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**STRATIGRAPHIC SECTIONS OF THE PHOSPHORIA FORMATION
IN MONTANA, 1947-48**

By R. W. Swenson, W. R. Lowell, E. R. Crossman, and D. A. Eastwick

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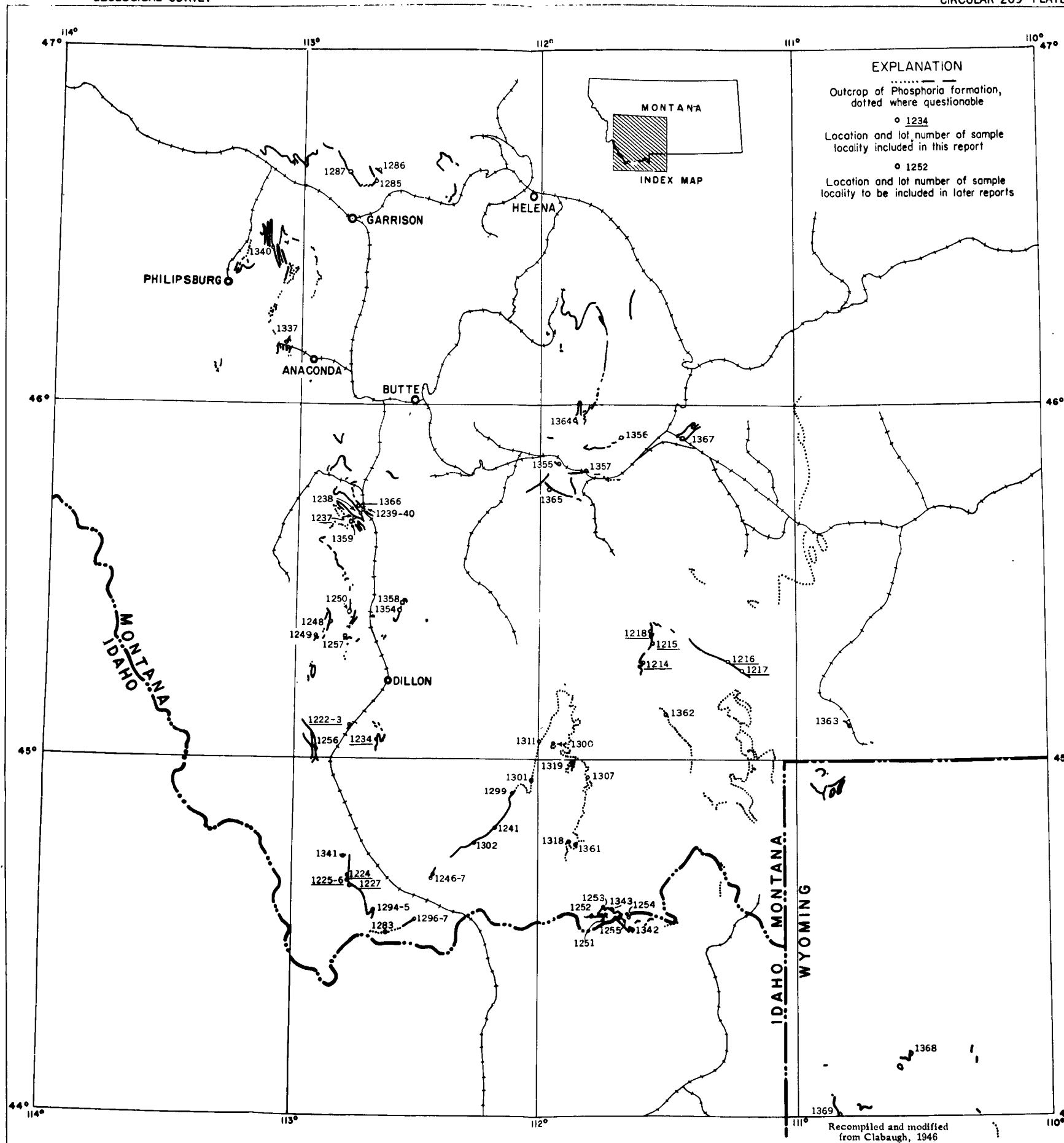
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PHOSPHORIA FORMATION OUTCROPS IN MONTANA AND LOCALITIES SAMPLED FOR PHOSPHATE

0 10 20 30 40 MILES

STRATIGRAPHIC SECTIONS OF THE PHOSPHORIA FORMATION IN MONTANA, 1947-48

INTRODUCTION

The U. S. Geological Survey has recently measured and sampled the Phosphoria formation at many localities in Montana and other western states. These data will not be fully synthesized and analyzed for several years, but segments of the data, accompanied by little or no interpretation, will be published as preliminary reports as they are assembled. This report, which contains abstracts of many of the sections measured in southwestern Montana (pl. 1), is one of this series. The field and laboratory procedures adopted in these investigations are described rather fully in a companion report (McKelvey and others, 1953).

Many people have taken part in this investigation. The program of which this work is a part was organized by V. E. McKelvey. J. G. Evans, F. S. Honkala, R. L. Konizeski, J. A. Mann, R. L. Parker, O. A. Payne, E. T. Ruppel, J. E. Smedley, L. A. Thomas, and W. H. Wilson participated in the description of strata and collection of samples referred to in this report. The laboratory preparation of samples for chemical analysis was done in Denver, Colo., under the direction of W. P. Huleatt.

The chemical analyses were made for the Survey by the U. S. Bureau of Mines at the Northwest Electrodevelopment Laboratory, Albany, Oreg., under the direction of S. M. Shelton and M. L. Wright. The spectrographic analyses were made by D. M. Mortimer, of the Bureau of Mines in Albany, and the oil-shale analyses were made by the Bureau of Mines Petroleum and Oil-Shale Experiment Station at Laramie, Wyo.

Compilation of the data has been largely by R. P. Sheldon and F. D. Frieske. Organization of the tabular data has been largely by Anita Cozzetto.

Acknowledgments

Special thanks are due A. E. Weissenborn, who gave much advice and help in carrying out the field program. The cost of the field and laboratory investigations has been borne partly by the Missouri River Basin Division of the Bureau of Reclamation and the Division of Raw Materials of the Atomic Energy Commission. Their support is gratefully acknowledged. It is a pleasure to acknowledge the fine cooperation extended to the field parties by the local residents and property owners who furnished information and services and gave access to property.

STRATIGRAPHY OF THE PHOSPHORIA FORMATION IN MONTANA

The Phosphoria formation in southwestern Montana consists in general of five members, two phosphatic shale members and three hard members (fig. 1). The

first description of these members (Klepper and others, 1948) was presented in a paper read at the Northwest Science meetings in Spokane, Wash., but the first published description was by Klepper (1950). The lower two hard members are dominated by limestone and the top by chert and sandstone or quartzite. Most of the members can be identified over a large part of the area of outcrop, though member correlation toward the east and northeast is much more difficult. The formation ranges in thickness from less than 100 feet to more than 800 feet.

The lowermost or A member is best developed toward the west and southwest and consists of limestone or dolomite, sandstone, mudstone, and chert, with a maximum thickness of nearly 350 feet. It overlies the Pennsylvanian Quadrant formation and is probably equivalent to the upper member of the Wells formation of southeastern Idaho and adjacent Wyoming and Utah (McKelvey, 1949).

The lower phosphatic shale or B member is about 50 feet thick near the southwest corner of the state but thins markedly to the north and east where in some areas it cannot be recognized. It contains a rich bed of minable phosphate in the Centennial Range.

The middle or C member consists of as much as 200 feet of limestone and/or chert and sandstone. The upper phosphatic shale or D member is rather similar to and much more uniform and widespread than the B member, though minable phosphate is present only toward the north end of the field where the full thickness of the phosphatic zone may consist of a single 3- to 5-foot bed of high-grade phosphate rock.

The uppermost or E member is the most widespread and uniform, averaging about 100 feet in thickness and consisting chiefly of siliceous rocks—siltstone, chert, and quartzitic sandstone. It is overlain by the Triassic Dinwoody formation in the greater part of the area and by the Jurassic Ellis group toward the north and northeast.

STRATIGRAPHIC SECTIONS

Analytical data and abstracts of stratigraphic sections measured at eight localities follow. Their locations as well as the locations of other sections to be reported later are shown in plate 1.

The semiquantitative spectrographic analyses are based upon comparisons with a standard plate representing known quantities of the elements tested for and made at the same exposure. Greater sensitivities for many elements can be obtained by additional exposures. The standard sensitivities for the elements noted in this report are as follows:

