Agricultural Minerals

BY

LEWIS S. PRATER
FOREWORD

In the past, agriculture and the mineral industry have not had many interests in common. In fact, at various times and places, these two great segments of our Western economy have even been hostile toward each other.

In recent years, however, agriculture and the mineral industry have come to have one great common interest: fertilizer.

Mineral fertilizer is essential to the continued productivity of farm land and is being used in increasing amounts each year. For example, phosphatic fertilizer consumption in the U. S. grew from about 6.5 pounds of available P₂O₅ per capita in 1900 to 13.8 pounds in 1940 and 27.4 pounds in 1950. The available P₂O₅ applied per acre increased from 2 pounds in 1900 to 6 pounds in 1940 and 12 pounds in 1950. The U. S. consumption of potash, another mineral fertilizer, increased more than 30 times in the first half of the 20th Century.

In this Circular, Lewis Prater, of the Idaho Bureau of Mines and Geology staff, outlines the ways in which minerals and mineral products are used in agriculture; in addition, he shows the close relationship between the mineral industry and the production of phosphatic fertilizer in the Pacific Northwest.

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AGRICULTURAL MINERALS

by

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IDAHO BUREAU OF MINES AND GEOLOGY

MOSCOW, IDAHO
PHOSPHATE FERTILIZER BEING SPREAD ON IDAHO FARMLAND NEAR TWIN FALLS
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INTRODUCTION

A proper balance of minerals in the soil is required for the normal growth and development of all plant life. Under average conditions the noncultivated plant is able to obtain from the soil all of the elements that it requires for its development. When the plant dies most of the mineral elements which it extracted from the soil in growing are returned to the soil. The situation is quite different, however, with reference to farming, where plant life is commercially cultivated. In this case maximum yield is always the objective and often an accelerated rate of growth is also desirable. The necessary plant foods must be available in the soil in sufficient quantities to accomplish these results. It is also quite obvious that, when farm crops are harvested, the minerals that the plant has taken from the soil are also removed. If the process is repeated often enough, the minerals must be replaced in order to sustain crop yield. The replacement is accomplished by adding fertilizers. The ultimate sources from which most of the chemical fertilizers must be obtained are rocks or minerals from the earth's crust.

One purpose of this paper is to describe some of the industrial minerals which can be utilized by agriculture and how these minerals are processed into commercial fertilizers. The discussion will be restricted mainly to the occurrence of such minerals in Idaho.

Some minerals can be utilized as fertilizer material in their natural state; others must be processed through one or more stages before they are suitable for agricultural use. In general, the processed or manufactured fertilizers are highly soluble compounds. Their mineral content becomes available to the plants almost immediately after application to the soil, but because of their solubility their effectiveness is short lived and repeated applications are necessary. Also there is considerable evidence that over application of such fertilizers, although providing ample quantities of the element or elements which they contain, may cause an imbalance of the other plant nutrients (Keller 1951).

Another approach to the problem of adding fertilizers is the use of minerals that are less soluble and/or decompose in the soil at a slower rate (Keller 1951). Because of this property they can provide plant nutrition over a longer period of time and
there is less danger of disturbing the natural balance of other plant foods. Most of the unprocessed natural minerals that have been, or might be, utilized as fertilizer materials are in this group. In general, the response of such materials on Idaho soils has been found to be rather poor, however, and the use of the highly soluble fertilizers in small amounts is recommended as being more effective. It should also be mentioned that in some instances materials advertised as "natural fertilizers" have been found by analysis to contain less of the plant nutrient elements than the soils to which they were being applied. Whether these materials were so labeled in ignorance or with intent to defraud is immaterial in this discussion. The subject is mentioned to emphasize the fact that it is unwise to buy any fertilizer without knowing its chemical analysis.

Different plants require different minerals for optimum growing conditions and it is not the purpose of this paper to discuss this aspect of the problem. It is one that is continually under study by the various agricultural experiment stations and research organizations. Much has been learned, but the role of some of the mineral elements that are required in trace amounts is still obscure.

