite (a sulphate of potassium, sodium, and aluminium of unusual value as a source of potash) in clay samples from the Kanowna District is of considerable importance. The United States Government indeed considered the discovery of a 4ft. lode of alunite in Colorado in June, 1918, of sufficient importance to cable out the fact to Australia and elsewhere amongst its official war cables.

The facts concerning the discovery of alunite at Kanowna and northward thereof, of jarosite and alunite at Northampton, and of a 30ft. bed of glauconite at Gingin, as well as the previously ascertained abundance of potash felspar throughout the South-West Division and Eastern Goldfields, are of sufficient interest to warrant their being made known at once to the agricultural and manufacturing communities, and it is to draw their attention to the already established facts concerning local sources of potash that the following pages have been written.

# II. GENERAL SOURCES AND USES OF POTASH.

## 1.—DEFINITIONS.

POTASSIUM, a soft white metal similar in most of its properties to *Sodium,* the latter being the metallic constituent of common salt. Chemical symbols, K for potassium, Na for sodium.

POTASH, oxide of potassium, composed of two atoms of potassium combined with every one atom of oxygen. Chemical symbol, $K_2O$. The term is also employed commercially to signify the hydrate of potassium (caustic potash), KOH; and the carbonate of potassium, $K_2CO_3$.

SODA, oxide of sodium, $Na_2O$. The term is also employed commercially to signify the hydrate (caustic soda), NaOH; and the carbonate, $Na_2CO_3$.

ALKALI, a substance whose solution in water neutralises acids and turns red litmus paper blue. The title is given particularly to the oxides and hydrates of potassium and sodium.

ALKALI METAL, one of the metals potassium or sodium.

SALT, the compound obtained by neutralising an acid by an alkali. *Common salt* is the product obtained by neutralising hydrochloric acid with soda. *Potassium chloride* is the salt obtained by neutralising hydrochloric acid with potash. *Potassium sulphate* is the salt obtained by neutralising sulphuric acid with potash. *Potassium carbonate* is the salt obtained by neutralising carbonic acid with potash.

SOLUBLE POTASH, or WATER-SOLUBLE POTASH, the potash in any fertiliser or mineral which is soluble in water. The whole of the potash in potassium sulphate and kainite is soluble in water. Such water soluble material is immediately utilisable by a plant as food.

ACID-SOLUBLE POTASH. The potash in any fertiliser or mineral which is soluble in a standard acid. This standard varies with different authorities. In soil analysis the standard acid adopted by several soil chemists in both England and America is 23 per cent. hydrochloric acid. This is the acid used as the standard in the Geological Survey Laboratory. Soil constituents and fertiliser constituents which are insoluble in water but soluble in this acid may be considered as slowly becoming available for plant food in soils.

ALKALI-SOLUBLE POTASH. The potash in any fertiliser or mineral which is soluble in dilute alkali solution, *e.g.*, 5 per cent. caustic soda. Since many soil waters are alkaline, such potash should rank with acid-soluble potash as a fertiliser in soils which are not acid (see Alunite, p. 20.)

INSOLUBLE POTASH. The potash in any fertiliser or mineral which is not dissolved by treatment with water, standard acid, or standard alkali, and may be looked upon as practically valueless for fertilising purposes.

AVAILABLE POTASH. The potash in a fertiliser or mineral which can be utilised immediately or within a few years by plants as food. It includes the water-soluble potash, the acid-soluble potash, and probably the alkali-soluble potash.

EXTRACTABLE POTASH. The potash in a mineral which can by commercial processes be converted into available potash, usually into water-soluble potash.

UNIT VALUE. This is the basis for fixing the market price of any crude mineral or such mineral products as fertilisers. It can be obtained by dividing the price charged in open market per ton by the number of per cents. (units) of valuable constituent present. Thus if potassium sulphate carrying 54.0 per cent. of potash is sold at £16 4s. per ton, the unit value is (£16 4s. ÷ 54.0), *i.e.*, six shillings per unit; this was the average rate in Western Australia in 1914.

Conversely, the equitable market value per ton of a fertiliser or mineral can be calculated, when the unit value is fixed, by multiplying the unit value by the number of per cents. of valuable constituent. Thus when the unit value of potash is 20s., crude potassium sulphate carrying 45.3 per cent. of potash is worth (20s. × 45.3), *i.e.*, £45 6s. per ton.

This unit value at any one time is approximately the same for potash of the same solubility in all kinds of fertilisers. Thus the unit value is the same for all water-soluble potash, whether this be in the form of sulphate, chloride, or other salt. It is, however, much less for acid-soluble or alkali-soluble potash than for water-soluble potash, since this is not so readily taken up by plants. Thus when water-soluble potash is quoted at 20s. per unit, an equitable value for acid-soluble or alkali-soluble potash would be 10s. or less per unit. Insoluble potash has no market value for agricultural purposes, but may have a value for manufacturing purposes.

The current unit value is held to apply to all fertilisers of average richness, but when through scarcity of high grade fertilisers, low-grade ones are put on the market, a discount must be made off the unit value when arriving at an equitable price for such low grade material in order to cover the extra cost of freight and handling. Thus at some particular time a current unit value of 20s. for potash might, in practice, be held to apply to all material carrying not less than 10 per cent. of fertilising materials (including phosphoric acid and nitrogen), but for poorer material the unit value might reasonably be taken at a discount of 1s. or more for each one per cent. below 10.

## 2.—INDUSTRIAL USES OF POTASSIUM COMPOUNDS.

Compounds of potassium, mainly salts of potassium, are of immense importance to civilised man in many directions, so much so that were all supplies of potash completely cut off, our mode of life, particularly in regard to feeding, would have to be distinctly modified. It is to be remembered, however, that while potassium is the essential and valuable constituent of potassium salts when used in agriculture, it is not so in many salts used for other purposes, and the potassium compound in such cases can be, and is to a large extent, replaced by the corresponding sodium compound, *e.g.*, in cyaniding gold ores. It is widely recognised that the use of potash salts in the past has been unduly fostered in many directions by German scientists and industrialists solely to keep up the price of German produced potash salts and make the world more and more dependent upon them.

Agriculture. By far the most important use of potash salts is as a food, or fertiliser, for plant crops. There are eight essential components of growing plants which must be drawn from the soil in order that these may thrive and yield suitable crops of tubers, stems, foliage, fruit or seed for the nourishment of man and beast. These are water, nitrogen, phosphorus, potassium, calcium, magnesium, iron, and sulphur. Of these eight it may be said that the soil usually contains abundance of the last four, and rain or irrigation supplies the first. Nitrogen, phosphorus, and potassium are very commonly deficient, and whichever is lacking must be supplied to the crop by man in the form of fertiliser. The plant is equally dependent upon all these necessaries and a deficiency of any one of them, even in the presence of a sufficiency of all others, exerts its full effect upon the crop in the direction of a corresponding restriction of growth. Since the plant can only absorb nourishment which is in solution in the soil water, it is essential that a sufficiency of all these necessary plant foods, including potash, must be present in a form which is water-soluble from the start, or becomes water soluble by fairly rapid degrees in the soil by reason of the chemical actions going on therein.

Of water-soluble compounds of potassium the most useful in agriculture is the sulphate, which when pure carries 54.0 per cent. of potash. Other water-soluble compounds frequently used are:—

| | |
|---|---|
| Potassium chloride (Sylvite) | Potash, 63·2 per cent. |
| Carnallite (double chloride of potassium and magnesium) | Potash, 17·0 per cent. |
| Kainite (Chlorosulphate of potassium and magnesium) | Potash, 19·0 per cent. |

The above percentages of potash are those present in the pure compounds. Commercial supplies always run somewhat less owing to the presence of impurities, particularly sodium compounds.

By far the greater part of the world's production of potash compounds is absorbed by the agricultural industry, the continued success of which, on all soils but those which contain abundant natural potash, is dependent upon an artificial supply. It is, of course, impossible to replace potash by soda as a plant food.

METALLURGY AND RELATED USES. For many years the cyanide process for the extraction of gold, a process which yields quite 30 per cent. of the whole gold supply of the world, was dependent upon a potassium salt, potassium cyanide, for its continuation. Even before the war, however, sodium cyanide had largely replaced potassium cyanide for this purpose, and will probably be used exclusively for this purpose in the future.

Small quantities of potassium nitrate are used in refining metals, and this and other potassium salts, such as potassium permanganate, are used in assaying and analytical processes. The corresponding sodium compounds could be used in place of the potassium compounds were it not for the impossibility of producing the sodium compounds in pure dry crystals.

EXPLOSIVES. Potassium nitrate is an essential constituent in large proportions of black powder, and of many less well known but now largely used explosives, *e.g.*, bobbinite, carbonite, jahnite, etc. Another potassium salt used for these purposes is the chlorate, used in cheddite, rackarock, and other powders. It is impossible for various reasons to substitute the corresponding sodium salt for the potassium salt in these cases.

Medicine. A very large number of compounds of potassium are used for therapeutic purposes, *e.g.*, potassium bromide. Many of these depend for their physiological action on the acidic component and not on the metallic, potassium, and in many of these cases the corresponding sodium compound can be successfully substituted. In others, however, it cannot.

Other Uses. Considerable quantities of potassium salts are used in photography, soap making, tanning, glass making, etc.

## 3.—BRIEF HISTORY OF THE POTASH SUPPLY.

The earliest source of potassium compounds was *wood ashes,* from which impure potassium carbonate was extracted by boiling with water. Up to the middle of last century this still continued to be the chief source of supply, Russia, Canada, and India yielding some thousands of tons of crude carbonate per annum.

The next important sources of potash to be developed were the waste liquors from the manufacture of beetroot sugar, the adherent sweat of sheep's wool, and sea water.

About the middle of the century the German Stassfurt salt deposits began to yield an appreciable amount of potassium compounds, and already in 1864 this had become one of the most important sources, the following estimate of the world's production having been made in that year:—

| | Tons per annum. |
|---|---|
| From wood ashes ... ... ... ... | 20,000 |
| From Stassfurt salts and sea water ... | 15,000 |
| From beetroot ... ... ... ... | 12,000 |
| From wool suint ... ... ... ... | 1,000 |

By 1898 the Stassfurt deposits were yielding 2,300,000 tons of crude potash salts, and by 1913 over 10,000,000 tons, beside which all other sources of potash had paled into insignificance.