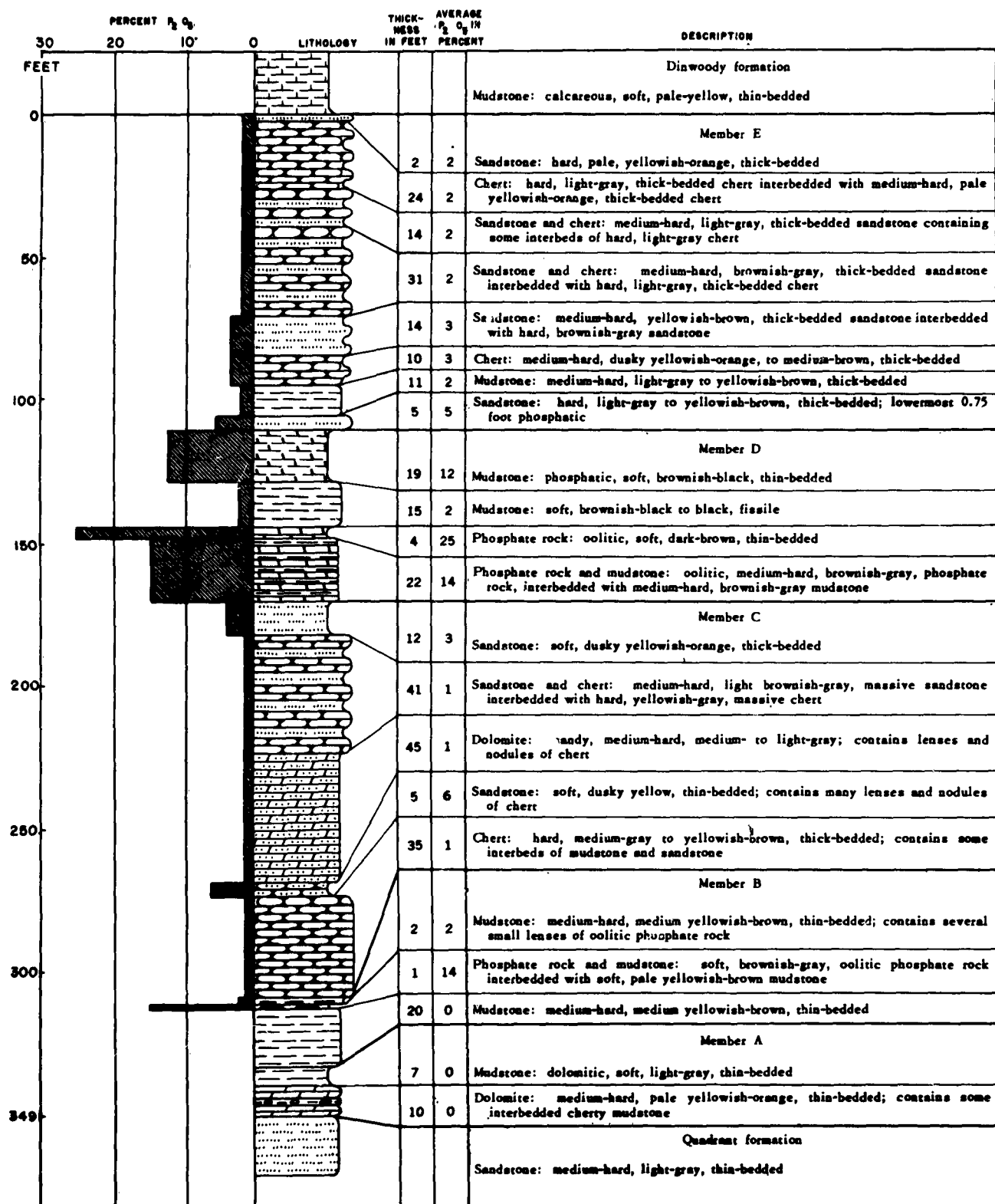


Figure 1. --Generalized section of Phosphoria formation at Sheep Creek, Montana

Element	Percent	Element	Percent
Al	0.005	Li	0.2
Sb	.05	Mg	.001
As	.1	Mn	.004
Ba	.08	Hg	.10
Be	.001	Mo	.004
Bi	.002	Ni	.01
B	.001	P	.8
Cd	.1	Pt	.01
Ca	.01	Si	.002
Cr	.02	Ag	.001
Co	.01	Na	.05
Cb	.01	Sr	.1
Cu	.001	Ta	1.0
Ga	.05	Sn	.01
Ge	.01	Ti	.002
Au	.01	W	.1
In	.05	V	.01
Fe	.005	Zn	.05
Pb	.1	Zr	.003

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JACK CANYON, MONTANA. LOT NO. 1218.

Phosphoria formation sampled in hand trench and outcrop about 900 feet above Jack Creek on north side of canyon in SE $\frac{1}{4}$ sec. 35, T. 5 S., R. 1 E., Madison County, Montana, on overturned and faulted west limb of Madison Range syncline. Beds strike N. 60° E. and dip 45° NW. Section measured by R. W. Swanson and sampled by J. G. Evans in September 1947. Samples analyzed by U. S. Bureau of Mines Laboratory, Albany, Oregon.

Bed no.	Rock description	Sample no.	Thickness (feet)	Chemical analyses (percent)					Cumulative thickness (feet)	Thickness x percent P ₂ O ₅ (cumulative)
				P ₂ O ₅	Al ₂ O ₃	Fe ₂ O ₃	Loss on ignition	Acid insoluble		
Dinwoody formation										
Td-1	Mudstone, calcareous	--	6.0	--	--	--	--	--	6.0	--
Td-2	Sandstone, calcareous, argillaceous	--	1.6	--	--	--	--	--	7.6	--
Phosphoria formation										
25	Chert and calcareous sandstone	RWS-107-47	8.2	0.8	1.6	2.6	12.2	68.4	8.2	6.56
24	Sandstone, calcareous, and chert	RWS-106-47	18.1	1.5	0.5	1.3	9.7	74.0	26.3	33.71
23	Sandstone, calcareous, and chert	RWS-105-47	12.8	1.5	0.5	1.9	6.5	81.3	39.1	52.91
22	Chert, sandstone, and limestone	RWS-104-47	8.4	0.8	0.9	2.6	4.7	85.0	47.5	59.63
21	Chert and quartzite	RWS-103-47	8.6	1.8	0.8	2.1	2.1	88.2	56.1	75.11
20	Sandstone	RWS-102-47	10.5	1.4	0.6	1.1	9.0	75.3	66.6	89.81
19	Quartzite	RWS-101-47	9.65	2.1	0.9	1.3	1.8	89.3	76.25	110.08
18	Chert and quartzite	RWS-100-47	6.2	1.3	0.9	3.5	2.0	88.5	82.45	118.14
17	Chert and mudstone	RWS-99-47	3.9	0.6	3.1	5.1	3.0	85.0	86.35	120.48
16	Chert and mudstone	RWS-98-47	5.25	1.3	1.8	4.3	4.1	83.1	91.60	127.30
15	Chert and mudstone	RWS-97-47	6.9	0.9	3.2	5.5	2.9	84.5	98.50	133.51
14	Phosphate rock, argillaceous	RWS-96-47	0.17	18.9	1.3	2.9	2.2	44.0	98.67	136.72
13	Chert and mudstone	RWS-95-47	2.4	1.2	6.0	5.2	4.2	81.3	101.07	139.60
12	Phosphate rock, argillaceous	RWS-94-47	0.5	22.9	1.4	2.6	1.8	37.4	101.57	151.05
11	Chert and calcareous mudstone (may include 2.45 feet repetition by faulting)	RWS-93-47	3.25	0.8	3.6	4.1	11.9	67.8	104.82	153.65
10	Chert and mudstone	RWS-92-47	4.05	0.6	4.7	4.7	2.4	87.3	108.87	156.08
9	Chert and mudstone	RWS-91-47	4.6	0.8	4.5	4.9	2.4	86.9	113.47	159.76
8	Chert and mudstone	RWS-90-47	4.4	0.6	4.3	4.1	2.5	87.5	117.87	162.40
7	Phosphate rock	RWS-89-47	1.15	28.8	1.9	1.4	4.5	19.0	119.02	195.52
6	Limestone, argillaceous	RWS-88-47	0.4	0.8	4.7	2.3	32.6	24.9	119.42	195.84
--	Feldspar porphyry	RWS-87-47	(3.0)	0.2	17.4	3.2	10.5	74.6	--	--
--	Feldspar porphyry	RWS-86-47	(1.1)	0.5	16.9	3.1	11.1	73.3	--	--
5	Sandstone, phosphatic, and phosphate rock	RWS-85-47	0.8	12.7	1.9	3.0	1.7	61.3	120.22	206.00
4	Quartzite	RWS-84-47	4.6	1.3	0.5	1.8	2.4	90.7	124.82	211.98
3	Quartzite, cherty	RWS-83-47	3.95	0.8	0.7	1.4	1.9	92.1	128.77	215.14
2	Quartzite and chert	RWS-82-47	2.5	0.7	1.0	1.9	0.8	94.2	131.27	216.89
1	Conglomerate, mudstone, and chert	RWS-81-47	0.6	2.4	2.8	3.1	7.3	73.8	131.87	218.33

Bed no.	Rock description	Sample no.	Thickness (feet)	Chemical analyses (percent)					Cumulative thickness (feet)	Thickness x percent P ₂ O ₅ (cumulative)	
				P ₂ O ₅	Al ₂ O ₃	Fe ₂ O ₃	Loss on ignition	Acid insoluble			
Quadrant formation											
Cq-1	Mudstone, calcareous, sandy, and argillaceous, calcareous sandstone	RWS- 80-47	1.3	0.7	6.5	3.2	9.6	70.4	1.3	--	
Cq-2	Sandstone, quartzitic, cherty	--	2.2	--	--	--	--	--	3.5	--	
Cq-3	Chert, sandstone, and limestone	--	11.5	--	--	--	--	--	15.0	--	
Cq-4	Limestone, chert, and quartzite	--	11.0	--	--	--	--	--	26.0	--	
Cq-5	Limestone, cherty	--	8.0	--	--	--	--	--	34.0	--	

SPECTROGRAPHIC ANALYSES—JACK CANYON, MONTANA. LOT NO. 1218.

Semi-quantitative analyses of samples of the Phosphoria formation, Jack Canyon, Montana (see immediately preceding pages for location of section, thickness and description of strata, and chemical analyses of samples), made by U. S. Bureau of Mines Laboratory, Albany, Oregon. In addition to the elements listed in the table below, Sb, As, Ba, Be, Bi, Cd, Co, Cb, Ga, Ge, Au, In, Pb, Li, Hg, Pt, Ta, Sn, and W were looked for in all samples but were not detected.

