DEPARTMENT OF THE INTERIOR
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TO ACCOMPANY MAP MR-74

MAPS SHOWING SELECTED GEOLOGY AND PHOSPHATE RESOURCES OF THE HARRINGTON PEAK QUADRANGLE, BEAR LAKE AND CARIBOU COUNTIES, IDAHO

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INTRODUCTION

PURPOSE OF INVESTIGATION

This report summarizes information on the thickness, grade, lateral continuity, phosphate resources, and ownership of phosphate-bearing units in the Meade Peak Phosphatic Shale Member of the Phosphoria Formation in the Harrington Peak quadrangle. This report is one of a series of quadrangle reports prepared by the Idaho Bureau of Mines and Geology under U.S. Geological Survey cost-sharing contract #14-08-0001-17925 to calculate phosphate resources in southeastern Idaho (fig. 1).

ACKNOWLEDGMENTS

The project was supervised by Bill Bonnichsen of the Idaho Bureau of Mines and Geology and Peter Oberlindacher of the Bureau of Land Management. Conda Partnership provided their geologic maps and trench data on the understanding that this confidential information would be used only in a regional analysis of phosphate resources. We thank the College of Mines and Earth Resources and the College of Forestry, University of Idaho, for the use of their cartographic facilities.

METHODS OF INVESTIGATION

The Harrington Peak quadrangle phosphate resource maps are based on published and unpublished data from industry, State, and Federal sources.

The interpretation of the structure of the Meade Peak Phosphatic Shale Member in the subsurface is based on cross sections constructed from U.S. Geological Survey and phosphate company geologic maps, cross sections and trench logs, supplemented by discussions with Bureau of Land Management geologists. Phosphate rock thickness and P_2O_5 assay values are used from only those trenches in the adjacent Dry Valley and Snowdrift Mountain quadrangles whose locations can be accurately plotted for elevation and land coordinates. Structure contours and overburden isopachs on the stratigraphic top of the Meade Peak are extended 600 feet along strike from the last known exposure of the Phosphoria Formation and are extrapolated to a depth of 1,500 feet. Phosphate resources of the Meade Peak are calculated for three categories of overburden thickness: 0 to 300 feet, 300 to 600 feet, and 600 to 1,500 feet (fig. 2).

Identified phosphate resources (U.S. Bureau of Mines and U.S. Geological Survey, 1980) are computed for the upper and lower phosphate units of the Meade Peak (fig. 3). Resource tonnages were determined according to the method used by Montgomery and Cheney (1967, p. 41) and Oberlindacher and Hovland (1979, p. 7). For the Harrington Peak quadrangle, more than twenty resource blocks (not shown on the map sheeets) were constructed based on structural similarities. The volume (V) of phosphate resource in each block is calculated by multiplying the true area of the stratigraphic top of the Meade Peak by the cumulative average thickness (t) of the upper and lower phosphate units. The true area is the planimetered map surface area (A) of each block multiplied by the secant of the average dip (d) of the Meade Peak (fig. 4):

(1) $V = At(\sec d)$

Resource tonnages (R) are calculated by multiplying the volume (V) of phosphate resource by the average density (ρ) of the phosphate rock:

(2) $R = V\rho$

An average density of 0.0787 short tons per cubic foot, derived from Oberlindacher and Hovland's (1979) average density value of 2.52 metric tons per cubic meter, is applied to convert the volume of phosphate resource (calculated in cubic feet) to short tons of phosphate resource (sheets 2 and 3).

Thickness, phosphate content, and stratigraphic position are the three factors that determine whether a sampling interval is included within the phosphate units to calculate resource tonnages. A "sampling interval" is a rock sample of known thickness and phosphate content, as derived from a drill hole or trench log. In this report, the Meade Peak is subdivided into five informally named units based on Hale's (1967) subdivisions of a typical section in the upper Dry Valley area, Caribou County, Idaho (fig. 3). These units are, from bottom to top: the lower waste, the lower phosphate, the middle waste, the upper phosphate, and the upper waste. The only units considered in the resource calculations in this report were the lower and upper phosphate units (fig. 3). Isolated minor phosphorite beds in the waste units are excluded from consideration.

