MAPS SHOWING SELECTED GEOLOGY AND PHOSPHATE RESOURCES OF THE UPPER VALLEY QUADRANGLE, CARIBOU COUNTY, 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 Upper Valley 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

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METHODS OF INVESTIGATION

The Upper Valley quadrangle phosphate resource maps are based on published and unpublished data from industry, State, and Federal sources.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, drill hole and trench logs, and cross sections, supplemented by discussions with 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 Upper Valley quadrangle, more than forty resource blocks (not shown on the 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 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. The Meade Peak is subdivided into five informally named units for this report 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.

(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 all phosphate open-pit mines and test pits were identified from false-color aerial photographs taken in 1979 by the U.S. Geological Survey.

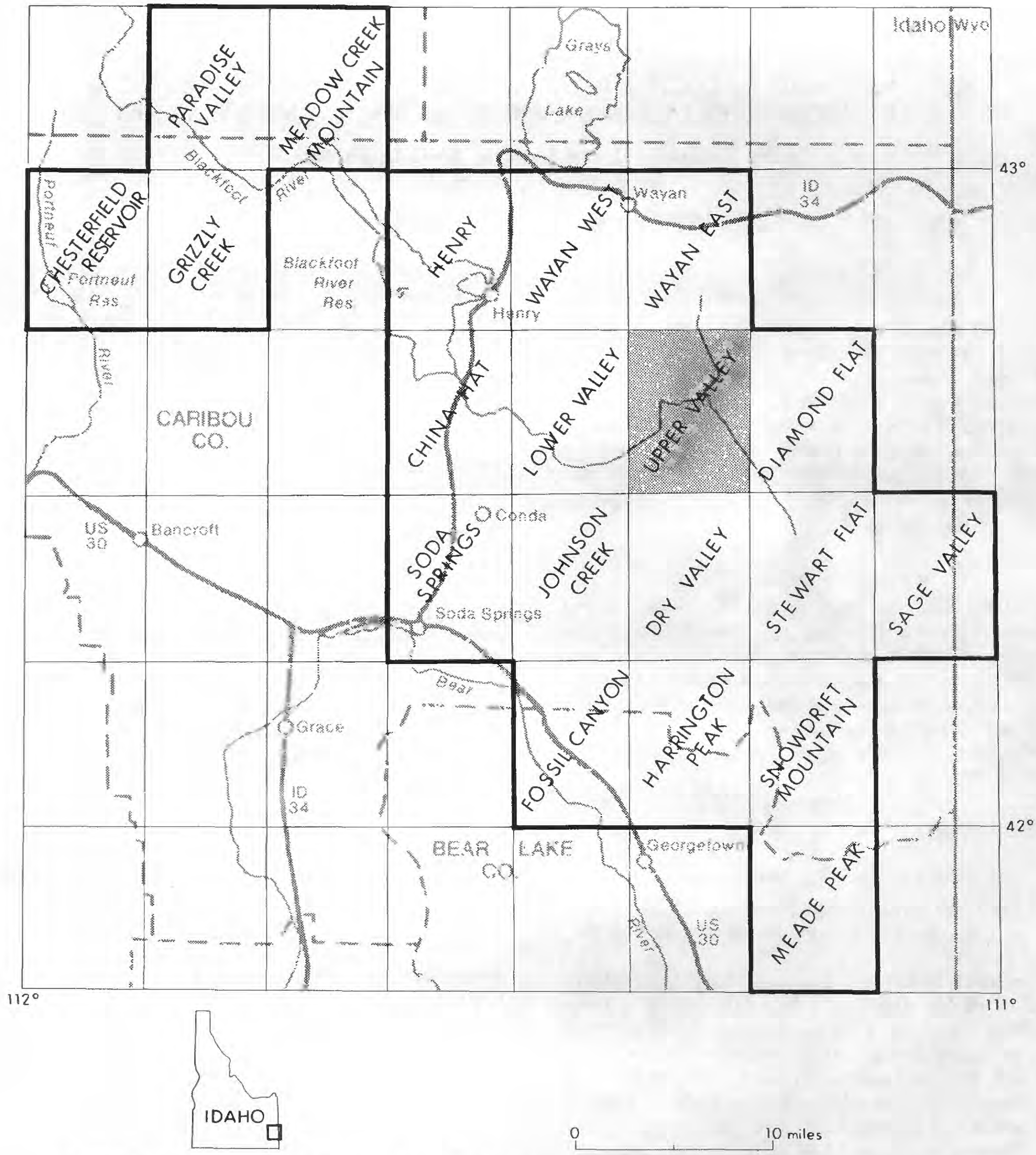


FIGURE 1.— Index map showing location of southeast Idaho phosphate area and Upper Valley quadrangle (shaded).

The locations of titles to surface and phosphate rights were 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 Upper Valley quadrangle is about 15 miles northeast of Soda Springs, Caribou County, Idaho (fig. 1). The quadrangle boundary includes T. 7 S., R. 44 E., and parts of Tps. 6, 7, and 8 S., Rs. 43 and 45 E., and Tps. 6 and 8 S., R. 44 E., Boise Principal Meridian. The area is accessible by graveled roads. A spur of the Union Pacific railroad runs through the area, connecting the Maybe Canyon Mine on Dry Ridge with the main line at Soda Springs.