At the outbreak of the war the position was that the whole world had been trained to depend upon an immense quantity of potassium salts available at a low price and produced practically wholly in Germany. For about 12 months after war started the stocks distributed through the world were sufficiently great to prevent any serious inconvenience, but thereafter the available supplies have become more and more inadequate to meet the demand, until at the present time there is a very serious shortage amounting to a veritable famine in most parts of the civilised world, including Australia. This has been reflected in the retail unit price for potassium fertilisers, which has risen from 3s. 3d. to over 28s. per unit in the

United States, with a total lack of supplies at any price in some countries. In Western Australia the pre-war price for fertiliser potash was 6s. per unit; this rose to over 20s., and a little later the local market became absolutely bare of supplies. Recently* potassic fertilisers have been sold at 22s. per unit in Sydney.

During the years when the cheap German salts glutted the market the other sources have been more and more neglected until they had become a negligible factor in the world's supply, but the growing shortage during the past few years has renewed interest in them and caused a vigorous search to be made in every direction for fresh sources of these indispensable compounds. In some countries this search has already led to the discovery and exploitation of previously unsuspected supplies on a scale which promises to render them in the near future to a large extent entirely independent of German supplies. Up to the present Australia has produced no potash for her own use or that of other countries, beyond the few tons of potash alum which have been made for some years past in Europe out of alunite raised in New South Wales.

## 4.—PRINCIPAL PRE-WAR SOURCES OF POTASH.

### SEA WATER.

The waters of all oceans and inland seas contain, in addition to common salt, appreciable quantities of other salts, including potassium compounds. Thus in the ocean it is known that the relative ratio of metallic potassium to metallic sodium is 36 to 1,000. Each 1,000 tons of sea water contain 26.4 tons of common salt and almost 15 cwt. of potassium chloride, or, in other words, for every 1,000 tons of common salt the ocean yields, it is capable of yielding also 27½ tons of potassium chloride. Fifty years ago an appreciable amount of potash was thus obtained on the coasts of France and elsewhere. The output from the ocean is, however, limited by the consumption of common salt.

In the waters of some inland seas the ratio of potassium to sodium is higher than in the ocean. Thus in the Dead Sea the ratio varies from 100 to 1,000 up to 300 to 1,000, according to various published analyses, as against 36 to 1,000 for ocean water.

### SALT BEDS.

The complete evaporation, under arid conditions, of inland seas or almost land locked gulfs leads to the deposition in the solid form of all the salts held in solution, and if these should be buried under wind-borne dust, or water-carried mud and other detrital material, they are preserved from re-solution during any later return

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* Spring Season, 1918.

of a more humid climate. Such is the origin of the famous German potash bearing salt beds and of the smaller and less well known beds in Spain and elsewhere. The German basin is of Cretaceous age and contains beds of several non-potassic salts, chiefly common salt, gypsum, anhydrite, and kieserite. In addition there are immense quantities of potassium minerals, all water-soluble, chiefly

Sylvite, chloride of potassium.
Carnallite, chloride of potassium and magnesium.
Kainite, sulphate and chloride of potassium and magnesium.
Polyhalite, sulphate of potassium, magnesium and calcium.

Similar but much smaller basins occur in Alsace, in the Eastern Carpathians, and in Spain. No such beds have ever been located in Australia, though there is a possibility of their existing under some of our salt lakes.

## WOOD ASHES.

Potassium salts being an essential food of plants, drawn from the soil and retained in the organism, the ashes derived from burning plants are found to contain, amongst other matters, this potash mostly in the form of carbonate but partly also as sulphate. Both of these are water-soluble salts which can be dissolved out with water and recovered by evaporation. The proportion of ash varies largely with different species of plants, ranging from less than one per cent. to over five per cent. Only a small proportion of this ash is potash, this proportion varying from as little as one per cent. in Scotch fir and jarrah, to as much as 20 per cent. in the ashes of elm, grape vine, and banana stalks. It is evident that the amount of potash recoverable from dry wood seldom exceeds one-half to one per cent., and it is only because of the immense amount of waste wood which must be got rid of at timber camps and mills, and in clearing operations, that this becomes an appreciable source of commercial salts. The chief woods burnt for potash in Canada are elm, birch, larch, and maple.

In India cheap labour has led to the use of domestic ashes as a source of potassium nitrate, production from this source having reached at times over 10,000 tons per annum.

## BEETROOT SUGAR WASTE.

The potash in sugar beets, amounting to about 0.5 per cent. of the root, is derived in the same way as that in the stems of plants, from the soil, but is recovered from the waste liquors after removing the sugar. These liquors are evaporated to dryness, ashed, and the ashes, which contain carbonate, chloride, and sulphate of potash, treated in the same way as wood ashes. This process has been practically confined to France, and, in earlier years, Germany.

### WOOL SUINT.

The suint or yolk (dried sweat, etc.), which forms about one-fifth to one-third of the weight of greasy wool, contains much potash in combination with fatty acids.* This potash is in some countries dissolved out of the wool by clean cold water, from which it can be recovered by evaporating to dryness, calcining, and then leaching as in the case of wood ashes. The crude potash salt thus obtained consists of about 70 per cent. potassium carbonate with a little chloride and sulphate.

## 5.—RECENTLY UTILISED OR PROPOSED SOURCES OF POTASH.

### FELSPAR.

Felspar is the name for a group of rock forming minerals of which only one, viz., potash felspar (scientifically, microcline or orthoclase), contains an appreciable quantity of potash. It is this mineral which is referred to in the following pages as "felspar." The mineral in its purest state consists of the compound, $KAlSi_3O_8$, and it contains:—

| | per cent. |
|---|---|
| Potash, $K_2O$ ... ... ... | 16·9 |
| Alumina, $Al_2O_3$ ... ... ... | 18·3 |
| Silica, $SiO_2$ ... ... ... ... | 64·8 |
| | 100·00 |

In nature from 1 to 6 per cent. of the potash is replaced by soda, leaving from 10 to 15 per cent. of potash. This potash is insoluble in water, and for all practicable purposes insoluble in acids; it is therefore from a fertilising standpoint not "available potash."

Since felspar in many parts of the world is a fairly abundant mineral, innumerable patents have been taken out during the past few years covering methods for making its potash "available," or "extractable," particularly for recovering it in a concentrated water-soluble condition. Most of these methods are expensive to operate and do not hold out much promise of providing an adequate quantity of potash for fertilising purposes, though they might well yield limited amounts of pure potash compounds for medicinal purposes, etc.

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* For information regarding potash in Australian wool see South Australia, Department of Chemistry, Bulletin No. 2, Part 1. Adelaide, 1916.

The only method of treating felspar which gives promise of yielding successfully large tonnages of potash salts at a low cost is that of utilising felspar in the manufacture of Portland cement and recovering the potash as a by-product. This process has already reached important dimensions in the United States, where, owing to the quantities of felspar present in the clays and as part of the mix, it is estimated that 67,000 tons of potash ($K_2O$) can be recovered annually from the flue dust of cement works. By deliberately substituting pure felspar for part of the clay, and by modifying the details of manufacture, this recovery of potash might well be trebled.

## OTHER INSOLUBLE OR DIFFICULTLY SOLUBLE POTASH-BEARING SILICATES.

There are several other insoluble silicates carrying potash which is has been proposed to utilise in the same ways as felspar. The most common of these is muscovite, known also as potash mica or simply mica. This is a very common mineral, but natural concentrations of it are somewhat rare. As, however, they often occur in association with felspar, the two minerals could be mined and utilised conjointly. The composition of pure potash mica is:—

| | per cent. |
|---|---|
| Potash, $K_2O$ ... ... ... | 11·8 |
| Alumina, $Al_2O_3$ ... ... ... | 38·5 |
| Silica, $SiO_2$ ... ... ... | 45·2 |
| Water, $H_2O$ ... ... ... | 4·5 |
| | 100·00 |

As in the case of felspar, natural micas always contain some soda replacing potash, so that the proportion of the latter usually runs from 8 to 11 per cent. The potash in this mineral is insoluble in water or standard acid.

Other far less abundant and therefore unimportant minerals associated with igneous rocks are nepheline and leucite, as well as rocks containing these minerals, all of which have been experimented with as a source of commercial potash.

## GLAUCONITE.

Glauconite is a mineral formed by precipitation in the ocean and hence only found on land in beds of ancient marine sediments, chiefly in a mixture of quartz and glauconite known as "greensand." This material forms large beds in England, France, Eastern United States, and at least one locality in Western Australia.

The exact composition of pure glauconite is still in doubt, but it appears to be a hydrous silicate of potassium, iron, aluminium, and magnesium, averaging about 7½ per cent. of potash, all of which is readily soluble in standard hydrochloric acid. Further details will be given in dealing with the Western Australian supplies.

Patents have been taken out in many parts of the world for the extraction of potash from this mineral.

### POTASH-BEARING BRINES OF ARID REGIONS.

The saline surface waters and underground waters of all arid regions contain an appreciable amount of potash, usually, however, associated with such an overwhelming proportion of sodium and magnesium compounds as to be of less importance than sea water as a source of potash. Searles Lake in California is reported to contain six million tons of potassium chloride in a concentrated form, capable of recovery at the present market rates for potash.

### SEAWEED (KELP).

Many seaweeds contain a much higher proportion of potash than such land plants as are available as sources thereof, and active search is being made all over the world for dense growths of seaweed with high proportions of the desired constituent. The available beds on the Pacific Coast of the United States are estimated to be capable of yielding 2¼ million tons of potassium chloride. To extract this potash the weeds are dried under protection from rain (which would wash away an appreciable amount of their values), then burnt to a clean ash, leached with water, and the solution evaporated. When a potassic fertiliser only is required the weeds are, in America, merely stove dried and ground to a fine powder.

Both the original weed and the ash derived from it are known as "kelp," which therefore becomes a word of doubtful significance.

### ALUNITE.

This is a mineral sulphate of aluminium and potassium with varying amounts of sodium replacing part of the potassium. The composition of pure alunite is $K_2O.3Al_2O_3.4SO_3.6H_2O$, that is:—

| | per cent. |
|---|---|
| Potash, $K_2O$ ... ... ... | 11·40 |
| Alumina, $Al_2O_3$ ... ... ... | 37·00 |
| Sulphuric oxide, $SO_3$ ... ... | 38·60 |
| Water, $H_2O$ ... ... ... | 13·00 |
| | 100·00 |

Owing to replacement by soda, the potash may range down to as low as 5.8 per cent.

Alunite is not soluble in water but is rapidly dissolved by dilute alkalis and very slowly by standard hydrochloric acid. The potash in it is therefore to be looked upon as available, a fact borne out in practice by field experiments by the United States Bureau of Soils which showed an average increase in crops of 14 to 16 per cent., when raw alunite was used as a fertiliser*

By a very simple roasting process the whole of the potash can be rendered water soluble, thus increasing and hastening its fertilising effects. Details will be given later when dealing with the Western Australia material. Such roasted alunite has been proved to be of the same fertilising value as German potassium sulphate or chloride when equal weights of potash are applied.