The fertilizer industry usually divides the plant nutrient elements into three main groups; primary, secondary and minor. It has long been known that the three principal mineral elements required for plant growth are: nitrogen, phosphorus and potassium. They are considered to be the primary fertilizer materials. Three elements that are considered to be of secondary importance to plant growth are: calcium, magnesium and sulfur. In general, the secondary elements, although used in large amounts by certain plants, are available in most soils in greater quantities than the primary three. Consequently deficiencies of the secondary elements are not as common as those of the primary three. The list of elements that are classified by the fertilizer industry as minor elements is lengthy but some that are known to be of vital importance are: iron, zinc, copper, manganese, molybdenum and boron. Many of these minor elements are, in all probability, just as important to plant growth as the primary or secondary elements but since they are required in such small amounts the rate of natural rock weathering is often fast enough to maintain them in the soil in sufficient quantities.

Some minerals are added to soils mainly as conditioners, although in some instances such compounds may act both as conditioners and as chemical fertilizers. Limestone or lime is used as a corrective on soils that are too acid, whereas sulfur tends to make a soil more acid. In most instances, however, it is uneconomic to add sulfur solely for the purpose of correcting alkalinity. As mentioned previously both lime and sulfur have value as chemical fertilizers for certain crops and areas.
Chemically inert compounds are sometimes added to soils to improve their physical properties. The light-weight rock and mineral materials such as pumice and expanded vermiculite might be included here. They are helpful to tightly compacted clayey soils that otherwise are impervious to moisture and aeration. These compounds add virtually nothing to the soil in the way of plant food. Economic factors usually prohibit the application of such materials for field use but expanded vermiculite is widely used in greenhouses.

Gypsum is another mineral that is quite commonly used as a soil conditioner.

**PHOSPHATE ROCK**

Phosphate rock is by far the most important of the industrial minerals in Idaho that are useful to agriculture. Phosphate rock is a term that can mean any rock having a high phosphorus content, but as generally used, it means the sedimentary rocks that contain significant quantities of one or more of the secondary calcium phosphate minerals.

The Idaho deposits of phosphate rock are a part of the Phosphoria formation of Permian age. The area in which outcrops of the Phosphoria occur starts at a point about 50 miles east of Salt Lake City and extends in a direction just west of north through Wyoming and Idaho to near Garrison, Montana. Other outcrops are also found farther north in Canada in the vicinity of Banff. More recently, significant deposits of phosphate rock have been recognized in Nevada, and this state is now also generally included in the area known as the western phosphate field.

It is a well established fact that by far the largest reserves of phosphate rock in the United States are in the western field and that the largest and most economically attractive of these deposits is in Idaho. Estimates on actual tonnages that are available vary because many of the deposits have not been completely explored and also a difference of one or two percent P₂O₅ in the designation between ore and waste can make a huge difference in ore tonnage. It is sufficient to state that the known reserves are ample to meet any anticipated demand for many, many years.

The geology of the Phosphoria formation has been described in considerable detail by a number of writers. Persons who are interested in pursuing this subject are referred to the following: McKelvey, 1949; Mansfield, 1927; Baker, et al., 1949; Thomas and Krueger, 1946. Each of these authors lists a bibliography on the subject.

The phosphate rock that is of economic interest is contained in the lower phosphatic shale member of the Phosphoria formation.
This lower shale member is a series of interbedded phosphatic shales, mudstones, dolomites and/or limestones totalling about 180 feet in thickness. The rock that is minable under present conditions consists of two and in some places three beds near the bottom of the member and a single bed toward the top of the member. Not all of the beds are minable, or even present, at all of the operating properties. In any instance, only a small fraction of the total 180 feet constitutes ore.

In general appearance phosphate rock may range from light brown to almost jet black. The black color is due to the presence of carbonaceous material. The texture of the rock may range from fine-grained, soft shaly to the more characteristic oolitic or granular material.

The phosphate-bearing mineral in sedimentary phosphate rock is a secondary fluorapatite. The theoretical formula for fluorapatite is 3CaO·CaF₂·3P₂O₅, but the mineral in phosphate rock is more complex with numerous substitutions in the apatite molecule. The hydroxyl and carbonate anions are the most important of these. Several names have been suggested for this mineral, Collophane has probably been most widely used, but more recently the name francolite has been gaining wider acceptance (Emigh 1958). The exact terminology is not important in this discussion.

