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GEOLOGY AND PHOSPHATE RESOURCES OF THE HAWLEY CREEK AREA, LEMHI COUNTY, IDAHO

By

Peter Oberlindacher and R. David Hovland

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CONTENTS

	Page
Abstract	1
Introduction	2
Acknowledgments	2
Previous investigations	2
Field investigations	3
General stratigraphy and structure	4
Phosphate resources	6
Other mineral resources	8
References cited	8

ILLUSTRATIONS

(Plates in pocket)

Plate 1. Geologic map and sections of parts of the Hawley Creek area.

2. Columnar stratigraphic sections and P_2O_5 content of the Retort Phosphatic Shale Member.

3. Structure contour map of parts of the Hawley Creek area.

TABLES

		Page
Table 1.	Stratigraphic section and P_2O_5 analyses of samples from Hawley Creek-North Trench CP-71	10
2.	Stratigraphic section and P_2O_5 analyses of samples from Hawley Creek Trench CP-72	17
3.	Indicated phosphate resources in the Retort Phosphatic Shale Member of the Phosphoria Formation, Hawley Creek area	18

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ABSTRACT

Phosphate resources occur within the Retort Phosphatic Shale Member of the Permian Phosphoria Formation in the Hawley Creek area, near Leadore, in east-central Idaho. About 12 square miles (31 km^2) of the Retort Member and enclosing rocks were mapped at a scale of 1:12,000 to evaluate the leasable Federal mineral resources. The Retort has an average thickness of 73 feet (22.3 m) and 12.9 linear miles (20.8 linear km) of outcrop within the area mapped.

Rock samples taken from a bulldozer trench were analyzed for phosphate content and for minor trace elements. Analyses show a cumulative thickness of 8.7 feet (2.7 m) of medium-grade phosphate rock (24 to 31 percent P_2O_5) and 33.4 feet (10.2 m) of low-grade phosphate rock (16 to 24 percent P_2O_5). Minor elements in the Retort include uranium, vanadium, fluorine, cadmium, chromium, nickel, molybdenum, silver, and rare earths. These minor elements are potential byproducts of any future phosphate production in the Hawley Creek area. In addition, analyses of six phosphate rock samples taken from a prospect trench show a cumulative thickness of 14.9 ft (4.5 m) at 17.6 percent P_2O_5.

Indicated phosphate resources are calculated for phosphate beds under less than 600 feet (183.0 m) of overburden. Approximately 36.5 feet (11.1 m), representing 50 percent of the total Retort Member, were measured in trench CP-71. There are 80.42 million short tons (72.96 million metric tons) of medium-grade phosphate rock, and 308.76 million short tons (280.10 million metric tons) of low-grade phosphate rock in the Retort Member within the map area. Because the thickness and grade of the phosphate beds for each block are based on the recovered section from CP-71, the calculated phosphate resource estimates represent a minimum.

Other mineral resources in the area are thorium (35 ppm) in a Precambrian (?) granite body located immediately west of the Hawley Creek area; oil and gas accumulations may occur beneath the Medicine Lodge thrust system in this part of the Beaverhead Mountains.

Paleozoic, Mesozoic, and Cenozoic rocks are present in the Hawley Creek area. Fold axes and thrust faults have a dominant northwest trend. These thrusts and folds are probably associated with the northeast-oriented stress field that existed in Late Cretaceous time. Evidence of younger, high-angle normal and reverse faults in the area also exists.

INTRODUCTION

The purpose of this field investigation was to determine the thickness, lateral continuity, and grade of phosphate-bearing units within the Retort Phosphatic Shale Member of the Permian Phosphoria Formation in the Hawley Creek area, east-central Idaho. The geologic investigation of the phosphate resources is part of the U.S. Geological Survey's ongoing program to classify and to evaluate leasable mineral resources on Federal lands.

The Hawley Creek area (pl. 1) is about 8 miles (12.9 km) east of Leadore, Lemhi County, east-central Idaho. The map area lies in the Beaverhead Mountains, part of the Bitterroot Range within the Northern Rocky Mountain province. Elevations range from 6,500 feet (1,982.5 m) along Hawley Creek to 10,125 feet (3,088.0 m) north of Dry Canyon.

This report presents a geologic map and description of the phosphate resources, measured stratigraphic sections and chemical analyses from two trenches cut across a part of the Retort Phosphatic Shale Member, a structure contour map of the Retort Member, indicated phosphate resource calculations, and a discussion of other potential mineral resources.

Acknowledgments

Baerbel Lucchitta, currently with the U.S. Geological Survey in Flagstaff, gave us a copy of her unpublished geologic map and Ph.D. dissertation of the Morrison Lake 15-minute quadrangle. Her geologic map and structural interpretations have contributed to our understanding of the regional geology.

W.C. Gere assisted in the trenching and sampling of the area. Clare Shemeta helped construct the structure map and calculate the phosphate resources.

Robert A. Gulbrandsen helped to determine P_2O_5 values for the hand-dug trench samples (CP-72), and provided density values for the phosphate resource calculations.