Alunite is in actual use as a source of industrial potash in several parts of the world at the present time.

# III. SOURCES OF POTASH IN WESTERN AUSTRALIA.

## 1.—Wood Ashes.

Immense quantities of timber as well as branches and tops are burnt each year in Western Australia during clearing operations, in getting rid of waste ends and sawdust at timber mills, and in steam raising on the goldfields and elsewhere. No use whatever is made of the resulting ashes or any attempt made to save and utilise the potash contained therein. The ash, however, from the burning of vegetation of all kinds during clearing for agricultural purposes is left on the ground, and serves to fertilise the soil in the immediate vicinity of the fires for a short time.

The amount of data available on which to base any opinion as to the feasibility of obtaining potash in the State from this source is extremely meagre and deals mainly with the waste from the sawmills, which consists of trunk timber. This part of a tree is known to contain less potash than the smaller branches and tops, regarding which we have no data, and besides, the two timbers, jarrah and karri, which are dealt with at our timber mills, are unusually poor in potash, compared with other timbers.

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* Circular No. 76, United States Department of Agriculture (1913).

The Forestry Department was able to supply me with the following figures:—

| — | Ash per cent. | Potash per cent. in ash. | Potash per cent. in wood. | Potash lbs. per ton of wood. | Potash lbs. per ton of ash. |
|---|---|---|---|---|---|
| Karri sawdust ... | 0·24 | 3·18 | 0·0076 | 0·17 | 71·2 |
| Karri shavings ... | 0·22 | 3·38 | 0·0074 | 0·16 | 75·7 |
| Karri chips ... | 0·56 | 3·50 | 0·0196 | 0·44 | 78·4 |
| Jarrah sawdust ... | 0·40 | 1·26 | 0·0050 | 0·11 | 28·2 |

Karri—*Eucalyptus diversicolor.*

Jarrah—*Eucalyptus marginata.*

With these compare:—

| | Ash per cent. | Potash per cent. of wood. |
|---|---|---|
| Beech ... ... ... | 0·58 | 0·145 |
| Oak ... ... ... ... | 1·35 | 0·153 |

From these figures it is seen that although an immense amount of waste jarrah is available each year, the amount of ash therefrom would be very small and the amount of potash extraordinarily so, being only worth 7s. 6d. per ton of ash in normal times, with potash quoted at 6s. per unit, or 22s. 6d. at 20s. per unit. It does not appear to be a commercial proposition to deal with it.

The case is somewhat different in regard to karri. Although the total ash in this tree is small, still the amount of potash in the ash is nearly three times what it is in jarrah, the value per ton of ash at 6s. per unit being 20s., or at 20s. per unit, 66s. 8d. Per ton of timber the corresponding figures are only 0.54d. and 1.80d.

These figures are those for timber only. The potash yield per ton for the whole tree is always greater in proportion, since more potash is present in the bark, leaves, and small branches than in the solid trunk. Even in these, however, the values must be too low to be worth commercial treatment.

The mines at Kalgoorlie use a large tonnage of wood (chiefly salmon gum) per annum as fuel, and the ashes have been suggested as a possible source of potash. A typical sample of the ashes from the mines showed:—

| | per cent. |
|---|---|
| Total potash ... ... ... | 1·50 |
| Acid soluble* potash ... ... | 1·11 |

These proportions are so small that one must consider the ashes useless, in view of the limited tonnage available.

---

*Standard 6E. HCl.—(23 per cent. HCl.)

Rumour has always credited the South-West Peppermint (*Agonis flexuosa*) with being richer in potash than other local trees. The following figures bear this out:—

PEPPERMINT, AGONIS FLEXUOSA.

| Nature of Sample. | Moisture in green wood. | Ashes in wood dried at 100 deg. | Water soluble alkalis in ash. |
|---|---|---|---|
| | per cent. | per cent. | per cent. |
| Complete section of stem of growing mature tree. Diameter, 11½ inches | 43·48 | 4·53 | $K_2O = 5 \cdot 96$<br>$Na_2O = 1 \cdot 42$ |

From these figures it is calculated that one ton of dried wood, or 36 cwt. of green wood, would yield crude potash salt worth 19½d. at 6s. per unit or 5s. 5d. at 20s. per unit. Peppermint ashes, therefore, as an immediate source of commercial potash are not to be overlooked.

*Method of Treatment.*—In view of the possibility of attempts being made to utilise the potash in peppermint or other wood ashes, a brief outline of the methods to be followed in extracting it will be given.

From the point of view of the potash manufacturer, the more important parts of the tree are those rejected by the timber miller; the whole of the tree, therefore, or the tops, etc., rejected by the miller are stacked and reduced to ashes as soon as possible after felling and at as low a temperature as possible. Appreciable loss of potash occurs by exposure of the felled tree to much rain, or by burning at too fierce a heat. Since the only potash in the ash which is of commercial value is that which is water soluble, the ashes during and after burning must be completely protected from rain or running water, a matter which presents no difficulty if the burning is done only during the dry season. The burning must be done in some situation well sheltered from the wind, and on a firm clay or other smooth floor from which the ashes can be easily and cleanly taken up. Incineration need not be perfect, but the less charcoal and wood left unburnt the better. The ashes will contain soluble carbonate, sulphate and chloride of potash, and some insoluble potassium silicates. The soluble potash is leached out with water, preferably hot, which may be done in a variety of ways. One common way is to have a number of barrels three-quarters full of water into which the ashes are shovelled until the water nearly reaches the top. The contents are thoroughly stirred once or twice, then allowed to settle. The clear or almost clear water is syphoned over into empty barrels and a fresh lot of ashes added to it, the mud in the first barrel being stirred once more with fresh water and then rejected. This treatment is continued until the water reaches a density of about 32deg. by Twaddell's hydrometer, when it is boiled down to dryness in iron vats. The resulting cake is broken out and is ready for sale as crude potash. For agricultural purposes it is well to mix it with half its own weight of powdery gypsum (kopi), which could be landed in Perth for about 15s. per ton.

### SEAWEED ASHES.

These are dealt with by Mr. I. H. Boas in an appended section.

### COAL ASHES.

The ashes from Collie coal contain the following amounts of potash:—

| —— | Ash per cent. | Potash per cent. of ash. | Potash per cent. of coal. |
|---|---|---|---|
| Proprietary Mine ... ... ... | 9·08 | 0·18 | 0·016 |
| Co-operative Mine ... ... ... | 7·14 | 0·20 | 0·014 |
| Scottish Mine (1) ... ... ... | 3·72 | 0·32 | 0·012 |
| Scottish Mine (2) ... ... ... | 2·52 | 0·12 | 0·003 |
| Cardiff Mine (1) ... ... ... | 5·11 | 0·07 | 0·004 |
| Cardiff Mine (2) ... ... ... | 5·45 | 0·23 | 0·012 |
| Cardiff Mine (3) ... ... ... | 3·94 | 0·27 | 0·011 |

Almost all of this potash is insoluble in water. It is evident that Collie coal ashes are valueless as a source of potash.

### FELSPAR.

The immense areas of granite exposed in extra-tropical Western Australia contain many small and large pegmatite veins of which potash felspar (microcline) is an important constituent, forming from 30 to 50 per cent., or even more, of the whole vein. The felspar in many of these veins could be very cheaply quarried and handpicked to a grade suitable for use as a source of potash.

Some of the localities where such veins have actually been exposed are as follows:—Boya, Mahogany Creek, Spencer's Brook, Toodyay, Balingup, Albany, Northampton, Payne's Find, Niagara, Londonderry.

Whilst some of these are too distant from Perth or other likely point of utilisation to be worth further consideration at present, others are quite conveniently situated, and many more would be revealed by a systematic search, particularly in the Darling Ranges.

The composition of some of these felspars is shown in the accompanying table. The figures show percentages of potash (all insoluble), ranging from 10.6 to 12.5 per cent., one of the richest being from Mahogany Creek, quite close to Perth, and all comparing favourably in value with commercial potash felspars from other parts of the world. In these felspars we have a source of potash infinitely richer than native timber trees, though not so readily extracted.

## West Australian Potash Felspars.

| No. ... ... ... ... ... | L. 1892 E. | L. 4259 D. | L. 310 B. | | | L. 2453 E. | L. 2454 E. |
|---|---|---|---|---|---|---|---|
| Sample ... ... ... ... | Bulk, 1st Grade, hand picked. | Average of of large loose crystals. | Large mass from pegmatite. | Small mass from pegmatite. | Crystal from Granite. | Average of large masses. | Average of large masses. |
| Locality ... ... ... ... | Mahogany Creek. | Boulder. | Parkers' Range. | Simons Hill. | Wakefield Pt., Albany. | 2 miles West of Niagara. | Ferndale, Balingup. |
| Analysis— | | | | | | | |
| Potash, $K_2O$ ... ... ... | 12·20 | 12·11 | 11·57 | 11·52 | 11·87 | 10·65 | 12·56 |
| Soda, $Na_2O$ ... ... ... | 3·08 | 3·44 | 3·04 | 2·38 | 2·90 | 4·00 | 2·86 |
| Alumina, $Al_2O_3$ ... ... | 65·46 | 19·74 | 18·96 | ... | 20·00 | ... | ... |
| Silica, $SiO_2$ ... ... ... | 19·11 | 63·14 | 64·79 | ... | 64·39 | ... | ... |
| Ferric oxide, $Fe_2O_3$ ... ... | ·10 | ·58 | trace | ... | *Nil* | ... | ... |
| Manganese oxide, MnO ... | *Nil* | ... | ... | ... | *Nil* | ... | ... |
| Chromium oxide, $Cr_2O_3$ ... | *Nil* | ... | ... | ... | *Nil* | ... | ... |
| Lime, CaO ... ... ... | *Nil* | ·55 | ·12 | ... | ·68 | ... | ... |
| Magnesia, MgO ... ... | trace | ·09 | ·23 | ... | *Nil* | ... | ... |
| Barium oxide, BaO ... ... | trace | ... | ... | ... | ... | ... | ... |
| Titanum oxide, $TiO_2$ ... ... | *Nil* | ·14 | ·05 | ... | ... | ... | ... |
| Water over 100 deg., $H_2O+$ ... | ·06 | ·41 | ·14 | ... | ·40 | ... | ... |
| Water under 100 deg., $H_2O-$ ... | *Nil* | ·10 | ·13 | ... | | | |
| Total ... ... ... | 100·01 | 100·30 | 99·03 | ... | 100·24 | ... | ... |
| Density ... ... | 2·568 | 2·55 | 2·57 | ... | 2·577 | | |
| Variety ... ... | Microcline Microperthite | Microcline Microperthite | Microcline Microperthite | ?. | Microcline Microperthite | Microcline Microperthite | Microcline Microperthite |

The potash in felspars being absolutely insoluble in water, and almost so in standard acid or weak alkali, is not in an available form. Many methods have been proposed and patented for making the potash available, but of all of them only that which yields it as a by-product in cement making is at present on a commercial footing. With the advent of a cement plant in the State in the near future we shall have a means of treating our felspars. It must be understood, however, that the output of potash from this source is strictly limited by the output of cement, being at most about 2 per cent. of the latter. For every 1,000 tons of cement we may expect to recover under favourable conditions about 10 tons of potash ($K_2O$), worth £1,000 with potash at 20s. per unit.