The phosphorus that is present in raw phosphate rock is virtually insoluble in most soils and therefore it is only in exceptional cases that any significant benefit is derived from adding raw rock as a fertilizer. Reacting raw phosphate rock with the proper quantity of a mineral acid converts the phosphorus into a form that is available to plant life. Sulfuric acid is the almost universal choice due mainly to its low cost and availability. Depending upon the quantity of acid used, the tricalcium phosphate in the raw rock is converted to either dicalcium phosphate, monocalcium phosphate or phosphoric acid. Liquid phosphoric acid (H₃PO₄) and monocalcium phosphate (CaH₄(PO₄)₂·H₂O) are water soluble and the phosphorus is highly available to plants. Dicalcium phosphate (CaHPO₄·2H₂O) is soluble in citrate solution and is usually considered somewhat less available for plant growth.

There are two principal grades of commercial phosphate fertilizer: superfosphate and concentrated (double, triple or treble) superfosphate. The manufacture of superfosphate will be discussed first.

Superphosphate is made by mixing finely ground raw phosphate rock with approximately the theoretical amount of acid to produce monocalcium phosphate. Assuming the composition of the raw rock to be simple tricalcium phosphate, the reaction is:

\[
\text{Ca}_3(\text{PO}_4)_2 + 2\text{H}_2\text{SO}_4 + 5\text{H}_2\text{O} \rightarrow \text{CaH}_4(\text{PO}_4)_2 \cdot \text{H}_2\text{O} + 2(\text{CaSO}_4 \cdot 2\text{H}_2\text{O})
\]
It is seen from the above equation that superphosphate is a hydrated mixture of monocalcium phosphate and calcium sulfate (gypsum). Commercial superphosphates always contain some dicalcium phosphate and a little unreacted tricalcium phosphate, because the reaction does not proceed to a single end product. It is essential that relatively high grade phosphate rock be used in the manufacture of superphosphate because the phosphorus content of the raw rock is diluted almost one half by the addition of the acid. Manufacturers of superphosphates usually specify that the raw rock which they use contain a minimum of 31.5 percent P₂O₅. Some specifications are based on BPL (bone phosphate of lime) content. To convert percent P₂O₅ to BPL multiply by 2.18, for example 31.5% = 68.7% BPL. Commercial superphosphate will contain 16-20% P₂O₅.

Concentrated superphosphate (double, triple or treble) is made by reacting phosphate rock with phosphoric acid to produce monocalcium phosphate. The composition of the phosphorus-bearing compound in concentrated superphosphate is therefore the same as in ordinary superphosphate but it is not diluted with gypsum in the concentrated super product.

The manufacturing process for concentrated superphosphate involves two principal steps. In the first step, raw phosphate rock is reacted with enough sulfuric acid to produce phosphoric acid and gypsum. The acid is separated from the gypsum by filtration; the gypsum usually going to waste unless it can be marketed as a by-product. The second step in the process is the reaction of more raw rock with the phosphoric acid. The equations for the two reactions are:

(1) \( \text{Ca}_3(\text{PO}_4)_2 + 3\text{H}_2\text{SO}_4 + 6\text{H}_2\text{O} \rightarrow 2\text{H}_3\text{PO}_4 + 3(\text{CaSO}_4 \cdot 2\text{H}_2\text{O}) \)

(2) \( \text{Ca}_3(\text{PO}_4)_2 + 4\text{H}_3\text{PO}_4 + 3\text{H}_2\text{O} \rightarrow 3(\text{CaH}_4(\text{PO}_4)_2 \cdot \text{H}_2\text{O}) \)

The final monocalcium phosphate product is allowed to cure and it is then pelletized to make a product with physical properties suitable for handling in farm drills. Commercial concentrated superphosphates contain 40-48 percent P₂O₅.