Major topographic features in the quadrangle include Upper Valley, Dry Valley, Rasmussen Valley, Rasmussen Ridge, Dry Ridge, Schmid Ridge, Webster Range, and Wooley Range, all of which trend northwest. The Blackfoot River and its tributaries—Lanes Creek, Diamond Creek, Angus Creek, and Dry Valley Creek—drain the area to the west. The Narrows, a twisting narrow canyon of the Blackfoot River, is also a prominent feature. Elevations range from 6,360 feet west of The Narrows at the northeast end of Lower Valley to 8,200 feet at the crest of Dry Ridge.

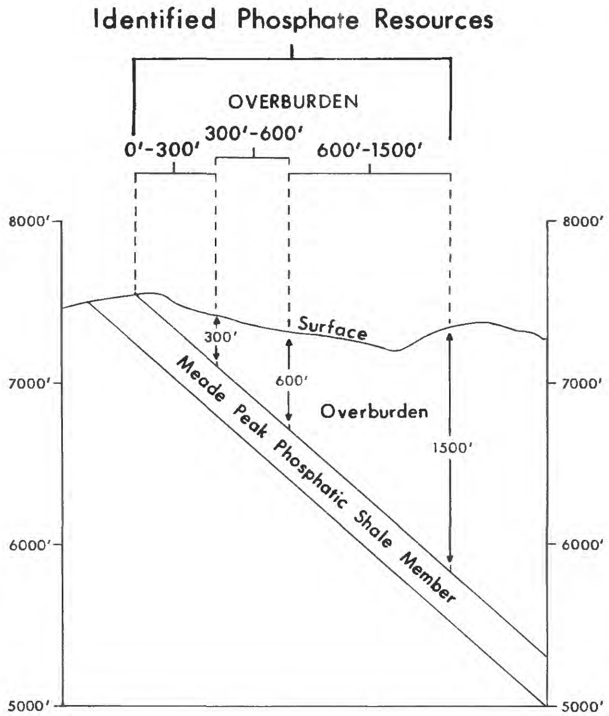


FIGURE 2.— Diagrammatic cross section showing identified phosphate resources for the Meade Peak Phosphatic Shale Member of the Phosphoria Formation.

FEDERAL LAND STATUS

Five combinations of titles to surface and phosphate rights occur in the Upper Valley quadrangle as shown on sheet 3: (1) Federal phosphate on Federal surface; (2) Federal phosphate on private surface; (3) State phosphate on State surface; (4) private phosphate on Federal surface; and (5) private phosphate on private surface. The Federal government holds phosphate title to 67 percent and surface title to 47 percent of the land in the Upper Valley 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 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 a gastropod resembling *Omphalotrochus*, or a thin, soft mudstone locally overlying the nodular phosphorite (McKelvey and others, 1959, p. 23).