Explanation of symbols

A = more than 10 percent
B = 5-10 percent
C = 1-5 percent
D = 0.1-1 percent
E = 0.01-0.1 percent
F = 0.001-0.01 percent
G = less than 0.001 percent
ND = not detected

Bed no.	Sample no.	Al	B	Ca	Cr	Cu	Fe	Mg	Mn	Mo	Ni	Si	Ag	Na	Sr	Ti	V	Zn	Zr
25	RWS-107-47	C	F	B	ND	G	C	C	E	F	E	A	G	ND	F	E	F	E	E
24	RWS-106-47	C	F	A	ND	G	C	C	E	F	E	A	G	ND	F	E	F	E	E
23	RWS-105-47	C	F	B	ND	G	C	C	E	F	E	A	G	ND	F	E	F	E	E
22	RWS-104-47	C	F	C	ND	G	C	C	E	F	E	A	G	ND	F	E	F	E	E
21	RWS-103-47	C	F	C	ND	G	C	D	E	F	E	A	G	ND	F	E	F	E	E
20	RWS-102-47	D	F	B	E	G	C	C	E	F	E	A	G	E	F	E	E	E	E
19	RWS-101-47	D	F	B	E	G	C	C	E	F	E	A	G	E	F	E	E	E	E
18	RWS-100-47	D	F	C	E	G	C	D	E	F	E	A	G	E	F	E	E	E	E
17	RWS-99-47	C	F	C	E	G	C	D	E	F	E	A	G	E	F	E	E	E	E
16	RWS-98-47	C	F	C	E	G	C	D	E	F	E	A	G	E	F	E	E	E	E
15	RWS-97-47	C	F	C	E	G	C	D	E	F	E	A	G	E	F	E	E	E	E
14	RWS-96-47	C	F	A	E	G	C	D	E	F	E	A	G	E	F	E	E	E	E
13	RWS-95-47	C	F	C	E	G	C	D	E	F	E	A	G	E	F	E	E	E	E
12	RWS-94-47	C	F	A	E	G	C	D	E	F	E	A	G	E	F	E	E	E	E
11	RWS-93-47	C	F	B	E	G	C	C	E	F	E	A	G	E	F	E	E	E	E
10	RWS-92-47	C	F	C	E	G	C	D	E	F	E	A	G	E	F	E	E	E	E
9	RWS-91-47	C	F	C	E	G	C	D	E	F	E	A	G	E	F	E	E	E	E
8	RWS-90-47	C	F	C	E	G	C	D	E	F	E	A	G	E	F	E	E	ND	ND
7	RWS-89-47	C	F	A	E	G	C	D	E	F	E	A	G	E	F	E	E	ND	ND
6	RWS-88-47	C	F	A	E	G	C	C	E	F	E	A	G	E	F	E	E	ND	ND
--	RWS-87-47	C	F	C	ND	G	C	D	E	F	E	A	G	D	F	E	E	ND	ND
--	RWS-86-47	C	F	C	ND	G	C	D	E	F	E	A	G	D	F	E	E	ND	ND
5	RWS-85-47	C	F	A	ND	G	C	D	E	F	E	A	G	D	F	E	E	ND	ND
4	RWS-84-47	D	F	C	ND	G	C	D	E	F	E	A	G	E	F	E	E	ND	ND
3	RWS-83-47	D	F	C	ND	G	C	D	E	F	E	A	G	E	F	E	E	ND	ND
2	RWS-82-47	D	F	C	ND	G	C	D	E	F	E	A	G	E	F	E	E	ND	ND
1	RWS-81-47	C	F	B	ND	G	C	D	E	F	E	A	G	E	E	E	E	ND	ND
Cq-1	RWS-80-47	C	F	B	ND	G	C	C	E	F	F	A	G	E	E	E	E	E	E

ASPEN VALLEY, MONTANA. LOT NO. 1215.

Phosphatic shale member of Phosphoria formation sampled in hand trench near top of ridge on west side of Aspen Valley, SE 1/4 sec. 11, T. 6 S., R. 1 E., Madison County, Montana, on overturned west limb of Madison Range syncline. Beds strike N. 45° E. and dip 55° NW. Section measured by R. W. Swanson and sampled by J. A. Mann and J. G. Evans in August 1947. Samples analyzed by U. S. Bureau of Mines Laboratory, Albany, Oregon.

Bed no.	Rock description	Sample no.	Thickness (feet)	Chemical analyses (percent)			Cumulative thickness (feet)	Thickness x percent P ₂ O ₅ (cumulative) ^b
				P ₂ O ₅	F	Acid Insoluble		
Phosphoria formation—top and base not exposed								
20	Sandstone	--	2.1	--	--	--	2.1	--
19	Quartzite	RWS-43-47	0.75	1.3	--	90.1	2.85	0.98*
18	Chert and mudstone	RWS-42-47	4.2	0.9	--	81.8	7.05	4.76
17	Chert and mudstone	RWS-41-47	2.5	0.6	--	84.0	9.55	6.26
16	Chert and mudstone	RWS-40-47	4.45	0.7	--	78.0	14.00	9.37
15	Mudstone	RWS-39-47	0.55	1.3	--	75.4	14.55	10.08
14	Phosphate rock, cherty	RWS-38-47	0.25	23.5	2.05	31.4	14.80	15.96
13	Limestone, argillaceous	RWS-37-47	1.0	0.5	--	37.6	15.80	16.46
12	Chert and mudstone	RWS-36-47	4.55	0.5	--	50.6	20.35	18.74
11	Chert and mudstone	RWS-35-47	4.45	0.7	--	82.1	24.80	21.85
10	Chert and mudstone	RWS-34-47	4.5	0.7	--	82.4	29.30	25.00
9	Chert and mudstone	RWS-33-47	2.25	0.5	--	84.9	31.55	26.12
8	Phosphate rock	RWS-32-47	1.6	31.0	3.0	11.8	33.15	75.82
7	Phosphate rock	RWS-31-47	0.3	26.9	2.97	18.0	33.45	83.80
6	Mudstone	RWS-30-47	0.45	1.4	--	72.3	33.90	84.42
5	Limestone	RWS-29-47	0.83	0.7	--	15.4	34.73	85.01
4	Mudstone, calcareous	RWS-28-47	0.7	3.7	--	56.7	35.43	87.60
3	Phosphate rock and mudstone	RWS-27-47	0.6	14.6	1.52	37.0	36.03	96.36
2	Phosphate rock and phosphatic sandstone	RWS-26-47	0.55	21.3	--	38.9	36.58	108.07
1	Sandstone	RWS-25-47	0.8	1.6	--	92.9	37.38	109.35**

* Cumulative data incomplete due to missing information.

** Note incompleteness of cumulative data.

SHELL CANYON, MONTANA. LOT NO. 1214.

Phosphoria formation measured and phosphatic shale member sampled in hand trench and outcrop on north side of Shell Creek canyon, SW 1/4 sec. 33, T. 6 S., R. 1 E., Madison County, Montana, near crest of small dome at west side of Madison Range syncline. Beds strike N. 5° W. and dip 12° W. Section measured by R. W. Swanson and sampled by J. A. Mann and J. G. Evans in August 1947. Samples analyzed by U. S. Bureau of Mines Laboratory, Albany, Oregon.

Bed no.	Rock description	Sample no.	Thickness (feet)	Chemical analyses (percent)			Cumulative thickness (feet)	Thickness x percent P ₂ O ₅ (cumulative)
				P ₂ O ₅	F	Acid insoluble		
Dinwoody formation								
Td-1 Limestone			25.0	--	--	25.0	--	
Phosphoria formation								
43	Sandstone, calcareous, cherty	--	0.75	--	--	--	0.75	--
42	Sandstone, calcareous, cherty	--	6.0	--	--	--	6.75	--
41	Chert and sandstone	--	3.4	--	--	--	10.15	--
40	Quartzite	--	2.8	--	--	--	12.95	--
39	Limestone, cherty	--	1.45	--	--	--	14.40	--
38	Chert and quartzite	--	4.3	--	--	--	18.70	--
37	Quartzite and chert	--	7.4	--	--	--	26.10	--
36	Chert and quartzite	--	5.8	--	--	--	31.90	--
35	Quartzite	--	2.9	--	--	--	34.80	--
34	Quartzite and chert	--	11.3	--	--	--	46.10	--
33	Quartzite	--	5.2	--	--	--	51.30	--
32	Sandstone and chert	--	3.3	--	--	--	54.60	--
31	Chert, contains sandstone lenses	--	3.0	--	--	--	57.60	--
30	Sandstone, quartzitic	--	5.3	--	--	--	62.90	--
29	Sandstone, quartzitic, cherty	--	1.7	--	--	--	64.60	--
28	Chert and quartzitic sandstone	--	4.6	--	--	--	69.20	--
27	Chert and quartzite	RWS-24-47	0.7	1.6	--	90.2	69.90	1.12*
26	Chert	RWS-23-47	3.2	0.6	--	86.7	73.10	3.04
25	Chert, contains thin mudstone partings	RWS-22-47	4.15	0.8	--	84.7	77.25	6.36
24	Chert, contains thin mudstone partings	RWS-21-47	5.0	0.5	--	85.0	82.25	8.86
23	Chert, contains thin mudstone partings	RWS-20-47	5.2	0.6	--	82.1	87.45	11.98
22	Chert, contains thin mudstone partings	RWS-19-47	5.1	0.9	--	82.3	92.55	16.57
21	Mudstone, calcareous	RWS-18-47	1.2	1.1	--	73.7	93.75	17.89
20	Phosphate rock, cherty	RWS-17-47	0.55	19.2	--	43.9	94.30	28.45
19	Mudstone, calcareous	RWS-16-47	1.15	0.8	--	50.0	95.45	29.37
18	Mudstone, calcareous	RWS-15-47	3.7	0.9	--	74.9	99.15	32.70
17	Mudstone, cherty, calcareous	RWS-14-47	0.75	0.6	--	72.0	99.90	33.15

* Cumulative data incomplete due to missing information.

Bed no.	Rock description	Sample no.	Thickness (feet)	Chemical analyses (percent)			Cumulative thickness (feet)	Thickness x percent P ₂ O ₅ (cumulative)
				P ₂ O ₅	F	Acid insoluble		
16	Mudstone	RWS-13-47	2.05	0.1	--	80.5	101.95	33.36
15	Phosphate rock, argillaceous	RWS-12-47	0.75	23.6	2.48	30.2	102.70	51.06
14	Phosphate rock	RWS-11-47	0.5	32.4	3.43	8.1	103.20	67.26
13	Phosphate rock	RWS-10-47	1.5	32.5	3.44	8.4	104.70	116.01
12	Mudstone	RWS-9-47	0.5	3.7	--	70.6	105.20	117.86
11	Limestone, argillaceous	RWS-8-47	1.2	0.5	--	20.0	106.40	118.46
10	Mudstone, calcareous	RWS-7-47	0.8	3.6	--	55.2	107.20	121.34
9	Mudstone, calcareous	RWS-6-47	0.45	6.0	0.79	47.3	107.65	124.04
8	Mudstone and phosphate rock	RWS-5-47	0.65	14.9	1.58	40.4	108.30	133.72
7	Sandstone, quartzitic, phosphatic and chert	RWS-4-47	1.0	9.5	---	70.5	109.30	143.22
6	Sandstone, quartzitic	RWS-3-47	1.9	1.1	--	90.1	111.20	145.31
5	Sandstone, quartzitic	RWS-2-47	0.85	1.0	--	93.3	112.05	146.16
4	Sandstone, quartzitic	RWS-1-47	0.7	0.8	--	92.2	112.75	146.79**
3	Sandstone, quartzitic	--	5.55	--	--	--	118.30	--
2	Chert	--	3.75	--	--	--	122.05	--
1	Sandstone, quartzitic and chert	--	2.5	--	--	--	124.55	--

Quadrant formation

Cq-1 Limestone, cherty	--	3.0	--	--	--	3.0	--
Cq-2 Sandstone, quartzitic	--	10	--	--	--	13.0	--

** Note incompleteness of cumulative data.

WEST FORK OF GALLATIN RIVER, MONTANA. LOT NO. 1216.