Figure 1 illustrates the manner in which the manufacture of phosphate fertilizers from western rock is dependent upon the mining of metallic sulfide minerals. All of the sulfuric acid consumed by the fertilizer manufacturers in the west is a by-product of the smelting of sulfide ores. In all instances the smelters are located near the producing mines and each acid plant is an integral part of the smelter.

Until recently, the universal practice has been to ship raw phosphate rock to the acid, rather than the reverse and consequently two of the three fertilizer plants shown on the map are located adjacent to metallic smelters. The one exception to the
FIG. 1 SKETCH MAP SHOWING LOCATIONS OF PRINCIPAL PHOSPHATE ROCK MINING AND PROCESSING FACILITIES, AND THE FLOW OF MATERIALS IN THE MANUFACTURE OF FERTILIZER AND ELEMENTAL PHOSPHORUS IN THE WESTERN FIELD
rule is where acid manufactured in the Coeur d'Alene mining dis-
trict of Idaho is shipped to southern Idaho for use in a fertili-
zzer plant, and there are indications that this practice may be
changed in the not too distant future.

Figure 1 also illustrates the importance of another phase
of phosphate rock mining and processing not directly connected to
agriculture—the production of elemental phosphorus in electric
furnaces. This is the most rapidly expanding phase of Idaho's
phosphate industry and it now consumes well over one half of the
raw phosphate rock mined in the state. Although currently essen-
tially none of the elemental phosphorus is being converted into
fertilizer compounds, it may some day constitute the starting
point for the manufacture of high analysis phosphate fertilizers.

There are a number of other, less commonly known fertilizer
products manufactured from phosphate rock. Some have been made
on only an experimental basis while others have had limited com-
mercial application. Among those which might be mentioned are:
(1) defluorinated phosphate rock, (2) phosphate rock-magnesium
silicate slag or glass, (3) calcium metaphosphate, (4) potassium
metaphosphate, (5) ammonium phosphate, (6) nitro-phosphates,
obtained by reacting phosphate rock with nitric acid. Ammonium
phosphate and the nitro-phosphates are becoming increasingly
important as fertilizer materials because they are sources of
both nitrogen and phosphorus.

In Idaho, phosphate fertilizers are needed generally on all
of the irrigated soils in the southern part of the state (Smith
and Baker 1952). It is required in rather large amounts by the
legumes, sugar beets and potatoes, with smaller amounts needed
by the grains and grasses.

NITRATES AND NITROGENOUS COMPOUNDS

Nitrogen is the plant food which is added in largest amounts
on Idaho farms (Painter and Baker 1937). It is recommended for
all crops except the legumes. The two forms of nitrogen which
are available to plant life are the ammonium (NH₄⁺) and the
nitratre (NO₃⁻) ions. Numerous chemical compounds carrying one or
both of these ions are marketed as commercial nitrogen fertili-
zers. Anhydrous ammonia (NH₃) and organic nitrogen are also used
as fertilizers, the nitrogen becoming available after conversion
either the ammonium or nitrate form.

The place of manufactured nitrates and ammonia is so well
established in the fertilizer industry that the natural nitrates
have little chance of competing in the west. Deposits of natural
nitrate salts occur widely distributed throughout the world, but
those in northern Chile are the only ones that have ever accounted
for any significant production. In recent years, even the own-
ers of these deposits have found it increasingly difficult to
compete with the synthetic nitrogen compounds. Almost all of the
nitrogen fertilizers used in the United States at the present

time are manufactured. The earth's atmosphere is the one unlimi-
ted source of nitrogen but to become available to most plants

this nitrogen must be "fixed" into soluble compounds. The effec-
tive duration of these compounds in the soil is short and seasonal
additions are usually required to maintain crop yields.

Numerous small deposits of nitrate salts are known to occur
in Idaho (Ross 1941) but almost all of them are cave deposits
where nitrogen of organic origin has accumulated. None are large
and none have ever been commercial producers—except possibly
for very restricted local use. Certainly there is nothing to
indicate that they will ever be of commercial value.

Nitrogen does not occur in any of the industrial minerals
and rocks that are slowly decomposed by weathering and consequently
there is no rock source from which it might be obtained on a long
range, sustained basis.

