Evaluation of Phosphate Resources in Southeastern Idaho

by

J. Dan Powell

State of Idaho
Cecil D. Andrus, Governor

Idaho Bureau of Mines and Geology
R. R. Reid, Director
EVALUATION OF PHOSPHATE RESOURCES IN SOUTHEASTERN IDAHO

Prepared as a part of a State wide Survey of the Mineral Resource Potential in Idaho

by

J. Dan Powell

IDAHO BUREAU OF MINES AND GEOLOGY
MOSCOW, IDAHO
# TABLE OF CONTENTS

<table>
<thead>
<tr>
<th>Section</th>
<th>Page</th>
</tr>
</thead>
<tbody>
<tr>
<td>ABSTRACT</td>
<td>1</td>
</tr>
<tr>
<td>INTRODUCTION</td>
<td>1</td>
</tr>
<tr>
<td>Location</td>
<td>1</td>
</tr>
<tr>
<td>Ownership of Phosphate Lands</td>
<td>1</td>
</tr>
<tr>
<td>Purpose and Extent of Investigation</td>
<td>2</td>
</tr>
<tr>
<td>Previous Work</td>
<td>5</td>
</tr>
<tr>
<td>Methods and Approaches</td>
<td>6</td>
</tr>
<tr>
<td>Acknowledgments</td>
<td>7</td>
</tr>
<tr>
<td>STRATIGRAPHY</td>
<td>9</td>
</tr>
<tr>
<td>Grandeur Tongue of Park City Formation</td>
<td>9</td>
</tr>
<tr>
<td>Phosphoria Formation, Meade Peak Member</td>
<td>9</td>
</tr>
<tr>
<td>Lower Waste Shales</td>
<td>10</td>
</tr>
<tr>
<td>Lower High Grade Bed</td>
<td>11</td>
</tr>
<tr>
<td>Lower Ore Shales</td>
<td>11</td>
</tr>
<tr>
<td>Middle Waste Shales</td>
<td>12</td>
</tr>
<tr>
<td>Upper Ore Shales</td>
<td>12</td>
</tr>
<tr>
<td>Upper High Grade Bed</td>
<td>13</td>
</tr>
<tr>
<td>Upper Waste Shales</td>
<td>13</td>
</tr>
<tr>
<td>MINERAL RESOURCE ANALYSIS</td>
<td>17</td>
</tr>
<tr>
<td>General Statements</td>
<td>17</td>
</tr>
<tr>
<td>Reserve Calculations</td>
<td>18</td>
</tr>
<tr>
<td>Evaluation Situations</td>
<td>20</td>
</tr>
<tr>
<td>Idaho Phosphate Potential</td>
<td>20</td>
</tr>
<tr>
<td>State Land and Revenues</td>
<td>25</td>
</tr>
</tbody>
</table>
TABLES

Table 1. Phosphate Reserves in Southeastern Idaho . . . 19
Table 2. Total Phosphate Mined on Public and Indian
        Lands from 1963–1971 . . . . . . . . . . . . . . . 26

ILLUSTRATIONS

Figure 1. Index and Location Map . . . . . . . . . . . . . . 3
Figure 2. Township Map Showing Phosphate Reserves . . 4
Figure 3. Stratigraphic Section . . . . . . . . . . . . . . . 14
Figure 4. Structure Section, Mable Canyon . . . . . . . 21
Figure 5. Structure Section, Dairy Syncline . . . . . . . 22
Figure 6. Structure Section North of Trail Canyon . . . 23
Figure 7. Structure Section near Johnson Creek Road . . 24

SELECTED BIBLIOGRAPHY . . . . . . . . . . . . . . . . . . 28
ABSTRACT

Idaho's abundant phosphate reserves occur in the Phosphoria Formation which is widely distributed over much of the southeastern part of the State. Previous estimates of the phosphate potential in Idaho are considered volumetrically accurate, but are considered impractical relative to projected mining activity in Idaho during the next 50 years. Phosphate mining in Idaho is an old and established industry. Consequently, much information on the geology and mining of phosphate-bearing rocks is already available in the published record. This information, combined with raw data collected from mining companies, on-location measurements made in 1973, and projected increased demands and costs comprise the basis of revised tonnage estimates of phosphate rock potentially and feasibly mineable in the next 25 to 50 years. Figures presented here conservatively indicate that about 450 million short tons of ore-grade phosphate rock can be mined before the year 2025, assuming only moderate increases in mining activity and market potential.

With somewhat less than 20% of total national production, Idaho annually ranks third or fourth among the nation's phosphate producers. However, within 10 years the production of eastern phosphates is expected to drop considerably as reserves in Florida and Tennessee are depleted. The Western Phosphate Field of Idaho, Montana, Wyoming, and Utah appears to contain about 70% of the nation's phosphate reserves, and significantly, southeastern Idaho has about 80 to 90% of the easily accessible western reserves. With the great increase in demand for phosphate products, and the declining reserves in the east, Idaho phosphate production should increase steadily in the foreseeable future provided that realistic land management practices are implemented.

Although most of the land containing mineable phosphate rock in southeastern Idaho belongs to the Federal Government, royalties from mining operations provide direct payments of hundreds of thousands of dollars to the State Treasury each year. These monies, along with those obtained from leases and eventual mining on State land, could provide millions of dollars in revenue over the next few decades.
INTRODUCTION

Location

Economically valuable phosphate deposits in the Western Phosphate Field occur locally over some 130,000 square miles in southeastern Idaho and adjacent Utah, Wyoming, and Montana. Of the billions of tons of potentially mineable phosphate rock in this large area, Idaho appears to hold about 90% of the economically extractable deposits. These deposits are centered in Caribou County, with significant extensions in Bannock, Bear Lake, Bingham, Bonneville, Clark, Fremont, and Teton Counties (Figure 1). The richest deposits in Idaho occur mainly within the boundaries of the Caribou National Forest, with deposits of lesser extent in the Targhee and Cache National Forests, and on the Fort Hall Indian Reservation.

