# MAPS SHOWING SELECTED GEOLOGY AND PHOSPHATE RESOURCES OF THE SNOWDRIFT MOUNTAIN QUADRANGLE, BEAR LAKE AND CARIBOU COUNTIES, IDAHO



By Pamela Dunlap Derkey,[1] Ken Paul,[1] Bea Johnston,[1] Pamela Palmer,[1] Alexandra Zemanek,[1] Mahasti Fakourbayat,[1] and R. David Hovland[2]

[1] Idaho Bureau of Mines and Geology
[2] Bureau of Land Management

## 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 Snowdrift Mountain 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 and Monsanto Chemical Intermediates Company provided their drill-hole 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The Snowdrift Mountain quadrangle phosphate resource maps are based on published and unpublished data from industry, State, and Federal sources.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, trench logs, and cross sections, supplemented by discussions with the Bureau of Land Management and company geologists. Phosphate rock thickness and $P_2O_5$ assay values are used from only those drill holes and trenches 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 Snowdrift Mountain quadrangle, forty resource blocks (not shown on the map sheets) 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 thickeness (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 ($\rho$) 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.

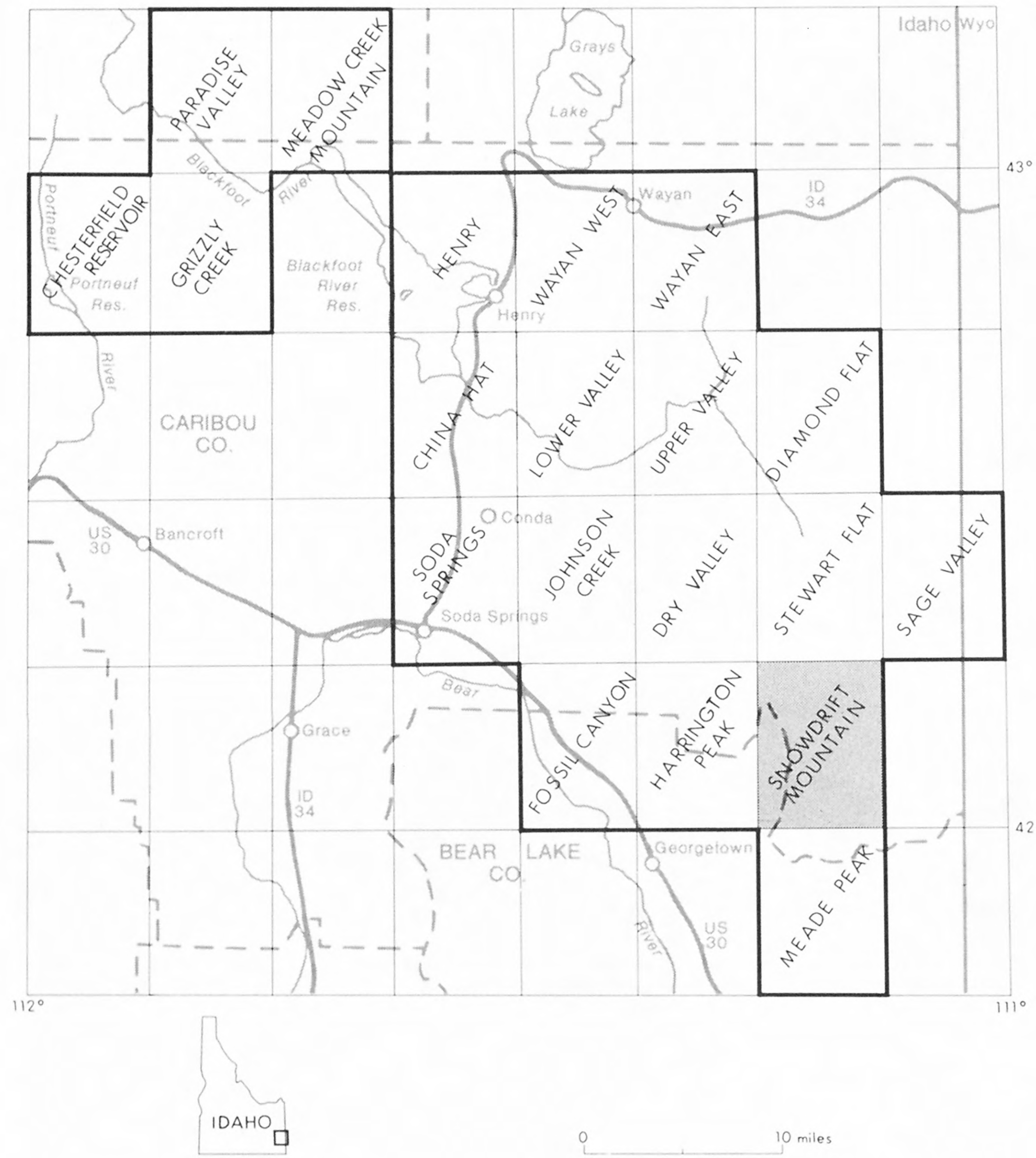