POTASH

Potassium-bearing compounds, especially those in fertilizers,
are commonly known as potash. More strictly defined, potash is
the chemical compound potassium oxide (K₂O). Potassium oxide
does not occur as a natural mineral, but it is a convenient common
denominator to which the potassium content of all natural potas-
sium-bearing minerals and manufactured compounds may be referred.

Potassium is one of the most abundant elements found in the
earth's crust but almost all of it is present in silicate miner-
als such as the orthoclase and microcline varieties of feldspar
(K₂O·Al₂O₃·6SiO₂) leucite (K₂O·Al₂O₃·4SiO₂) and muscovite mica
(K₂O·3Al₂O₃·6SiO₂·2H₂O). These minerals are common constituents
of many types of rock and consequently they are present in varying
amounts in the soils derived from the weathering of these
rocks. As measured by man's timetable, however, the rate at
which the potassium in silicate minerals becomes available to
plant life is extremely slow. Because of this, none of the potas-
sium silicate minerals can be used as primary sources of potassium
in fertilizers.

The saline deposits which contain numerous water soluble
salts of potassium, sodium, magnesium, etc., are virtually the
sole source of the potassium used in the manufacture of fertili-
zers. According to the Mineral Yearbook for 1963, 95 percent of
the potassium recovered from these salts is sold for agricultural
use. About 90 percent of our total domestic production of potas-
sium salts comes from the deposits near Carlsbad, New Mexico,
with the Searles Lake, California deposits and miscellaneous other
sources accounting for the remainder. No deposits of potash salts
are known to occur in Idaho.
The names and chemical compositions of the five potassium-bearing minerals that occur in most abundance in the saline deposits are: (Smith 1949).

- Sylvite: $\text{KCl}$
- Langbeinite: $2\text{MgSO}_4 \cdot \text{K}_2\text{SO}_4$
- Polyhalite: $\text{K}_2\text{SO}_4 \cdot \text{MgSO}_4 \cdot 2\text{CaSO}_4 \cdot 2\text{H}_2\text{O}$
- Kainite: $\text{MgSO}_4 \cdot \text{KCl} \cdot 3\text{H}_2\text{O}$
- Carnallite: $\text{KCl} \cdot \text{MgCl}_2 \cdot 6\text{H}_2\text{O}$

Sylvite has the highest $\text{K}_2\text{O}$ content (63.2% equivalent) of all of the above minerals and it is the most important commercial source of potash. The trend in the industry in recent years has been toward high analysis materials to the extent that about 90 percent of current mill shipments analyze 60-62% $\text{K}_2\text{O}$ equivalent.

**SULFUR**

Elemental sulfur is not as widely used as an agricultural mineral as gypsum but it does have some application. Microorganisms in the soil oxidize elemental sulfur quite rapidly to form $\text{SO}_3$ which combines with water to form sulfuric acid. Besides being added directly to the soil, sulfur is also an important constituent in many spray and dusting compounds used for insect control and in treating various plant diseases. Much of the sulfur used in these applications ultimately finds its way into the soil.

The only occurrence of native sulfur in Idaho that has received any serious attention is the series of deposits near Soda Springs in Caribou County. These deposits and possible metallurgical treatment of the material have been briefly described in the literature (Richards and Bridges 1911, Staley and Prater 1945). The native sulfur is present in a fault breccia and it is associated with limestone, quartzite and tuff; the latter being the most abundant gangue material.

According to Richards and Bridges a considerable amount of sulfur was produced from the Soda Springs deposits in 1901 and 1902, but the operations failed to make a profit and the plant was dismantled in 1910. Some production was recorded during World War I but since then the deposits have been idle.

The extent of the deposits is not accurately known because virtually no development work has been done on them. It has been estimated, however, that there may be one million tons of material containing 10 percent sulfur available (Richards and Bridges 1911). Under present economic conditions these deposits cannot be utilized as ore for the production of elemental sulfur and any use which may be found for the sulfur in the agricultural field will probably be limited to the application of the raw material.
Freight costs would prohibit shipping such low grade material any great distance and consequently the market would be confined to what could be consumed locally.

