MAPS SHOWING SELECTED GEOLOGY AND PHOSPHATE RESOURCES OF THE STEWART FLAT 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 phosplate-bearing units in the Meade Peak Phosphatic Shale Member of the Phosphoria Formation in the Stewart Flat 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The Stewart Flat quadrangle phosphate resource maps are based on published and unpublished data from industry, State, and Federal sources.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 drill hole and trench logs, 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 Stewart Flat quadrangle, more than 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 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) $V = At \text{ (sec d)}$

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.

(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.

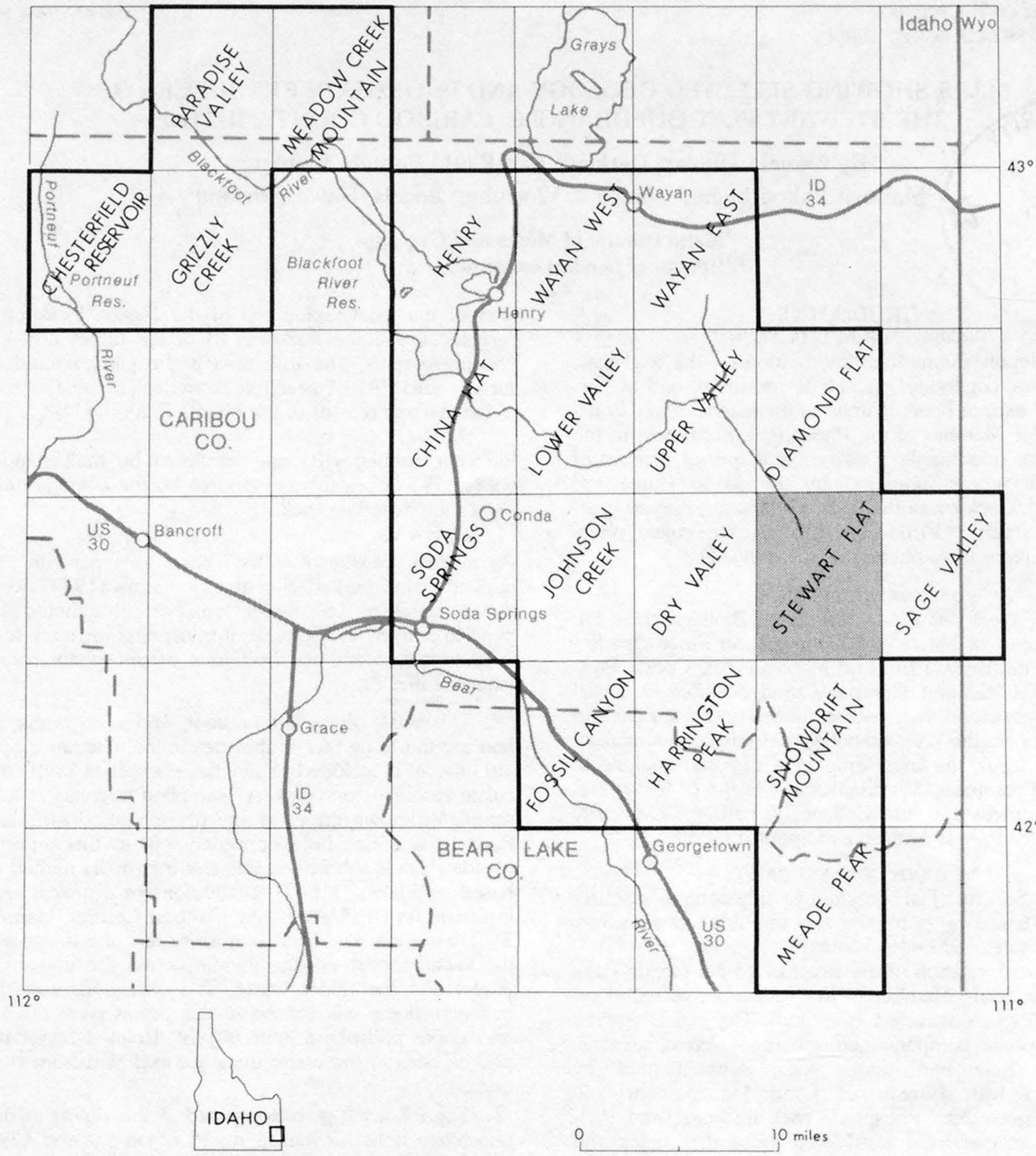


FIGURE 1.—Index map showing the location of 7½-minute quadrangles in the southeast Idaho phosphate area including the Stewart Flat quadrangle (shaded).