PREVIOUS INVESTIGATIONS

In the early 1950s, C.P. Ross (in Cressman, 1954) reported phosphatic float along Hawley Creek 9 miles (14.5 km) east of Leadore, Idaho. Cressman (1954) confirmed "the presence of float of high-grade phosphate rock and bedded chert very similar in appearance to the Rex chert member of the Phosphoria." On the basis of a section measured at the surface, Cressman concluded that "the Phosphoria consists of about 700 feet of cherty dolomite overlain by 150 feet of bedded chert. Phosphate rock occurs at two horizons, one 80 feet below the bedded chert and the other 140 feet below the chert. The phosphatic zones are very poorly exposed, but the amount of high-grade phosphate rock in the float suggests the possibility of a mineable thickness of phosphate."

Cressman's (1954) measured section of the Phosphoria Formation was incorporated by McKelvey and others (1959, pl. 3) into a composite correlation diagram of the Phosphoria Formation. The correlation diagram showed the following units: the Meade Peak Phosphatic Shale, Rex Chert, cherty shale, and Tosi Chert Members of the Phosphoria Formation, and the Grandeur and Franson Tongues of the Park City Formation.

The surface section measured by Cressman in 1954 at Hawley Creek was revised and published by Cressman and Swanson (1964, p. 558). Their stratigraphic section shows a phosphorite bed 0.4 feet (0.1 m) thick, overlain by a covered interval 78 feet (23.8 m) thick. This phosphorite bed, about 79 feet (24.1 m) below the Tosi Chert Member was referred to as the Retort Phosphatic Shale Member of the Phosphoria Formation. A covered interval, 8 feet (2.4 m) thick and about 140 feet (42.7 m) below the overlying Tosi Chert Member, is shown in the stratigraphic position where Cressman had previously reported a lower phosphate unit. Neither the Meade Peak nor the overlying Rex Chert Member is shown in the revised section.

Lucchitta (1966) mapped, at a scale of 1:30,700, the northern two-thirds of the Morrison Lake 15-minute topographic quadrangle, including the Hawley Creek area. She mapped the Tosi Chert Member of the Phosphoria Formation as a seperate unit but combined the underlying Retort Phosphatic Shale Member of the Phosphoria Formation with the Park City Formation.

Studies by Scholten (1957) and Ruppel (1976) have also contributed to establishing a regional, structural and stratigraphic framework for the Hawley Creek area.

FIELD INVESTIGATIONS

A reconnaissance of the Hawley Creek area in June 1976 was followed by a 3-week sampling and selected mapping program in August 1976. We collected phosphate samples of the Retort Phosphatic Shale Member from a bulldozer trench (CP-71) in sec. 24, T. 16 N., R. 27 E., and also from an existing prospect trench (CP-72) in sec. 36, T. 16 N., R. 27 E., (pl. 1).

During July and August 1977, assisted by William C. Burkett, we mapped the Retort Phosphatic Shale Member and enclosing rocks at a scale of 1:12,000.

The procedures applied to the excavation and sampling of trench CP-71 are summarized as follows. The main trench was cut to a length of 200 feet (61.0 m) and to a maximum depth of 14 feet (4.3 m). A second, parallel trench, 70 feet (21.4 m) long, was cut 10 feet (3.1 m) to the east. The second trench exposed the lower part of the Retort Member and underlying Park City Formation. Both trenches were cut perpendicular to the strike of bedding to expose true bedding thickness. Trench CP-71 was backfilled and the top soil replaced upon completion of the sampling.

Samples were recovered from the lower and middle parts of the Retort Member in trench CP-71. Procedures for sampling and rock descriptions are similar to those by Gere and others (1966), and by Cressman and Swanson (1964). Approximately 10 feet (3.1 m) of the middle section of the Retort Member is faulted out by a high-angle reverse fault. The amount of missing section is based on the average thickness of the Retort Member, determined from three measured surface sections. The upper beds of the Retort Member in trench CP-71 are deeply weathered, and could not be sampled.

Seven pits were hand-dug across the Retort Member in an existing prospect trench (CP-72). The maximum depth of the pits is about 3 feet (0.9 m).

The detailed stratigraphic sections for sample sites CP-71 and CP-72 with the composition and P_2O_5 content of each measured rock unit are shown in table 1 and table 2, respectively. A columnar section of the Retort Member from CP-71 and CP-72 is shown on plate 2.

GENERAL STRATIGRAPHY AND STRUCTURE

Paleozoic, Mesozoic and Cenozoic age rocks are present in the mapped Hawley Creek area. The nomenclature and correlation of the mapped formations have been developed and summarized by Cressman (1954), McKelvey and Carswell (1956), McKelvey and others (1959), Cressman and Swanson (1964), Lucchitta (1966), and by Ruppel (1976).

The oldest formation exposed in the map area is the Kinnikinic Quartzite of Ordovician age. The formation is exposed in the southern part of the mapped area north of Dry Creek along the west side of a thrust fault. The Kinnikinic, a fine-grained white quartzite, forms a massive cliff along the thrust contact. The Kinnikinic Quartzite was described in detail by Lucchitta (1966, p. 26).