Part of Phosphoria formation sampled in hand trench and outcrops on slope north of West Fork of Gallatin River, NW 1/4 sec. 32, T. 6 S., R. 4 E., Gallatin County, Montana, from strata dragged up beneath Gardiner thrust fault. Beds strike N. 35° W. and dip 45-50° SW. Section measured by R. W. Swanson and sampled by J. A. Mann and J. G. Evans in September 1947. Samples analyzed by U. S. Bureau of Mines Laboratory, Albany, Oregon.

Bed no.	Rock description	Sample no.	Thickness (feet)	Chemical analyses (percent)		Cumulative thickness (feet)	Thickness x percent P ₂ O ₅ (cumulative)
				P ₂ O ₅	Acid insoluble		
Phosphoria formation—lower part only							
25	Sandstone, quartzitic and chert	--	10.5	--	--	10.5	--
24	Quartzite, contains chert concretions	--	2.0	--	--	12.5	--
23	Limestone, contains chert concretions	--	0.7	--	--	13.2	--
22	Chert and quartzite	--	5.5	--	--	18.7	--
21	Chert, quartzite, and mudstone	RWS-63-47	8.85	0.8	90.1	27.55	7.08*
20	Quartzite	RWS-62-47	0.65	2.0	89.2	28.20	8.38
19	Chert and mudstone	RWS-61-47	7.5	0.7	84.8	33.95	12.41
18	Chert and mudstone	RWS-60-47	--	0.6	90.7	37.35	14.45
17	Chert and mudstone	RWS-59-47	--	0.7	91.0	41.80	17.56
16	Mudstone, phosphatic	RWS-58-47	0.3	14.9	56.3	42.10	22.03
15	Mudstone	RWS-57-47	1.35	0.9	81.1	43.45	23.25
14	Mudstone	RWS-56-47	1.8	0.8	88.1	45.25	24.69
13	Mudstone	RWS-55-47	0.85	0.8	81.1	46.10	25.37
12	Mudstone	RWS-54-47	2.5	1.1	84.2	48.60	28.12
11	Phosphate rock, argillaceous	RWS-53-47	0.45	22.2	39.4	49.05	38.11
10	Phosphate rock, argillaceous	RWS-52-47	0.7	26.2	27.0	49.75	56.45
9	Sandstone, phosphatic	RWS-51-47	1.5	8.3	70.2	51.25	68.90
8	Sandstone	RWS-50-47	1.6	0.6	88.1	52.85	69.86
7	Mudstone, contains quartzitic sandstone concretions	RWS-49-47	1.3	1.1	81.3	54.15	71.29
6	Chert, calcareous mudstone, and quartzite	RWS-48-47	1.35	1.5	55.0	55.50	73.31
5	Quartzite, cherty	RWS-47-47	2.2	1.4	91.9	57.70	76.39
4	Mudstone, sandy, contains quartzitic concretions	RWS-46-47	1.15	2.2	87.2	58.85	78.92
3	Mudstone, calcareous and quartzite	RWS-45-47	1.05	0.9	77.1	59.90	79.87
2	Sandstone, quartzitic	RWS-44-47	1.2	0.8	95.2	61.10	80.83**
1	Quartzite	--	4.3	--	--	65.40	--
Quadrant formation							
Cq-1	Chert	--	1.8	--	--	1.8	--
Cq-2	Chert and sandstone	--	6.3	--	--	8.1	--

* Cumulative data incomplete due to missing information.

** Note incompleteness of cumulative data.

PORCUPINE CREEK, MONTANA. LOT NO. 1217.

Part of Phosphoria formation sampled in hand trench and outcrops on slope 1½ miles north of Porcupine Creek, NE¼ sec. 10, T. 7 S., R. 4 E., Gallatin County, Montana, from strata dragged up beneath Gardiner thrust fault. Beds strike N. 40° W. and dip 75° SW. Section measured by R. W. Swanson and sampled by J. A. Mann and J. G. Evans in September 1947. Samples analyzed by U. S. Bureau of Mines Laboratory, Albany, Oregon.

Bed no.	Rock description	Sample no.	Thickness (feet)	Chemical analyses (percent)		Cumulative thickness (feet)	Thickness x percent P ₂ O ₅ (cumulative)
				P ₂ O ₅	Acid insoluble		
Phosphoria formation—lower part only							
20	Sandstone	--	6.0	--	--	6.0	--
19	Chert, contains sandstone lenses	--	2.6	--	--	8.6	--
18	Sandstone	--	4.8	--	--	13.4	--
17	Sandstone, quartzitic	RWS-79-47	0.6	1.6	93.1	14.0	0.96*
16	Chert, contains mudstone partings	RWS-78-47	4.6	0.8	82.1	18.6	4.64
15	Chert, contains mudstone partings	RWS-77-47	3.9	0.4	86.0	22.5	6.20
14	Chert, contains mudstone partings	RWS-76-47	3.6	0.9	84.8	26.1	9.44
13	Chert, contains mudstone partings	RWS-75-47	1.55	3.3	87.0	27.65	14.56
12	Chert, contains mudstone partings	RWS-74-47	1.0	0.8	87.4	28.65	15.36
11	Chert, contains mudstone partings	RWS-73-47	0.95	0.6	86.0	29.60	15.93
10	Chert, contains mudstone partings	RWS-72-47	1.65	1.1	87.4	31.25	17.75
9	Sandstone	RWS-71-47	0.6	6.9	76.6	31.85	21.89
8	Mudstone, calcareous	RWS-70-47	0.8	1.4	60.8	32.65	23.01
7	Limestone, argillaceous	RWS-69-47	0.7	0.4	45.5	33.35	23.29
6	Mudstone	RWS-68-47	2.9	1.6	81.8	36.25	27.93
5	Phosphate rock and mudstone	RWS-67-47	1.0	22.9	35.0	37.25	50.83
4	Limestone, contains sandstone concretions	RWS-66-47	1.25	0.8	59.3	38.50	51.83
3	Mudstone, contains sandstone concretions	RWS-65-47	0.6	1.8	78.5	39.10	52.91
2	Sandstone, quartzitic	RWS-64-47	0.67	2.6	86.7	39.77	54.65**
1	Sandstone	--	9.5	--	--	49.27	--
Quadrant formation							
Cq-1	Sandstone	--	1.5	--	--	1.5	--
Cq-2	Sandstone and chert	--	11.4	--	--	12.9	--
Cq-3	Sandstone	--	10.0	--	--	22.9	--

* Cumulative data incomplete due to missing information.

** Note incompleteness of cumulative data.

Bed no.	Rock description	Sample no.	Thickness (feet)	Chemical analyses (percent)			Cumulative thickness (feet)	Thickness x percent P ₂ O ₅ (cumulative)
				P ₂ O ₅	F	Acid insoluble		
D-35	Mudstone, phosphatic	WRL- 35-47	0.5	10.1	--	53.8	10.2	126.00
D-34	Mudstone	WRL- 34-47	0.4	4.8	0.41	71.5	10.6	127.92
D-33	Phosphate rock, argillaceous	WRL- 33-47	0.4	22.4	--	23.5	11.0	136.88
D-32	Mudstone, calcareous	WRL- 32-47	0.3	2.9	--	55.8	11.3	137.75
D-31	Phosphate rock, argillaceous	WRL- 31-47	0.3	19.0	--	33.0	11.6	143.45
D-30	Mudstone, calcareous	WRL- 30-47	4.0	4.2	--	42.6	15.6	160.25
D-29	Mudstone, calcareous	WRL- 29-47	5.0	2.9	--	49.9	20.6	174.75
D-28	Mudstone, calcareous	WRL- 28-47	0.8	2.7	--	61.3	21.4	176.91
D-27	Mudstone, calcareous	WRL- 27-47	2.1	0.6	--	65.9	23.5	178.17
D-26	Mudstone, calcareous	WRL- 26-47	1.6	1.6	--	67.9	25.1	180.73
D-25	Mudstone, calcareous	WRL- 25-47	2.7	2.0	--	63.3	27.8	186.13
D-24	Mudstone, calcareous	WRL- 24-47	1.2	1.6	--	65.5	29.0	188.05
D-23	Mudstone, calcareous	WRL- 23-47	1.2	0.6	--	63.6	30.2	188.77
D-22	Mudstone, calcareous	WRL- 22-47	1.6	1.1	--	35.0	31.8	190.53
D-21	Mudstone, calcareous	WRL- 21-47	0.8	1.2	--	69.4	32.6	191.49
D-20	Mudstone	WRL- 20-47	1.7	1.8	--	71.5	34.3	194.55
D-19	Mudstone, calcareous	WRL- 19-47	1.2	2.9	--	50.2	35.5	198.03
D-18	Phosphate rock	WRL- 18-47	0.3	27.4	3.8	19.3	35.8	206.25
D-17	Mudstone, calcareous	WRL- 17-47	0.8	4.4	--	60.6	36.6	209.77
D-16	Phosphate rock	WRL- 16-47	1.2	33.1	4.1	6.7	37.8	249.79
D-15	Mudstone, calcareous	WRL- 15-47	1.4	6.8	--	52.3	39.2	259.01
D-14	Phosphate rock, argillaceous	WRL- 14-47	1.7	22.6	--	24.62	40.9	297.43
D-13	Limestone	WRL- 13-47	0.9	3.9	--	18.6	41.8	300.94
D-12	Mudstone, phosphatic	WRL- 12-47	0.8	10.0	--	49.1	42.6	308.94
D-11	Phosphate rock and mudstone	WRL- 11-47	0.5	22.8	--	21.3	43.1	320.34
D-10	Mudstone and phosphate rock	WRL- 10-47	1.3	11.0	--	48.3	44.4	334.64
D-9	Phosphate rock, argillaceous	WRL- 9-47	1.3	24.4	2.48	24.7	45.7	366.36
D-8	Mudstone, calcareous	WRL- 8-47	0.5	0.2	--	68.3	46.2	366.46
D-7	Mudstone and phosphate rock	WRL- 7-47	1.5	14.7	1.28	48.2	47.7	388.51
D-6	Mudstone	WRL- 6-47	1.0	5.3	0.68	71.2	48.7	393.81
D-5	Phosphate rock, argillaceous	WRL- 5-47	1.6	17.2	--	35.9	50.3	421.33
D-4	Phosphate rock, argillaceous, contains gypsum	WRL- 4-47	1.4	20.3	--	27.5	51.7	449.75
D-3	Mudstone, phosphatic, contains gypsum	WRL- 3-47	0.9	8.8	--	62.1	52.6	457.67
D-2	Mudstone	WRL- 2-47	0.8	3.3	--	75.8	53.4	460.31
D-1	Mudstone, phosphatic	WRL- 1-47	1.2	13.8	1.33	45.9	54.6	476.87