Ownership of Phosphate Lands

Most of the land containing valuable phosphate deposits in southeastern Idaho is owned by the Federal Government. However, substantial amounts of phosphate lands adjacent to and near Federal holdings are owned privately or by the State of Idaho. Included in the State holdings are almost 125,000 acres, mostly of Idaho public school indemnity lands, on which the U.S. Government has retained all of the phosphate rights. In addition the State holds mineral rights on about 12,000 acres of land owned by the Federal Government. In some cases private individuals have been granted patents on land previously owned by the United States, but for which the Federal Government still retains the phosphate rights.

During the early 1900's the U.S. Government determined that natural phosphate rock, among other mineral products, should be protected and preserved as a part of the essential mineral reserves of the country. Since 1908 large blocks of the Federal phosphate lands have been withdrawn from mining for classification studies. Having been studied and classified as "phosphate" or "non-phosphate" lands (Figure 2) most of these lands have since been restored to use as public domain, and phosphate mining rights are available under the Mineral Leasing Act of 1920. Classified Federal phosphate lands in Idaho include more than 276,000 acres out of a total of slightly over 300,000 classified acres in the Western Phosphate Field (Service and Popoff, 1964, p. 71; and Service, 1966, p. 178). A more complete review of this aspect of the history of Idaho phosphate ownership is in Brunelle (1967, p. 259-263).

As of November, 1973, about 90,000 acres of land in Idaho are held under lease or prospecting permits for phosphate rock. The following table summarizes in rounded figures the approximate distribution of leases and permits.
Phosphate Holdings

<table>
<thead>
<tr>
<th></th>
<th>Acres</th>
<th>%</th>
</tr>
</thead>
<tbody>
<tr>
<td>Federal leases</td>
<td>46,000</td>
<td>51</td>
</tr>
<tr>
<td>Federal prospecting permits</td>
<td>19,000</td>
<td>21</td>
</tr>
<tr>
<td>Patented land (fee)</td>
<td>9,000</td>
<td>10</td>
</tr>
<tr>
<td>Indian leases</td>
<td>4,000</td>
<td>5</td>
</tr>
<tr>
<td>State leases</td>
<td>12,000</td>
<td>13</td>
</tr>
<tr>
<td></td>
<td>90,000</td>
<td>100</td>
</tr>
</tbody>
</table>

Data provided by Mr. Gordon C. Trombley, Commissioner, Department of Public Lands, State of Idaho; compiled by Mr. Edward W. Middlemist.

Purpose and Extent of Investigation

This investigation of the phosphate reserves in Idaho was begun in response to the needs of the State, and that of industry and its relationship to land use planning agencies. The present study is only a part of the first year's effort by the Idaho Bureau of Mines and Geology to review the mineral resource potential in Idaho. Although the mining industry is not the single most important industry in the State, Idaho has a long history of providing the nation with significant quantities of mineral materials. Considerable revenues accrue to the State each year from the mining industry. For example, the minerals marketed from Idaho mines in 1973 reached a value in excess of $130,000,000. An additional 80 to 90 million dollars were paid to employees of the mining industry in Idaho during the same period.

In order to assess the potential for utilization of Idaho's mineral wealth, many studies such as the present one are needed to provide the basic quantitative information on the location, extent, and if possible, the potential reserves of the various mineral resources. Recently the Federal Government has moved to require that the various managing agencies shall produce land use plans covering all public domain. At this writing, the State of Idaho is also attempting to produce a state-wide land use plan. If these plans are to be finalized in the best interest of the State, a large amount of basic mineral resource data must be made available to planners. Otherwise many areas that are perhaps best suited to mining and other compatible land uses cannot be adequately accommodated in a broad land use plan.

Accordingly, this report is presented mainly for evaluation of phosphate potential in Idaho. To that end the report is primarily directed at State and Federal planning agencies and those who do not already possess broad information on available reserves and their locations. The writer has attempted to show the quantity of phosphate rock which can feasibly be mined, and the general location of these reserves. A detailed study on a lease by lease basis is a task well beyond the scope of this study. Therefore, mining companies that are already involved in recovering phosphate rock and associated by-products in Idaho will find this report too broad for their use in everyday operations and planning. It should be pointed out that a detailed report covering the whole spectrum of phosphate mining in Idaho has been published by the U.S. Bureau of Mines (Service, 1966) which includes a different and older
Figure 1. Index and Location Map Showing Phosphoria Formation Outcrop Pattern.
Figure 2. Township Map Showing Federal Phosphate Reserve and Caribou National Forest.
viewpoint on phosphate reserves. Service's report presents reserves of phosphate rock in four grades available by both surface and subsurface methods. These figures are considered fairly accurate for that classification system, but the outlook for mining is changing. The present report attempts to give a more realistic view of how much of each of two grades of phosphorite can be mined in the next few decades, assuming a continuing increase in demand and a corresponding increase in mining operations.

Previous Work

Phosphate mining in Idaho is a well established industry. Consequently, much information on the geology and mining of phosphate-bearing rocks is already available in the published record. Several reports published in the early 1900's record the stratigraphy and general geology of southeastern Idaho, and most of these treat some aspect of the Phosphoria Formation and its phosphate potential. The most comprehensive of these publications is that of Mansfield (1927) in which general geology, geography and mineral resources in southeastern Idaho are described and mapped.