GYPSUM

Agricultural gypsum is still sometimes known by its old name of "land plaster." It performs several functions when added to soil. Primarily it is the common additive used to supply sulfur needed as plant food by the legumes and certain other plants. Ammonium sulfate is equally as effective for supplying sulfur as a plant food, but it is generally considered uneconomic to use ammonium sulfate for the legumes which do not require nitrogen. Adding gypsum to tightly compacted, clayey soils improves the physical condition of these soils. Gypsum is also sometimes used in attempts to reclaim soils that are alkaline due to the presence of sodium, eg., "black alkali soils." The function of the gypsum is to replace the sodium on the soil colloids with calcium; the sodium being converted to sodium sulfate which can be leached out. Gypsum does not alter soil acidity to the extent that elemental sulfur does.

Gypsum for agricultural use is obtained from two principal sources. As mentioned previously, single superphosphate is approximately 50 percent gypsum and this fertilizer is an important source of it. Natural gypsum is the other principal source. A potential source which may some day be of importance, particularly in Idaho, is the by-product gypsum produced in the manufacture of concentrated superphosphate.

Gypsum occurs in nature mixed with various impurities. Most of the impurities are relatively insoluble and they are not objectionable in material for agricultural use except that they dilute the sulfur content of the gypsum. Because of this, gypsum rock having a lower calcium sulfate content than that required for making wallboard, etc., the largest use of gypsum, is often acceptable for agricultural purposes.

In Idaho agricultural gypsum is needed principally on the farms in the northern part of the state where it is recommended for growing the legumes (Smith and Baker 1952). Some is used in southern Idaho for soil reclamation.

Gypsum is known to occur in a number of localities in Idaho. The deposits that have received the most attention are the ones along the Snake River about 20 air miles north of Weiser. The gypsum deposits in this area are not continuous. They consist of a series of lenses of varying thickness and purity. Some lenses as much as 30 feet thick have been observed (McDivitt 1952). The principal impurity is a greenish chloritic material, much of it being scattered through the gypsum as irregular nodules. Preliminary tests on this gypsum rock indicate that it can be upgraded
by crushing and screening (Prater 1947) but the beneficiated product contains several percent acid insolubles and little more than two thirds of the gypsum is recovered.

A smaller but more accessible deposit of gypsum is located three miles east of Montpelier, on the south side of Montpelier Canyon (Stone 1920). A prospect hole in the deposit indicates that the gypsum is quite pure and that the bed is at least four feet thick. The lateral extent is not known.

Many other occurrences of gypsum in Idaho consist of thin beds of the material interbedded with shales, limestones, etc. Deposits of this type have no economic significance in the foreseeable future.

Under present economic conditions it seems unlikely that the gypsum from any of the Idaho deposits can compete with that from other sources for use in the manufacture of wallboard and for plaster. As the demand for building materials in the northwest grows the picture may change but now it appears that the only market for Idaho gypsum is in the agricultural field. Actually there has been some intermittent production of gypsum from the Weiser deposits with most, if not all, of the product being sold for agricultural use. The U. S. Bureau of Mines reports (Area Report B-61) that the Rock Island Gypsum Co. operated their property for a portion of 1957. No production figures are available, but the total amount of gypsum produced from the Weiser deposits to date has been small. There is no recorded production from any other deposit of gypsum in Idaho.

Consumption of agricultural gypsum in the United States has increased from 79,000 tons in 1933 to a high of 866,000 tons in 1952. Due mainly to a decrease in the financial encouragement offered to farmers for using gypsum under the Agricultural Conservation Program, the consumption dropped in 1953 and again in 1954 to 663,000 tons. The product had an average value of $3.77 per ton in 1954. (North and Jansen 1954). Agricultural gypsum is a low priced commodity which cannot be shipped far from its source—a situation which should encourage the development of local sources for Idaho agriculture.