The following guidelines used in this report to define phosphate units are based on Montgomery and Cheney (1967), Oberlindacher and Hovland (1979), and generally accepted phosphate mining practices in southeastern Idaho:

> (1) The upper and lower boundaries of the phosphate units are defined by the uppermost and lowermost sampling intervals that are 1 foot or more thick and contain at least 16 percent P_2O_5, except where adjoining sampling intervals less than 1 foot thick with 16 or more percent P_2O_5 are added together to meet the 1-foot thickness requirement. Within a phosphate unit, all sampling intervals with 16 or more percent P_2O_5 are included in the resource calculation regardless of thickness.
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> (2) Within the phosphate units,

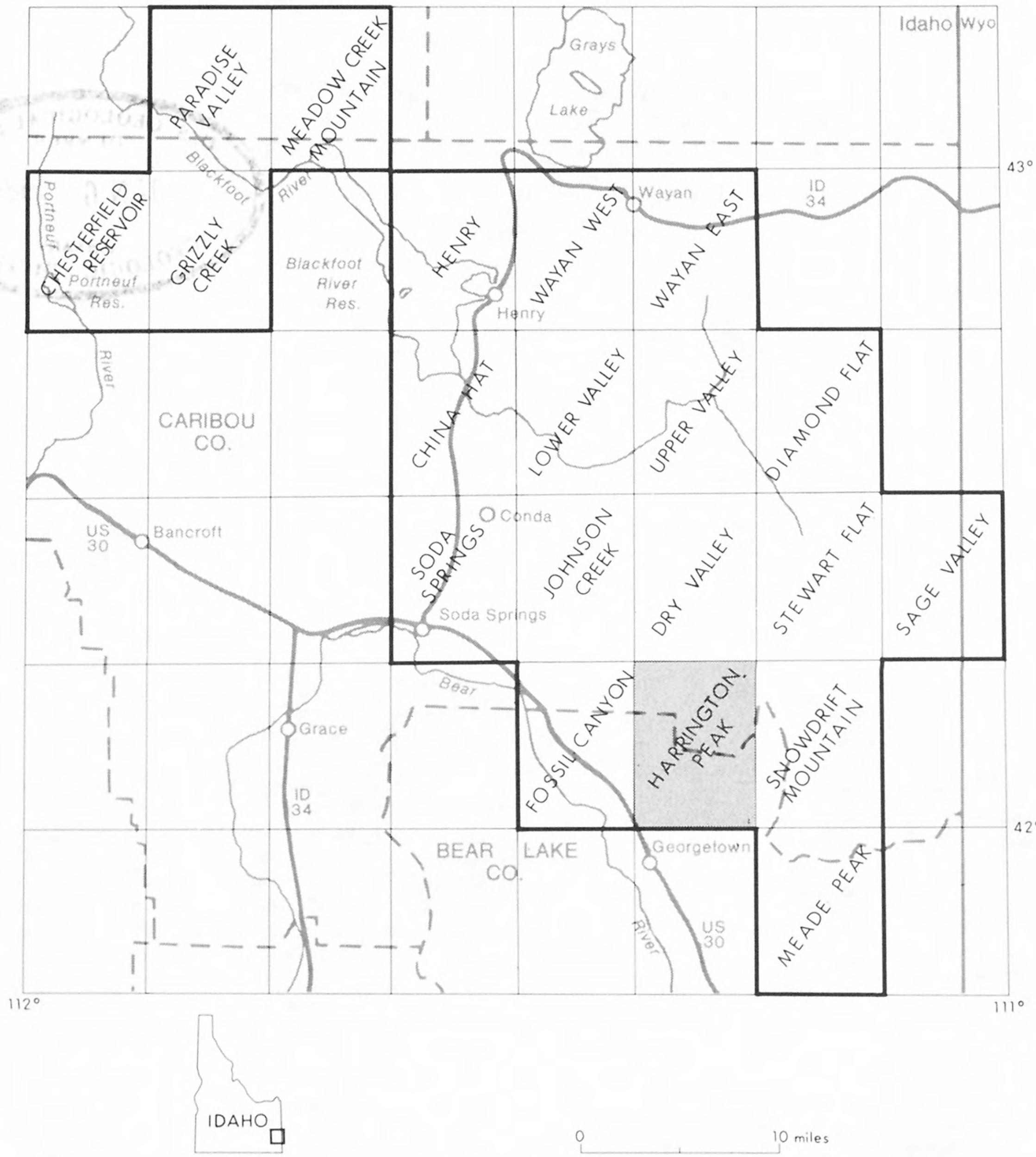


FIGURE 1.—Index map showing the location of 7½-minute quadrangles in the southeast Idaho phosphate area including the Harrington Peak quadrangle (shaded).

sampling intervals and sequences of contiguous sampling intervals containing less than 16 percent P_2O_5 and measuring at least 2 feet thick are excluded from the resource calculation.