C member of Phosphoria formation, lot no. 1223

C-11	Sandstone	WRL-276-47	2.2	15.1	1.39	56.1	2.2	33.22
C-10	Sandstone and chert	WRL-275-47	2.7	3.9	--	77.2	4.9	43.75

DALY'S SPUR, MONTANA. LOT NOS. 1222 AND 1223.

Phosphoria formation sampled near Daly's Spur, west side of Beaverhead River; A, B, C, and E members, lot no. 1223, sampled in hand trench and natural exposures, SW $\frac{1}{4}$ SW $\frac{1}{4}$ sec. 36; and D member, lot no. 1222, in hand trench, NW $\frac{1}{4}$ SW $\frac{1}{4}$ sec. 36, T. 8 S., R. 10 W., Beaverhead County, Montana. Beds strike north to N. 30° E. and dip 30-40° W. Section measured by W. R. Lowell and sampled by D. A. Bostwick, R. L. Parker, and E. T. Ruppel in July 1937. Samples analyzed by U. S. Bureau of Mines Laboratory, Albany, Oregon.

Bed no.	Rock description	Sample no.	Thickness (feet)	Chemical analyses (percent)			Cumulative thickness (feet)	Thickness x percent P ₂ O ₅ (cumulative)
				P ₂ O ₅	F	Acid insoluble		
Dinwoody formation—base not exposed								
E member of Phosphoria formation, lot no. 1223—top not exposed								
	Dinwoody-Phosphoria contact concealed by basalt flow, estimated thickness of covered E member	--	20.0	--	--	--	20.0	--
E-10	Quartzite	WRL-286-47	23.7	2.2	--	89.4	43.7	52.14*
E-9	Chert	WRL-285-47	12.5	1.5	--	91.0	56.2	70.89
E-8	Quartzite, chert, and sandstone	WRL-284-47	9.8	2.2	--	89.5	66.0	92.45
E-7	Chert, sandy	WRL-283-47	20.4	1.5	--	90.1	86.4	123.05
E-6	Chert, sandy	WRL-282-47	22.3	1.6	--	89.6	108.7	158.73
E-5	Chert	WRL-281-47	7.4	2.5	--	87.3	116.1	177.23
E-4	Chert, sandy	WRL-280-47	14.7	1.7	--	89.1	130.8	202.22
E-3	Mudstone, contains gypsum	WRL-279-47	0.5	2.2	--	78.3	131.3	203.32
E-2	Chert	WRL-278-47	3.6	2.6	--	86.3	134.9	212.68
E-1	Quartzite, cherty, phosphatic	WRL-277-47	1.2	16.6	--	50.6	136.1	232.60**
--	Chert	WRL-46-47	--	5.9	--	78.5	--	--
WRL-46-47 is correlative with WRL-277-47 but occurs in same trench as D member.								
D member of Phosphoria formation, lot no. 1222								
D-45	Mudstone	WRL-45-47	1.0	3.5	--	80.0	1.0	3.50
D-44	Mudstone	WRL-44-47	1.3	3.2	--	78.5	2.3	7.66
D-43	Mudstone	WRL-43-47	1.4	1.8	--	66.7	3.7	10.18
D-42	Phosphate rock, argillaceous	WRL-42-47	0.8	25.3	2.44	30.1	4.5	30.42
D-41	Mudstone, phosphatic	WRL-41-47	0.7	13.7	1.17	51.1	5.2	40.01
D-40	Phosphate rock, argillaceous	WRL-40-47	0.3	28.6	--	22.2	5.5	48.59
D-39	Mudstone, phosphatic	WRL-39-47	1.2	17.0	1.60	45.1	6.7	68.99
D-38	Phosphate rock and phosphatic mudstone	WRL-38-47	1.5	22.1	--	32.8	8.2	102.14
D-37	Mudstone, calcareous	WRL-37-47	0.9	6.1	--	45.5	9.1	107.63
D-36	Phosphate rock, argillaceous	WRL-36-47	0.5	22.2	--	32.0	9.7	120.95

* Cumulative data incomplete due to missing information.

** Note incompleteness of cumulative data.

C-9	Sandstone, calcareous	WRL-274-47	8.7	0.8	--	46.9	13.6	50.71
C-8	Sandstone	WRL-273-47	11.0	1.3	--	90.8	24.6	65.01
C-7	Chert and sandstone	WRL-272-47	9.0	0.2	--	95.1	33.6	66.81
C-6	Sandstone and cherty mudstone	WRL-271-47	14.5	0.5	--	92.8	48.1	74.06
C-5	Sandstone and chert	WRL-270-47	2.8	1.3	--	91.3	50.9	77.70
C-4	Sandstone	WRL-269-47	7.4	2.5	--	78.2	58.3	96.20
C-3	Sandstone, cherty	WRL-268-47	9.2	5.4	0.71	80.0	67.5	145.88
C-2	Sandstone and chert	WRL-267-47	11.0	1.9	--	87.6	78.5	166.78
C-1	Sandstone and chert	WRL-266-47	12.1	1.1	--	92.5	90.6	180.09

B member of Phosphoria formation, lot no. 1223

B-5	Mudstone	WRL-265-47	3.1	6.7	0.68	67.0	3.1	20.77
B-4	Mudstone	WRL-264-47	0.8	6.0	--	69.6	3.9	25.57
B-3	Phosphate rock	WRL-263-47	0.4	35.7	3.56	6.4	4.3	39.85
B-2	Mudstone	WRL-262-47	0.3	4.5	--	76.5	4.6	41.20
B-1	Phosphate rock	WRL-261-47	0.7	36.4	3.57	5.2	5.3	66.68

A member of Phosphoria formation, lot no. 1223

A-10	Sandstone	WRL-260-47	2.4	4.4	--	81.4	2.4	10.56
A-9	Sandstone and mudstone	WRL-259-47	3.3	0.5	--	82.0	5.7	12.21
A-8	Sandstone, cherty	WRL-258-47	1.4	0.8	--	90.5	7.1	13.33
A-7	Mudstone	WRL-257-47	4.2	0.6	--	80.0	11.3	15.85
A-6	Sandstone, calcareous	WRL-256-47	3.0	0.1	--	76.6	14.3	16.15
A-5	Limestone	WRL-255-47	2.8	0.2	--	18.9	17.1	16.71
A-4	Mudstone	WRL-254-47	0.7	0.5	--	79.3	17.8	17.06
A-3	Limestone	WRL-253-47	3.5	0.0	--	2.6	21.3	17.06
A-2	Mudstone	WRL-252-47	1.5	0.4	--	80.6	22.8	17.66
A-1	Limestone	WRL-251-47	6.7	0.3	--	1.9	29.5	19.67

Quadrant formation

--	Thickness of Quadrant formation exposed in cliff	--	400	--	--	--
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SHEEP CREEK, MONTANA. LOT NO. 1234.

Phosphoria formation sampled in two bulldozer trenches near Sheep Creek Canyon, NW $\frac{1}{4}$ SW $\frac{1}{4}$ sec. 23, T. 9 S., R. 9 W., Beaverhead County, Montana, on west side of Small Horn Canyon anticline. Beds strike N. 23-41° E. and dip 30-45° NW. Section measured by L. A. Thomas, E. R. Cressman, O. A. Payne, V. E. McKelvey, D. A. Bostwick, F. S. Honkala, and J. E. Smedley and sampled by W. H. Wilson, Payne, R. L. Konizeski, Thomas, and Cressman in June 1948. Samples analyzed for P₂O₅ and acid insoluble by U. S. Bureau of Mines Laboratory, Albany, Oregon, and for other constituents by Trace Elements Section Laboratory, U. S. Geological Survey, Washington, D. C.