LIMESTONE

Limestone and lime are terms that are sometimes confused with one another. Limestone is a sedimentary rock that is composed mainly of the mineral calcite (calcium carbonate). When limestone is calcined it decomposes to form quicklime (calcium oxide). The equation for this reaction is:

$$\text{CaCO}_3 + \text{heat} \rightarrow \text{CaO} + \text{CO}_2$$

Quicklime is a perishable commodity because it has a great affinity for water, including the water vapor in the air. It is converted
to hydrated lime (calcium hydroxide) quite rapidly unless stored in a sealed container. The equation for this reaction is:

$$\text{CaO} + \text{H}_2\text{O} \rightarrow \text{Ca(OH)}_2 + \text{heat}$$

Natural limestones may range in composition from almost pure calcium carbonate to rock that contains numerous impurities in significant quantities. Magnesium carbonate is probably the most common associate, and limestones that contain appreciable amounts of magnesium are termed dolomitic limestones. When the amount of magnesium is about equal to the amount of calcium the rock is called dolomite. For these dolomitic rocks, magnesium may be substituted for calcium in the equations that were written above for the calcining and hydration processes.

Either raw limestone rock or hydrated lime may be used for agricultural purposes. Both accomplish the same results, although raw limestone rock is much slower acting. The principal function of both is to neutralize excess acidity. Secondary they are a source of calcium for plant food and those that are dolomitic also supply magnesium.

In Idaho the situation with reference to limestone is one of abundant supply and minor use. Because the demand has been small, most of the known deposits have not been developed to any extent. Limestone is known to occur in Idaho, however, reasonably close to all of the farming areas and it will be readily available if or when a demand for agricultural lime arises. In the northern part of the state large deposits occur near Bayview and Lakeview on Pend Oreille Lake. Farther south there are numerous deposits in Nez Perce, Lewis and Clearwater Counties. Many of the limestones in this area are dolomitic, which detracts from their value for some purposes but should not be harmful for agricultural lime; in fact it should be beneficial because magnesium is known to be an important plant food (Johnson 1935). In the southeastern part of the state, near the Utah and Wyoming borders, immense beds of limestone occur in the sedimentary rocks of the region. Limestone is less abundant in south central and southwestern Idaho but scattered deposits have been reported from throughout the area.

ROCK DUSTS AND METALLURGICAL WASTE PRODUCTS

As the need for fertilizers continues to grow, untried mineral sources and new methods of providing them may become expedient. Long-range soil improvement by the application of rock dusts has been receiving increasing attention in recent years especially in areas having acid soils. The value of such practices on alkaline soils is more doubtful (Keller 1951). It is in such approaches to the problem that the geologist or minerals engineer is in a position to work with the soils technologist.

The use of rock dusts containing some of the potassium silicate minerals is one possibility that has been suggested.
Leucite, which is found principally in extrusive volcanic rocks, is probably the most desirable of all of the potassium silicate minerals in this respect (Smith 1949), but its occurrence is not widespread. Glassy volcanic rocks such as pumice and volcanic ash which may contain 25% $K_2O$ occur in abundance in Idaho. They weather quite rapidly, as measured in geologic time, but there is considerable doubt as to whether the potassium would be liberated on Idaho soils at a rate fast enough to have any significant value as plant food.

Some of the waste products from metallurgical operations may have potential value in the field of agriculture. Slags from smelting operations have received considerable attention as possible sources of fertilizer materials. Basic slag obtained from the smelting of iron ores, both blast furnace and open hearth, have probably received the most attention in this respect (Jacob 1953).

Slags are artificial mineral glasses consisting mainly of calcium and iron silicates but they also contain numerous other metallic oxides, depending mainly upon the type of material that is being smelted. Almost all slags contain some magnesia and many contain minor quantities of manganese, sodium and potassium. Lead blast furnace slag usually carries a significant quantity of zinc. Slag from the basic open hearth smelting of iron ores contains from 6 to 12 percent $P_2O_5$ making this product especially attractive for agricultural use on acid soils. Because all slags are mainly glass they decompose much more rapidly than the natural crystalline rocks, even though the chemical analysis of the rock and of the slag may be essentially the same.