The next youngest unit mapped is the Quadrant Formation of Pennsylvanian age. The base of the formation is not exposed. The top is gradational with the overlying Park City Formation. Lucchitta (1966) divides the formation into three members. A lower member about 200 feet (61.0 m) thick consists of quartzite interbedded with sandy limestone. The middle member, about 720 feet (219.6 m) thick, contains sandy and cherty limestone and calcareous quartzite interbeds near the top. The upper member includes calcareous quartzite, interbedded with sandy dolomite and subordinate limestone.

The overlying Park City Formation of Permian age consists of thickbedded dolomite with limestone and chert interbeds. Sandy dolomite and sandstone units are abundant near the top of the formation. The formation is about 630 feet (192 m) thick in the map area.

Samples Pc-1 through Pc-4 from the uppermost part of the Park City Formation consist of silty and sandy dolomite and silty sandstone (table 1). According to McKelvey and others (1959, p. 19), the Franson Tongue is difficult to distinguish from the Grandeur Member of the Park City Formation where the Meade Peak and Rex Chert Members of the Phosphoria Formation are absent.

Until the regional stratigraphic relationships are studied in detail the thick carbonate, sandstone, and chert units between the Retort Member of the Phosphoria Formation and the underlying Quadrant Formation are referred to as the Park City Formation, undivided.

The Permian Phosphoria Formation conformably overlies the Park City Formation. Both the Retort Phosphatic Shale and the overlying Tosi Chert Members are recognized and mapped. The Meade Peak and the Rex Chert Members are not recognized in the map area. The Retort Phosphatic Shale Member was named by Swanson in McKelvey and others (1959) after Retort Mountain located about 10 air miles (16.1 km) south of Dillon, Mont., and 35 air miles (56.4 km) northeast of Hawley Creek. At the type locality, the Retort is 60 feet (18.3 m) thick. At Big Sheep Canyon, 21 miles (33.8 km) due east of Hawley Creek, the Retort is 83 feet (25.3 m) thick. the member is about 73 feet (22.3 m) thick in the Hawley Creek area, consisting of silty and argillaceous phosphorite, phosphatic siltstone and phosphatic mudstone, dolomitic sandstone, sandy dolomite, and minor chert interbeds. Rip-up phosphorite clasts, angular to subrounded, in a silty sand or mudstone matrix are in samples Rt-10, Rt-11, and Rt-12, of trench CP-71. Similar rip-up phosphorite clasts are recognized in a surface phosphate section measured at Snaky Canyon in the southern Beaverhead Mountains (Oberlindacher and Hovland, 1976, unpub. data).

The Retort Member is poorly exposed but forms a distinct swale between the more resistant underlying Park City Formation and the overlying Tosi Chert Member of the Phosphoria Formation.

On his initial visit to the Hawley Creek area in 1954, Cressman reported that the bedded chert above the high-grade phosphate rock was "similar in appearance to the Rex chert member of the Phosphoria," but in the published measured surface section of the Hawley Creek area (Cressman and Swanson, 1964), the Rex Chert Member is not mentioned. The measured section shows only the Retort and the overlying Tosi Chert Members. The Tosi according to Cressman (1954) is about 147 feet (44.8 m) thick. In the map area, the thickness of the member ranges from 152 feet (46.3 m) to 283 feet (86.3 m). The member is a dark-gray, hard to very hard, thick-bedded ledge-forming unit, with sandy chert lenses and fine-grained brownish sandstone interbeds. The contact between the Tosi and the underlying Retort was not exposed in trenches CP-71 or CP-72. A 2-foot-thick chert and cherty shaly siltstone unit was exposed in a hand-dug trench above CP-72 near the contact between the Retort and the overlying cliff-forming Tosi. The chert and cherty shaly siltstone unit between the Retort and Tosi Members are estimated not to exceed 4 feet (1.2 m) in thickness. The beds are mapped as part of the Retort.

Much of the mapped area is underlain by the Lower Triassic Dinwoody Formation. The basal part of the formation which overlies the Tosi Chert Member consists of shaly and fissile siltstone, yellow-tan to light brown in color, with minor beds of fossiliferous limestone that weather to a distinctive brownish gray. Higher up in the section, limestone beds and interbedded calcareous siltstone become more abundant. What is recognized as the upper part of the Dinwoody Formation in this area may actually include beds of the younger Thaynes Formation. The Meekoceras-bearing limestone that marks the base of the Thaynes Formation was not recognized in the field.

Lucchitta (1966, p. 70) estimated the thickness of the Dinwoody Formation to be at least 1,000 feet (305.0 m). The formation forms smooth grass-covered slopes and hills. Exposures are few and discontinuous. A good exposure of the Dinwoody and underlying Phosphoria formations is along the west boundary of sec. 30, T. 16 N., R. 28 E. The contact with the underlying Phosphoria Formation is conformable.

Tertiary volcanic rocks unconformably overlie the Triassic and older rocks. The volcanic rocks mapped range from andesites to basaltic rocks varying in color from gray to grayish pink. Lucchitta (1966, p. 75) described the volcanic rock sequence in greater detail. The surficial deposits that we mapped include undifferentiated colluvium, terrace and fan deposits, older alluvium, and landslide and talus deposits of Quaternary age. Probable glacial lateral moraine deposits east of Wheetip Creek are also mapped as surficial deposits. Younger Quaternary alluvium is confined to the Hawley Creek, the Rocky Canyon, and the Little Bear Creek drainages.

