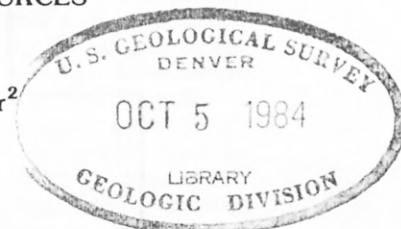


MAPS SHOWING SELECTED GEOLOGY AND PHOSPHATE RESOURCES  
OF THE FOSSIL CANYON QUADRANGLE, BEAR LAKE  
AND CARIBOU COUNTIES, IDAHO

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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 Fossil Canyon 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 Bonnicksen of the Idaho Bureau of Mines and Geology and Peter Oberlindacher of the Bureau of Land Management. Alumet provided their drill-hole data on the understanding that this confidential information would be used only in a regional analysis of phosphate resources. We wish to 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The Fossil Canyon quadrangle phosphate resource maps are based on published and unpublished data from industry, State, and Federal sources.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 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 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 Fossil Canyon quadrangle, fifteen 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 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 ( $\rho$ ) 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. 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

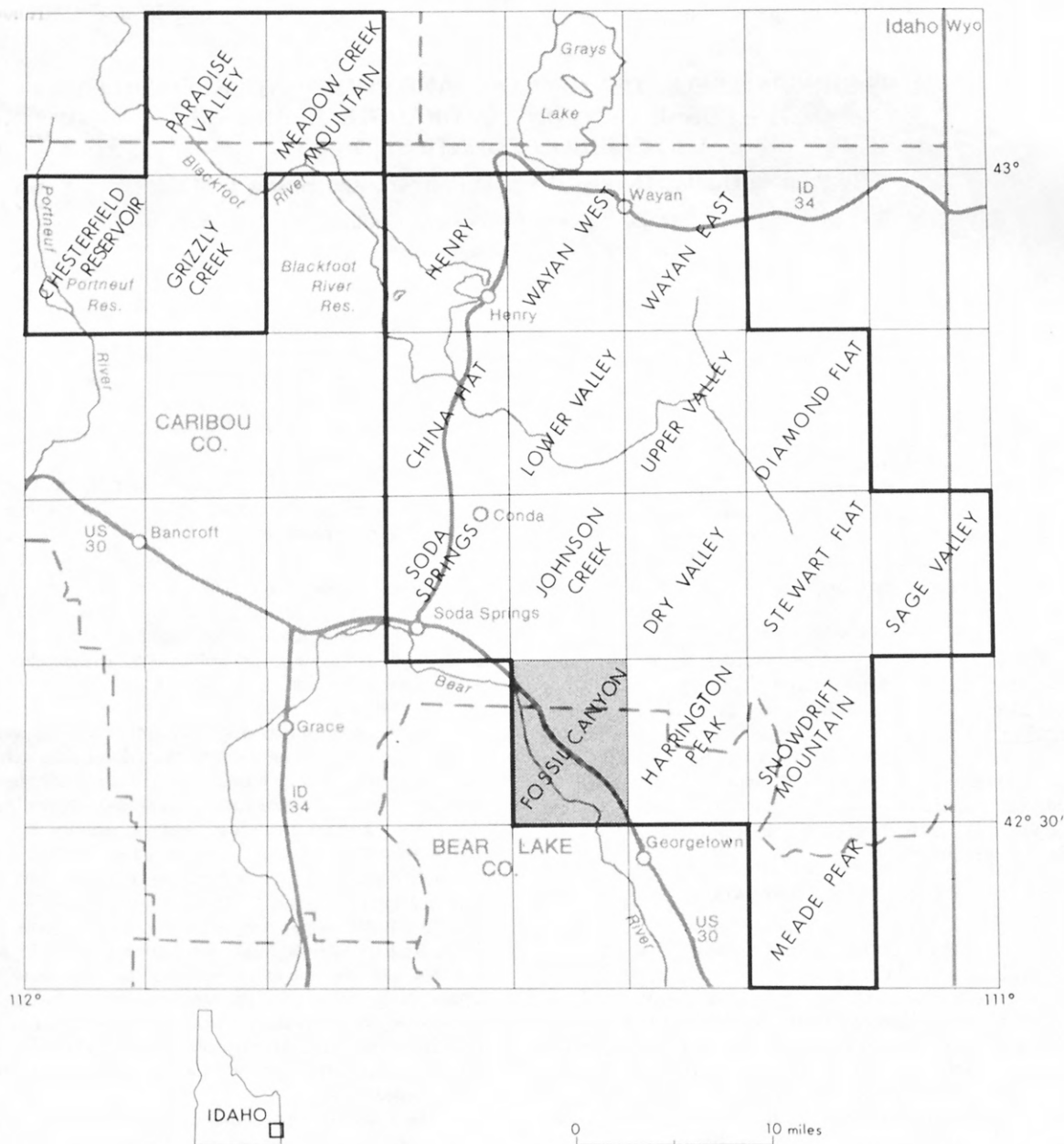


FIGURE 1.—Index map showing location of southeast Idaho phosphate area and Fossil Canyon quadrangle (shaded).

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 Diamond Gulch open-pit phosphate mine was identified from false-color aerial photographs taken in 1979 by the U.S. Geological Survey.

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 Fossil Canyon quadrangle is about 6 miles southeast of Soda Springs, and 2 miles northwest of Georgetown, Idaho (fig. 1). The quadrangle boundary includes parts of Tps. 9, 10, and 11 S., Rs. 42 and 43 E., Boise Principle Meridian. U.S. Route 30 is the major

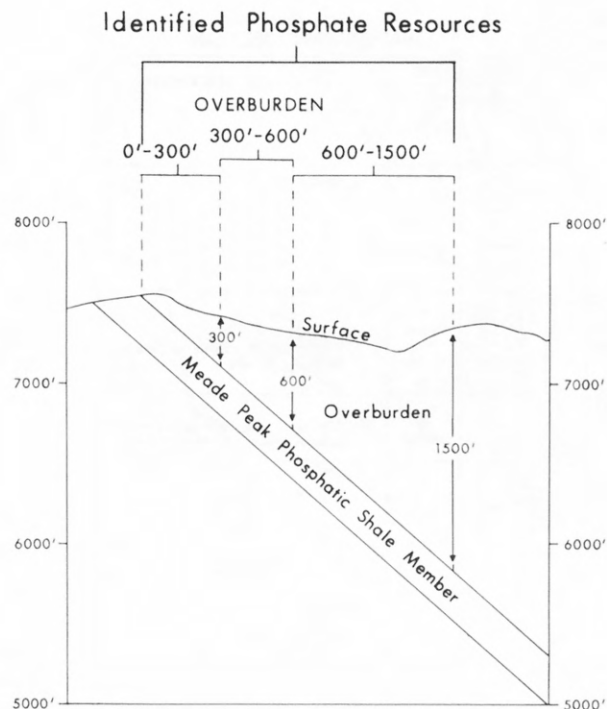