Phosphate production in Idaho increased greatly after World War II and subsequent to the War the U.S. Geological Survey initiated a thorough study of Federal phosphate lands and the chemistry and distribution of phosphate-bearing rocks. Notable among these published accounts are those of Sheldon, McKelvey, Swanson and others (see bibliography). In 1954 the U.S. Geological Survey published a bibliography of the geology of the Western Phosphate Field (Harris, and others, 1954) in which all previous work is cross-indexed by authors, geographic areas and subjects.

In 1956 and in 1959 McKelvey and others published details of the regional stratigraphy of the Phosphoria Formation and equivalent units in the Western Phosphate Field. Cressman and Gulbrandsen (1955), Gulbrandsen and others (1956), and Cressman (1964) provided detailed geologic maps of parts of the rich phosphate areas in Caribou and Bear Lake Counties. The reports issued by the Idaho Bureau of Mines and Geology (McDivitt, 1956) and (Savage, 1961) are at least partly concerned with phosphate mineral resources in southeastern Idaho. In the middle 1960's all of the previously gained knowledge of the general geology, stratigraphy and mining of phosphate-bearing rocks in the Western Phosphate Field was usefully compiled and summarized in several major publications. The Intermountain Association of Geologists, 15th Annual Field Conference Guidebook (Hale, 1967a) provided a broad look at the whole problem of phosphate occurrence, distribution, exploration, and recovery. About the same time a series of five reports was published by the U.S. Bureau of Mines (Service and Popoff, 1964; Popoff and Service, 1965; Service, 1966; Coffman and Service, 1967; Service and Peterson, 1967) which contain by far the most comprehensive picture of the phosphate industry in the Western Phosphate Field. In this series (especially Service, 1966, part 9, Idaho) the Bureau of Mines has compiled information on the history of phosphate mining in Idaho, geology and distribution of phosphate deposits, reserves, land ownership, lease locations, projected trends in the phosphate industry, and an extensive bibliography and appendix.
Finally, the Idaho Bureau of Mines and Geology (Day, 1973) has published a paper dealing with trends in the phosphate industry in Idaho. This paper describes the various mining, milling and manufacturing operations and discusses transportation, marketing and future of the industry in Idaho.

Methods and Approaches

Many of the critical factors regarding the exploration, mining, processing, transportation and marketing of phosphate rock and products have recently been adequately considered (Service, 1966; Day, 1973). Therefore most of the effort in preparation of the present report has been directed toward determining the amount of phosphate rock that can be feasibly mined over the next few decades. To that end much information on thickness, grade and lateral extent of surface and near subsurface phosphate rock has been compiled from published reports, from mining company files, and by direct outcrop measurements. The writer spent approximately two months in southeastern Idaho visiting and describing nearly all of the important phosphate occurrences.

Aside from collecting data on thickness, grade and extent of the deposits, the major problem has been to make realistic judgments of the extent of extractable reserves. Mining methods, topography, geologic conditions (structure and configuration of the deposits), and amount of overburden and waste rock to be removed during the mining operations have been considered in making the final estimates of reserves.

Due to the broad scope of this study a simplified method of reserve calculation is used, within which establishment of the final tonnage figures are made according to the various extraction difficulties noted in each area. Specifically, the following factors are considered in arriving at the basic numbers used in reserve calculations.

. Thickness and grade of individual phosphatic beds.
. Thickness of individual waste strata in the prospective interval.
. Strike length of the prospective strata.
. Average down-dip mining width at each major locality.
. Volumetric amount and type of overburden to be removed.
. Topographic control of access to various deposits.

In order to protect any competitive advantage held by the various mining companies that provided data for this report, the reserves have been reported by townships, or in a few cases by groups of townships (Table 1). Within the core of the phosphate producing area, each township contains at least two different leases.
Acknowledgments

To a considerable extent, any success in the present study is directly related to the full cooperation and assistance of many persons connected with the phosphate industry in Idaho, and to the staff of the Idaho Bureau of Mines and Geology. The many persons associated with the several mining companies, who gave needed counsel, provided guidance through their various mining operations, and allowed access to important information in their files, are too numerous to mention individually. In lieu of such a list, the following companies are acknowledged as providers of significant contributions of data, for which the writer and the Bureau of Mines and Geology are especially grateful: Agricultural Products Company, F.M.C. Corporation, Monsanto Chemical Company, J.R. Simplot Company, and J.A. Terteling Company.

Much of the field work was conducted on Federal lands managed by the U.S. Forest Service. The writer acknowledges with thanks the staff of the Caribou National Forest in providing camping space, planimetric maps and complete cooperation in discussions of land use plans.

Special thanks are due Leonard J. Garrand, consulting mineral engineer, Salt Lake City, Utah, for discussions on the general subject of phosphate reserve estimation. In spite of the considerable counsel received from various individuals during the course of this study, the writer takes complete responsibility for the results. Finally, it is a pleasure to acknowledge John W. Buffa, a graduate student at the University of Idaho, who gave (without pay) a month of his time in assisting the writer in the field.
Sedimentary and igneous rocks ranging in age from Precambrian to Cenozoic crop out in southeastern Idaho. All of these rocks have been previously described by various workers, beginning with Mansfield and various associates, (1911-1952) who are mainly responsible for the application of stratigraphic names and descriptions given to many of the Paleozoic and Mesozoic sedimentary units in the area.