The Beaverhead Mountains consist of folded and faulted Precambrian, Paleozoic, and younger rocks. Lucchitta (1966) suggested that a northeast-oriented compressional stress field at the end of the Cretaceous Period produced a series of folds within a regional anticlinorium. Continued northeast compression eventually forced Precambrian and lower Paleozoic rocks to yield in northwest-striking thrust faults, the most prominent one for this area being the Hawley Creek thrust fault along the western boundary of the map area. area.

The main trace of the Medicine Lodge fault system extends northward across the Beaverhead Mountains. Ruppel (1976) considered the Mississippian, Pennsylvanian, Permian, and Triassic rocks in the Hawley Creek area to be an anomalous group of rocks that does not fit the local stratigraphic framework. The mapped formations are considered to be part of a former-stratified lower plate that became incorporated in the upper plate as thrust slices. Movement along this thrust fault system may have been as much as 100 miles (161.0 km) northeastward. Paleozoic and Mesozoic rocks in front of the thrust faults are compressed and deformed into asymmetric and overturned folds. A prominent set of folds is developed north of Hawley Creek Canyon and also in the Dry Canyon area. The folds are broken by a series of minor faults trending parallel or oblique to the fold axes, and by several faults perpendicular to the fold axes. A major northeast-trending high-angle fault with a strike-slip component follows Rocky Canyon. The vertical displacement along the fault is 1,400 feet (427.0 m). Another northeast-trending high-angle fault north of Dry Canyon has a relative displacement of 900 feet (274.5 m). The fault could not be traced much beyond the saddle west of Peak 9028T. The mapped contacts between formations north of the saddle are conformable.

PHOSPHATE RESOURCES

Phosphate is the most significant mineral resource in the Hawley Creek area. The phosphate occurs in the Retort Phosphatic Shale Member as oolites and pellets (less than 2 mm in diameter), nodules (larger than 2 mm in diameter), and as cementing material concentrated in dark-gray laminae. The

phosphate mineral is a variety of apatite called carbonate fluorapatite. The composition of apatite in the Retort Member at Hawley Creek is discussed by Kuniyoshi, (1978, unpublished data).

Approximately 12.9 miles (20.8 km) of the Retort Member crop out within the mapped area. Indicated phosphate resources are calculated for phosphate beds under less than 600 feet (183.0 m) of overburden. The total tonnage of phosphate resources in the area is the sum of values calculated within 44 seperate blocks that isolate areas of similar structural configuration (pl. 3). Approximately 36.5 feet (11.1 m), representing 50 percent of the total Retort member, were recovered from trench CP-71. Because the thickness and grade of the phosphate beds for each block are based on the recovered section from CP-71, the calculated phosphate resource estimates represent a minimum.

Because phosphate beds sampled in trenches CP-71 and CP-72 are weathered, the P_2O_5 analyses may not be fully representative of the unweathered part of the Retort at depth. P_2O_5 analyses of weathered phosphate beds have been found to be slightly higher (due to the removal by leaching of carbonate minerals and organic matter) when compared to underlying unweathered phosphate rock (McKelvey and Carswell, 1956, p. 485).

Analyses from trench CP-71 show that cumulative thicknesses of interbeds of medium- and low-grade phosphate beds range as follows: medium grade (24 to 31 percent P_2O_5), 8.7 feet (2.7 m); and low grade (16 to 24 percent P_2O_5), 33.4 feet (10.2 m). Each phosphate bed was used only once for calculating any one-grade cutoff, but the same bed may have been averaged with adjacent beds for the different grades shown.

The amount of the phosphate resource in each block was calculated in a manner similar to the method used by Montgomery and Cheney (1967, p. 41). The volume of the phosphate resource in a block is determined by multiplying the true area by the cumulative thickness at low and medium phosphate grades. The true area is the planimetered map surface area multiplied by the secant of the average dip angle for the block.

The density of phosphate beds varies with percent P_2O_5. An average density of 2.52 metric tons per cubic meter is applied to convert the volume of phosphate resources to metric tons. This average density value takes into consideration both weathered rock under less than 300 feet (91.5 m) and unweathered rock down to 600 feet (183.0 m) or less of overburden. This average density value is derived from the density values listed in the table below.

GRADE	DENSITY (Metric tons/m^3)	
Percent P_2O_5	Weathered phosphate rock	Unweathered phosphate rock
24-31	2.39*	2.64*
16-24	2.47**	2.56*

* From Gulbrandsen (oral commun., 1978).
** From Service and Popoff (1964, p. 4).

A total of 80.42 million short tons (72.96 million metric tons) of medium-grade phosphate rock, and 308.76 million short tons (280.10 million metric tons) of low-grade phosphate rock are calculated for the Retort within the mapped area (table 3).

Minor elements including fluorine, uranium, vanadium, cadmium, chromium, nickel, molybdenum, silver, and rare earths are concentrated in the Retort Member (Kuniyoshi 1978, unpublished data). These minor elements are potential byproducts of phosphate production in the Hawley Creek area.