Bed no.	Rock description	Sample no.	Thickness (feet)	Chemical analyses (percent)					Cumulative thickness (feet)	Thickness x percent P ₂ O ₅ (cumulative)
				P ₂ O ₅	Al ₂ O ₃	Fe ₂ O ₃	Loss on ignition	Acid insoluble		
Dinwoody formation—basal bed only										
Td-1	Mudstone, calcareous	DAB- 80	--	1.0	8.1	4.0	10.0	71.4	--	--
E member of Phosphoria formation										
E-11	Sandstone; fos. col. no. 48-KPM-43 ¹ Mudstone and chert Chert and mudstone Sandstone, chert, and mudstone; fos. col. no. 48-KPM-42 Sandstone and chert Sandstone and chert Sandstone and chert Sandstone Mudstone and chert Mudstone Sandstone and chert Sandstone, phosphatic; fos. col. no. 48-KPM-41	DAB- 79	1.9	1.7	2.5	4.6	1.5	87.9	1.9	3.23
E-10		LAT- 78	10.2	1.6	5.1	3.0	2.3	87.3	12.1	19.55
E- 9		LAT- 77	13.7	2.1	4.4	3.4	1.8	88.9	25.8	48.32
E- 8		LAT- 76	13.5	1.7	2.3	3.5	1.5	88.6	39.3	71.27
E- 7		ERC- 75	14.0	2.4	2.1	3.9	1.0	86.9	53.3	104.87
E- 6		ERC- 74	17.1	2.6	2.9	2.8	1.3	88.1	70.4	149.33
E- 5		ERC- 73	13.6	2.7	1.0	4.0	1.0	87.0	84.0	186.05
E- 4		DAB- 72	10.5	3.3	2.2	3.2	1.2	86.5	94.5	220.70
E- 3		DAB- 71	10.8	1.6	4.8	2.3	2.8	88.3	105.3	237.98
E- 2		DAB- 70	4.1	3.0	1.0	3.2	0.8	87.9	109.4	250.28
E- 1			DAB- 69	0.75	17.2	2.2	1.5	2.8	51.1	110.15
D member of Phosphoria formation										
D-48	Mudstone, phosphatic Mudstone; fos. col. no. 48-KPM-40 Mudstone, phosphatic; fos. col. no. 48-KPM-39 Mudstone; fos. col. no. 48-KPM-38 Mudstone Mudstone Mudstone, phosphatic Mudstone, phosphatic Phosphate rock, argillaceous Mudstone and phosphate rock OAP-385 represents the same bed as OAP-9 but was collected from a more weathered zone.	VEM- 1	0.9	16.2	7.4	3.6	8.0	43.6	0.9	14.58
D-47		VEM- 2	1.3	7.4	9.2	2.4	9.7	64.6	2.2	24.20
D-46		VEM- 3	2.3	12.5	8.7	2.3	10.0	51.9	4.5	52.95
D-45		VEM- 4	1.3	1.7	11.2	1.9	9.3	79.0	5.8	55.16
D-44		JES- 5	2.2	3.2	9.9	4.3	13.4	70.4	8.0	62.20
D-43		JES- 6	0.5	1.6	8.8	2.0	11.8	76.3	8.5	63.00
D-42		JES- 7	1.6	15.6	6.7	2.8	11.1	45.9	10.1	87.96
D-41		JES- 8	1.4	9.2	9.0	3.3	14.2	54.4	11.5	100.84
D-40		OAP- 9	0.5	22.1	4.7	2.3	7.5	34.5	12.0	111.89
--		OAP-385	(0.3)	23.8	4.1	1.8	6.9	28.7	--	--
D-39		Mudstone	OAP- 10	0.4	3.8	12.2	3.1	16.8	67.0	12.4
D-38	Phosphate rock, argillaceous	OAP- 11	0.3	18.3	7.0	2.4	14.0	34.4	12.7	118.90

D-37	Mudstone	OAP-12	0.3	6.7	10.3	3.6	12.8	60.7	13.0	120.91
D-36	Phosphate rock, argillaceous	OAP-13	1.9	17.6	6.5	2.1	13.2	36.3	14.9	164.35
D-35	Phosphate rock, argillaceous	LAT-14	0.5	25.8	2.9	1.9	6.8	28.1	15.4	167.25
--	Phosphate rock, argillaceous	LAT-386	(0.5)	25.4	2.8	1.0	9.3	27.1	--	--
LAT-386 represents the same bed as LAT-14 but was sampled where the unit appeared to contain more argillaceous material.										
D-34	Phosphate rock, argillaceous	FSH-15	0.8	20.2	4.8	1.6	9.0	37.7	16.2	183.41
D-33	Mudstone and phosphate rock	FSH-16	0.85	20.2	5.8	2.1	10.5	35.6	17.05	200.58
D-32	Mudstone	FSH-17	0.8	6.4	9.6	2.5	14.1	60.9	17.85	205.70
D-31	Phosphate rock, argillaceous	FSH-18	0.8	26.0	3.9	1.5	8.9	25.5	18.65	226.50
D-30	Mudstone	FSH-19	2.7	5.2	10.2	3.2	18.4	60.5	21.35	240.54
D-29	Mudstone	ERC-20	1.0	1.4	10.7	2.9	20.8	72.7	22.35	241.94
D-28	Mudstone	LAT-21	2.2	3.5	10.0	3.4	16.4	64.2	24.55	249.64
D-27	Mudstone, calcareous; fos. col. no. 48-KPM-37	LAT-22	1.5	2.4	9.2	3.7	30.1	53.3	26.05	253.24
D-26	Mudstone	LAT-23	0.9	1.6	9.8	4.1	30.5	54.2	26.95	254.58
D-25	Mudstone, calcareous	LAT-24	2.8	1.4	10.9	3.7	21.1	63.2	29.75	258.60
D-24	Mudstone, calcareous	ERC-25	0.9	4.5	11.1	4.7	20.9	64.3	30.65	262.65
--	Mudstone	ERC-387	(0.85)	2.7	1.1	3.5	22.1	63.4	--	--
ERC-387 represents the same bed as ERC-25 but was sampled where the unit appeared to contain more argillaceous material.										
D-23	Mudstone, calcareous	ERC-26	1.9	1.6	10.6	4.1	30.6	56.7	32.55	265.69
D-22	Mudstone, calcareous	ERC-27	0.8	2.2	9.0	2.8	26.2	63.6	33.35	267.45
D-21	Mudstone, calcareous	ERC-28	0.75	3.8	10.0	1.9	30.0	58.0	34.10	270.30
D-20	Phosphate rock, argillaceous; fos. col. no. 48-KPM-36	LAT-29	1.05	26.2	5.6	2.9	14.3	24.0	35.15	297.81
D-19	Phosphate rock	LAT-30	0.65	31.9	3.9	1.9	8.1	13.8	35.80	318.54
D-18	Phosphate rock, argillaceous	LAT-31	1.55	24.0	5.6	1.5	16.8	21.2	37.35	355.74
D-17	Phosphate rock and mudstone	DAB-32	0.85	21.3	6.8	1.7	20.0	23.7	38.20	373.85
D-16	Phosphate rock and mudstone	DAB-33	1.33	16.4	6.7	3.7	19.6	35.0	39.53	395.66
D-15	Phosphate rock and mudstone; fos. col. no. 48-KPM-35	DAB-34	1.16	14.6	7.9	2.6	19.0	39.0	40.69	412.60
D-14	Mudstone, phosphatic	ERC-35	1.2	14.0	8.8	2.5	22.5	39.1	41.89	429.40
D-13	Mudstone and phosphate rock	ERC-36	1.2	14.7	8.3	2.2	19.8	39.8	43.09	447.04
D-12	Phosphate rock and mudstone; fos. col. no. 48-KPM-34	ERC-37	1.7	18.8	6.0	2.0	25.5	23.7	44.79	479.00
D-11	Phosphate rock	DAB-38	0.54	32.3	2.6	1.0	7.1	11.9	45.33	496.44
D-10	Phosphate rock and mudstone; fos. col. no. 48-KPM-33	DAB-39	2.2	15.5	7.3	2.9	17.0	40.2	47.53	530.54
D-9	Mudstone	DAB-40	0.5	6.5	10.2	3.6	8.0	72.8	48.03	533.79
D-8	Phosphate rock and mudstone	DAB-41	2.4	12.3	9.5	2.6	14.2	50.7	50.43	563.31
D-7	Phosphate rock, argillaceous	DAB-42	1.3	15.9	10.5	2.7	17.6	37.4	51.73	583.98
D-6	Mudstone and phosphate rock	DAB-43	1.75	21.7	6.3	2.5	10.5	32.6	53.48	621.96

¹ Fossil collection made by K. P. McLaughlin, Paleontology and Stratigraphy Branch, U. S. Geological Survey.

Bed no.	Rock description	Sample no.	Thickness (feet)	Chemical analyses (percent)					Cumulative thickness (feet)	Thickness x percent P ₂ O ₅ (cumulative)
				P ₂ O ₅	Al ₂ O ₃	Fe ₂ O ₃	Loss on ignition	Acid insoluble		
D-5	Mudstone, phosphatic	ERC-44	1.5	10.4	9.7	3.8	14.5	56.8	54.98	637.56
D-4	Mudstone	ERC-45	2.4	6.0	11.1	3.5	16.0	65.7	57.38	651.96
D-3	Mudstone	ERC-46	0.8	6.6	11.9	4.4	10.4	69.5	58.18	657.24
D-2	Mudstone and phosphate rock	DAB-47	1.2	15.0	8.0	7.1	5.6	46.2	59.38	675.24
D-1	Phosphate rock and mudstone; fos. col. no. 48-KPM-32	DAB-48	0.5	27.0	2.0	1.7	2.4	28.7	59.88	688.74

C member of Phosphoria formation

C-14	Sandstone, argillaceous	DAB-49	2.9	3.4	3.7	2.9	2.5	85.9	2.9	9.86
C-13	Sandstone	ERC-50	2.3	3.6	3.1	1.7	9.4	68.6	5.2	18.14
--	Sample of mudstone nodules within bed C-13	ERC-388	--	5.1	4.3	2.6	5.7	70.0	--	--
C-12	Sandstone, cherty; fos. col. no. 48-KPM-31	ERC-51	7.2	3.2	3.0	2.5	1.6	89.1	12.4	41.18
C-11	Chert and sandstone	ERC-52	5.5	2.7	2.2	2.4	1.3	89.2	17.9	56.03
C-10	Chert and sandstone	LAT-53	15.0	0.6	2.1	2.4	1.4	94.1	32.9	65.03
C-9	Chert and sandstone	LAT-54	20.5	0.9	4.1	2.9	2.3	91.3	53.4	83.48
--	Mudstone	LAT-391	--	1.8	11.0	4.9	9.0	71.4	--	--
--	Mudstone, calcareous	LAT-390	--	2.0	14.3	4.8	11.8	66.9	--	--
--	Mudstone, calcareous	LAT-389	--	5.2	13.5	6.0	12.4	58.2	--	--
Lat-391, LAT-390, and LAT-389 represent three thin clay layers within bed C-9.										
C-8	Limestone, argillaceous	LAT-55	8.4	1.2	2.0	1.9	29.7	32.2	61.8	93.56
C-7	Sandstone and limestone, cherty	ERC-56	9.2	0.5	1.3	3.4	16.0	58.8	71.0	98.16
C-6	Limestone, sandy	ERC-57	21.0	0.6	1.1	1.1	34.3	23.3	92.0	110.76
C-5	Limestone, sandy, cherty	ERC-58	6.8	3.1	3.0	1.8	26.0	35.6	98.8	131.84
C-4	Sandstone, cherty	DAB-59	4.9	5.9	1.1	3.7	1.3	78.3	103.7	160.75
--	Sandstone, cherty	DAB-392	--	3.7	0.9	2.8	1.0	90.3	--	--
DAB-392 was a grab sample of less weathered rock in bed C-4.										
C-3	Mudstone and chert; fos. col. no. 48-KPM-30	DAB-60	8.7	0.6	2.5	4.2	1.3	90.7	112.4	165.97
C-2	Chert and sandstone	DAB-61	9.6	0.8	2.1	3.9	1.3	91.8	122.0	173.65
C-1	Chert	LAT-62	17.0	2.2	2.4	2.9	1.6	89.1	139.0	211.05