FIGURE 1.—Index map showing the location of 7½-minute quadrangles in the southeast Idaho phosphate area including the Snowdrift Mountain quadrangle (shaded).

(2) Within the phosphate units, 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 boundaries of the Georgetown Canyon open-pit phosphate mine were 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 leaseable 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 Snowdrift Mountain quadrangle is about 20 miles southeast of Soda Springs, Idaho (fig. 1). The quad-

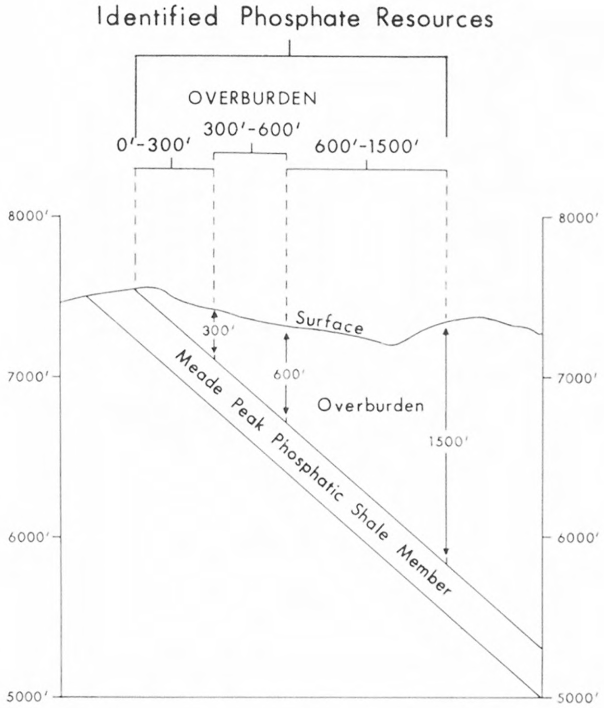



FIGURE 2.—Diagrammatic cross section showing identified phosphate resources of the Meade Peak Phosphatic Shale Member of the Phosphoria Formation.

rangle boundary includes T. 10 S., R. 45 E., and parts of Tps. 9, 10, and 11 S., Rs. 44 and 46 E., and Tps. 9 and 11 S., R. 45 E., Boise Principal Meridian. The area is accessible by graveled roads.

Major topographic features in the quadrangle include the north-trending Gannett Hills, Webster Range, Preuss Range, Snowdift Mountain, Freeman Ridge, and Dry Ridge, and the north- to northeast-trending Crow Creek. Crow Creek and its tributaries drain most of the area. Elevations range from about 6,500 feet at the northeast end of Crow Creek to 9,773 feet at the southern end of Snowdrift Mountain.