A large part of the Hawley Creek area is currently (1979) under Federal phosphate prospecting-permit applications.

OTHER MINERAL RESOURCES

A study by Staatz, Bunker, and Bush (1972) described some localized concentrations of 100 ppm thorium in small zones and fractures within the Precambrian (?) granite body immediately west of the subject area. The average thorium content of this granite body is about 35 ppm, too low to be a source of thorium in the near future (Staatz, Bunker, and Bush, 1972, p. B55).

Ruppel (1976, p. 20) suggested that Paleozoic and Mesozoic sedimentary rocks, including both source and reservoir rocks favorable for the accumulation of petroleum and natural gas, are concealed by the Medicine Lodge thrust system in east-central Idaho. According to Ruppel (oral commun., Feb. 16, 1977), Hawley Creek is the approximate northern boundary of these autochthonous Paleozoic and Mesozoic rocks in the Beaverhead Mountains.

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TABLE 1.- STRATIGRAPHIC SECTION AND P_2O_5 ANALYSES OF SAMPLES FROM HAWLEY CREEK - NORTH TRENCH CP-71, HAWLEY CREEK AREA, IDAHO

[The Retort Phosphatic Shale Member of the Phosphoria Formation was measured and described in a bulldozer trench in the SE1/4 NW1/4, sec. 24, T. 16 N., R. 27 E.; the Tosi Chert Member of the Phosphoria Formation and upper part of the undivided Park City Formation were measured and described from natural exposure. Measured and described (from base to top) by P. Oberlindacher and R. D. Hovland in August 1976. Analyzed for P_2O_5 by N. Skinner, and H. Smith, U.S. Geological Survey, Reston, VA, using the "single solution" method as described by Shapiro (1975). Colors were determined by comparison with the "Rock-Color Chart" distributed by the National Research Council (Goddard, 1948), supplemented by the Munsell Soil Color Charts (Munsell Color, (1975)]

Sample No.	Unit No.	Thickness ft	Thickness (m)	Description	P_2O_5 (percent)
				Tosi Chert Member of Phosphoria Formation (top not exposed)	
CP-71-31	Tb-2	68.5+	(20.9+)	Chert: dark-gray (2.5 Y 4/0), hard to very hard, brittle, ledge-forming unit, very thick-bedded; contains some thin sandy chert lenses and fine grained sandstone interbeds with Fe oxide stains, and minor scattered bioclastic zones. Two joint sets; both are prependicular to bedding, dominant set is oriented N-S, some slickensides along joint surfaces. Siliceous veinlets are oriented perpendicular and parallel to bedding.	0.13
CP-71-30	Tb-1	23.14	(7.06)	Covered: predominantly chert float with some cherty sandstone and sandstone float.	--
				Retort Phosphatic Shale Member of Phosphoria Formation	
CP-71-29	Rt-25	25.7	(7.8)	Covered: (samples collected from several shallow hand-dug trenches less than 2 ft deep). Float samples consist of phosphatic sandstone, sandy siltstone, phosphorite and chert.	--

TABLE 1.- STRATIGRAPHIC SECTION AND P_2O_5 ANALYSES OF SAMPLES FROM HAWLEY CREEK - NORTH TRENCH CP-71, HAWLEY CREEK AREA, IDAHO - Continued

Sample No.	Unit No.	Thickness ft	Thickness (m)	Description	P_2O_5 (percent)
				Retort Phosphatic Shale Member of Phosphoria Formation - Continued	
CP-71-28	Rt-24	3.9	(1.2)	Siltstone: dolomitic, phosphatic, weathered, moderate-yellowish-brown (10 YR 5/4), some Fe oxide stains. Contains minor clay interbeds near base; soft, thin-bedded, 1.7 ft thick, overlain by a thin chert bed grading up to a mudstone, dolomitic, phosphatic, brownish-gray (10 YR 3/1), aphanitic, hard, thick-bedded, and blocky, thickness approximate.	13.3
CP-71-27	Rt-23	2.2	(0.7)	Phosphorite: brownish-gray (10 YR 4/1), oolitic, and phosphatic mudstone, laminated, oolitic, soft to medium-hard, thin to thick-bedded, some Fe oxide stains. Phosphatic mudstone unit is 0.7 ft thick and is 0.4 ft above lower contact.	30.9
CP-71-26	Rt-22	1.2	(0.4)	Dolomite lens: brownish-gray (10 YR 4/1), medium-hard to hard, thick-bedded. Lens is about 11 ft long.	3.4
CP-71-25	Rt-21	2.2	(0.7)	Phosphorite, silty, and Mudstone: with laminar phosphorite interbeds, weak-red (2.5 YR 4/2), to moderate-yellowish-brown (10 YR 5/4), soft, thin-bedded, some Fe oxide stains.	24.1
CP-71-24	Rt-20	0.6	(0.2)	Phosphorite: brownish-gray (10 YR 4/1) and interbedded siltstone, moderate-yellowish-brown (10 YR 5/4), medium-hard, thin-bedded.	29.7