FIGURE 2.—Diagrammatic cross section showing identified phosphate resources for the Meade Peak Phosphatic Shale Member of the Phosphoria Formation.

access highway to the area from Soda Springs and Georgetown. Many other paved and gravel-surfaced roads provide access to the more remote regions. The main line of the Union Pacific railroad also goes through the area, paralleling U.S. Route 30.

Major topographic features in the quadrangle include the Aspen Range, the Bear River Valley, and Nounan Valley, all of which trend northwest. Bear River and its tributaries drain the area. Elevations range from 5,815 feet on the lower end of Bear River to 8,330 feet along the crest of the Aspen Range.

#### FEDERAL LAND STATUS

Six combinations of titles to surface and phosphate rights occur in the Fossil Canyon quadrangle as shown on sheet 3: (1) Federal phosphate on Federal surface, (2) Federal phosphate on State surface, (3) Federal phosphate on private surface, (4) State phosphate on State surface, (5) State phosphate on private surface, (6) private phosphate on private surface. The Federal government holds phosphate title to 63 percent and surface title to 35 percent of the land in the quadrangle. As of August 1980, 2 percent of the Federal phosphate title was leased, but none was under preference right lease application.

#### 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).

The Meade Peak Phosphatic Shale Member averages 145 feet in thickness, determined from selected drill-hole and trench data in the Fossil Canyon and adjacent Johnson Creek quadrangles. Within the Fossil Canyon quadrangle, the Meade Peak crops out over a discontinuous strike length of about 5.5 miles. Based on available drill-hole and trench data, the phosphate rock within the Meade Peak in the quadrangle averages 43 feet in thickness with a weighted average of 25.1 percent  $P_2O_5$ . A detailed stratigraphic section of the Meade Peak in the Fossil Canyon quadrangle has been published by the U.S. Geological Survey for trench 1265 at Swan Lake Gulch (McKelvey and others, 1953).