(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 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 Stewart Flat quadrangle is about 19 miles east of Soda Springs, Idaho (fig. 1). The quadrangle boundary includes parts of Tps. 8 and 9 S., Rs. 44, 45, and 46 E., Boise Principal Meridian. The area is accessible by graveled roads.

Major topographic features in the quadrangle include the north-trending Webster Range, Freeman Ridge, Stewart Flat, and Dry Ridge. Diamond Creek and its tributaries drain most of the area between Webster Range and Dry Ridge. Draney Peak in the Webster Range and Freeman Pass on Freeman Ridge are also prominent features. Elevations range from 6,670 feet on the west flank of Dry Ridge to 9,131 feet at Draney Peak.

FEDERAL LAND STATUS

The Federal government holds phosphate and surface

Identified Phosphate Resources

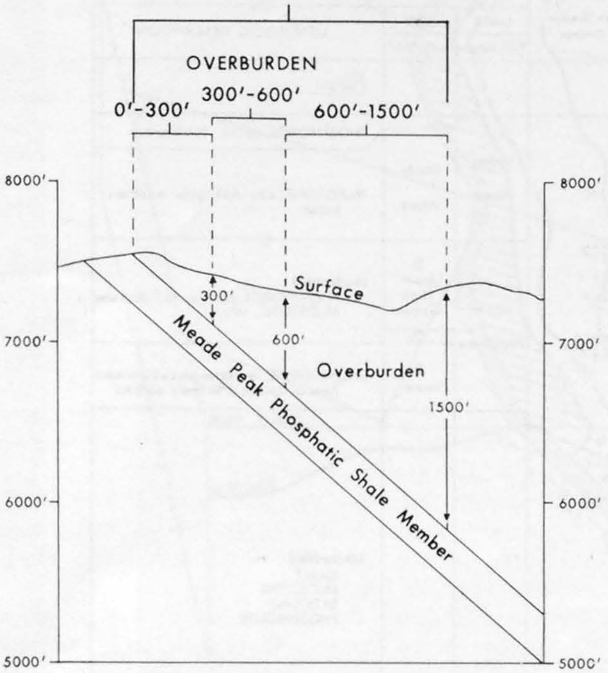


FIGURE 2.—Diagrammatic cross section showing identified phosphate resources of the Meade Peak Phosphatic Shale Member of the Phosphoria Formation.

titles to all land in the Stewart Flat quadrangle (sheet 3). As of August 1980, about 15 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 Stewart Flat quadrangle, the Meade Peak Phosphatic Shale Member averages 180 feet in thickness, determined from selected drill-hole and trench data in the Stewart Flat quadrangle and the northern part of the adjacent Snowdrift Mountain quadrangle. The Meade Peak crops out over a discontinuous strike length of about 24 miles within the Stewart Flat quadrangle. Based on the available data, the phosphate rock within the Meade Peak in the quadrangle averages 57 feet in thickness with a weighted average of 24.7 pecent P_20_5. Detailed stratigraphic sections of the Meade Peak have been published by the U.S. Geological Survey for five trenches in the quadrangle (Sheldon and others, 1953; Montgomery and Cheney, 1967).

STRUCTURE

The Stewart Flat quadrangle is characterized by several regional folds which plunge gently to the north and a few major north-trending faults. These structures are broken by numerous small transverse faults.

The Meade Peak Phosphatic Shale Member dips moderately west on the west limb of the Boulder Creek anticline (sheet 1, section *D-D'*), but dips eastward steeply on the east limb of Snowdrift anticline and shallows to moderate angles at great depth (sheet 1, section *C-C'*). The member wraps around the gently plunging north end of the anticline on Freeman Ridge. Structure contours (sheet 1) and identified resources (sheets 2 and 3) located north of this northernmost Meade Peak exposure are based on the geology of the overlying Rex Chert Member of the Phosphoria Formation. Based on cross-sectional data, the Diamond Creek fault truncates phosphate resources with between 600 and 1,500 feet of overburden on the northwest side of the nose of the anticline. Dips on the western limb of Snowdrift anticline are also steep locally as in sec. 16, T. 9 S., R. 45 E. and west of Freeman Pass (sheet 1, section *C-C'*). There, the Meade Peak retains a fairly consistent westerly dip in the subsurface, based on cross-sectional data. Structural contours and identified resources are projected: (1) along strike on both limbs of Snowdrift anticline where surficial Quaternary deposits mask the Phosphoria Formation and (2) around the nose of the anticline where the Rex Chert Member does not crop out continuously.