(3) Within the phosphate units, isolated sampling intervals less than 2 feet thick with less than 16 percent P_2O_5 are included in the resource calculation.

The boundary of the western part of the Georgetown Canyon mine, an open-pit phosphate mine, was identified from false-color aerial photographs taken in 1979 by the U.S. Geological Survey.

The information about ownership of surface and phosphate rights was obtained for Federal lands from the U.S. Bureau of Land Management's leasable mineral and master title plats and for State lands from the Idaho Department of Lands' land plats. These sources also were used to locate Federal phosphate leases, Preference Right Lease Applications (PRLAs), Known Phosphate Leasing Areas (KPLAs), and State phosphate leases. Titles to surface and phosphate rights on private land are from both the Federal and State plats. Private phosphate leases, leases on land with private title to both surface and phosphate rights, are not shown.

LOCATION AND TOPOGRAPHY

The Harrington Peak quadrangle is about 12 miles southeast of Soda Springs, Idaho (fig. 1). The quadrangle boundary includes parts of Tps. 9, 10, and 11 S., Rs. 43

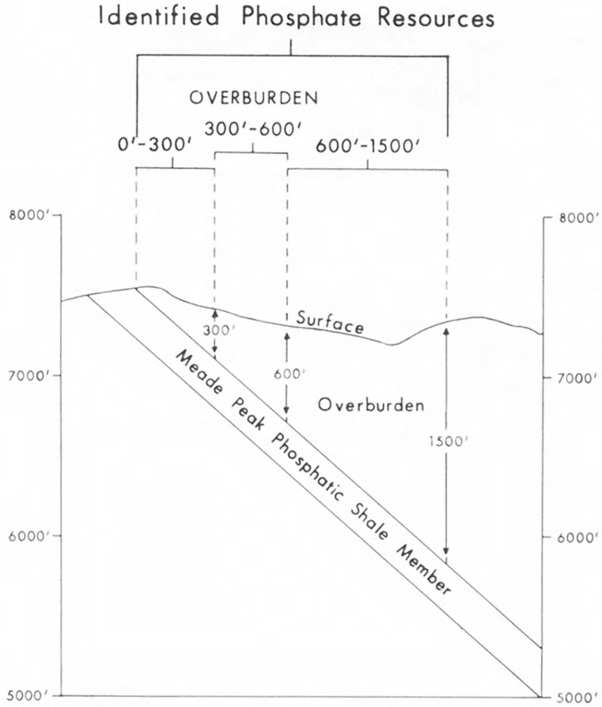


FIGURE 2.—Diagrammatic cross section showing identified phosphate resources of the Meade Peak Phosphatic Shale Member of the Phosphoria Formation.

and 44 E., Boise Principal Meridian. The area is accessible by gravel-surfaced roads.

Major topographic features in the quadrangle include, from east to west, the Preuss Range, Georgetown Canyon, Dry Ridge, Schmid Ridge, Left Hand Fork of Georgetown Canyon, Harrington Peak, Big Basin, and the Aspen Range. Slug Creek and its tributaries drain the north-central part of the area. Elevations range from about 6,150 feet in the southwest corner of the quadrangle to 9,450 feet in the Preuss Range.

FEDERAL LAND STATUS

Four combinations of titles to surface and phosphate rights occur in the Harrington Peak quadrangle as shown on sheet 3: (1) Federal phosphate on Federal surface, (2) Federal phosphate on private surface, (3) State phosphate on private surface, and (4) private phosphate on private surface. The Federal government holds phosphate title to 93 percent and surface title to 90 percent of the land in the Harrington Peak quadrangle. As of August 1980, less than one percent of the Federal phosphate title was leased.

GEOLOGY OF THE MEADE PEAK PHOSPHATIC SHALE MEMBER OF THE PHOSPHORIA FORMATION

STRATIGRAPHY

In Idaho, the Phosphoria Formation of Permian age disconformably overlies the Park City Formation of Permian age and the Wells Formation of Pennsylvanian and Permian age and is unconformably overlain by the Dinwoody Formation of Triassic age (McKelvey and others, 1959; Peterson, 1980). The Phosphoria grades northward into the Shedhorn Sandstone in south-central Montana and northwestern Wyoming, and southward and eastward into the Park City Formation in northeastern Utah and west-central Wyoming (McKelvey and others, 1959). The Park City Formation, a carbonate sequence, in turn grades eastward into the Goose Egg Formation, a red-bed evaporite sequence (McKelvey and others, 1959).