B member of Phosphoria formation

B-6	Mudstone, sandy	RLP-393	2.0	2.2	9.5	3.3	4.1	85.0	2.00	4.40
B-5	Mudstone and phosphate rock	RLP-63	1.45	14.5	7.2	3.2	4.3	51.2	3.45	25.42
B-4	Mudstone	RLP-395	5.9	0.7	8.6	2.9	3.6	90.7	9.35	29.56
B-3	Mudstone, calcareous	RLP-394	0.7	0.8	4.2	3.9	17.2	58.9	10.05	30.12
B-2	Mudstone	RLP-64	7.4	0.3	2.8	2.6	1.5	93.0	17.45	32.34
B-1	Mudstone	LAT-65	6.5	0.4	2.1	2.5	1.3	89.0	23.95	33.64

--	Mudstone, calcareous	LAT-396	(0.2)	0.4	16.3	3.5	14.6	61.2	--	--
LAT-396 represents a 0.2 foot layer containing quartz crystals in bed B-1.										
A member of Phosphoria formation										
A-2	Mudstone, calcareous	DAB-66	6.7	0.3	4.6	2.3	17.9	60.7	6.7	2.01
A-1	Limestone, argillaceous, fos. col. nos. 48-KPM-27 and 48-KPM-28	DAB-67	10.5	0.3	3.1	2.3	24.9	47.5	17.2	5.16
Quadrant formation										
Cq-1	Sandstone	DAB-68	--	0.1	2.5	2.0	1.8	98.5	--	--

SPECTROGRAPHIC ANALYSES - SHEEP CREEK, MONTANA. LOT NO. 1234.

Semi-quantitative analyses of samples of the Phosphoria formation, Sheep Creek, Montana (see immediately preceding pages for location of section, thickness and description of strata, and chemical analyses of samples), made by U. S. Bureau of Mines Laboratory, Albany, Oregon. In addition to the elements listed in the table below, Sb, As, Ba, Be, Bi, Cd, Ga, Ge, Au, In, Li, Hg, Pt, Ta, Sn, and W were looked for in all samples but were not detected.

Explanation of symbols

A = more than 10 percent E = 0.01-0.1 percent
 B = 5-10 percent F = 0.001-0.01 percent
 C = 1-5 percent G = less than 0.001 percent
 D = 0.1-1 percent ND = not detected

Bed no.	Sample no.	Al	B	Ca	Cr	Co	Cb	Cu	Fe	Pb	Mg	Mn	Mo	Ni	Si	Ag	Na	Sr	Ti	V	Zn	Zr
Td-1	DAB-80	C	F	A	ND	ND	ND	G	C	ND	C	E	F	F	A	ND	E	ND	E	E	E	F
E-11	DAB-79	C	F	C	ND	ND	ND	G	C	ND	D	E	F	F	A	ND	E	ND	E	E	E	E
E-10	LAT-78	C	E	C	F	ND	ND	G	B	ND	D	E	F	F	A	ND	E	F	E	E	ND	ND
E-9	LAT-77	C	E	C	F	ND	ND	G	B	ND	D	E	F	F	A	ND	E	F	E	E	ND	ND
E-8	LAT-76	C	E	C	F	ND	ND	G	B	ND	D	E	F	F	A	ND	E	F	E	E	ND	ND
E-7	ERC-75	C	F	C	E	ND	ND	G	C	ND	D	E	F	F	A	ND	E	ND	E	E	E	E
E-6	ERC-74	C	F	C	E	ND	ND	G	C	ND	D	E	F	F	A	ND	E	ND	E	E	E	E
E-5	ERC-73	C	F	C	E	ND	ND	G	C	ND	D	E	F	F	A	ND	E	ND	E	E	E	E
E-4	DAB-72	C	F	C	E	ND	ND	G	C	ND	D	E	F	F	A	ND	E	ND	E	E	E	E
E-3	DAB-71	C	F	C	E	ND	ND	G	C	ND	D	E	F	F	A	ND	E	ND	E	E	E	E
E-2	DAB-70	C	F	C	E	ND	ND	G	C	ND	D	E	F	F	A	ND	E	ND	E	E	E	E
E-1	DAB-69	C	F	A	E	ND	ND	G	C	ND	D	E	F	F	A	ND	E	ND	E	E	E	E
D-48	VEM-1	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--
D-47	VEM-2	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--
D-46	VEM-3	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--
D-45	VEM-4	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--
D-44	JES-5	C	F	D	D	ND	ND	G	C	ND	D	E	E	E	A	F	E	ND	E	D	E	E
D-43	JES-6	C	F	D	D	ND	ND	G	C	ND	D	E	E	E	A	F	E	ND	E	D	E	E
D-42	JES-7	C	F	D	D	ND	ND	G	C	ND	D	E	E	E	A	F	E	ND	E	D	E	E
D-41	JES-8	C	F	D	D	ND	ND	G	C	ND	D	E	E	E	A	F	E	ND	E	D	E	E
D-40	OAP-9	C	F	D	D	ND	ND	G	C	ND	D	E	E	E	A	F	E	ND	E	D	E	E
--	OAP-385	B	F	A	E	ND	ND	G	C	ND	D	E	E	E	A	G	E	E	D	D	E	E
D-39	OAP-10	B	E	C	E	ND	ND	G	B	ND	C	E	E	E	A	G	E	F	D	D	E	E
D-38	OAP-11	C	F	A	E	ND	ND	G	C	ND	D	E	E	E	A	G	E	F	D	D	E	E
D-37	OAP-12	C	F	A	E	ND	ND	G	C	ND	D	E	E	E	A	G	E	F	D	D	E	E
D-36	OAP-13	C	F	A	E	ND	ND	G	C	ND	D	E	E	E	A	G	E	F	D	D	E	E
D-35	LAT-14	C	F	A	D	ND	ND	G	C	ND	D	E	E	E	A	F	E	ND	E	D	E	E

Bed no.	Sample no.	Al	B	Ca	Cr	Co	Cb	Cu	Fe	Pb	Mg	Mn	Mo	Ni	Si	Ag	Na	Sr	Ti	V	Zn	Zr
--	LAT-390	B	F	C	E	F	E	G	A	ND	C	D	F	D	A	G	E	F	D	E	E	E
C-8	LAT-389	B	F	C	E	ND	ND	G	A	ND	C	D	F	D	A	G	E	F	D	E	E	E
C-7	LAT-55	C	F	A	ND	ND	ND	G	C	ND	A	E	F	E	A	ND	F	ND	E	E	E	E
C-6	ERC-56	C	F	B	ND	ND	ND	G	C	ND	B	E	F	E	A	ND	F	ND	E	E	E	E
	ERC-57			A	E	ND	ND															
C-5	ERC-58	C	F	A	E	ND	ND	G	C	ND	B	E	F	E	A	ND	F	ND	E	E	E	E
C-4	DAB-59	C	F	B	ND	ND	ND	G	C	ND	D	E	F	E	A	G	F	ND	E	E	E	E
--	DAB-392	C	F	C	E	ND	ND	G	C	ND	D	E	F	E	A	ND	F	ND	E	E	E	E
C-3	DAB-60	C	F	C	E	ND	ND	G	C	ND	D	E	F	E	A	G	F	ND	E	E	E	E
C-2	DAB-61	C	F	C	E	ND	ND	G	C	ND	D	E	F	E	A	G	F	ND	E	E	E	E
C-1	LAT-62	C	F	C	F	ND	ND	G	B	E	E	E	F	E	A	G	E	F	E	E	E	E
B-6	RLP-393	B	F	C	E	F	E	G	B	E	D	F	F	E	A	F	E	F	D	E	E	E
B-5	RLP-63	B	F	A	E	ND	ND	G	C	ND	D	E	F	E	A	F	E	F	D	E	E	E
B-4	RLP-395	B	F	D	F	F	ND	G	B	ND	C	E	F	E	A	G	E	F	D	E	E	E
B-3	RLP-394	B	F	C	F	F	ND	G	B	ND	D	E	F	E	A	G	E	F	D	E	E	E
B-2	RLP-64	B	F	D	F	ND	ND	G	B	ND	D	E	F	E	A	G	E	F	D	E	E	E
B-1	LAT-65	B	E	D	F	F	ND	G	A	ND	C	E	F	E	A	G	E	F	D	E	E	E
--	LAT-396	B	F	C	F	F	E	G	B	ND	D	E	F	E	A	G	E	F	D	E	E	E
A-2	DAB-66	C	F	A	E	ND	ND	G	C	ND	C	E	F	F	A	ND	E	ND	E	E	E	E
A-1	DAB-67	C	F	A	E	ND	ND	G	C	ND	C	E	F	F	A	ND	E	ND	E	E	E	E
Cq-1	DAB-68	C	F	C	E	ND	ND	G	C	ND	D	E	F	F	A	ND	E	ND	E	E	E	E

OIL SHALE ANALYSES—SHEEP CREEK, MONTANA. LOT NO. 1234.