##### STRUCTURE

The major regional structures in the Fossil Canyon quadrangle include three major normal fault blocks—the uplifted Aspen Range block to the northeast, the Bear River Valley graben, and an uplifted block to the southwest. The west front of the Aspen Range is marked by a zone of unnamed north- to northwest-trending normal faults, most of which are downthrown on the west. The Bannock overthrust of Mansfield (1927) has been reinterpreted as two separate faults: the Paris thrust to the west and an unnamed westward-dipping normal fault to the east (Armstrong and Cressman, 1963). The Phosphoria Formation crops out on the highly faulted west front of the Aspen Range.

North of Swan Lake Gulch, the Meade Peak

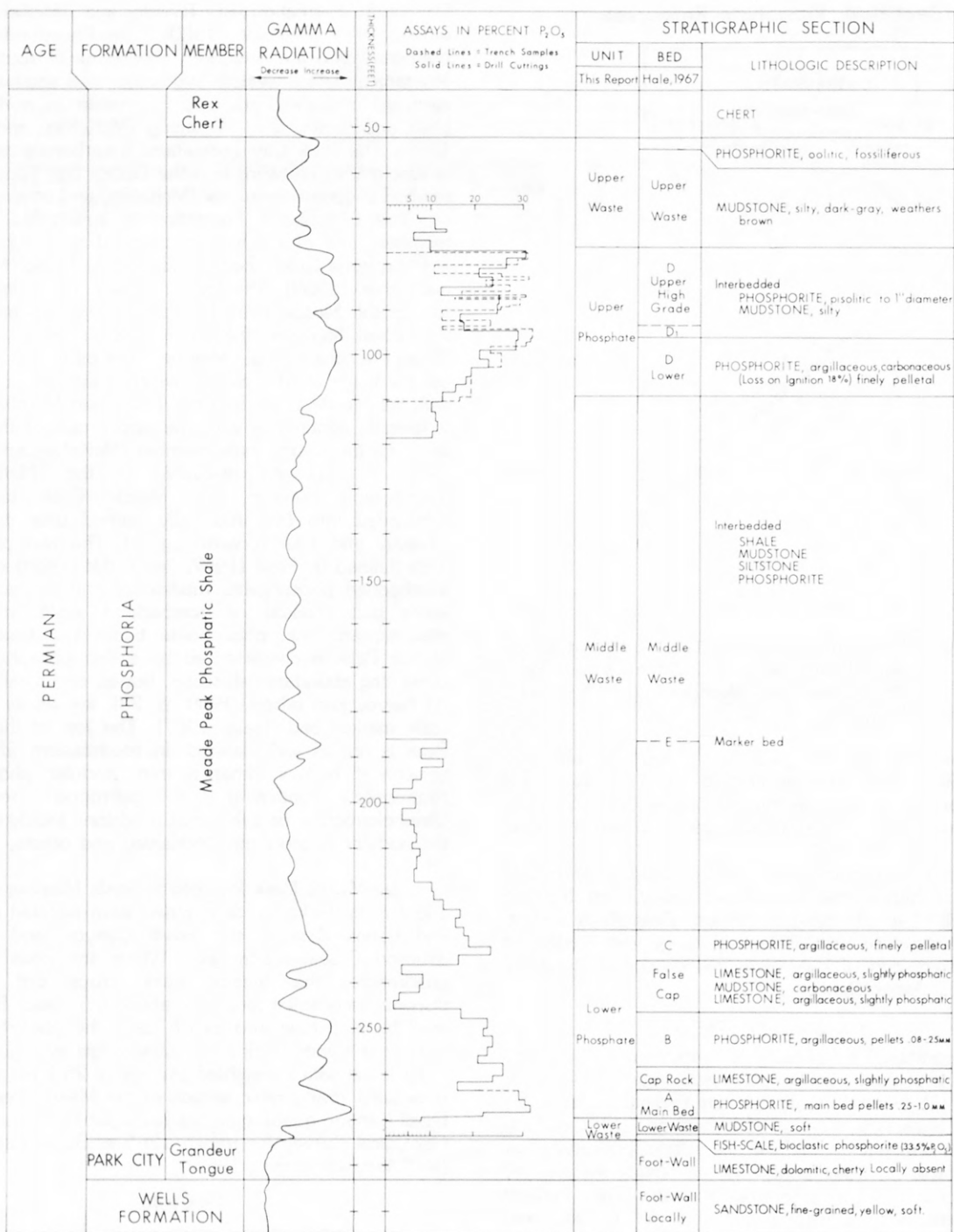


FIGURE 3.—Typical Permian section, upper Dry Valley area, Caribou County, Idaho (from Hale, 1967).