Because of the special nature of this report, only the details relevant to the Phosphoria and adjacent formations are included in this section (Figure 3). For further regional information on the Phosphoria Formation, the reader is referred to McKelvey and others (1959) and Hale (1967a).

The Phosphoria Formation of Permian age is divisible into three members, from oldest to youngest: Meade Peak Phosphatic Shale, Rex Chert, and an upper, unnamed cherty shale member. Virtually all of the phosphate mined in this area is in the Meade Peak Member, and mining operations are continually forced to contend with the essentially non-productive units adjacent to the Meade Peak. The unit most commonly underlying the Meade Peak from Bonneville County southward to the Utah State line is the Grandeur tongue of the Park City Formation (McKelvey and others, 1967). Where the Grandeur tongue is absent, the upper sandy unit of the Wells Formation is in direct contact with the Meade Peak Member (Mansfield, 1927, p. 72; and McKelvey and others, 1967, p. 15). In any undisturbed section of the Phosphoria the Meade Peak Member is overlain either by the Rex Chert Member or more rarely the cherty shale member.

Grandeur Tongue of the Park City Formation

The Grandeur tongue of the Park City Formation underlies the Meade Peak phosphatic shale in most of the exposures in southern Bonneville, Caribou and Bear Lake Counties. In this area the unit consists of interbedded gray, fossiliferous cherty dolomite, reddish to brownish gray silty dolomite, and cherty dolomitic limestone. The Grandeur tongue reaches an approximate maximum thickness of about 150 feet, but is absent locally. The typical thickness is between 70 and 80 feet. In fresh, more completely dolomitized sections, bedding is not distinct, but prolonged weathering brings out the definite thin-beded aspects. Locally, a very thin ( < .5 foot) phosphorite bed occurs in the Grandeur tongue. The contact between the Grandeur and the overlying Meade Peak is abrupt but apparently conformable. In most sections the Grandeur overlies the distinctly yellowish gray sandy limestone of the Wells Formation.

Phosphoria Formation, Meade Peak Member

The Meade Peak phosphatic shale member is the basal unit of the Phosphoria Formation. The member ranges in thickness from 60 to over 200 feet in southeastern Idaho. In Caribou County, the average thickness is about 180 feet. Sections containing much less than 150 feet of Meade Peak are
almost always thinned by faulting. The member is poorly exposed in most areas owing to its weak resistance and its tendency to promote vegetal cover. On the semi-arid hillslopes of much of southeastern Idaho, carbonate units below the Meade Peak and the cherty units above are not normally covered by heavy plant growth. Thus, the outcrop of the Meade Peak commonly stands out as a 200 to 400 feet wide belt of standing timber or seral brush.

The Meade Peak Member contains the only economically extractable phosphate rock found in southeastern Idaho. Fortunately, outcrops of the Member are numerous in much of the area owing to the arcuate belt of generally north trending folds and thrust faults (Eardley, 1967, p. 35). Caribou County and the surrounding Caribou National Forest hold the greatest areas of Meade Peak outcrop. Here the Meade Peak is exposed repeatedly in the flanks of asymmetrical folds. Typically the outcrops are soil covered and actually occur as shallow strike valleys between ridges of the more resistant adjacent units.

Generally the Meade Peak Member is composed of a lower phosphatic shale sequence, a thick middle sequence of shale with minor phosphate, and an upper sequence of phosphatic shale and thin phosphorite. Details of each rock type found within these three sequences in a complete section of Meade Peak are described below.

Hale (1967b, p. 150-153) suggested a rather detailed set of bed designations for the Meade Peak Member which has either been adopted by some mining companies or has been generally recognized by the phosphate mining industry. In all cases the individual companies use bed designations that fit their own properties and mining situations. For purposes of this report on phosphate reserves the writer found it convenient and efficient to lump together some of the rock types. Comparison of the Hale (1967b) terminology and that used in this report is in Figure 2.

Seven aggregate stratigraphic intervals in the Meade Peak are used in compiling reserve tonnage and waste shale figures. In ascending order these seven units are: lower waste shales, lower high grade ore, lower ore shales, middle waste shales, upper ore shales, upper high grade ore, and upper waste shales (Figure 2).

Lower Waste Shales

The lower waste shale interval has at its base a black nodular phosphorite, ranging in thickness from 0.2 to 0.4 foot, and containing abundant fish scales and other fossil material. This is the "fish scale marker" bed of various authors. The bed persists over most of the present phosphate producing areas in southeastern Idaho. Although this basal unit normally contains high P₂O₅ values (> 31%), it is rarely taken in mining operations because of its thinness and its vertical isolation from other potential ore horizons. The bed is included in the lower waste interval.
Above the basal thin phosphorite in the lower waste interval is a sequence of brown shaly mudstones which ranges in thickness in unfaulted sections from 4 to 7 feet. This interval is present in all sections visited by the writer, although at many localities the mudstone contains several thin carbonate beds. The $P_2O_5$ value of this unit is normally less than 10%. The contact between this mudstone and the overlying phosphorite is sharply gradational, and in weathered sections there is a distinct color change from lighter below to much darker brown above.

**Lower High Grade Bed**

The lower unit of the "footwall" or "lower" ore zone, here called the lower high grade bed is the single most important and persistent phosphorite unit in the Meade Peak Member. This dark brown to black coarsely pelletal phosphorite is commonly light ashy gray when weathered. The lower high grade bed averages about 5.5 to 6 feet in thickness over the area, and persists from Bear Lake to the Centennial Mountains. The average $P_2O_5$ content of this bed is more than 31%, with an upper limit of over 36% in a few sections. The lower high grade bed in many sections is overlain by one or more thin carbonate beds. In sections where these carbonates are not present, the high grade unit passes upward into shaly pelletal phosphorite of the lower ore shale horizon.