The Phosphoria Formation is subdivided into six members, four of which are recognized at the type locality at Phosphoria Gulch, Bear Lake County, Idaho (McKelvey and others, 1959). The four members are, from bottom to top: the Meade Peak Phosphatic Shale Member, the Rex Chert Member, the cherty shale member, and the Retort Phosphatic Shale Member. The other two members are the lower chert member, which is laterally continuous with the Meade Peak, and the Tosi Chert Member, which is laterally continuous with the upper part of the Retort and with the cherty shale member (McKelvey and others, 1959, p. 21). As discussed in the "Methods of Investigation" section, the Meade Peak has been subdivided into five informally named units based on lithology and P_2O_5 content (fig. 3). The two phosphate units defined by Hale (1967; fig. 3, this report) consist of interbedded phosphorite, mudstone, and limestone. The waste units consist of interbedded shale, mudstone, siltstone, and thin phosphorite beds. The base of the Meade Peak is characterized by a thin phosphorite bed containing abundant fish scales, bones, and small nodules (McKelvey and others, 1959, p. 23), known as the fish-scale marker bed (Hale, 1967). The top of the Meade Peak is not as well defined. In southeastern Idaho, the uppermost bed is either a thin, nodular phosphorite, commonly containing gastropods resembling *Omphalotrochus*, or a thin, soft mudstone locally overlying the nodular phosphorite (McKelvey and others, 1959, p. 23).

In the Harrington Peak quadrangle, the Meade Peak Phosphatic Shale Member averages 168 feet in thickness, determined from selected trench data in the adjacent Dry Valley and Snowdrift Mountain quadrangles. The Meade Peak crops out over a discontinuous strike length of about 10 miles. Based on available trench data, the phosphate rock within the Meade Peak in the Harrington Peak quadrangle averages 55.2 feet in thickness with a weighted average of 24.6 percent P_2O_5.

STRUCTURE

The major structures in the Harrington Peak quadrangle are several normal to overturned north- to northeast-trending folds, the Meade overthrust and several unnamed faults. The Meade Peak Phosphatic Shale Member is exposed (1) east of Big Basin along the western limb of the Dairy syncline (axial trace not shown in this area), (2) in several small fault blocks west of Slug Creek, (3) on the western limb of the Schmid syncline, (4) on the western limb and around the southern closure of the Georgetown syncline, and (5) in the extreme southeastern corner of the quadrangle (Cressman, 1964, pl. 3).

Dips in the Meade Peak range from shallow to overturned along the western limb of the Dairy syncline east of Big Basin (sheet 1, section *A-A'*). The overturned parts of the Meade Peak return to normal low-angle easterly dips at about 400 feet in depth. A north-trending high-angle normal fault terminates the Meade Peak on the east. There are no identified phosphate resources with greater than 600 feet of overburden in this area. In the area west of Slug Creek, there are no identified phosphate resources with greater than 600 feet of overburden.