### FEDERAL LAND STATUS

Four combinations of titles to surface and phosphate rights occur in the Snowdrift Mountain quadrangle as shown on sheet 3: (1) Federal phosphate on Federal surface, (2) Federal phosphate on private surface, (3) State phosphate on State surface, and (4) private phosphate on private surface. The Federal government holds phosphate title to 88 percent and surface title to 83 percent of the land in the Snowdrift Mountain quadrangle. As of August 1980, about 10 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 he 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 Snowdrift Mountain quadrangle, the Meade Peak Phosphatic Shale Member averages 171 feet in thickness, determined from selected drill-hole and trench data. Much of the thickness variation may be the result of weathering, deformation, and faulting. The variation does not seem to follow a systematic trend of thinning or thickening along strike; rather, the unit appears to pinch and swell locally. Similar local thickness variations occur on a smaller scale for phosphate rock in the upper and lower phosphate units of the Meade Peak. Within the quadrangle, the Meade Peak crops out over a discontinuous strike length of about 29 miles. Based on the available drill hole and trench data, the phosphate rock within the Meade Peak in the Snowdrift Mountain quadrangle averages 58 feet in thickness with a weighted average of 23.9 percent $P_2O_5$. Detailed stratigraphic sections of the Meade Peak have been published by the U.S. Geological Survey for four trenches in the quadrangle (McKelvey and others, 1953; O'Malley and others, 1953; Smart and others, 1954; Swanson and others, 1956).

### STRUCTURE

The Snowdrift Mountain quadrangle is characterized by folds that range from open to tight and overturned, and the Meade overthrust zone, all of which are north- to northeast-trending, and by a few major west- to northwest-trending transverse faults. The Meade Peak Phosphatic Shale Member crops out on the upper plate of the Meade overthrust zone (Cressman, 1964, pl. 1).

The Meade Peak is vertical to overturned on the east limb of Dry Valley anticline (sheet 1, section *A-A'*). The Meade Peak is thinned and truncated at depth by several