**Lower Ore Shales**

The lower ore shale is a complex unit containing pelletal shaly phosphorite, phosphatic shale, carbonaceous shale, and carbonate-rich beds. The average aggregate thickness of the unit in unfaulted sections is around 40 feet in Caribou County. The lowest bed (or beds) is locally called the "caprock limestone". When present it is composed of 4 feet or less of dark brown argillaceous dolomite or dolomitic limestone. The caprock typically contains considerable phosphate, with the $P_2O_5$ content ranging up to about 25%, depending on the amount of leaching and secondary concentration. In some mining operations the caprock is taken as ore. In this report the caprock limestone interval is commonly included in gross reserve calculations for the lower ore zone.

Beds above the caprock interval of the lower ore shale ("B" bed of Hale, 1967b) are typically pelletal phosphatic shales or shaly phosphorite. These beds are dark brown, soft, and more fissile than the higher grade beds below. The $P_2O_5$ content in beds just above the caprock limestone typically ranges from about 22% to a high of about 30%, averaging around 26.5%. These figures are fairly persistent over the core of the phosphate area in southeastern Idaho. These middle beds of the lower ore shale range in thickness from less than 10 feet to over 25 feet. The top of these beds is commonly marked by a limestone interval called the "false cap". However, this limy section is not always present and when that is the case, thickness measurements of the phosphatic interval below are highly interpretive.
The false cap interval of the lower ore zone is commonly a series of dark brown shales and argillaceous limestone or dolomite beds, averaging about 8 feet in combined thickness. Although distinct carbonate beds are not always present, a calcareous interval is demonstrable unless faulting has eliminated that part of the section. At a few localities leaching has enriched the P₂O₅ content in the false cap beds so that they are taken as ore. However, the average P₂O₅ content is consistently below 10%. In sections where thick beds of limestone are absent, the same interval contains calcareous, carbonaceous, and weakly phosphatic shale and mudstone.

Phosphatic shale and phosphorite units lying above the false cap interval form the uppermost beds of the lower ore shales. These beds, designated "C" by Hale (1967b) are mostly phosphatic mudstones containing pellletal phosphorite and soft dark brownish gray shale units. Thin discontinuous carbonate beds and nodules are characteristic of this upper interval of the lower ore horizon. Laterally this stratigraphic interval persists over most of southeastern Idaho, and its thickness ranges from less than 5 feet to about 18 feet. In Caribou County the average P₂O₅ content of these beds is about 22%, but locally the percentage reaches a high of near 28%. Most mining operations take these beds for consumption as "mill shales", or for blending with other mudstones as feed for beneficiating units. This unit grades upward into the less phosphatic middle waste shales.

Middle Waste Shales

The middle waste shale section lies above the lower ore interval, and contains only a few thin phosphorite beds. The section consists predominately of dark grayish brown to brown silty mudstone and shale, with local concentrations of carbonaceous matter and discontinuous beds of calcareous rock. A few thin phosphatic shales occur within the interval, but they are too thin to be economically recovered. The average P₂O₅ content in the entire middle waste section is less than 10%.

Thicknesses of the middle waste shales range from 25 to 135 feet in undisturbed sections, and average around 90 feet in the area northeast of Soda Springs. Generally in the western part of southeastern Idaho this waste shale interval is thin and silty, becoming thicker and more argillaceous to the east. The eastward thickening seems to be at the expense of the lower part of the upper ore shales.

In most mining situations the middle waste section must be stripped and removed to waste piles outside of the intended mining area. Where beds are nearly flat-lying removal of these shales is necessary to reach the lower ore horizons. However, in a few locations where dips are more nearly vertical, islands of middle waste shales may be left standing, providing excavation depths are not great.

Upper Ore Shales

The upper ore shales consist of dark brownish gray phosphatic and
carbonaceous mudstone and shale, and finely pelletal phosphorite. These units are generally soft and locally calcareous, and lie in sharp gradation above the middle waste shales. The upper ore shale zone persists all across southeastern Idaho and is productively significant at a few localities. Northwest of Soda Springs the upper ore shales reach a maximum thickness of about 40 feet. East and north of Soda Springs these same beds are thinner, having a maximum thickness of about 27 feet. Average $P_2O_5$ values in the upper ore shales lie between 16 and 26% with only a few localities having significant thicknesses of phosphatic shale of high grade quality. However, mining and ultimate blending of these lower grade shales with higher grade rock is common practice.

Locally the upper ore shales contain considerable uranium, vanadium and other rare elements (Love, 1961), especially in the more carbonaceous facies to the south. Most of these trace elements are contained within the pelletal phosphate (oolites) in the higher grade phosphorite (C. Knowles, personal communication, 1973). In the carbonaceous shales the trace elements seem to be concentrated in the organic matrix.

Upper High Grade Bed

In most sections a thin upper phosphorite bed is present just above the upper ore shales. In some areas these two intervals are separated by a thin (about 2 feet) light brown silty clay bed. The upper high grade bed is a relatively hard, coarsely pelletal, black argillaceous phosphorite that weathers to brownish gray or ashy gray. This unit reaches a maximum thickness of about 7 feet in one or two localities, but averages only slightly over 2 feet throughout. At numerous localities the upper high grade bed is not well developed, and is not mined as high grade rock. However, its interval commonly contains high $P_2O_5$ values and is mined along with adjacent lower grade shales in order to increase the overall $P_2O_5$ content of the upper ore horizon. The phosphorous content recorded a percent $P_2O_5$ everywhere exceeds 20%, and averages slightly over 24%. Some thin beds containing over 31% $P_2O_5$ are known. In most mining situations the whole upper ore horizon is taken together as feed for electric furnaces or benefication units.