The west limb of Georgetown syncline is nearly vertical to overturned along Dry Ridge (sheet 1, section *B-B'*). Where vertical to overturned, the Meade Peak returns to a steep normal dip between 200 and 500 feet in depth based on the geology by Montgomery and Cheney (1967, pl. 2, sections *D-D'* and *E-E'*). The structure at the northern end of Dry Ridge is complex. Exposures of the Meade Peak are faulted and warped by small normal and high-angle thrust faults and overturned folds (sheet 1, section *A-A'*). Dips on the unit at depth are generally quite steep.

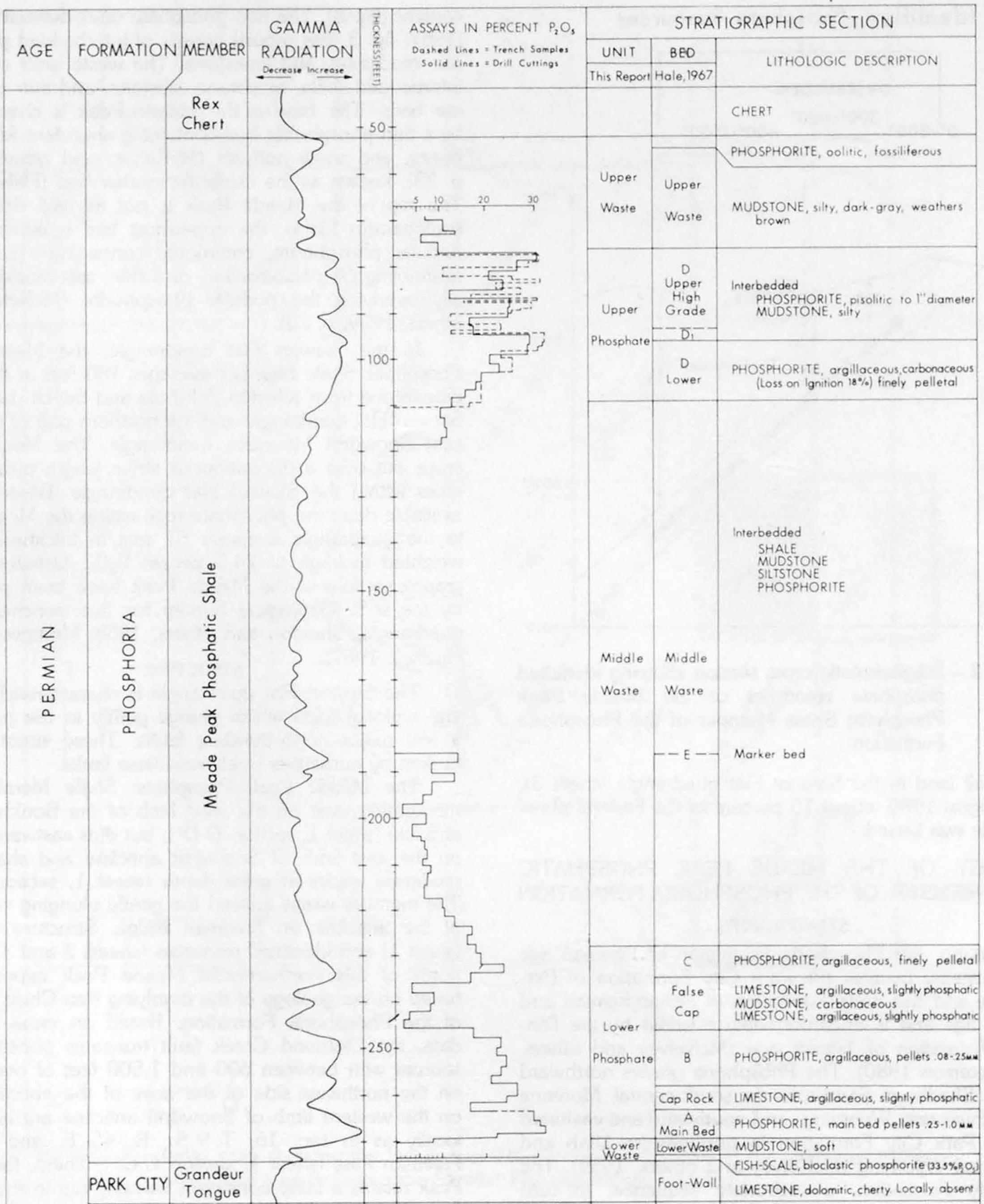
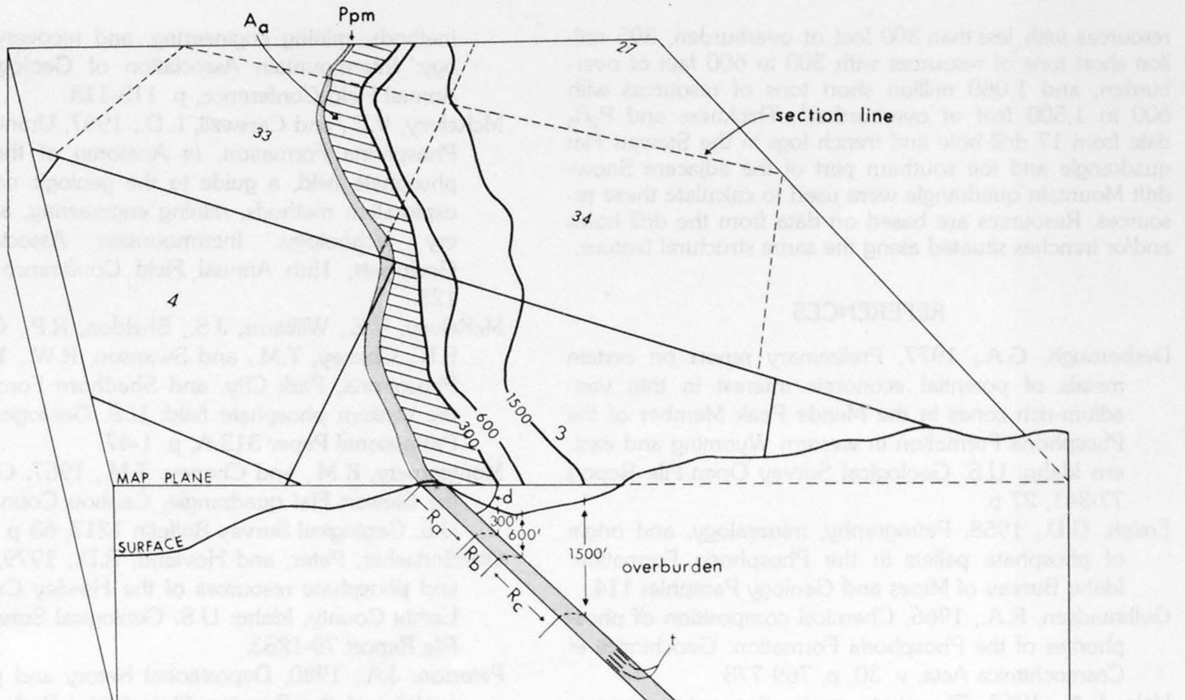


FIGURE 3.— Typical Permian section, upper Dry Valley area, Caribou County, Idaho (from Hale, 1967).

The areas of double and triple overlap represent areas where the Meade Peak is folded under itself once or twice at depth. These areas were measured as much as three times to account for all of the identified phosphate resources. Structural contours are not shown for the overturned portions of the Meade Peak on Dry Ridge. The western limit of the overturned Meade Peak is projected to the surface to show how far west the unit extends before returning to a normal dip.

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). 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).



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 1,500′ 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.

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 1,960 million short tons of identified phosphate resources with a weighted average of 24.7 percent P_2O_5 is within the Meade Peak Phosphatic Shale Member in the Stewart Flat quadrangle: 504 million short tons of resources with less than 300 feet of overburden, 395 million short tons of resources with 300 to 600 feet of overburden, and 1,060 million short tons of resources with 600 to 1,500 feet of overburden.[1] Thickness and P_2O_5 data from 17 drill-hole and trench logs in the Stewart Flat quadrangle and the southern part of the adjacent Snowdrift Mountain quadrangle were used to calculate these resources. Resources are based on data from the drill holes and/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.