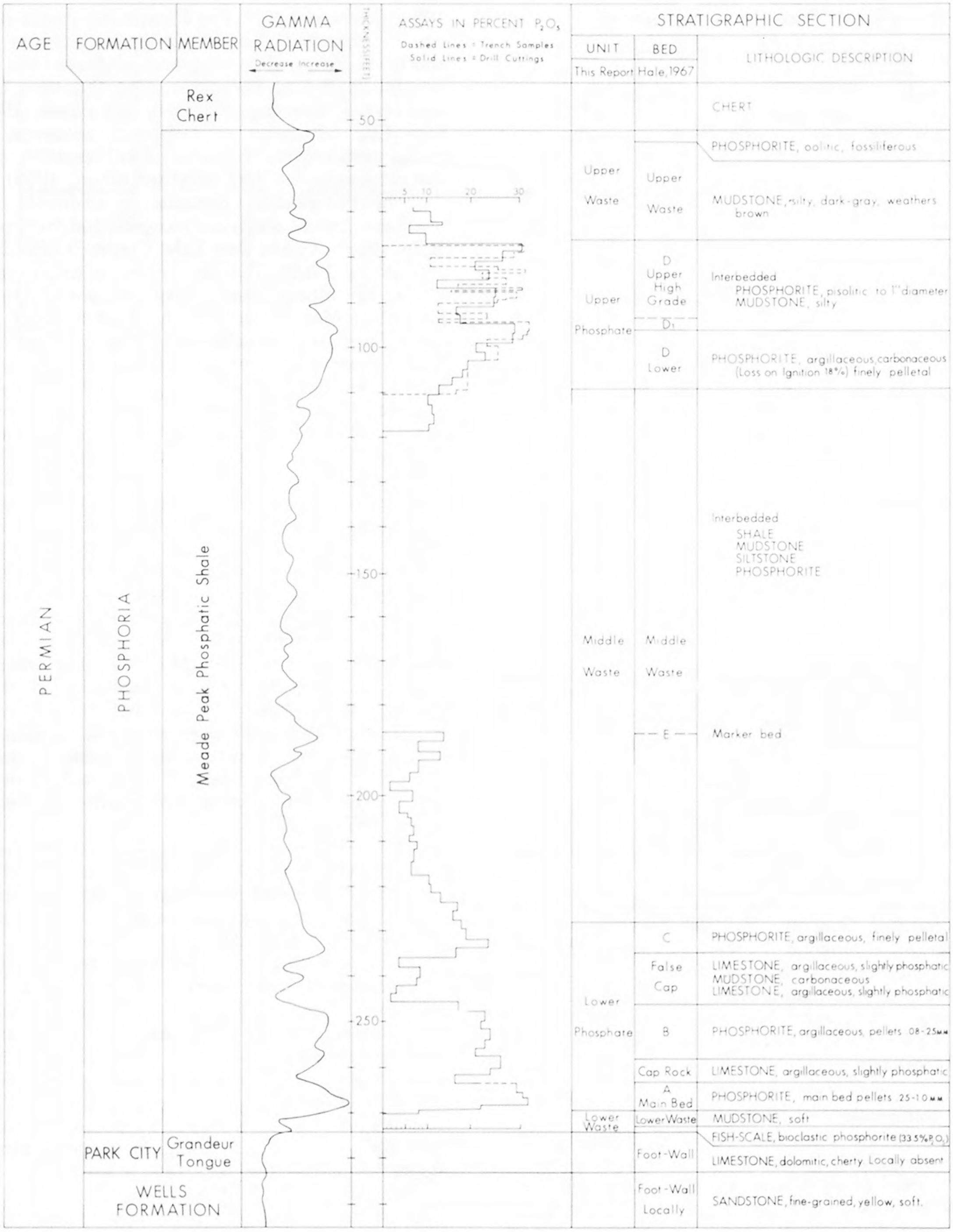



FIGURE 3.—Typical Permian section, upper Dry Valley area, Caribou County, Idaho (from Hale, 1967).

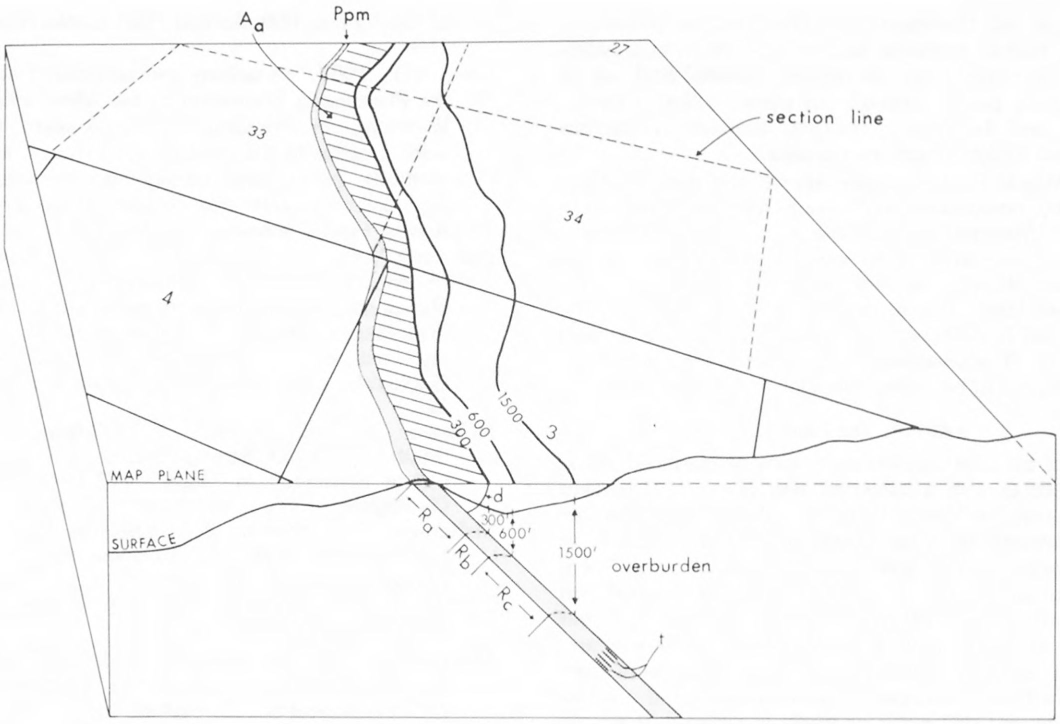
thrusts that occur in this area (Cressman, 1964).