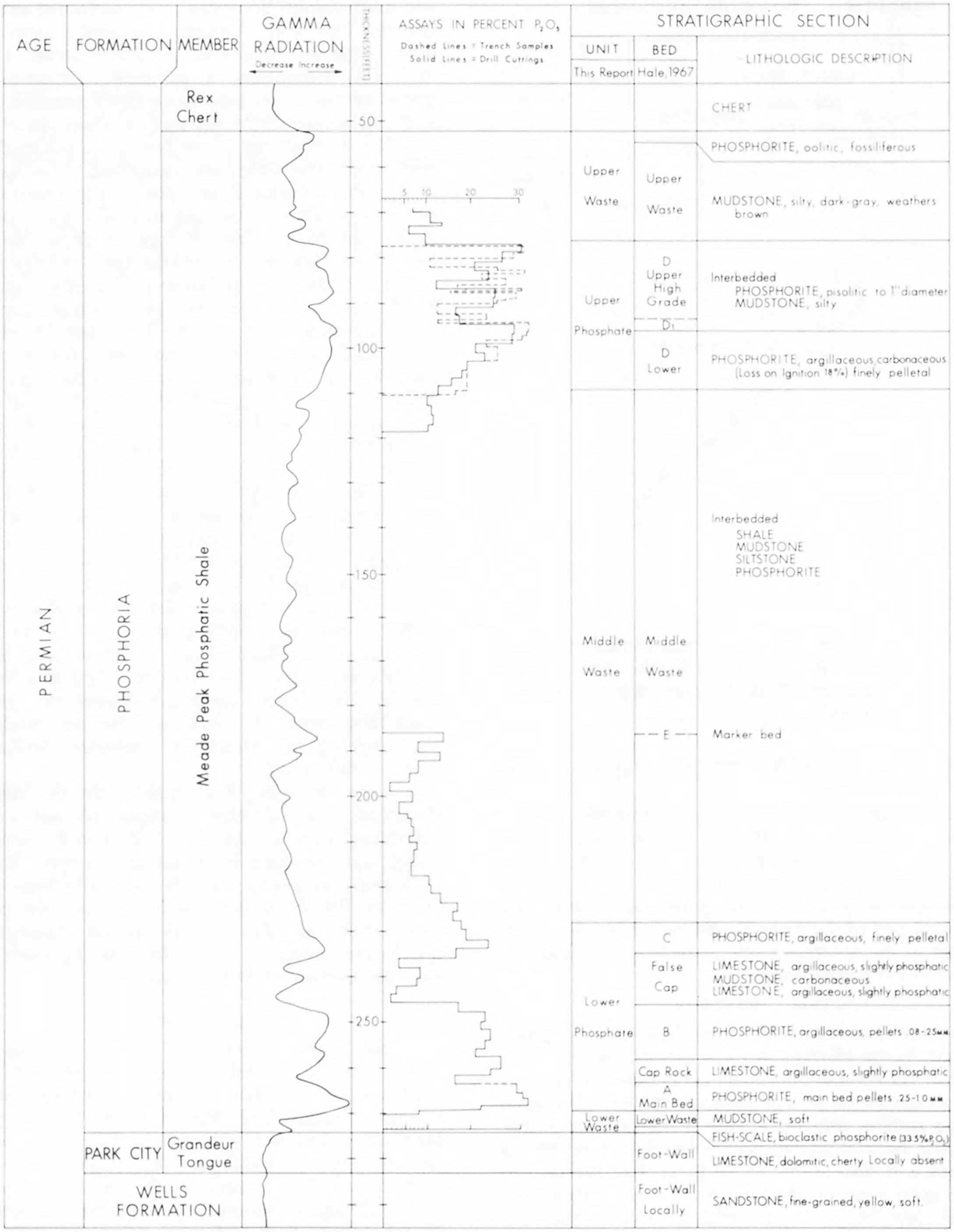
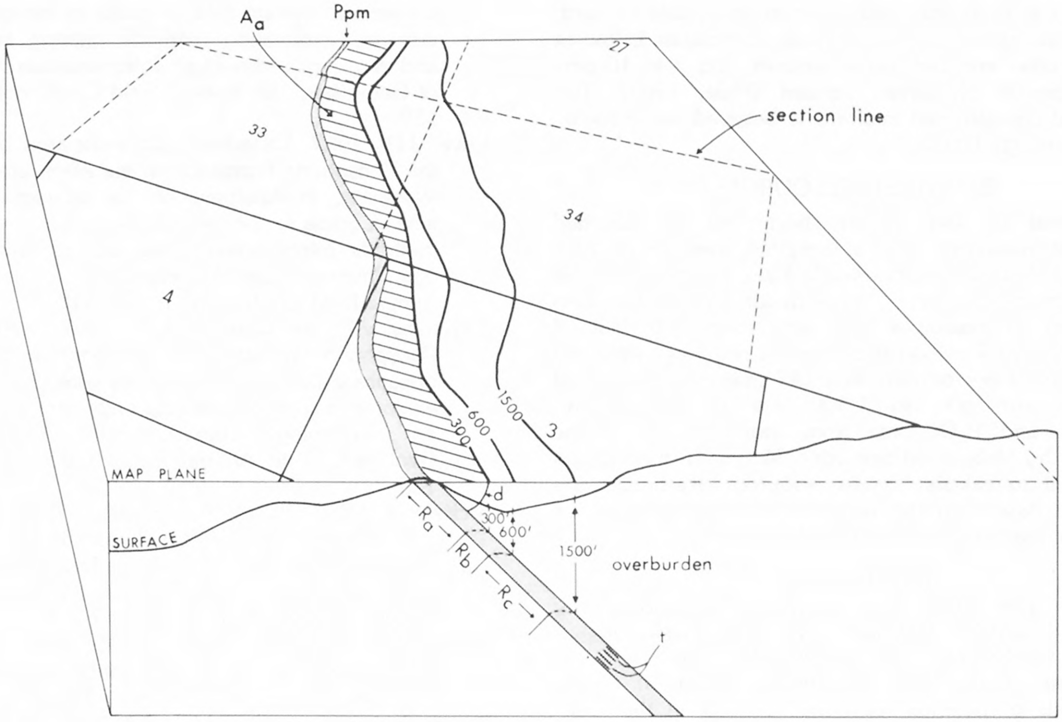