In the Upper Valley quadrangle, the Meade Peak Phosphatic Shale Member ranges from 110 to 233 feet in thickness, determined from selected drill hole and trench data. Much of this 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 Upper Valley quadrangle, the Meade Peak crops out over a discontinuous strike length of about 13 miles.

The total phosphate content, measured in weighted average percent P_2O_5, of the upper and lower phosphate units combined, is fairly consistent along strike. Variations in the values are more noticeable when the two units are considered separately. The variation in thickness and P_2O_5 content for both phosphate units within the quadrangle is perhaps best exemplified by average values for the major structurally similar parts of the Meade Peak:

	Average thickness (feet)	P_2O_5 (weighted average percent)
1. West limb of Snowdrift anticline		
upper phosphate unit ---	17	25.5
lower phosphate unit ---	29.8	24.8
TOTAL --------------	47	25.2
2. East limb of Snowdrift anticline		
(a) west of Lanes Creek fault		
upper phosphate unit ---	21.1	27.0
lower phosphate unit ---	52.0	25.1
TOTAL --------------	73.1	26.0
(b) east of Upper Valley fault		
upper phosphate unit ---	18.3	23.2
lower phosphate unit ---	26.7	22.7
TOTAL --------------	45.0	23.0
3. Upper plate of Henry thrust		
upper phosphate unit ---	22	24.0
lower phosphate unit ---	24.7	24.7
TOTAL --------------	47	24.4
4. East limb of Schmid syncline		
upper phosphate unit ---	19	23.5
lower phosphate unit ---	24.3	23.5
TOTAL --------------	43	23.5