TABLE 1.- STRATIGRAPHIC SECTION AND P_2O_5 ANALYSES OF SAMPLES FROM HAWLEY CREEK - NORTH TRENCH CP-71, HAWLEY CREEK AREA, IDAHO - Continued

Sample No.	Unit No.	Thickness ft	Thickness (m)	Description	P_2O_5 (percent)
				Retort Phosphatic Shale Member of Phosphoria Formation - Continued	
CP-71-23	Rt-19	0.7	(0.2)	Phosphorite: brownish-gray (10 YR 3/1), oolitic, hard to very hard, thick-bedded, limonite stains, small calcite-filled vugs along fractures, and reworked phosphate clasts.	28.4
CP-71-22	Rt-18	0.54	(0.16)	Phosphorite: silty, sandy, very pale brown (10 YR 7/3), with some red (2.5 YR 5/6) Fe oxide stains, laminated, medium-hard, thin-bedded, some carbonaceous phosphorite nodules. Sharp upper contact, gradational lower contact.	19.2
CP-71-21	Rt-17	0.21	(0.06)	Mudstone: some beds slightly phosphatic, carbonaceous lenses, grayish-orange (10 YR 7/4), with red (2.5 YR 5/6) Fe oxide stains, soft, thin-bedded.	5.9
CP-71-20	Rt-16	2.1+	(0.6+)	Phosphorite: silty, sandy, dolomitic, dark-yellowish-brown (10 YR 4/2) to brownish-black (10 YR 2/1), medium-hard, thin to thick-bedded, fractured, blocky, some Fe oxide stains and minor faulting. Fault, N 60° E trend, vertical, about 10 ft of section missing.	17.4
CP-71-19	Rt-15	5.5+	(1.7+)	Siltstone: dolomitic, phosphatic, dark-yellowish-brown (10 YR 4/2), slightly phosphatic at lower contact. Grades upward from siltstone to fine sandy siltstone, pale-brown (10 YR 5/3), medium-hard, calcite coatings along bedding planes, carbonaceous, some weathered chert inclusions, some phosphatic laminations and Fe oxide stains. Minor faulting.	12.1

TABLE 1.- STRATIGRAPHIC SECTION AND P_2O_5 ANALYSES OF SAMPLES FROM HAWLEY CREEK - NORTH TRENCH CP-71, HAWLEY CREEK AREA, IDAHO - Continued

Sample No.	Unit No.	Thickness ft	Thickness (m)	Description	P_2O_5 (percent)
				Retort Phosphatic Shale Member of Phosphoria Formation - Continued	
CP-71-18	Rt-14	2.3+	(0.70+)	Siltstone: phosphatic, medium gray (7.5 YR 5/0), cherty, brecciated, with sandy siltstone, moderate-orange (7.5 YR 6/6), medium-hard to hard, very thick-bedded, some limonite coatings, phosphorite clasts?, calcite veinlets and vugs, some minor faulting.	9.3
CP-71-17	Rt-13	1.9	(0.6)	Mudstone: phosphatic, pale-brown (10 YR 5/3), some phosphatic clasts with 2-3 mm thick laminae. Grades upward to mudstone, some Fe oxide staining, clay zone less than 0.05 ft thick at upper contact, medium-hard, thin to thick-bedded.	12.0
CP-71-16	Rt-12	0.5	(0.2)	Phosphorite: cherty, dark-gray (7.5 YR 4/0), with some reworked phosphorite clasts (angular to subrounded up to 10 mm in diameter), in a silty sandstone matrix; medium-hard, thick-bedded, with calcite coatings along joints and in solution cavities. Some red (2.5 YR 4/8) Fe oxide staining. Uppermost 0.05 ft is moderate-brown (7.5 YR 3/4) claystone.	26.2
CP-71-15	Rt-11	1.80	(0.55)	Siltstone: phosphatic, sandy, moderate-yellowish-brown (10 YR 5/4), weathers to pale-reddish-brown (10 YR 5/3). Grades upward to a carbonaceous, phosphatic?, sandy siltstone (some red Fe oxide stains); carbonaceous laminae are as much as 2 in. thick, dark gray phosphorite clasts are about 2 in. in diameter, (subangular to subrounded), lower contact gradational.	7.8

TABLE 1.- STRATIGRAPHIC SECTION AND P_2O_5 ANALYSES OF SAMPLES FROM HAWLEY CREEK - NORTH TRENCH CP-71, HAWLEY CREEK AREA, IDAHO - Continued