FIGURE 3.—Typical Permian section, upper Dry Valley area, Caribou County, Idaho (from Hale, 1967).

The Meade Peak dips moderately to the east on the western limb of the Schmid syncline. Identified phosphate resources are not extended to the east of the synclinal axis beneath the alluvium.

On the western limb of the Georgetown syncline, the Meade Peak dips steeply east and is offset by several transverse faults (sheet 1, sections *B-B′* and *C-C′*). As many as three westward-dipping thrust faults have offset the Meade Peak at depth in the northern part of the syncline. Because of the thrusting, the 600-foot overburden isopach is not very extensive in this northern area. Thrusting has created two areas termed "fault overlap" zones noted on the accompanying sheets. Structure contours are not shown within these fault overlap zones. The Meade Peak shallows to a moderate dip angle around the southern closure of the Georgetown syncline.

The Meade Peak dips moderately to the west in the extreme southeastern corner of the quadrangle. All of the identified phosphate resources here are covered by less



Explanation and sequence of calculations:

(1) $V_a = A_a t(\sec d)$

(2) $R_a = V_a \rho$

V_a = volume of resources under less than 300′ of overburden

A_a = measured map surface area of resources under less than 300′ of overburden

t = cumulative average thickness of the upper and lower phosphate units

d = average dip of the Meade Peak Phosphatic Shale Member of the Phosphoria Formation

R_a = resources under less than 300′ of overburden

R_b = resources under 300′ to 600′ of overburden

R_c = resources under 600′ to 1500′ of overburden

ρ = average density of phosphate rock = 0.0787 short tons per cubic foot

FIGURE 4.—Block diagram showing method of calculating phosphate resources.

than 300 feet of overburden.

MINERALOGY AND GEOCHEMISTRY

Altered phosphorite within the Meade Peak Phosphatic Shale Member consists, for the most part, of medium-grained, rounded pellets of microcrystalline apatite aggregates (Emigh, 1958; Gulbrandsen, 1966). The typical Meade Peak phosphorite is approximately 80 percent apatite, 10 percent quartz, 5 percent muscovite-illite, 2 percent organic matter, 1 percent dolomite-calcite, 1 percent iron oxide, and 1 percent other components (Gulbrandsen, 1966).

According to Gulbrandsen (1966),the apatite is a fluorapatite, $Ca_5(PO_4)_3F$, with sodium substituting for calcium, and carbonate and sulfate substituting for the phosphate radical. Also substituting, to a lesser extent, for calcium are strontium, uranium, thorium, yttrium, lanthanum, neodymium, and ytterbium. Pelletal and oolitic phosphate beds with greater than 31 percent P_2O_5 and greater than 3 feet in thickness generally contain 0.01 to 0.02 percent uranium (McKelvey and Carswell, 1967). Several elements--arsenic, cadmium, chromium, copper, molybdenum, nickel, antimony, selenium, vanadium, zinc, and silver(?)--occur in the organic fraction of the phosphorite (Gulbrandsen, 1966).

Vanadium occurs within several shale and mudstone beds of the Meade Peak. One zone of economic interest (about 5 to 10 feet below the upper phosphate unit) averages 4 feet in thickness and 0.7 percent vanadium pentoxide, and is associated with small amounts of selenium, molybdenum, zinc, nickel, cobalt, titanium, and cadmium (Love, 1967). Desborough (1977) found vanadium in, or associated with, organic material in leached samples from thin beds of vanadium-rich shale and mudstone in phosphate-rich zones; chromium in a 10-A mica in unleached phosphate nodule samples; zinc and cadmium in sphalerite; silver associated with the organic material and not as a silver sulfide phase; selenium in pyrite, sulfur in pyrite, sphalerite, and the organic material; titanium in titanium dioxide; and molybdenum in powellite.