The Meade Peak dips moderately to steeply on both limbs of the nearly isoclinal Snowdrift anticline (sheet 1, sections *B-B'*, *C-C'*, *D-D'*, and *E-E'*). The Meade Peak shallows to moderate dip angles at depth on the western limb of the Snowdrift anticline (sheet 1, sections *B-B'* and *D-D'*). Many small transverse faults offset the Meade Peak along the western limb of the Snowdrift anticline.

The Meade Peak dips gently westward on the east limb of Webster syncline (sheet 1, sections *C-C'* and *E-E'*). There are less than 1,500 feet of overburden covering the Meade Peak along the southern three-fourths of the syncline. At its northern end, the syncline plunges gently northward, allowing the unit to be buried beneath greater than 1,500 feet of overburden in the core of the fold. The Webster syncline is truncated at its southern end by the transverse Sand Wash fault (Cressman, 1964).

Several minor isolated outcrops of the Meade Peak occur south of the Sand Wash fault in the core of several local synclines. Resource estimates are not computed for these minor phosphate occurrences.

The Meade Peak crops out in two isolated areas




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

$\rho$ = average density of phosphate rock = 0.0787 short tons per cubic foot

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

along the east limb of the Boulder Creek anticline. The southernmost exposure of the Meade Peak dips from 50 to 60 degrees to the southeast. The northern exposure of the Meade Peak is located north of the Sand Wash fault. At this locality the Meade Peak dips 60 degrees to the east. Identified phosphate resources in this area are truncated at a depth of about 400 feet by a thrust fault of the Meade overthrust zone.

## 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 than altered phosphorite, 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 in the rock is believed to be highly irregular and gradational.

### IDENTIFIED RESOURCES

A total of 1,360 million short tons of identified phosphate resources with a weighted average of 23.9 percent $P_2O_5$ is within the Meade Peak Phosphatic Shale Member in the Snowdrift Mountain quadrangle: 471 million short tons of resources with less than 300 feet of overburden, 299 million short tons of resources with 300 to 600 feet of overburden, and 591 million short tons of resources with 600 to 1,500 feet of overburden[1]. Thickness and $P_2O_5$ data from 21 drill hole and trench logs 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, 15th 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., Davidson, D.F., O'Malley, F.W., and Smith, L.E., 1953, Stratigraphic sections of the Phosphoria Formation in Idaho 1947-1948, pt. 1: U.S. Geological Survey Circular 208, 49 p.

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.

O'Malley, F. W., Davidson, D. F., Hoppin, R. A., and Sheldon, R. P., 1953, Stratigraphic sections of the Phosphoria Formation in Idaho, 1947-48, pt. 3: U.S. Geological Survey Circular 262, 43 p.

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.

Smart, R.A., Waring, R.G., Cheney, T.M., and Sheldon, R.P., 1954, Stratigraphic sections of the Phosphoria Formation in Idaho 1950-1951: U.S. Geological Survey Circular 327, 22 p.

Swanson, R.W., Carswell, L.D.,Sheldon, R.P., and Cheney, T.M., 1956, Stratigraphic sections of the Phosphoria Formation, 1953: U.S. Geological Survey Circular 375, 30 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 $P_2O_5$