Sample No.	Unit No.	Thickness ft	Thickness (m)	Description	P_2O_5 (percent)
				Retort Phosphatic Shale Member of Phosphoria Formation - Continued	
CP-71-14	Rt-10	1.35	(0.41)	Chert: dolomitic, phosphatic, light-brownish-gray (5 YR 5/1), with interbedded reworked clasts up to 0.25 ft thick, and some thin phosphorite and siltstone laminae, and reddish-brown Fe oxidation. Grades upward to a silty dolomite; light-brownish-gray (10 YR 6/1), very hard, thick-bedded, calcite veinlets and slickenslides along joints, upper contact gradational, lower contact sharp.	12.1
CP-71-13	Rt-9	0.05-0.17	(0.02-0.05)	Mudstone: phosphatic, pale-brown (10 YR 5/2), red Fe oxide staining, thin dark-gray phosphorite laminae. Grades to crumbled and smeared mudstone near upper contact, thin-bedded, soft.	17.1
CP-71-12	Rt-8	2.5	(0.8)	Siltstone: dolomitic, phosphatic, sandy, pale-brown (10 YR 5/3), medium-hard, thick-bedded, upper and lower contacts are gradational.	10.9
CP-71-11	Rt-7	2.5	(0.8)	Phosphorite: argillaceous, moderate-yellowish-brown, (10 YR 4/4), soft, friable, 0.25 ft thick. Grades upward to phosphorite, oolitic, brownish-gray (10 YR 4/1), thin-bedded, medium-hard.	27.5
CP-71-10	Rt-6	0.5	(0.2)	Mudstone: dolomitic, grayish-brown (10 YR 4/3) to moderate-yellowish-brown (10 YR 4/4), medium-hard, thin-bedded, blocky, thin dark phosphorite? laminae, gradational upper and lower contacts.	5.5

TABLE 1.- STRATIGRAPHIC SECTION AND P_2O_5 ANALYSES OF SAMPLES FROM HAWLEY CREEK - NORTH TRENCH CP-71, HAWLEY CREEK AREA, IDAHO - Continued

Sample No.	Unit No.	Thickness ft	Thickness (m)	Description	P_2O_5 (percent)
				Retort Phosphatic Shale Member of Phosphoria Formation - Continued	
CP-71-9	Rt-5	0.55	(0.17)	Phosphorite: argillaceous, moderate-yellowish-brown (10 YR 4/4), soft, friable, thin-bedded.	21.3
CP-71-8	Rt-4	0.8	(0.2)	Phosphorite: dolomitic, argillaceous, dark-yellowish-brown (10 YR 4/2) to brownish-gray (10 YR 3/1), oolitic, medium-hard, thin-bedded with laminations. A 0.3-ft-thick phosphorite bed at top.	21.6
CP-71-7	Rt-3	1.2	(0.4)	Sandstone, dolomitic and Dolomite, sandy: pale-red (10 YR 6/2) to light-brownish-gray (10 YR 5/1), with thin, fissile, laminated phosphate beds less than 0.03 ft thick; very hard, thick-bedded, aphanitic, some calcite coatings.	2.9
CP-71-6	Rt-2	1.2	(0.4)	Phosphorite, silty and Siltstone, phosphatic: with some interbeds of mudstone, siltstone and clay, brownish-gray (10 YR 4/1) to very dark-grayish-brown (10 YR 3/2), hard to medium-hard, thin-bedded. Basal oolitic phosphorite bed is 0.2 ft thick, very hard, and grades up to a 0.1-ft-thick phosphatic siltstone bed, and a 0.1-ft-thick siltstone bed.	23.5
CP-71-5	Rt-1	0.05	(0.02)	Mudstone: phosphatic, (gouge zone), fissile, medium-hard, 0.01-ft-thick chert and phosphate bed at bottom of Retort Phosphatic Shale Member.	16.8

TABLE 1.- STRATIGRAPHIC SECTION AND P_2O_5 ANALYSES OF SAMPLES FROM HAWLEY CREEK - NORTH TRENCH CP-71, HAWLEY CREEK AREA, IDAHO - Continued

Sample No.	Unit No.	Thickness ft	Thickness (m)	Description	P_2O_5 (percent)
				Park City Formation (undivided)	
CP-71-4	Pc-4	1.5	(0.50)	Dolomite: silty, dark-yellowish-brown (10 YR 4/2), to brownish-gray (10 YR 4/1), hard, thick-bedded, fine laminations, secondary calcite coatings along joints. A 0.1-ft-thick lenticular bed of slightly phosphatic?, carbonaceous mudstone near bottom of unit.	0.38
CP-71-3	Pc-3	0.09	(0.03)	Chert: lenses and nodules, black (2.5 Y 2/0), hard, brittle, calcite coatings and veinlets; chert is bioclastic in places.	0.21
CP-71-2	Pc-2	45.41	(13.85)	Dolomite, sandy and Sandstone, dolomitic (interbedded): light-brownish-gray (10 YR 6/1) to light-gray (5 YR 7/1) to grayish-orange pink (5 YR 7/2), medium-hard to hard, thick to very-thick bedded. Some thin quartzite beds; light-gray (5 YR 7/1), and lenses of ferruginous sandstone, dark-reddish-gray (10 R 3/1), some fossiliferous beds.	1.1
CP-71-1	Pc-1	26.0	(7.9)	Sandstone: silty, light-yellowish-brown (10 YR 6/4), medium-hard to hard, thin-bedded, very fine sand, ledge former, weathers platy, cross-bedded?, some shark teeth fragments. Some interbeds of silty sandy dolomite, light-brownish-gray (10 YR 5/1), hard, thick-bedded, dendritic manganese oxide stains on joint surfaces. Covered Interval-lower section not described.	0.14