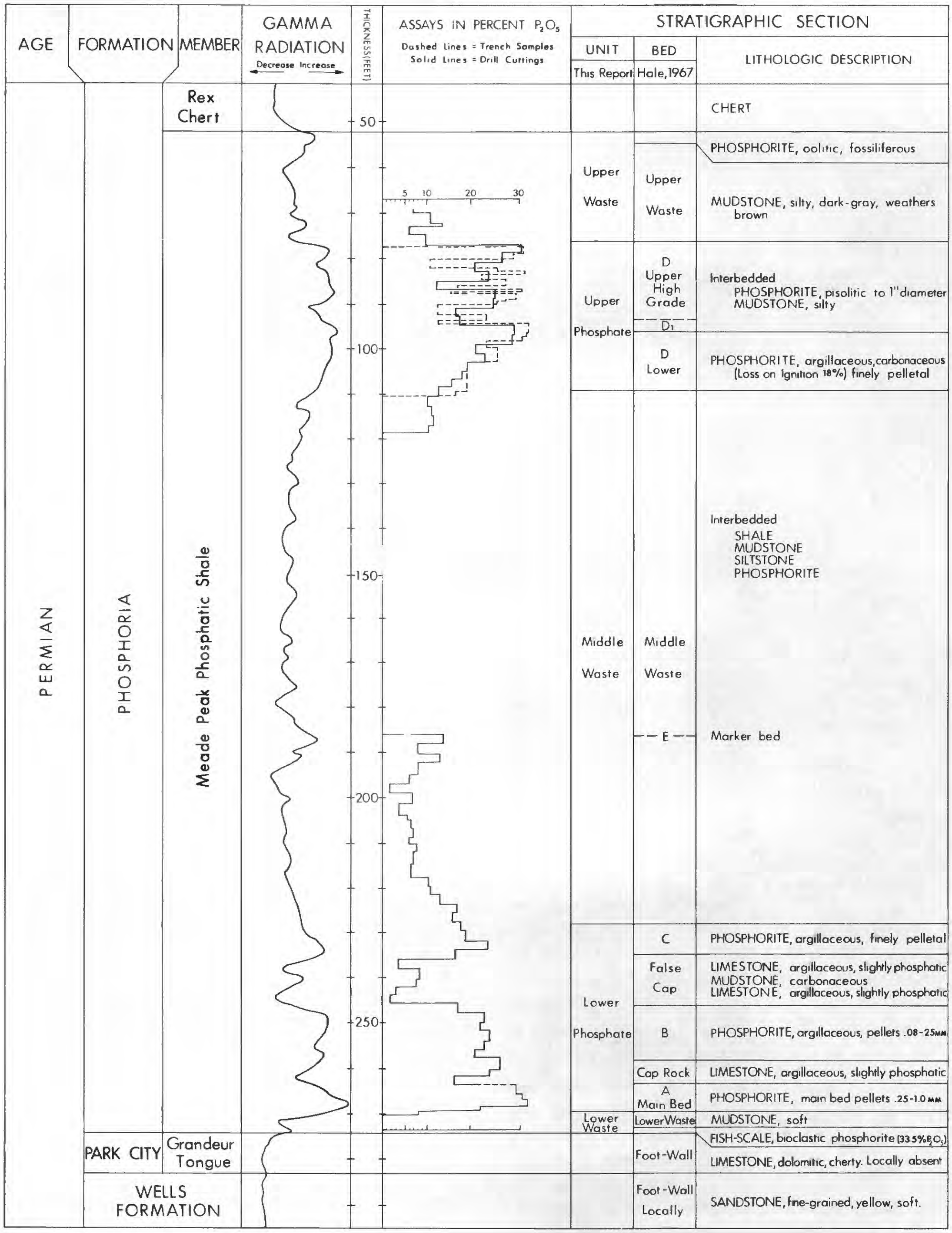


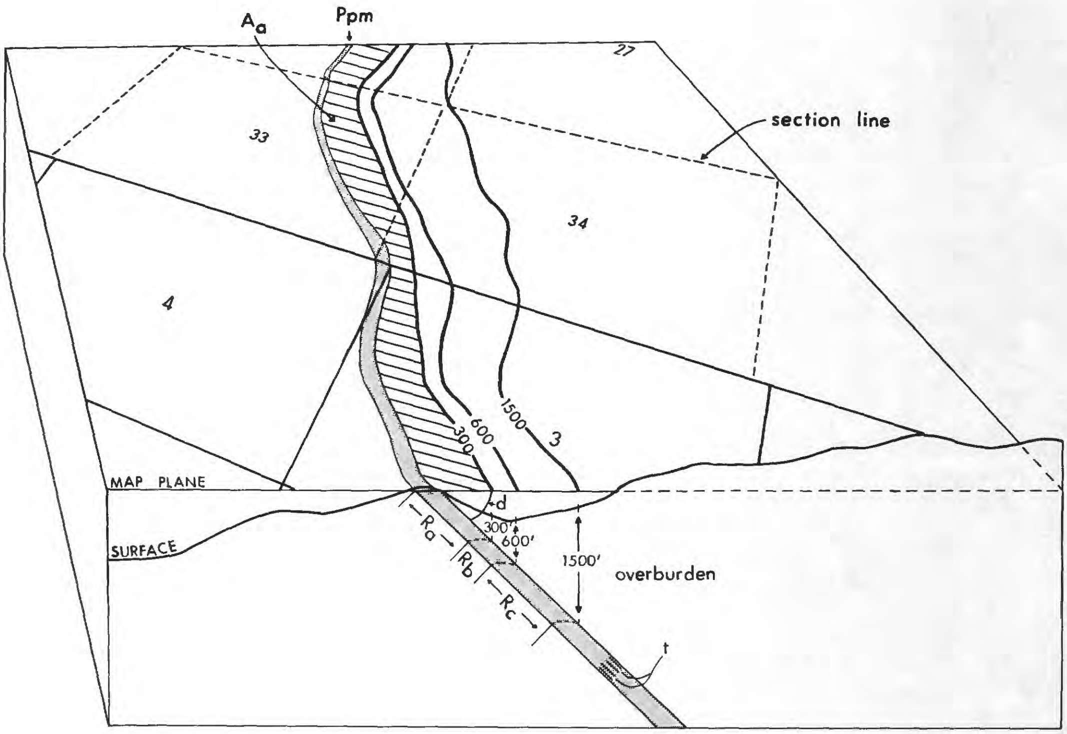
FIGURE 3.—Typical Permian section, upper Dry Valley area, Caribou County, Idaho (from Hale, 1967).