The flue gases from most smelting and roasting operations carry dust and fume containing numerous chemical elements that are essential to plant life. Unfortunately fume obtained from the smelting of metallic ores often contains other elements that are poisonous to animal life or toxic to plants. Because of this and because the fume and dust products are recycled to recover the valuable constituents it does not seem that the final residue from the fume and dust treatment at metallic smelters will ever have much value as fertilizer material. Dusts from the processing of nonmetallic minerals may have more promise. It is known that potassium is concentrated in the dust recovered from cement kilns and from the electric furnaces that reduce phosphate rock to elemental phosphorus. The latter product also contains several percent $P_2O_5$. The possibility of utilizing the dust from cement kilns has been considered (Jacob 1953) and certainly the dust from phosphate furnaces should be equally valuable.

The use of mill tailings as a source of sulfur and miscellaneous metallic elements is a remote possibility that might be suggested. Deposits of metallic sulfide minerals are found in many localities in Idaho; in fact, deposits of these minerals have
been the foundation of our state's mineral industry. In milling these ores to recover the marketable values, the iron sulfide minerals, pyrite, pyrrhotite, etc., are rejected as a tailing product whenever possible. In some instances these reject products carry a significant quantity of sulfur and when exposed to atmospheric conditions the sulfur is oxidized quite rapidly. Because it is never possible to recover all of the valuable mineral in any milling operation, many mill tailings contain minor quantities of elements, such as zinc, required in trace amounts by plant life. As far as the author knows, mill tailings have never been utilized as a combination source of agricultural sulfur and trace elements and perhaps they would not be suitable. Certainly they could not be used without testing for the presence of elements that might be toxic to plant life and shipping costs would limit the radius over which such low analysis materials could be distributed. They do, however, constitute a product that is already finely ground and available at the mill site for very low cost.

MINOR ELEMENTS

Elements that are required by plant life in minor quantities are most conveniently supplied as high analysis salts, usually mixed with other fertilizers for addition to the soil. There is little likelihood of substituting materials of lower analyses unless such materials have some auxiliary value as fertilizers or soil conditioners.

Copper is added as the sulfate (blue vitreol) and zinc is usually supplied in similar form, although metallic zinc, zinc oxide and zinc chloride are used for some applications.

Boron deficiencies in soil are remedied by adding borax, which is a natural mineral but nevertheless a high-analysis compound. No deposits of borax are known to occur in Idaho. Tourmaline, which is a complex silicate mineral containing boron, is much too insoluble to be considered as a boron fertilizer, although soils derived from the weathering of rocks containing tourmaline as an accessory mineral are seldom deficient in boron. In Idaho, boron deficiencies have been detected in the soils in the northern part of the state (Colwell and Baker 1939).

Manganese is an essential element in plant growth, but the amount required is small and in most soils there is enough of it present to meet all requirements. When deficiencies occur they are corrected by additions of manganese sulfate. Naturally occurring manganese ores (oxides) have been tried as fertilizers with generally unsatisfactory response (Johnson 1935). If it were possible to use the natural manganese oxides for this purpose it might constitute a market for some of the "off grade" manganese ore deposits that occur in several localities throughout Idaho. The principal deposits are in Bannock and Butte Counties with others known to occur in Bear Lake, Lemhi, Washington, Adams, and
Shoshone Counties. In general the deposits are too low grade to be utilized as manganese ore but constitute a considerable reserve if a use could be found for such material.

CONCLUSION

The use of fertilizers on U. S. farms has been increasing at a rapid rate and almost certainly this trend will be continued, probably at an accelerated rate. In the western United States in particular, farm land which up to now has been productive without the use of fertilizers is gradually becoming depleted in some elements and these will have to be replaced if the land is to be kept in production. Furthermore farming is becoming a highly scientific and competitive enterprise in which only the efficient operator can survive. These factors should contribute to a fuller utilization of some of Idaho’s industrial minerals as fertilizers and soil conditioners.

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BIBLIOGRAPHY

The references which are listed below supply additional information on the subject of agricultural minerals, their occurrences and uses. The list includes the references that are cited in the text. It is in no means a complete bibliography on the subject because such a list would be far too long for a report of this nature.


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