*Method of Treatment.*—The ground felspar is added to the limestone-clay mixture, in which it is made to replace a large proportion of the clay, the ideal condition being to have all the silica needed for the mix added in the form of felspar. If no clay is used or if the limestone is unusually siliceous, bauxite from the Darling Ranges may be added to keep the proportion of alumina and iron right, since felspar is more siliceous than kaolin. Otherwise a clay carrying very little free quartz must be used, such as certain clays from Belmont, Mt. Kokeby, Mujar, etc.

At the temperature at which the cement mixture is burnt to clinker (about 1,400deg. Centigrade), the greater part of the potash is driven off in fume, which is collected preferably by electrical precipitation. If a small percentage (1 or 2) of common salt is added to the raw mix a much larger proportion of the potash is recovered without in any way deteriorating the cement.

The small amount of mica always present in the clay and limestone of the raw mix also yields up its potash in the same way as felspar.

The flue dust recovered contains potash in three forms, viz., the great part readily soluble in water, some only slowly soluble in water, and a small proportion insoluble. This dust may be sold direct on the basis of its water soluble potash or may be treated by one of several processes to increase the proportion of water soluble potash before marketing.*

## GLAUCONITE.

Glauconite is a hydrous silicate of iron and potassium, carrying about 7½ per cent. of potash, and occurring in small dark green grains mixed with quartz sand etc., in marine sediments. At Gingin, close to the railway station, an almost horizontal bed of glauconite-sand (green-sand) over 30 feet thick has been proved to exist under

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* 1918. Journ. Ind. & Eng. Chem. X, 106. A. R. Merz : Direct Heat treatment of Cement mill dust to increase its water soluble potash contents.

a thin cover of chalk. This sand is a mixture of quartz and glauconite with a little calcite, and has the following composition:—

GLAUCONITE SAND, GINGIN.

| — | 492E. Outcrop of bed. | 2180E. Top 20ft. under chalk. | 2179E. Next 10ft. | 493E. Chalky outcrop. |
|---|---|---|---|---|
| Potash... ... ... ... | 2·94 | 2·60 | 2·52 | 1·99 |
| Soda ... ... ... ... | ·14 | ·06 | ·13 | ·23 |
| Lime ... ... ... ... | 1·54 | ... | ... | 15·07 |
| Magnesia ... ... ... | 1·69 | ... | ... | 1·49 |
| Phosphoric oxide ... ... | ·32 | ... | ... | ·20 |
| Silica and insol. ... ... | 66·70 | ... | ... | 48·56 |

At this point therefore, Molecap Hill, there appears to be a large tonnage* of green sand but of a low grade, viz., £2 10s. worth of potash per ton at the assumed rate of 20s. per unit. This is the only point from which samples have been collected, though there is a large area hereabouts of similar beds, portions of which may well carry more glauconite and less quartz, and therefore be richer in potash.

The whole of the potash is glauconite is readily soluble in standard hydrochloric acid, so that wherever it occurs as a normal constituent of the soils its potash would be considered as available for plant food. There is evidence also that glauconite decomposes fairly rapidly in soils which are not markedly alkaline. In the absence of all supplies of potash this mineral is well worth trying in its raw condition, or better still mixed with superphosphate†, on our South-Western lands as a source of potash. Its utilisation on any large scale will, however, depend on the possibility of discovering a cheap mechanical process of concentration to increase the grade of the ore before chemical treatment.

Glauconite is specially valuable in these times as a source of pure potash compounds for medicinal or scientific purposes and for glass making, since by a very simple process almost pure caustic potash can be obtained from it.

*Method of Treatment.*—For recovery of crude potash for fertilising purposes glauconite may be added to a raw cement mix in place of felspar or mica.

For preparing high grade potassium compounds the green sand, preferably raised to at least 6 per cent. $K_2O$ by mechanical means, is finely ground and mixed with from 5 to 25 per cent. of slaked

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* 80,000 tons to the acre if the bed be 30ft. thick throughout.

† The free acid in superphosphate will render much if not all of the potash in glauconite water-soluble.

lime and put into a large digester with twice its weight of water. The mixture is then heated up by superheated steam and kept under a pressure of about 225lbs. for two to four hours*. At the end of this time the contents are filtered, the filtrate being an almost pure solution of caustic potash, which is used over again for a fresh extraction until sufficiently strong to be evaporated down, and made into stick potash, or potassium sulphate, etc., as required.

The solid residue from the filters can be moulded into sand-lime brick of good quality.

### JAROSITE AND NATROJAROSITE.

These are two closely related minerals found under similar circumstances. Typical jarosite is a hydrous sulphate of iron and potassium(2); typical natrojarosite the corresponding compound of sodium.(3) All natural jarosites, however, contain some sodium, and all natural natrojarosites contain some potassium. Thus jarosite contains from 4.78 to 9.40 per cent. of potash with from a trace to 3.13 of soda; whilst natrojarosite contains from a trace to 4.77 of potash and from 3.14 to 6.39 of soda. Jarosite is always a possible source of potash, whilst only those natrojarosites which are comparatively rich in potash are suitable for this purpose.

Neither of these minerals has ever previously been suggested as a source of potash, perhaps because they have been looked upon as rare minerals. In the Geological Survey Laboratory I have ascertained:—

(1.) That in Western Australia these minerals occur in several localities, viz., Kundip, Upper Kalgan River, Comet Vale, Northampton, and Nullagine.

(2.) In one locality, Northampton, jarosite and highly potassic natrojarosite are somewhat widely distributed and appear to be in sufficient quantities to warrant exploitation.

(3.) That commercially valuable potash salts can be extracted from jarosite at a very small cost, and with a very high percentage extraction.

(4.) That the residue after extraction of potash is a valuable pigment.

Already a preliminary attempt has been made to work the Northampton deposits on a commercial scale. In this district the minerals occur at and near the surface in lodes usually associated with graphite. The lodes appear to be shear zones in gneissic granite, the mineral arising from interaction between weathering

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* 1918. Ind. & Eng. Chem. X, 6. H. W. Charlton, Recovery of Potash from Greensand.

(2) $K_2O\ 3Fe_2O_3\ 4SO_3\ 6H_2O$.

(3) $Na_2O\ 3Fe_2O_3\ 4SO_3\ 6H_2O$.

pyrite and the potash-bearing silicates of the rock. Typical analyses show:—

JAROSITE AND NATROJAROSITE, NORTHAMPTON.

| — | (1.) | (2.) | (3.) | (4.) |
|---|---|---|---|---|
| Potash... ... ... ... | 5·78 | 5·55 | 2·16 | 2·99 |
| Soda ... ... ... ... | ·62 | ·82 | ·66 | 2·52 |
| Sulphuric oxide ... ... | 20·34 | ... | ... | 19·17 |
| Iron oxide ... ... ... | 33·09 | ... | ... | 36·31 |
| Graphite ... ... ... | 9·04 | ... | ... | *Nil* |
| Insoluble ... ... ... | ? | ... | ... | 28·54 |
| Water, etc. ... ... ... | ? | ... | ... | 10·47 |
| | | | | 100·00 |

(1), (2). Main Jarosite lode, Weebe Well, one mile N.W. of Northampton.

(3). Second Jarosite lode, Weebe Well.

(4). Natrojarosite lode, five miles S.E. of Northampton.

A lower grade lode with graphite was found one mile South of Northampton. On the Upper Kalgan River a jarosite deposit has been found, but nothing is yet known regarding its extent.

Natrojarosite very poor in potash has been found at Kundip, but the district should certainly be prospected for higher grade mineral.

The whole of the potash in jarosite is insoluble in water, but is dissolved rapidly by standard hydrochloric acid and much more slowly by dilute alkali solution. Jarosite should therefore have some fertilising power if applied to the soil in its raw state. It is preferable, however, to roast the mineral before use, as this reduces its weight by one-third and converts all the insoluble potash into water-soluble potassium sulphate, which may be leached out and crystallised for agricultural or other purposes. If the potash is only required as a fertiliser the roasted mineral can be used without leaching, freight being then paid on a large amount of non-fertilising iron oxide.

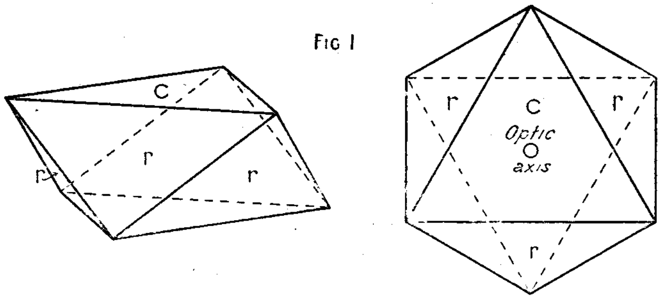
Roasted ore of grade equal to (1) and (2) above would contain 8.5 per cent. of water soluble potash, and would be worth £8 10s. per ton with adjustment for freight. The extracted crude potash salt would amount to 12.1 per cent. of the weight of ore and would contain 46.7 per cent. water soluble potash and be worth £47 14s. per ton (at 20s. per unit). The iron oxide residue has been valued at £12 to £18 per ton as a pigment.

*Method of Treatment.*—The crude ore, as free as possible from siliceous gangue, is crushed to pass a 10-mesh sieve and roasted in a mechanical or hand-rabbled reverberatory furnace at a temperature between 700deg. and 750deg. until no further fumes of sulphur trioxide are given off. By this time the mineral will have lost one-third of its weight, all the water and three-quarters of the total $SO_3$ having been driven off. Loss of potash will occur if the roasting be too prolonged or done at too high a temperature. The roasted ore now consists of water soluble sulphate of potassium and sodium, and insoluble iron oxide and gangue. This may be used direct as a fertiliser, when freight is not too expensive.