The Meade Peak has been altered and naturally beneficiated by postdepositional weathering (supergene enrichment). Unaltered phosphorite is hard, carbonaceous, calcareous to dolomitic, and lower in phosphate content, whereas the altered rock is partially consolidated, low in organic matter and carbonate minerals, and 3 to 10 percent higher in phosphate content (Hale, 1967). The weathered-unweathered interface is believed to be highly irregular and gradational.

IDENTIFIED RESOURCES

A total of 486 million short tons of identified phosphate resources with a weighted average of 24.6 percent P_2O_5 is within the Meade Peak Phosphatic Shale Member in the Harrington Peak quadrangle: 265 million short tons of resources with less than 300 feet of overburden, 73.7 million short tons of resources with 300 to 600 feet of overburden, and 147 million short tons of resources with 600 to 1,500 feet of overburden.[1] Thickness and P_2O_5 data from four trenches in the adjacent Dry Valley and Snowdrift Mountain quadrangles were used to calculate these resources. Resources are based on data from the nearest drill holes or trenches situated along the same structural feature.

REFERENCES

Cressman, E.R., 1964, Geology of the Georgetown Canyon-Snowdrift Mountain area, southeastern Idaho: U.S. Geological Survey Bulletin 1153, 105 p.

Desborough, G.A., 1977, *Preliminary report* on certain metals of potential economic interest in thin vanadium-rich zones in the Meade Peak Member of the Phosphoria Formation in western Wyoming and eastern Idaho: U.S. Geological Survey Open-File Report 77-341, 27 p.

Emigh, G.D., 1958, Petrography, mineralogy, and origin of phosphate pellets in the Phosphoria Formation: Idaho Bureau of Mines and Geology Pamphlet 114.

Gulbrandsen, R.A., 1966, Chemical composition of phosphorites of the Phosphoria Formation: Geochimica et Cosmochimica Acta, v. 30, p. 769-778.

Hale, L.A., 1967, Phosphate exploration using gamma-radiation logs, Dry Valley, Idaho, *in* Anatomy of the western phosphate field, a guide to the geologic occurrence, exploration methods, mining engineering, and recovery technology: Intermountain Association of Geologists, 15h Annual Field Conference, p. 147-159.

Love, J.D., 1967, Vanadium and associated elements in the Phosphoria Formation in the Afton area, western Wyoming, *in* Anatomy of the western phosphate field, a guide to the geologic occurrence, exploration methods, mining engineering, and recovery technology: Intermountain Association of Geologists, 15th Annual Field Conference, p. 115-118.

McKelvey, V.E., and Carswell, L.D., 1967, Uranium in the Phosphoria Formation, *in* Anatomy of the western phosphate field, a guide to the geologic occurrence, exploration methods, mining engineering, and recovery technology: Intermountain Association of Geologists, 15th Annual field Conference, p. 119-123.

McKelvey, V.E., Williams, J.S., Sheldon, R.,P., Cressman, E.R., Cheney, T.M., and Swanson, R.W., 1959, The Phosphoria, Park City, and Shedhorn Formations in the western phosphate field: U.S. Geological Survey Professional Paper 313-A, p. 1-47.

Montgomery, K.M., and Cheney, T.M., 1967, Geology of the Stewart Flat quadrangle, Caribou County, Idaho: *U.S. Geological Survey Bulletin 1217*, 63 p.

Oberlindacher, Peter, and Hovland, R.D., 1979, Geology and phosphate resources of the Hawley Creek area, Lemhi County, Idaho: U.S. Geological Survey Open-File Report 79-1283.

Peterson, J.A., 1980, Depositional history and petroleum geology of the Permian Phosphoria, Park City, and Shedhorn Formations, Wyoming and southeastern Idaho: U.S. Geological Survey Open-File Report 80-667, 42 p.

U.S. Bureau of Mines and U.S. Geological Survey, 1980, Principles of a resource/reserve classification for minerals: U.S. Geological Survey Circular 831, 5 p.

[1]Resources calculated to three significant figures for phosphate rock containing 16 or more percent P_2O_5