Based on available drill hole and trench data, the phosphate rock within the Meade Peak in the Upper Valley quadrangle averages 51 feet in thickness with a weighted average of 24.6 percent P_2O_5. Detailed stratigraphic sections of the Meade Peak have been published by the U.S. Geological Survey for four trenches (1232, 1233, 1258, 1259) in the Upper Valley quadrangle (McKelvey and others, 1953; O'Malley and others, 1953). Semiquantitative spectrographic determinations have been published for trenches 1232 and 1233 (McKelvey and others, 1953).

STRUCTURE

The Meade Peak Phosphatic Shale Member is structurally deformed by the northwest-trending Snowdrift anticline; Schmid and Georgetown synclines; Henry thrust fault; Enoch Valley, Lanes Creek, and Upper Valley faults; and by the east-trending Rasmussen and Blackfoot tear faults. Dips in the Meade Peak vary from low angle on the east flank of Snowdrift anticline to overturned near the Blackfoot fault.

Several assumptions concerning fault-plane attitudes and offsets were made to determine the structure of the Meade



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.

Peak in the subsurface. The fault-plane dip and stratigraphic throw values listed below were assumed for the entire strike length of the Henry thrust (Peter Oberlindacher, oral commun., 1980) and the Enoch Valley and Lanes Creek faults (Rioux and others, 1975).

Fault	*Dip*	*Stratigraphic throw*
1. Enoch Valley	80°W	600 feet
2. Lanes Creek	83°E	400 feet
3. Henry thrust	30°W	150 feet

The Rasmussen and Blackfoot faults are assumed to be vertical. The dip of the unnamed fault north of the Rasmussen fault is between 47°E and 58°E, and the stratigraphic throw ranges from 0 to 1,150 feet based on average thicknesses and dips of the Phosphoria and Dinwoody Formations. No quantitative data are available for the unnamed faults that parallel the Meade Peak west of the Henry thrust and west of the Lanes Creek fault; thus, these faults are not incorporated into the subsurface interpretations. Other faults which offset the Meade Peak are too minor, at a 1:24,000 map scale, to be incorporated into the subsurface interpretations.

The surface geology in the area between the Henry and Blackfoot faults, north of The Narrows, is extremely complex. Drill-hole data are not available to clarify the subsurface structural relationships; thus, the subsurface interpretation is tenuous. All structure contours, overburden isopachs, and resource blocks in this area are constructed on overturned parts of the Meade Peak.

The Meade Peak is overturned on Dry Ridge immediately south of the Blackfoot fault, probably as a result of left lateral motion along the fault. According to Peter Oberlindacher (oral commun., 1980), the Meade Peak probably returns to a normal dip of 44°E at a depth no greater than 600 feet. Structure contours were not constructed on the overturned Meade Peak in this area (sheet 1). The hinge-line trace of the stratigraphic top of the Meade Peak is shown to indicate approximately how far west the unit extends in the subsurface, assuming that the Meade Peak returns to a normal dip at 600 feet in depth. Overburden isopachs, which are constructed on the stratigraphic top of the Meade Peak, reflect overturning of the Meade Peak in this area, as exemplified by isopach crossovers (sheets 2, 3).

MINERALOGY AND GEOCHEMISTRY

Altered phosphorite within the Meade Peak Phosphatic Shale Member consists, for the most part, of medium-grained, rounded pellets composed 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). Through electron microprobe studies of samples from thin beds of vanadium-rich shale and mudstone in the phosphate-rich zones, Desborough (1977) found vanadium in, or associated with, organic material in leached samples; 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 648 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 Upper Valley quadrangle: 155 million short tons of resources with less than 300 feet of overburden, 140 million short tons of resources with 300 feet to 600 feet of overburden, and 353 million short tons of resources with 600 feet to 1,500 feet of overburden[1]. Thickness and P_2O_5 data from 66 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.

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