To save freight in agriculture, and to make the potash available for other trade purposes, the roasted ore is leached with warm* water, and the clear solution of potassium and sodium sulphate evaporated and crystallised, yielding crude potassium sulphate carrying more or less sodium sulphate. This is admirably suited for fertilising or for sale to a chemical works for the preparation of various commercial salts, whilst the residue only requires fine grinding to yield a red brown pigment of the highest quality.

*Detection of Jarosite.*—Jarosite always occurs at or near the surface. The colour is yellow of various shades. In texture it is either earthy, resembling a yellow ochre, or firm and dense. The hardness ranges from one for the earthy variety to 3½ for the dense variety. The density is 3.20.

FIG I



JAROSITE CRYSTALS

A. In clinographic projection. B. As seen under the microscope.

Jarosite is insoluble in water but readily soluble in hot hydrochloric acid, giving a yellow solution which reacts for sulphate, iron and potassium ions. On heating to a dull red heat jarosite gives off strong fumes of sulphuric acid. The roasted ore is dark red in colour, and on leaching with warm water gives a solution of potassium and sodium sulphates.

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* Not cold water. Water at 100° C. dissolves one-quarter of its weight of potassium sulphate; at 15° C. only one-ninth.

Under the microscope powdered jarosite is usually seen to be well crystallised in minute flat yellow crystals having the appearance shown in Fig. 1. The crystals are uniaxial, and the flat discs are in position to give extinction throughout rotation, or an uniaxial figure in convergent light.

## ALUNITE AND NATROALUNITE.

These two closely related minerals are highly prized at the present time, as they yield water-soluble potash salts at little cost for treatment and are likely to be found in reasonably large bodies. Typical alunite is a hydrous sulphate of aluminium and potassium,(1) typical natroalunite being the corresponding compound of aluminium and sodium.(2) All natural alunites, however, contain some sodium, and all natural natroalunites contain some potassium. Alunite contains from 5.79 to 11.36 per cent. of potash, with a trace to 3.80 per cent. of soda; whilst natroalunite contains a trace to 5.78 per cent. of potash, and 3.81 to 7.78 of soda. All alunites, therefore, are suitable sources of industrial potash, but natroalunites are only suitable sources when they are comparatively rich in potash, say over 3 per cent.

Alunite is found in many parts of the world in solid veins or beds, or in nodules in kaolinic rocks. For many years it has been known and worked on a small scale as a source of alum at Bullah Delah in New South Wales. More recently it has been found in South Australia at Carrickalinga and Warnertown, and researches carried out in the Geological Laboratory have proved its presence in several parts of the Kanowna District and at Northampton. Its wide distribution at Kanowna has been confirmed by personal inspection by the Acting Government Geologist, Mr. T. Blatchford. From his report it appears that the alunite occurs as fairly well defined veins up to 24 inches wide in kaolinised rock and as scattered nodules of various sizes embedded in the same. The full text of his report is attached. Already attempts are being made to open up several of the deposits at Kanowna.

The original samples of this mineral received from Kanowna were of natroalunite from Wyatt's P.A. 506, 1½ miles S.E. of the railway station, and of alunite from the Deep Lead on G.M.L. 1159, two miles N.W. of the railway station. The first was snow white and earthy in texture, extremely like a rather firm white clay; it could easily be broken between the fingers. The second was in hard white nodules, fine grained and not unlike magnesite, but not so hard

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(1) $K_2O.\,3Al_2O_3.\,4SO_3.\,6H_2O$. (2) $Na_2O\ 3Al_2O_3\ 4SO_3\ 6H_2O$.

or so fine in grain. The composition of these, and of a white alunite-bearing clay from G.M.L. 918 was:—

ALUNITE, KANOWNA.

| G.S.L. No. ... | 2054E | 2437E | 1853E |
|---|---|---|---|
| Locality ... ... | Wyatt's, P.A. 506 | G.M.L. 1159 | G.M.L. 918 |
| Water over 100° ... | 15·45 | 14·55 | 2·80 |
| Potash ... ... | 5·42 | 9·32 | 3·10 |
| Soda ... ... | 4·07 | 2·14 | ·40 |
| Alumina ... ... | 36·46 | 35·01 | 13·08 |
| Sulphuric oxide ... | 37·64 | 37·84 | 1·24 |
| Iron oxide ... | ·24 | ·79 | ·68 |
| Lime ... ... | *Nil* | *Nil* | *Nil* |
| Magnesia ... ... | *Nil* | *Nil* | ·36 |
| Silica ... ... | ·95 | ·45 | 78·44 |
| Moisture ... ... | ·06 | *Nil* | ·03 |
| | 100·29 | 100·10 | 100·13 |
| Analyst ... ... | E. S. Simpson | H. Bowley | H. Bowley |

A complete list of partial analyses made of samples collected by Mr. T. Blatchford and others is given in the accompanying table (p. 42), and the localities where they were obtained are shown on the map and section (Plates 1 and 2) which accompanies his report.

The minerals associated with the alunite are finely divided quartz and kaolin, with at times, *e.g.*, in No. 1853, an insoluble potash mineral which is almost certainly muscovite mica. A little iron hydrate is sometimes present, and water soluble salts, chiefly common salt, are invariably present to an extent varying from 1 to 7 per cent. Before making the above analysis of No. 1853, these salts were washed out and found to have the following composition:—

| | Per cent. of whole ore. |
|---|---|
| Sodium chloride ... ... ... | 5·95 |
| Magnesium chloride ... ... | ·86 |
| Magnesium sulphate ... ... | ·27 |
| Calcium sulphate ... ... ... | ·29 |
| Total, soluble salts ... ... | 7·37 |

This high percentage is exceptional and is contained in a clay with very little alunite. The high grade mineral from Wyatt's claim carries only about 1 to 1½ per cent. of soluble salts. Any higher percentage than this it would be wise to remove by exposure to rain before manufacturing potash compounds from the mineral.

In most cases at Kanowna the matrix is sufficiently softer than the high grade ore to permit of hand-picking the latter. It was found in the case of No. 2047, from Wyatt's P.A. 506, that the hard central portion of the nodules contained 99 per cent. alunite and 5.62 per cent. of potash, while the softer crust, which easily rubbed off, contained only 67 per cent. alunite and 3.34 per cent. potash.

Reference to the map of Kanowna shows the wide distribution of alunite in the vicinity and augurs well for its development in commercial quantities. It must be remembered that alunite is a mineral usually confined to the belt of weathering, and will not therefore be found extending to any very great depth. The highest grade Kanowna mineral contained 9.32 per cent. potash, *i.e.,* £9 4s. worth of potash per ton of ore at 20s. per unit, and occurred in hard nodules taken from a bore on the Deep Lead at a depth of 140 feet on G.M.L. 1159. The next best carried 8.66 per cent. potash and was found exposed in a breakaway east of G.M.L. 862, on ground now reserved by the Crown. Slightly lower grade ore was found on M.L. 12, on a dump 400 yards north of Wyatt's shaft, its grade being 7.56 per cent. potash. These and the hand-picked material from Wyatt's P.A. 506 are all sufficiently rich in potash to be worth working for industrial purposes under existing conditions.

Little is known of the alunite at Northampton beyond the fact that it forms a hard discontinuous wall to the jarosite lode at Weebe Well. A typical specimen contained 18.10 per cent. of insoluble sulphuric oxide, equal to 46.0 per cent. of alunite. The alkalis were: potash, 6.08 per cent.; soda, 0.30 per cent. This occurrence is worthy of further exploration, as indeed is the whole of the Northampton district.

*Method of Treatment.*—The treatment of alunite and natroalunite for recovery of crude potash salts is both simple and inexpensive. It proceeds upon the same lines as that of jarosite, except that the roasting must be done at a somewhat higher temperature.* The ore is weathered or washed to remove common salt and magnesium compounds if these exceed one per cent. It is dried and crushed to pass a ten-mesh sieve and roasted at a temperature between 800deg. and 900deg. C. until no further sulphuric oxide is given off. The melting of common salt, which takes place at 819deg. C., is a convenient indication by which to judge the temperature. It is found that the addition of carbonaceous material, such as sawdust, to the charge shortens the time of roasting. If the ore be under-roasted, alum will be present in the charge when drawn, and will lessen its value for commercial purposes. If, on the other hand, the ore be roasted too long at too high a temperature, loss of potash will ensue from the formation of potassium aluminate and silicate. In roasting, the ore will lose from 40 to 50 per cent. of its weight. The roasted ore can be used direct as a fertiliser if freight is not too expensive, but to save freight it is usual to leach the roasted ore

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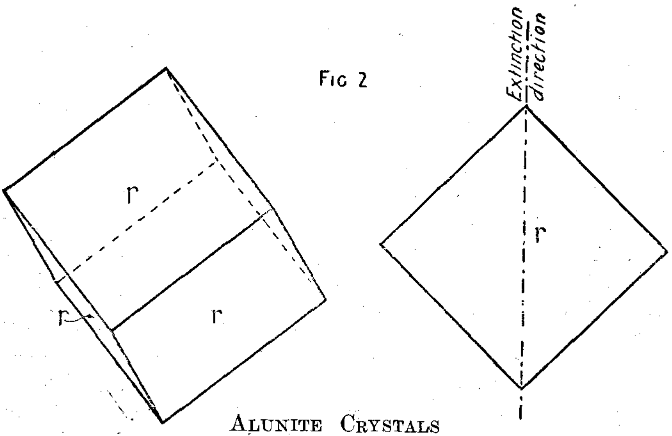
* For minor details of this treatment see Commonwealth Advisory Council of Science and Industry, Bulletin No. 3, Alunite Deposits of Australia. Melbourne, 1917.

with hot water and filter-press it. The solution from it, which contains the potassium and sodium as sulphates, is evaporated nearly to dryness, and the salts thus obtained are saleable as fertiliser or as a source of pure potash compounds, mixtures of potassium and sodium sulphates being very readily separated by crystallisation owing to the difference in solubilities. Potassium sulphate is soluble in 9 parts of cold or 4 parts of boiling water, whilst sodium sulphate is soluble in 6 parts of cold water or its own weight of boiling water.

*Detection of Alunite.*—Alunite always occurs at or near the surface. The colour is usually pure white or slightly tinted with yellow or pink. In texture it is either fairly soft and friable, resembling then a rather hard white clay, or dense and firm, resembling a very fine-grained limestone or magnesite. The break of the more friable varieties is typical, being snappy like a biscuit. The hardness ranges from one, for the clay-like variety, to four for the very dense variety. The density is the same as that of quartz (2.65).