Upper Waste Shales

This uppermost unit of the Meade Peak Member is brownish gray to medium brown, moderately hard and fissile silty shale and muddy siltstone. Locally the upper waste shales are slightly siliceous near the top. The upper waste interval also includes a very thin (< 0.5 foot) black, pelletal to nodular phosphorite bed, much like that at the base of the Meade Peak Member. The average $P_2O_5$ content of the upper waste interval is less than 5%. The total stratigraphic thickness of these beds generally decreases from west to east across the area, having a maximum of 27 feet northwest of Soda Springs and a minimum of 16 feet to the southeast. In the phosphate producing areas northeast of Soda Springs the average thickness is about 18 feet.
Figure 3. Stratigraphic section of part of the Phosphoria Formation and the underlying Park City Formation, showing bed designations used in this report.
The contact between the upper waste shale of the Meade Peak Member and the overlying Rex Chert Member of the Phosphoria is abrupt. At most localities the uppermost thin, nodular phosphorite bed of the Meade Peak lies directly below hard nodular chert or cherty shale. Locally the upper phosphorite bed is silicified.
MINERAL RESOURCE ANALYSIS

General Statements

Service (1966) determined that almost 6 billion tons of phosphate rock of all grades remained to be mined in Idaho. This figure is based upon calculated volumes available for surface mining and for underground mining to a depth of 100 feet below entry level (Service, 1966, p. 7). This figure also includes over 1.5 billion tons of low grade phosphatic shales (10 to 18% P₂O₅), most of which cannot normally be mined at a profit without further increases in beneficiation technology and further process cost reductions. Rock of this quality is not included in the reserve estimates presented here.

At this time there are no underground mines operating in Idaho. Twenty to thirty years ago, most of the phosphate mining was conducted with underground methods, but open-pit operations have replaced the more expensive and less efficient underground mines. Because of the competition and relatively low profit operations involved, little underground mining is expected in the next 50 years, or until the best of the easily accessible surface-mineable deposits are depleted. However, certain isolated deposits having other more favorable aspects, such as very high quality rock, may indeed be mined by underground methods. These deposits notwithstanding, the 6 billion ton figure of Service (1966) is not a practical estimate of mineable reserves in Idaho. Service’s (1966, p. 10) surface-mineable reserve figures are probably high for the two highest grades of ore reported, and excessively high for the remaining grades, assuming mining and processing methods do not change drastically. This is not to say that these tonnages do not exist, but that abundant quantities of more easily accessible ore are available.

Manufactured phosphate products are mostly consumed as fertilizer, detergent, mineral supplements, and in a variety of other industrial uses. Two general processing methods are utilized in the initial stages of the manufacture of these products. Much of the raw material is utilized in the first method which pulverizes, beneficiates and treats without chemically decomposing the original phosphate minerals. Most of the products of this type of physical processing are consumed directly as fertilizer. High and moderately high grade phosphate rock (> 25% P₂O₅, depending on the rock) is required in this type of operation. The second method involves reduction of the phosphate compounds to elemental phosphorous in an electric furnace. The phosphorous is then used in the manufacture of phosphoric acid from which a variety of by-products is made. Medium grade phosphatic shales (18 to 26% P₂O₅, depending upon blending or beneficiation) are normally required for this process which utilizes feed averaging from 24 to 25.5%.
Reserve Calculations

In estimating the practical reserves for the two major processes, two categories of potential phosphate ore are reported: (a) short tons of high grade phosphate rock containing more than 31% P₂O₅; and (b) short tons of medium to high grade ore shales averaging about 25.5% P₂O₅. The high grade rock commonly occurs at two levels (lower high grade and upper high grade). These are reported separately where the grade is lower than the desired level for electric furnace processing. Therefore, the presence of the upper high grade strata, even in thin beds, is significant. When present, these high grade beds effect a corresponding increase in the mineable ore section at any given locality.

Reserves of phosphate ore and estimated volume of waste shales, all from the Meade Peak phosphatic member of the Phosphoria Formation are shown in Table 1. The first two columns of Table 1 show the township and range locations of the estimated reserves. The next three columns show the reserves estimated in millions of short tons. The lower and upper high grade beds are listed separately, along with the ore grade shales. The last column shows the volume of in-place waste beds (in millions of cubic yards).

Data on thickness of individual beds in the Meade Peak were selected from published work, company files, and from original measurements collected by the writer. The second dimension (lateral extent, or strike length) required for volume and tonnage calculations was measured directly from maps or obtained by interview with various mining company officials. When strike lengths were measured from geologic topographic maps the writer made certain judgments relating to the open-pit mining feasibility along strike. Accordingly, the total strike length in each township was reduced substantially where structural and topographic situations were found to be deleterious to efficient mining. Many of these reductions were originally determined from direct field observations. No attempt has been made herein to report calculated strip ratios in determining mining feasibility. However, certain areas of Phosphoria outcrop that are plainly beneath excessive overburden were correspondingly reduced in length for calculation purposes.