TABLE 2.- STRATIGRAPHIC SECTION AND P_2O_5 ANALYSES OF SAMPLES FROM HAWLEY CREEK TRENCH CP-72, HAWLEY CREEK AREA, IDAHO

[The Retort Phosphatic Shale Member of the Phosphoria Formation was measured and described from seven hand-dug pits in an existing prospect trench immediately north of Hawley Creek in sec. 36, T. 16 N., R. 27 E. Measured and described by P. Oberlindacher and R. D. Hovland in June 1976. Analyzed for P_2O_5 by R. A. Gulbrandsen, P. Oberlindacher, R. D. Hovland, and S. Kuniyoshi, U.S. Geological Survey, Menlo Park, CA, using the "single solution" method as described by Shapiro (1975). Colors were determined by comparison with the "Rock-Color Chart" distributed by the National Research Council (Goddard, 1948), supplemented by the Munsell Soil Color Charts (Munsell Color, 1975)]

Sample No.	Thickness[1] ft	(m)	Description	P_2O_5 (percent)
			Retort Phosphatic Shale Member of Phosphoria Formation	
	9.6	(2.9)	Covered section.	--
HC-7	1.3	(0.4)	Mudstone, silty, phosphatic, calcareous.	8.0
	11.8	(3.6)	Covered section.	--
HC-6	4.4	(1.3)	Mudstone, silty, phosphatic, dolomitic.	12.9
	10.0	(3.1)	Covered section.	--
HC-5	1.3	(0.4)	Phosphorite, silty.	25.3
	5.2	(1.6)	Covered section.	--
HC-4	3.1	(0.9)	Siltstone, phosphatic.	17.2
HC-3	1.3	(0.4)	Siltstone, phosphatic, sandy, dolomitic.	7.3
HC-2	2.6	(0.8)	Phosphorite, silty.	27.0
HC-1	.9	(0.3)	Phosphorite, oolitic.	32.5
	22.5	(6.9)	Covered section.	--

[1]Thickness values are approximate because samples were collected within a zone of surface creep. Total thickness of the Retort Shale in this section is about 74 ft (22.6 m).

TABLE 3.-Indicated phosphate resources in the Retort Phosphatic Shale Member of the Phosphoria Formation, Hawley Creek Area, Idaho

	Million Tons			
	Low Grade (16 to 24 percent P_2O_5)[2]		Medium Grade (24 to 31 percent P_2O_5)[3]	
Block Number	short	(metric)	short	(metric)
1	9.99	(9.06)	2.60	(2.36)
2	6.35	(5.76)	1.65	(1.50)
3	9.23	(8.37)	2.40	(2.18)
4	6.45	(5.85)	1.68	(1.52)
5	5.56	(5.04)	1.44	(1.31)
6	5.69	(5.16)	1.48	(1.34)
7	9.24	(8.38)	2.40	(2.18)
8	1.21	(1.10)	0.32	(0.29)
9	3.95	(3.58)	1.03	(0.93)
10	2.60	(2.36)	0.67	(0.61)
11	7.05	(6.40)	1.84	(1.67)
12	1.97	(1.79)	0.52	(0.47)
13	1.37	(1.24)	0.35	(0.32)
14	11.68	(10.60)	3.04	(2.76)
15	4.70	(4.26)	1.22	(1.11)
16	4.02	(3.65)	1.05	(0.95)
17	9.34	(8.47)	2.44	(2.21)
18	0.45	(0.41)	0.12	(0.11)
19	11.64	(10.56)	3.03	(2.75)
20	3.46	(3.14)	0.90	(0.82)
21	27.45	(24.90)	7.20	(6.53)
22	9.87	(8.95)	2.57	(2.33)
23	13.47	(12.22)	3.51	(3.18)
24	22.96	(20.83)	5.97	(5.42)
25	7.78	(7.06)	2.03	(1.84)
26	2.80	(2.54)	0.73	(0.66)
27	5.24	(4.75)	1.37	(1.24)
28	9.70	(8.80)	2.52	(2.29)
29	12.06	(10.94)	3.14	(2.85)
30	11.32	(10.27)	2.95	(2.68)
31	8.77	(7.96)	2.28	(2.07)
32	4.88	(4.43)	1.25	(1.13)
33	4.81	(4.36)	1.26	(1.14)
34	4.05	(3.67)	1.06	(0.96)
35	4.33	(3.93)	1.12	(1.02)
36	6.26	(5.68)	1.63	(1.48)
37	3.23	(2.93)	0.84	(0.76)
38	1.97	(1.79)	0.52	(0.47)
39	7.17	(6.50)	1.86	(1.69)
40	5.54	(5.03)	1.44	(1.31)
41	5.43	(4.93)	1.41	(1.28)
42	4.88	(4.43)	1.27	(1.15)
43	5.59	(5.07)	1.46	(1.32)
44	3.25	(2.95)	0.85	(0.77)
Total	308.76	(280.10)	80.42	(72.96)

[1]Resources calculated for phosphate rock between the ground surface and the 600 ft isopach contour of overburden.

[2]Cumulative bed thickness is 33.4 ft with a weighted average of 16.8 percent P_2O_5.

[3]Cumulative bed thickness is 8.7 ft with a weighted average of 27.2 percent P_2O_5.