Alunite is insoluble in water and almost insoluble in acids, but dissolves readily in warm dilute (5 per cent.) caustic soda. On heating to a bright red heat alunite gives off strong fumes of sulphuric acid. The roasted ore on leaching with warm water gives a solution of potassium and sodium sulphates. The reactions for sulphate ion given by this solution and by the caustic soda solution of the unroasted ore are characteristic.

FIG 2



ALUNITE CRYSTALS

A. In clinographic projection. B. As seen under the microscope.

The appearance of powdered alunite under the microscope is very characteristic. The powder is seen to consist entirely of minute cubical crystals, *vide* Fig. 2. These are not true cubes of the isometric system, but are rhombohedra approximating to cubes. This is shown by their optical properties, the crystals being anisotropic with diagonal extinction. The refractive index is almost identical with that of oil of cassia (1.58).

Perth, 4th October, 1918.

## Appendix I.

# EXAMINATION OF WESTERN AUSTRALIAN SEAWEEDS FOR POTASH AND IODINE.

By I. H. Boas, M.Sc.

The shortage of potash salts, caused by the war, led me early in 1916 to begin an examination of the seaweeds of Western Australia for their potash contents, with a view to their possible utilisation for potash manures. Incidentally the iodine contents of some samples has been determined, as this constituent might also be extracted with advantage.

By the courtesy of the Chief Inspector of Fisheries, I obtained samples of weed from various parts of the coast. These consisted mainly of two broad leafed, gelatinous species, and some of the finer forms common on the local beaches.

The kelp industry has received a tremendous lift since the war owing to supplies of potash being cut off, and even before the war it had begun to revive. In the United States a large amount of work has been carried out into the utilisation of seaweed, and plants have been erected for treating very large quantities of the giant kelps which are very abundant on the Pacific Coast. A small experimental plant has also been erected in Tasmania during the past few years.

There are places along the coast of this State where the broad leafed species (*Ecklonia radiata*) is abundant, and it seems feasible to work these commercially if their potash content is sufficiently high.

In order to reduce all analyses to a basis upon which they could be compared, some experiments were made on the moisture content of the weeds. This varies enormously with the weather conditions. One sample of weed lost 70.2 per cent. of its weight on hanging in a draught for four days, and then still contained about 20 per cent. moisture. From day to day the moisture varied, remaining, however, somewhere in the neighbourhood of this figure. One sample picked up 11 per cent. of moisture in 24 hours owing to a change in the weather. Experiments showed that the weight of the weed was constant after drying at 100deg. C. for two hours, and it was decided to calculate all results to the weight of the weed so dried. It is difficult to make use of many of the published analyses because authors unfortunately omit to state upon what basis they are calculated.

Another reason for steam-drying the weed was that when air dry it burns badly and gives a black ash, which it is impossible to burn white without using high temperatures. The dried weed, on the other hand, burns easily to a clean grey ash which is easily extracted.

Care must be taken in burning the dried weed to keep the combustion from becoming too vigorous, with a corresponding increase in temperature. If the temperature is excessive, part of the ash fuses and is then difficult to extract. In addition there is a loss of iodine and of water soluble potash if the weed is sandy, due probably to formation of silicate of potash.

Some time was spent in investigating the methods for estimating potash, and after many trials the perchloric acid method was adopted, the details of which are described by W. A. Davis in the Journal of Agricultural Science, Vol. V., Pt. 1, October, 1912. It was found that the potash obtained by six extractions with hot water was identical in amount with that extracted by water after twice evaporating to dryness with hydrochloric acid.

The iodine was estimated by distillation with 30 parts of dilute sulphuric acid and four parts of ferric sulphate, the latter being added to counteract the interfering effect of the sulphides in the ash.

In the cases of the first five weeds examined, estimations were also made of total halogen, sulphate and total alkalis, and the sodium calculated by difference.

The results in the table below were obtained on the following samples:—

I. From Bunbury. Sample apparently from the beach and much covered with sand. Part of this sample was washed under the tap for a few minutes to remove sand.
II. Same as I., but sand brushed off with a stiff dry brush.
III. From Albany. Very sandy. Picked off beach.
IV. From Mandurah. Fresh and clean.
V. From Little Island, N. of Fremantle. Taken direct from the ocean and free from sand.

ANALYSES OF ASH.*

| — | Water soluble Ash. | Potash, $K_2O$. | Iodine. | Total Halogen as Cl. | Sulphate. | Total alkalis. |
|---|---|---|---|---|---|---|
| I. ... | 48·43 | 17·33 | 2·62 | 5·46 | 13·26 | 49·72 |
| II. ... | 58·40 | 20·58 | ·97 | 20·11 | 7·11 | 55·98 |
| III. ... | 45·30 | 13·40 | 1·05 | 14·74 | 6·87 | 43·92 |
| IV. ... | 63·76 | 19·27 | 3·39 | 23·78 | 7·09 | 60·37 |
| V. ... | 68·50 | 24·60 | 2·66 | 27·33 | 6·46 | 67·90 |

* The analyses were made by Mrs. R. R. Baxter, B.Sc., and Mr. J. L. Jenkinson.

Analyses calculated to Dry Matter in Weed.

| — | Water in air-dried weed. | Ash per cent. on air-dry sample. | Ash per cent. on steam-dried sample. | Potash, $K_2O$. | Soda, $Na_2O$. | Iodine. | Halogen as Cl. | Sulphate. | Water soluble. |
|---|---|---|---|---|---|---|---|---|---|
| I. ... | 18 | 13·3 | 16·2 | 2·81 | 1·33 | 0·42 | 0·88 | 2·14 | 7·83 |
| II. ... | 20 | 21·2 | 26·5 | 5·45 | 4·00 | 0·26 | 5·33 | 1·88 | 15·47 |
| III. ... | 26 | 21·6 | 29·2 | 3·91 | 1·75 | 0·31 | 4·30 | 2·01 | 13·23 |
| IV. ... | 26 | 17·9 | 24·2 | 4·66 | 6·06 | 0·82 | 5·75 | 1·72 | 15·43 |
| V. ... | 22·8 | 25·0 | 32·4 | 7·97 | 4·43 | 0·86 | 8·85 | 2·09 | 22·19 |

The results in I. show very clearly the loss due to washing with fresh water, and indicate how essential it is to protect the gathered weed from rain. Apparently the alkalis are present as halides, as very little sulphate is washed out.

V. shows the great improvement due to its being fresh from the ocean and uncontaminated with sand. If this is a fair sample of the clean weeds of this State, it shows that our weeds are poorer in potash than the giant kelps of America, which in some cases contain much larger proportions and, on the average, run from 8 to 12 per cent. potash ($K_2O$). However, the American weeds have very little iodine, whilst the Western Australian weeds are comparatively rich in this constituent.

For comparison, the Scotch kelp ashes are marketed with anything from 5 up to 24 per cent. potash, and they average under 10 per cent. on the dry weed, so that our weeds are quite as rich in potash and richer in iodine.

One determination only was made of nitrogen, and this showed about one per cent., which is similar to the nitrogen content of other kelps.

Two samples of kelp ash were afterwards examined which had been prepared by some workers on the North Beach. They had been ashed in a billycan and were badly fused. The ashes contained 15.5 per cent. potash, and 16.6 per cent. potash; and if the samples had been carefully burned, these figures would probably have run higher.

A sample of weed received recently from Rockingham ashed easily. The ash contained 28.9 per cent. of potash, equivalent to 10.5 per cent. on the dry weed.

Several pounds of ash were extracted with boiling water and the solution evaporated to dryness. An analysis of the extract gave:—

| | per cent. |
|---|---|
| Water, $H_2O$ ... ... ... ... | 1·8 |
| Potassium chloride, $KCl$ ... ... | 57·3 |
| Sodium chloride, $NaCl$ ... ... | 19·3 |
| Sodium sulphate, $Na_2SO_4$ ... ... | 16·3 |
| Sodium carbonate, $Na_2CO_3$ ... ... | 5·6 |
| | 100·3 |

It is desirable that analyses should be made of as many species of the weeds as possible, carefully taken from the ocean and preserved from rain, and also that a survey should be made to determine where large occurrences of the weeds are available for cutting.

## Appendix II.

## THE ALUNITE DEPOSITS AT KANOWNA.

By T. Blatchford, B.A.

### *Introduction.*

The existence of the mineral alunite on the Eastern Goldfields was first determined by one of the Chemical Staff while examining a sample sent in for free assay by Mr. C. Webb. The locality of the sample was given as "near Edjudina." Natroalunite had previously (1915) been detected at Kalgoorlie.

Later on, while burning clay test-pieces in the pottery furnace, Mr. Bowley detected the presence of sulphuric anhydride, and on drawing the charge found that several of the test pieces had fused. This led to the discovery of alunite in a sample forwarded by Mr. Wyatt, of Kanowna, in answer to the official newspaper advertisements asking for samples of clays.

Alunite has also been detected in samples coming from the North Lead, Kanowna, collected by the late John Rollo.

In consequence of these discoveries I have made a personal inspection and, where possible, sampled the places at Kanowna where the mineral was known to exist. In addition, a preliminary sampling was made of any likely rock in order to try and ascertain whether the occurrence of alunite was extensive.

The following is the result of the inspection and sampling:—

1.—*Wyatt's Claim*:

Wyatt's Claim (P.A. 506) is situated on the old Shamrock Gold Mining Lease (M.A. 36), about 1½ miles South-East of Kanowna township.

The only surface workings on this claim apart from those of the old Shamrock Gold Mine, long since fallen in, are two vertical shafts, 27 and 20 feet deep. (Plate 1.)

At a depth of 24 feet in the North shaft two drives have been put in 20 feet South and 17 feet East. This mining was originally carried out in the search for white clays, both to export and for local use in the manufacture of whiting and calcimine. The clay mined for these purposes is perfectly white, very soft, and fine-grained, and practically free from grit. Up to the present only a few tons have been sent away, and most of this came from the South drive and the Western portion of the East drive. It was found that as the drive proceeded East the clay became more charged with grit, and work was stopped in that direction.

It was also noticed that under the levels, nodular masses and imperfect veins of a much harder white rock occurred, more particularly in the bottom of the South drive. Not knowing at the time that these nodules and veins were alunite, and being unsuitable for their purpose, the owners naturally avoided them as much as possible, hence little development had been done to exploit the occurrence. Subsequently a sample of the hard material was sent to this office and determined as alunite.

As the alunite is not easily distinguished from most of the clay, the samples collected by myself were broken systematically so as to find an approximate value of the deposit as a whole. The appended results demonstrate that to obtain a payable alunite product, hand-picking or sorting of some kind will have to be resorted to.