After making a considerable number of calculations of strip ratios and observations in the field and from detailed geologic maps, an overall average down dip mining width of 250 feet was selected for the third dimension in the volumetric estimate. The 250 feet figure represents the writer's best estimate of mining width averaged throughout the effective length of the exposures. No attempt was made to consider depth of weathering, which in any mining situation partially controls the grade of the ore at various depths. Explanations of some of the evaluation situations (Figures 3-6)
Table 1

High quality phosphate reserves in the Meade Peak Member of the Phosphoria Formation in southeastern Idaho. Tonnages expressed in millions of short tons available by surface mining. Further explanation in text.

<table>
<thead>
<tr>
<th>Location</th>
<th>Waste Shales Million Cubic Yards</th>
</tr>
</thead>
<tbody>
<tr>
<td>Township-S</td>
<td>Range-E</td>
</tr>
<tr>
<td>4</td>
<td>40-43</td>
</tr>
<tr>
<td>5</td>
<td>38-40</td>
</tr>
<tr>
<td>6</td>
<td>42</td>
</tr>
<tr>
<td>7</td>
<td>44</td>
</tr>
<tr>
<td>8</td>
<td>7</td>
</tr>
<tr>
<td>9</td>
<td>44</td>
</tr>
<tr>
<td>10</td>
<td>44</td>
</tr>
<tr>
<td>42</td>
<td>42</td>
</tr>
<tr>
<td>43</td>
<td>32.94</td>
</tr>
<tr>
<td>44</td>
<td>1.18</td>
</tr>
<tr>
<td>45,46</td>
<td>3.7</td>
</tr>
<tr>
<td>43</td>
<td>2.24</td>
</tr>
<tr>
<td>44</td>
<td>4.98</td>
</tr>
<tr>
<td>45,46</td>
<td>8.01</td>
</tr>
<tr>
<td>44</td>
<td>1.46</td>
</tr>
<tr>
<td>45</td>
<td>3.68</td>
</tr>
<tr>
<td>44,45</td>
<td>1.80</td>
</tr>
<tr>
<td>Totals</td>
<td>53.61</td>
</tr>
</tbody>
</table>

Total reserves available by surface mining, all grades shown: 450,770,000 tons
are presented in the succeeding section of this report.

Calculated estimates were made for the ore grades and the waste shales according to the following method.

Stratigraphic thickness in feet \times \text{strike length in feet} \times 250 \text{ feet} \times \text{down-dip mining width} = \text{volume (cubic feet)} \div 27 = \text{volume in cubic yards}.

\text{Cubic yards} \times \text{density of material in tons/cubic yard} = \text{calculated ore reserve tonnage (short tons)}.

Standardized average densities expressed in tons/cubic yard include:
(a) high grade phosphate rock - 2.42; (b) ore shales - 2.25; and (c) waste shales - 2.1.

Evaluation Situations

Four structural cross-sections showing possible, or typical, mining situations have been selected to demonstrate the numerous circumstances involved in actual removal of ore, and in arriving at final judgments on practical reserve figures. Figures 3 through 6 are designed and drawn to scale using hanging wall and foot wall pit slopes of 40°. Some situations allow considerably steeper pit slopes, and therefore correspondingly greater mining depths within the economic stripping ratio employed for that property. Stripping ratios in each of the figures is from 3:1 to 3.5:1 (in place cubic yards of overburden: ton of ore). Explanation of symbols and horizontal scale for all figures are shown in Figure 3.

Idaho Phosphate Potential

Conservatively estimated, southeastern Idaho probably contains about 450.77 million short tons of phosphate ore that can conceivably and practically be mined in the foreseeable future. At present mining rates, nowhere near that tonnage will be mined, but if demand and prices for western phosphates rise according to projection in the next few years, a considerable portion of the easily accessible phosphate rock could be extracted. In the writer's opinion, a quantity equal to the above figure will probably be mined within the next 25 to 50 years. However, by that time technological advances should allow the utilization of more low grade ores. This would substantially increase the reserve figures for any given location, and assure that much smaller amounts of land area would be disturbed than would be expected if only high grade ores were removed. If demand and technology continue to increase greatly beyond the next 40 to 50 year period, then the total surface-mineable reserve figures suggested by Service (1966) could be an accurate estimation of available phosphate.

In some areas eastern phosphate is being heavily depleted by mining. In populus Florida, the present national production leader, the environmental movement has severely shortened the reserve outlook. Without well con-
Figure 4. Section of Phosphoria Formation and adjacent units in Mabie Canyon, Sec. 10, T 8 S, R 44 E, Caribou County. Redrawn in part from Cressman and Gulbrandsen, Pl. 27, Sec. A-A'.
Figure 5. Section of Phosphoria Formation and adjacent units in the north end of Dairy Syncline, Sec. 19, 20, T 9 S, R 44 E, Caribou County. Redrawn in part from Cressman and Gulbrandsen, 1955 Pl. 27, Sec. E-E'.
Figure 6. Section of Phosphoria Formation and adjacent units north of Trail Creek Canyon, Sec. 13, T 8 S, R 42 E, Caribou County. Redrawn in part from Gulbrandsen and others, 1956, Pl. 1, Sec. A-A'.
Figure 7. Section of Phosphoria Formation and adjacent units south of the Johnson Creek Road in Sec. 8, T 9 S, R 43 E, Caribou County. Redrawn in part from Gulbransen and others, 1956, Plate 1, Sec. C-C'.
ceived land use plans, the same fate could await the Idaho phosphate situation. With the rapid decline of accessible phosphate in the producing areas of the eastern U.S., a major shift to western phosphate utilization is forecast. World-wide, only the United States and parts of North Africa and Russia contain truly significant phosphate reserves. This situation leaves the Western Phosphate Field in a favorable position to become the major western hemisphere source of phosphate rock and by-products in the foreseeable future. Idaho probably contains 80 to 90 percent of the known high quality, easily accessible open-pit reserves in the Western Phosphate Field.