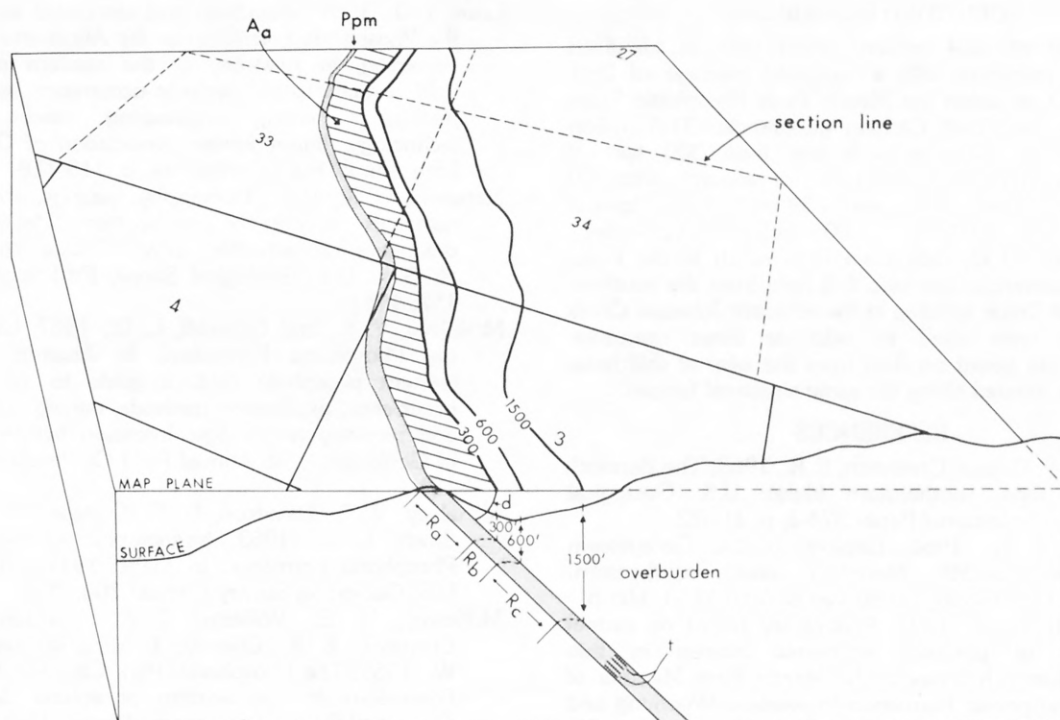
Phosphatic Shale Member appears to be part of an overturned faulted anticline (sheet 1, section A-A'). Within the downthrown fault wedge, the Meade Peak is less than 100 feet thick and dips gently northwest.

Several faulted slices of the Meade Peak crop out en echelon between Swan Lake Gulch and Dry Canyon (sheet 1, sections B-B' and C-C'). Most of these faults are normal, downthrown on the west, and have fault planes that dip moderately west (Cressman, 1964). However, the easternmost long, jagged fault trace (in secs. 20, 28, and

29, T. 9 S., R. 43 E.) may actually represent a low-angle, west-dipping thrust with the Chesterfield Range Group and the Wells Formation comprising the lower plate.

#### 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



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.

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,  $\text{Ca}_5(\text{PO}_4)_3\text{F}$ , 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  $\text{P}_2\text{O}_5$  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 46.4 million short tons of identified phosphate resources with a weighted average of 25.1 percent  $P_2O_5$  is within the Meade Peak Phosphatic Shale Member in the Fossil Canyon quadrangle: 31.3 million short tons of resources with less than 300 feet of overburden, 10.8 million short tons of resources with 300 to 600 feet of overburden, and 4.39 million short tons of resources with 600 to 1,500 feet of overburden.<sup>1</sup> Thickness and  $P_2O_5$  data from one trench in the Fossil Canyon quadrangle and one drill hole from the southern part of Trail Creek syncline in the adjacent Johnson Creek quadrangle 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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<sup>1</sup>Resources calculated to three significant figures for phosphate rock containing 16 or more percent  $P_2O_5$ .