At present one has the impression that the alunite occurs in horizontal or flatly inclined veins more or less continuous with a considerable amount of sporadic nodules, varying in size from peas to several inches in diameter. In the East and West drive and in the shaft a section of one vein is well marked, and is some 24 inches wide with nodules extending over a further section of 21 inches immediately below. There is also a smaller vein in the South end of South crosscut off East and West drive, but this could not be found in the North side of the East drive.

As the shaft has been sunk in an alluvial flat, there are no outcrops. The extent of the deposit is therefore unknown, but, owing to the shallow depth, can easily and quickly be determined by systematic prospecting.

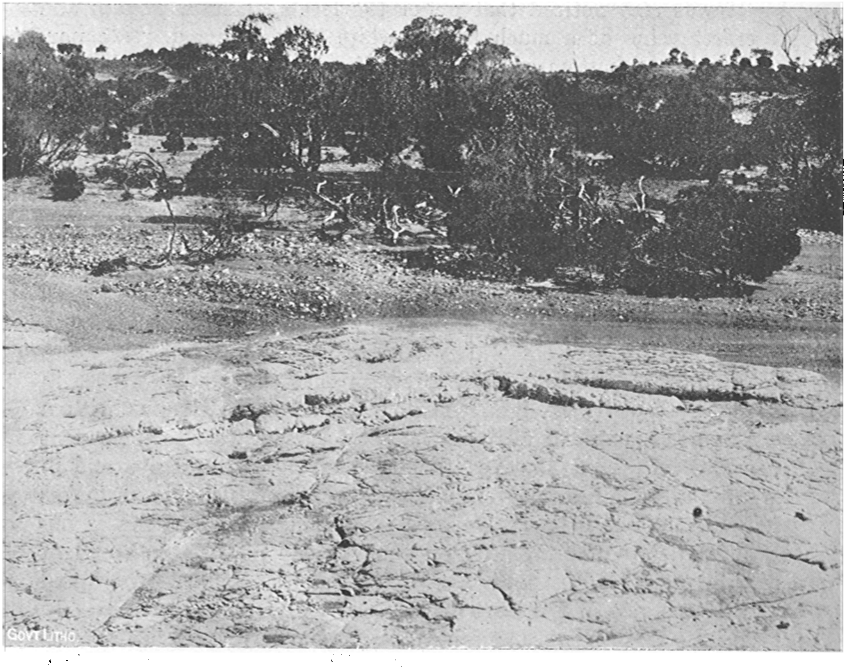
In the South shaft, which is 30 feet deep, two samples drawn from the bottom and West side yielded traces only of alunite.

*Mineral Lease* 14x.—This lease adjoins Wyatt's P.A. on the West. Two shafts have been sunk to 40 feet through surface loam and kaolin. Sporadic nodules composed of 80 per cent. alunite were met with in the bottom of the Northern shaft, but the extent of the nodules was not exposed. White veinlets, yielding 83 per cent. alunite, occur in some of the nodules. The nodules are of no great size and would not comprise a great proportion of the ore unless hand-picked.

In the bottom of the Southern shaft on this lease a vein of alunite 6 to 8 inches in thickness was intersected, which sampled 42.4 per cent. alunite. The vein has a slight Easterly dip. Sporadic nodules (consisting of 84 per cent. alunite) occur in a short West crosscut from the bottom of the shaft.

*Mineral Lease* 17x.—One shaft has been sunk on the North-East corner of this lease to a depth of 45 feet.

Fig. 3. No. 1656.

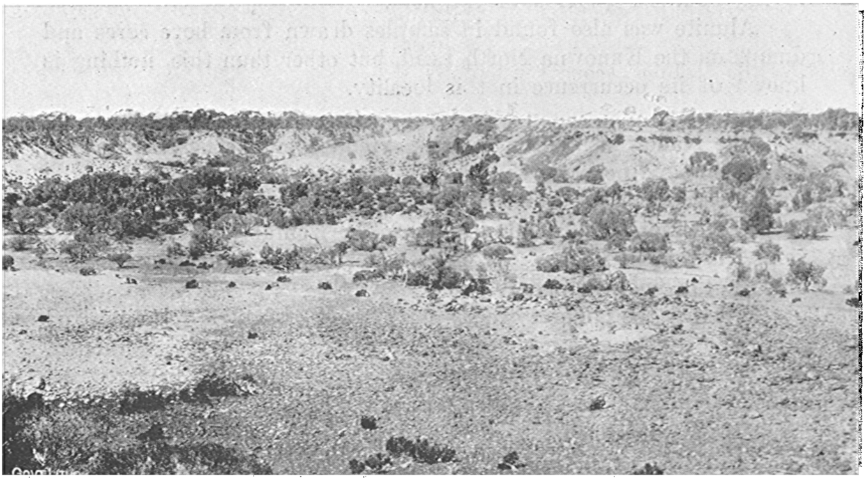


**Horizontal Vein of Alunite, 6in. wide, 6chs. N. of G.M.L. 862x, Kanowna.**

Traces of alunite were found in a white, fairly hard rock cut in the bottom of this shaft.

*Mineral Lease* 12x.—On the dump of an old shaft situated near the centre of this lease some nodules of almost pure alunite were found, in which the potash contents were in the ratio of three to one of the soda. Unfortunately, the shaft had fallen in and was inaccessible. Two other shafts along the Eastern boundary of the lease were in progress, but had not intersected any alunite veins.

Fig. 4. No. 1655.



**Breakaways N. of G.M.L. 862x, looking E., Kanowna.**

In a breakaway just to the North of this lease alunite veins have been found, but other than that they prove the occurrence of the mineral the discovery is not an important one.

Immediately to the North of P.A. 513x a shaft has been sunk to a vertical depth of 20 feet. Scattered nodules were encountered at this depth which yielded 55 per cent. alunite.

In the "breakaways" lying immediately to the North of the Government Dam (W.R. 4354), a series of samples gave traces only of alunite.

Similar results were obtained from the cliffs lying to the West of the Kanowna racecourse.

Much more encouraging results were obtained from the "breakaways" lying to the North and East of the North-East corner of G.M.L. 862x (Fig. 4). There the underlying rocks are exposed over a considerable area. They consist of coarse-grained conglomerates, grits, and a fine-grained creamy rock closely resembling a hard mudstone. The latter rock is laid bare over an area of some 4-6 chains by 10 chains.

Numerous narrow veins of alunite occur throughout this belt. Unfortunately, the veins are usually horizontal, so that their frequency cannot be determined until the deposit is exploited with shafts or bores (Fig. 3).

The encasing mudstone contains only traces of alunite when sampled apart from the veins. The veins vary from mere threads to a maximum thickness of not more than 6 inches.

A comparison of the appended results show that the potash contents of the veins in this locality are much higher than those in the Southern portion of the field.

Alunite was also found in samples drawn from bore cores and dumps on the Kanowna North Lead, but other than this, nothing is known of its occurrence in this locality.

*Summary:*

The Kanowna alunite deposits extend over a considerable area of country and occur in the sedimentary series of rocks as depicted on the accompanying plan. (Plate 2.)

The mineral is found usually in horizontal or flatly inclined veins, varying in thickness from mere threads to two feet, occurring only in the finer sediments.

Whether the mineral occurs in sufficient quantities to be worked profitably cannot at present be stated for reasons already mentioned. The possibilities and high price of potash should, however, be sufficient inducement to warrant further development.

ALUNITE AND NATROALUNITE, KANOWNA.

| Locality. | G.S.L. No. | Index No. on Plan. | Insoluble Sulphuric oxide per cent. | Calculated Alunite (Aprox.) per cent. | Total Potash per cent. | Total Soda per cent. |
|---|---|---|---|---|---|---|
| Wyatts P.A. 506 ... | 2047a | A. | ... | 99·0 | 5·62 | 3·64 |
| | 2047b | B. | ... | 67·2 | 3·34 | 2·94 |
| | 2054 | C. | 37·64 | 99·0 | 5·42 | 4·07 |
| | 2560 | 1 | 22·30 | 57·0 | 4·48 | 2·92 |
| | 2561 | 2 | 2·21 | 5·6 | ... | ... |
| | 2562 | 3 | 7·48 | 19·0 | ... | ... |
| | 2563 | 4 | 1·40 | 3·7 | ... | ... |
| | 2564 | 5 | 2·85 | 7·2 | ... | ... |
| | 2565 | 6 | 12·57 | 31·9 | 3·30 | 2·72 |
| | 2566 | 7 | 5·12 | 13·0 | ... | ... |
| | 2567 | 8 | 1·39 | 3·5 | ... | ... |
| | 2568 | 9 | ·45 | 1·1 | ... | ... |
| | 2569 | 10 | ·73 | 1·8 | ... | ... |
| | 2570 | 11 | 13·13 | 33·3 | 3·40 | 2·58 |
| | 2930 | 12 | ·22 | ·5 | ... | ... |
| | 2931 | 13 | 26·74 | 67·9 | ... | ... |
| | 2937 | 14 | ·12 | ·3 | ... | ... |
| | 2938 | 15 | 27·01 | 68·6 | ... | ... |