In addition to the reserves indicated in Table 1, scattered areas in southeastern Idaho contain phosphorite that could not be feasibly mined by surface methods. In these areas much less than 10% of the phosphorite would be mined open-pit, and those only in conjunction with underground operations. Some of these areas have histories of surface and underground mining, such as the deposits near Hot Springs, Paris, Bloomington, Montpelier, and Georgetown in Bear Lake County, and the Centennial Mountains deposits in Clark County. Many of these areas have already been depleted, at least for surface mining, and mined tonnages have been subtracted from estimated reserves. The total underground reserves of all grades in these areas may exceed 50 million tons, but lack of information precludes practical estimates.

In spite of the higher costs involved in underground operations, other favorable conditions may eventually allow some of the potential subsurface deposits to be mined. Among these factors are increased market prices, proximity to rail transportation, additional market potential for raw phosphate ore shipped outside of Idaho, local very high grade phosphorite, and high uranium-vanadium content (for by-product use) in the Phosphoria Formation (Love, 1961). Any of these factors could cause the onset of underground mining with phosphates mined directly or recoverable as a by-product in the mining of minor but important elements.

State Land and Revenues

The State of Idaho annually receives a considerable amount of revenue from rents and royalties related to variously owned phosphate lands. As seen in the earlier section on ownership, the pattern of ownership of phosphate lands and mineral rights is complicated. The following statements describe the sources of the various revenues related to phosphate lands in Idaho.

---

1 Much of the information herein was compiled by Mr. Edward W. Middlemist acting for the Commissioner of Public Lands, Mr. Gordon C. Trombley.
1. **Rents and royalties from leases on land where the State owns the mineral (phosphate) rights.** The annual rent is computed on a sliding scale with the first year rent at 25¢ per acre, the second and third years at 50¢ per acre, and $1.00 per acre thereafter, including renewals.

   A minimum royalty of 75¢ per acre is paid to the State from the leases, beginning 5 years after the execution of a lease. Minor exceptions exist in a few leases. In addition, a direct royalty payment of 25¢ per dry net ton of mined ore is made to the State by the lessee.

2. **Income from U.S. Government owned phosphate rights.** The 25¢ per ton royalty payment from the lessee goes to the Federal Government. From these monies the U.S. Government pays to the Idaho General Fund an amount equaling 37½% of all phosphate royalties received from land in Idaho.

3. **Royalties from U.S. Government phosphate rights.** An additional 52½% of the Federal royalties from phosphate is placed in the Federal Reclamation Fund for Idaho (These monies do not come to the State Treasury).

As an example, revenues accruing to the State of Idaho Treasury in 1971 are shown below.

<table>
<thead>
<tr>
<th>Description</th>
<th>Amount</th>
</tr>
</thead>
<tbody>
<tr>
<td>Rents and royalties from State leases</td>
<td>$10,341.00</td>
</tr>
<tr>
<td>Royalties from Federal leases (at 37½%)</td>
<td>$301,875.00</td>
</tr>
<tr>
<td>@ 3.22 million tons</td>
<td>$312,216.00</td>
</tr>
</tbody>
</table>

Phosphate rock mined on Federal land in Idaho from 1963-1971 is shown in Table 2.1 (See also Day, 1973, p. 11, Chart 1)

<table>
<thead>
<tr>
<th>Total Production, Public and Indian Lands</th>
<th>Year</th>
</tr>
</thead>
<tbody>
<tr>
<td>1,500,000 tons</td>
<td>1963</td>
</tr>
<tr>
<td>1,990,000</td>
<td>1964</td>
</tr>
<tr>
<td>2,450,000</td>
<td>1965</td>
</tr>
<tr>
<td>3,440,000</td>
<td>1966</td>
</tr>
<tr>
<td>3,050,000</td>
<td>1967</td>
</tr>
<tr>
<td>3,350,000</td>
<td>1968</td>
</tr>
<tr>
<td>4,040,000</td>
<td>1969</td>
</tr>
<tr>
<td>3,660,000</td>
<td>1970</td>
</tr>
<tr>
<td>3,220,000</td>
<td>1971</td>
</tr>
<tr>
<td>Total 26,700,000 (rounded figures)</td>
<td></td>
</tr>
</tbody>
</table>

Much of the State lands containing phosphate lie within the Federal Phosphate Reserve (See Figure 2). Within this Reserve, all State lands have lost their phosphate rights to the Federal Government. The loss was the result of a historically complex sequence of legislative and judicial events regarding "in lieu" land selection. This loss of phosphate rights to 124,252.35 acres has cost the State of Idaho many hundred thousands of dollars since 1914. An attempt to recover these losses through additional in lieu selection of lands of equal value, or by other means, is presently being prepared by the Attorney General of the State of Idaho.

In 1973 approximately 6 million tons of phosphate rock was mined in Idaho from Federal lands. Mining companies which produced this phosphate paid the Federal Government about 1.5 million dollars in royalties. From this amount the Treasury of the State of Idaho should receive $562,500 (37.5%). As of January, 1974, the State of Idaho received from leases on State land, rents and royalties amounting to $10,341.85 each year. A few other factors are involved but the State of Idaho should receive directly about $575,000 from phosphate mining in Idaho for 1973.

Given the 450.77 million ton figure for projected phosphate mining during the next 50 years, the minimum royalty paid to the State of Idaho by the Federal Government should be in the neighborhood of 170 million dollars.
SELECTED BIBLIOGRAPHY