ALUNITE AND NATROALUNITE, KANOWNA—*continued.*

| Locality. | G.S.L. No. | Index No. on Plan. | Insoluble Sulphuric oxide per cent. | Calculated Alunite (Aprox.) | Total Potash per cent. | Total Soda per cent. |
|---|---|---|---|---|---|---|
| M.L., 12x ... | 2539 | D. | ... | 75·0 | 5·54 | 2·04 |
| | 2571 | 16 | 37·32 | 99·0 | 7·56 | 2·56 |
| M.C.1, near Water Reserve 4354 | 2572 | 17 | ·04 | trace | ... | ... |
| | 2584 | 18 | ·88 | 2·2 | ... | ... |
| | 2585 | 19 | ·04 | trace | ... | ... |
| | 2586 | 20 | ·02 | trace ? | ... | ... |
| | 2587 | 21 | ·02 | trace ? | ... | ... |
| | 2588 | 22 | ·02 | trace ? | ... | ... |
| North-west corner of Racecourse | 2573 | 23 | ·04 | trace | ... | ... |
| | 2574 | 24 | ·23 | ·6 | ... | ... |
| | 2575 | 25 | ·08 | ·2 | ... | ... |
| | 2576 | 26 | ·05 | ·1 | ... | ... |
| | 2577 | 27 | ·10 | ·2 | ... | ... |
| G.M.L., 1325 ... | 2591 | 28 | ·02 | trace ? | ... | ... |
| | 2592 | 29 | ·06 | ·2 | ... | ... |
| G.M.L., 918 ... | 1853 | E. | 1·24 | 3·1 | 3·10 | ·40 |
| | 2589 | 30 | ·54 | 1·4 | ... | ... |
| | 2590 | 31 | ·02 | trace | ... | ... |
| G.M.L., 1159 ... | 2437 | F. | 37·84 | 99·0 | 9·32 | 2·14 |
| East of G.M.L. 862 | 2578 | 32 | ·08 | ·2 | ... | ... |
| | 2579 | 33 | ·05 | ·1 | ... | ... |
| | 2580 | 34 | ·09 | ·2 | ... | ... |
| | 2581 | 35 | ·14 | ·3 | ... | ... |
| | 2582 | 36 | ·75 | 1·9 | ... | ... |
| | 2583 | 37 | 35·88 | 91·1 | 8·66 | 2·88 |
| | 2932 | 38 | 1·07 | 2·7 | ... | ... |
| | 2933 | 39 | 32·51 | 82·5 | ... | ... |
| | 2934 | 40 | 3·14 | 7·9 | ... | ... |
| | 2935 | 41 | 33·86 | 86·0 | ... | ... |
| | 2936 | 42 | 1·22 | 2·6 | ... | ... |
| G.M.L., 1134 ... | 2924 | 43 | 21·75 | 55·2 | ... | ... |
| M.L., 14x ... | 2925 | 44 | 31·23 | 79·3 | ... | ... |
| | 2926 | 45 | 32·79 | 83·2 | ... | ... |
| | 2927 | 46 | 16·70 | 42·4 | ... | ... |
| | 2928 | 47 | 33·36 | 84·7 | ... | ... |
| M.L., 17x ... | 2929 | 48 | ·18 | ·4 | ... | ... |

## ALUNITE AND NATROALUNITE, KANOWNA.

*Location of Samples.*

| Sample No. | Location. | Remarks. |
|---|---|---|
| 1 | Wyatt's—South face, south drive, bottom section | Over 24in. |
| 2 | Do. South face, south drive, top section | Over 48in. |
| 3 | Do. Cuddy in west side, south drive ... | Over 3ft. 6in. |
| 4 | Do. East side south drive, 10ft. south of shaft | Over 5ft. 6in. |
| 5 | Do. East side south drive, 15ft. south of shaft | Over 5ft. 6in. |
| 6 | Do. Across vein in shaft, south side ... | Over 24in. |
| 7 | Do. Bottom section of No. 6 ... ... | Over 21in. |
| 8 | Do. Section north of east face of east crosscut | Over 4ft. 6in. |
| 9 | Do. East face, east crosscut ... ... | Over 3ft. 6in. |
| 10 | Do. Top section of south face south drive, east crosscut | Over 4ft. 0in. |
| 11 | Do. Bottom section of No. 10, across vein | Over 24in. |
| 12 | Do. Across bottom of south shaft ... | Over 36in. |
| 13 | Do. In south drive from north shaft ... | Across vein 10in. thick |
| 14 | Do. West side south shaft ... ... | Over 36in. |
| 15 | Do. Sample of three veins in south drive from north shaft | Over 18in. |
| 16 | Nodules from dump of central shaft M.L. 12x | |
| 17–22 | From breakaways on M.C. 1, north of W.R. 4354 | |
| 23–27 | From breakaways west of Kanowna Racecourse | |
| 28–31 | From Kanowna North Lead | |
| 32–36 | From cliffs of breakaways east and north of G.M.L. 862x | Samples from finer sediments |
| 37 | Sample of broken portions of vein 120 yards east of N.E. peg, G.M.L. 862x | |
| 38 | Sample mudstone containing No. 37 ... | Over 7in. |
| 39 | Sample flat vein 70 yards south-east from 38 | |
| 40 | Yellow vein of alunite in vicinity of No. 39 | |
| 41 | Softer vein associated with No. 40 | |
| 42 | White rock outcropping near N.E. corner peg of 862x | Over 10in. |
| 43 | Nodules found in bottom of shaft on G.M.L. 1134 | |
| 44 | White nodules in north shaft, M.L. 14x | |
| 45 | White veinlets in sample 44 | |
| 46 | Alunite vein in bottom of south shaft, M.L. 14x | Over 6in. |
| 47 | Nodules in drive from bottom of south shaft, M.L. 14x | |
| 48 | Sample of bottom of shaft, M.L. 17x | |
| A. | Wyatt's P.A. 506, bottom of Shaft at 27 feet | Large lumps. |
| B. | Do. do. do. | Fines rubbed off surface of lumps |
| C. | Do. do. do. | Hard vein |
| D. | M.L. 12x ... ... ... ... ... | Picked alunite |
| E. | G.M.L. 918, North Lead ... ... ... | White clay |
| F. | Borehole on G.M.L. 1159, North Lead ... | Pebbles from clay |

N.B.—In this table samples which are numbered were collected by the Acting Government Geologist in person, those which are lettered were sent in to the Department by prospectors.

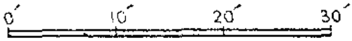
# INDEX.

BULLETIN No. 77, PLATE I

# PLAN AND SECTION OF NORTH SHAFT ON WYATT'S P.A. 506x

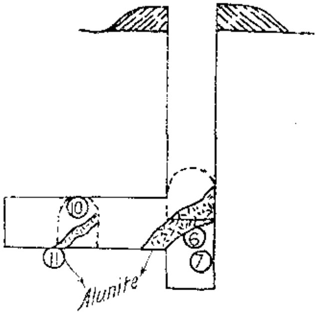
# KANOWNA.

## N. E. COOLGARDIE G. F.

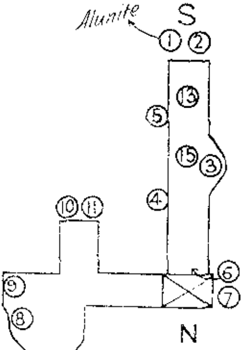


Scale of Feet.

## SECTION.



## PLAN.



The Hon. C.A. Hudson M.L.A.
Minister for Mines

Figures denote numbers of samples. ①

C.B. Kidson, del.

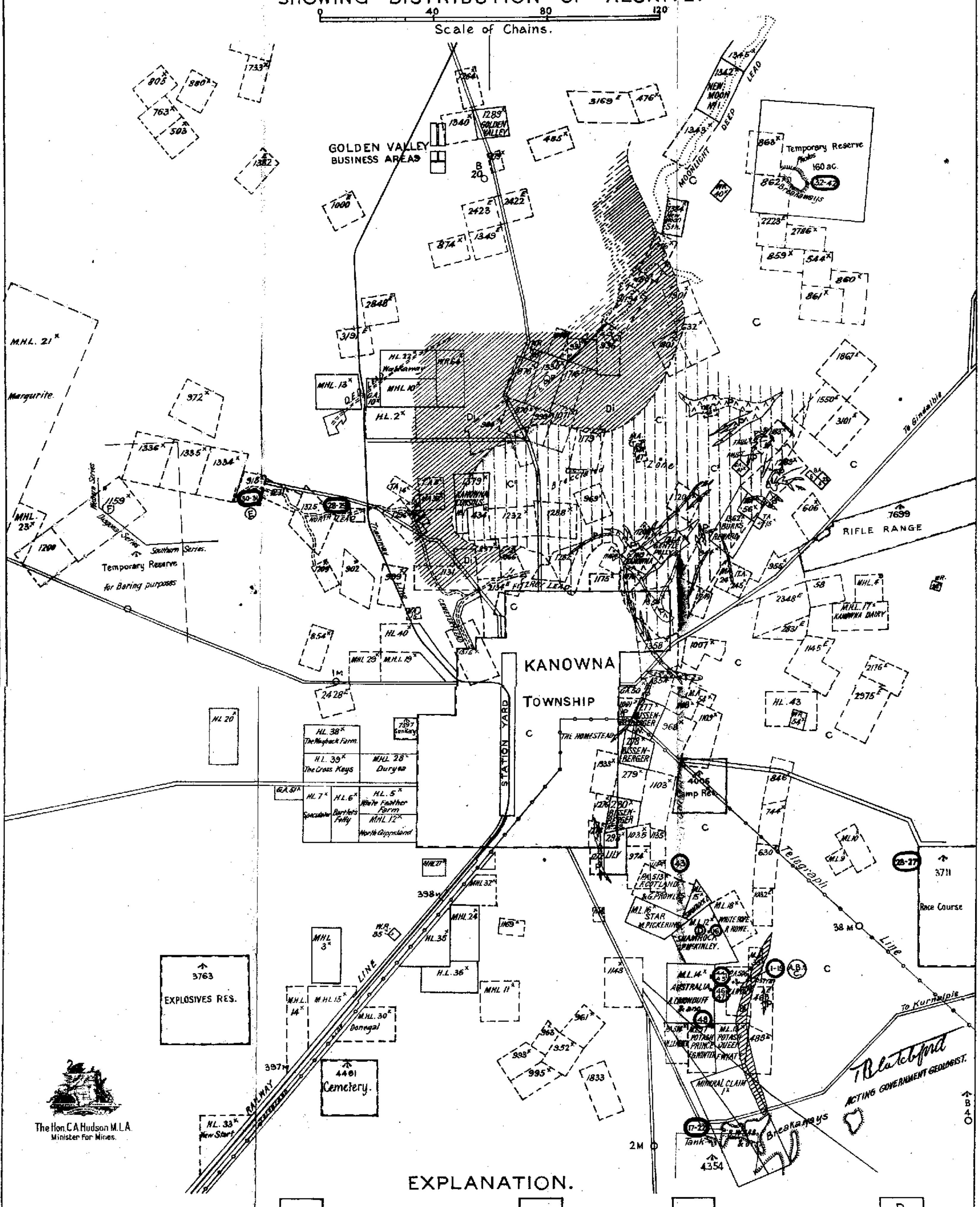
H.J. Pether, Government Lithographer, Perth, W.A.

BULLETIN Nº77. PLATE II.

# GEOLOGICAL MAP OF KANOWNA.

N. E. COOLGARDIE G.F.

SHOWING DISTRIBUTION OF ALUNITE.



T. Blatchford
ACTING GOVERNMENT GEOLOGIST.

The Hon. C.A. Hudson M.L.A.
Minister For Mines.

## EXPLANATION.

| | |
|---|---|
| Greenstones *(epidiorites, amphibolites &c.)* | Di |
| Sedimentary series, *(Conglomerates &c.)* | C |
| Brecciated sediments | C' |
| Acid eruptives, Porphyries &c. | P |
| Location of samples. | ① |

C.B. Kidson, del.

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