Oil shale analyses of samples of the D member of the Phosphoria formation, Sheep Creek, Montana (see immediately preceding pages for location of section, thickness and description of strata, and chemical analyses of samples), made by U. S. Bureau of Mines Petroleum and Oil-Shale Experiment Station, Laramie, Wyoming, by the modified Fischer-Retort method. None of the samples showed a tendency to coke.

Bed no.	Sample no.	Yield of products						Specific gravity of oil at 60°/60°F.	Properties of spent shale	
		Weight (percent)				Gallons per ton			Loss on ignition	Ash
		Spent shale				Oil	Water			
		Oil	Water	Gas + loss						
D-48	VEM- 1	--	3.8	95.1	1.1	--	9.1	3.6	91.5	
D-47	VEM- 2	--	4.2	94.0	1.8	--	10.1	4.3	89.7	
D-46	VEM- 3	--	4.6	93.2	2.2	--	11.0	4.2	89.0	
D-45	VEM- 4	--	4.0	94.4	1.6	--	9.6	4.9	89.5	
D-44	JES- 5	--	6.5	91.3	2.2	--	15.6	5.3	86.0	
D-43	JES- 6	--	4.8	93.3	1.9	--	11.5	5.5	87.8	
D-42	JES- 7	--	5.4	92.9	1.7	--	12.9	5.0	87.9	
D-41	JES- 8	0.5	5.8	91.6	2.1	1.3	13.9	6.8	84.8	
D-40	OAP- 9	--	3.5	95.7	0.8	--	8.4	3.5	92.2	
--	OAP-385	--	3.2	95.7	1.1	--	7.7	3.5	92.2	
D-39	OAP- 10	1.0	6.4	90.1	2.5	2.6 ¹	15.3	7.3	82.8	
D-38	OAP- 11	0.7	5.0	91.7	2.6	1.8	12.0	6.4	85.3	
D-37	OAP- 12	--	6.2	91.9	1.9	--	14.9	6.2	85.7	
D-36	OAP- 13	--	5.2	92.5	2.3	--	12.5	6.3	86.2	
D-35	LAT- 14	--	3.1	96.1	0.8	--	7.4	4.8	91.3	
--	LAT-386	0.4	3.4	94.8	1.4	0.9 ¹	8.1	4.7	90.1	
D-34	FSH- 15	--	3.8	94.1	2.1	--	9.1	4.3	89.8	
D-33	FSH- 16	--	4.5	93.9	1.6	--	10.8	4.1	89.8	
D-32	FSH- 17	--	5.5	92.1	2.4	--	13.2	6.4	85.7	
D-31	FSH- 18	--	3.4	95.1	1.5	--	8.1	4.2	90.9	
D-30	FSH- 19	--	7.5	89.4	3.1	--	18.0	7.9	81.5	
D-29	FSH- 20	2.9	5.6	88.9	2.6	7.0	13.4	9.9	79.0	
D-28	ERC- 21	--	7.0	89.6	3.4	--	16.8	7.8	81.8	
D-27	LAT- 22	8.2	5.2	82.7	3.9	20.0	12.5	12.5	70.2	
D-26	LAT- 23	7.8	6.0	82.9	3.3	18.8	14.4	14.8	68.1	
D-25	LAT- 24	5.3	4.4	87.8	2.5	12.8 ¹	10.5	10.1	77.7	
D-24	ERC- 25	1.9	7.7	87.3	3.1	4.7 ¹	18.6	10.4	76.9	
--	ERC-387	2.6	6.5	85.7	5.2	6.6 ¹	15.6	10.7	75.0	
D-23	ERC- 26	9.7	4.3	82.7	3.3	23.6	10.3	14.2	68.5	
D-22	ERC- 27	3.2	7.2	85.8	3.8	7.8	17.3	11.9	73.9	

¹ Estimated

Bed no.	Sample no.	Yield of products						Specific gravity of oil at 60°/60° F.	Properties of spent shale		
		Weight (percent)			Gallons per ton				Loss on ignition	Ash	
		Oil	Spent shale		Gas + loss	Oil					Water
			Water								
D-21	ERC- 28	7.8	5.6	81.3	5.3	18.9	13.4	0.991	13.0	68.3	
D-20	LAT- 29	--	7.5	91.1	1.4	--	18.0	--	6.1	85.0	
D-19	LAT- 30	--	4.2	94.4	1.4	--	10.2	--	6.0	88.4	
D-18	LAT- 31	1.9	5.3	89.8	3.0	4.8 ¹	12.7	--	8.0	81.8	
D-17	DAB- 32	3.2	5.0	89.0	2.8	7.6	12.0	1.002	7.8	81.2	
D-16	DAB- 33	3.3	5.0	88.8	2.9	8.4 ¹	12.0	--	9.2	79.6	
D-15	DAB- 34	3.7	4.8	88.8	2.7	8.9	11.5	0.994	9.0	79.8	
D-14	ERC- 35	4.3	5.6	87.0	3.1	10.4	13.4	0.990	9.4	77.6	
D-13	ERC- 36	3.7	5.2	87.7	3.4	8.9	12.5	0.986	9.8	77.9	
D-12	ERC- 37	5.5	5.0	86.6	2.9	13.4	12.0	0.990	9.0	77.6	
D-11	DAB- 38	--	3.0	96.7	0.3	--	7.2	--	3.4	93.3	
D-10	DAB- 39	2.5	5.4	89.9	2.2	6.4 ¹	12.9	--	8.0	81.9	
D-9	DAB- 40	0.8	5.7	92.6	0.9	1.9 ¹	13.7	--	3.4	89.2	
D-8	DAB- 41	--	4.8	94.8	0.4	--	11.4	--	6.4	88.4	
D-7	DAB- 42	--	8.5	91.1	0.4	--	20.4	--	7.2	83.9	
D-6	DAB- 43	--	5.5	93.1	1.4	--	13.2	--	5.1	88.0	
D-5	ERC- 44	--	7.5	89.7	2.8	--	18.0	--	8.0	81.7	
D-4	ERC- 45	--	8.0	88.8	3.2	--	19.2	--	7.6	81.2	
D-3	ERC- 46	--	5.5	94.2	0.3	--	13.2	--	3.8	90.4	
D-2	DAB- 47	--	3.2	96.5	0.3	--	7.7	--	2.2	94.3	
D-1	DAB- 48	--	1.5	98.5	0.0	--	3.6	--	1.6	96.9	

¹ Estimated

HIDDEN PASTURE CREEK, MUDDY CREEK, AND BIG SHEEP CANYON, MONTANA. LOT NOS. 1224, 1225, 1226 and 1227.

Phosphoria formation sampled in hand trenches and natural exposures on east limb of Dixon Mountain syncline; D and E members, lot no. 1224, sampled in NE $\frac{1}{4}$ SW $\frac{1}{4}$ sec. 26; B and C members, lot no. 1225, in SE $\frac{1}{4}$ SW $\frac{1}{4}$ sec. 35; and upper part of A member, lot no. 1226, in NE $\frac{1}{4}$ NW $\frac{1}{4}$ sec. 35, T. 13 S., R. 10 W.; lower part of A member, lot no. 1227, sampled in NW $\frac{1}{4}$ NW $\frac{1}{4}$ sec. 11, T. 14 S., R. 10 W., Beaverhead County, Montana. Beds strike northwest and dip 30-40° SW. Section measured by W. R. Lowell and sampled by D. A. Bostwick, E. T. Ruppel, and R. L. Parker in August 1947. Samples analyzed by U. S. Bureau of Mines Laboratory, Albany, Oregon.

Bed no.	Rock description	Sample no.	Thickness (feet)	Chemical analyses (percent)						Cumulative thickness (feet)	Thickness x percent P ₂ O ₅ (cumulative)
				P ₂ O ₅	Al ₂ O ₃	Fe ₂ O ₃	V ₂ O ₅	F	Loss on ignition		
Dinwoody formation — not measured											
E member of Phosphoria formation, lot no. 1224											
E-34	Mudstone	--	25.0	--	--	--	--	--	--	25.0	--
E-33	Mudstone, cherty	WRL-222-47	3.5	1.5	--	--	--	--	--	78.9	5.25
E-32	Mudstone, cherty	WRL-221-47	4.0	1.3	--	--	--	--	--	71.7	10.45
E-31	Mudstone, cherty	WRL-220-47	5.0	1.3	--	--	--	--	--	74.6	16.95
E-30	Mudstone, cherty	WRL-219-47	4.2	1.8	--	--	--	--	--	74.6	24.51
E-29	Mudstone, cherty	WRL-218-47	4.2	1.2	--	--	--	--	--	75.5	29.55
E-28	Mudstone, calcareous	WRL-217-47	0.8	0.9	--	--	--	--	--	66.6	46.7
E-27	Mudstone, calcareous	WRL-216-47	1.3	1.9	--	--	--	--	--	75.3	32.74
E-26	Quartzite	WRL-215-47	4.6	1.2	--	--	--	--	--	76.1	38.26
E-25	Chert	WRL-214-47	5.0	0.6	--	--	--	--	--	80.9	41.26
E-24	Chert	WRL-213-47	5.0	1.0	--	--	--	--	--	80.3	46.26
E-23	Chert and mudstone	WRL-212-47	4.7	1.2	--	--	--	--	--	80.3	51.90
E-22	Chert	WRL-211-47	5.0	1.5	--	--	--	--	--	78.9	59.40
E-21	Chert	WRL-210-47	1.7	1.4	--	--	--	--	--	85.0	61.78
E-20	Chert	WRL-209-47	4.4	2.2	--	--	--	--	--	77.8	71.46
E-19	Limestone	WRL-208-47	0.8	0.5	--	--	--	--	--	3.0	71.86
E-18	Chert	WRL-207-47	4.9	1.3	--	--	--	--	--	74.3	78.23
E-17	Chert	WRL-206-47	4.5	1.6	--	--	--	--	--	75.5	85.43
E-16	Chert	WRL-205-47	1.9	1.3	--	--	--	--	--	85.7	87.90
E-15	Limestone	WRL-204-47	1.0	0.5	--	--	--	--	--	1.4	88.40
E-14	Chert	WRL-203-47	2.2	1.5	--	--	--	--	--	76.4	91.70
E-13	Chert	WRL-202-47	5.0	1.4	--	--	--	--	--	78.7	98.70
E-12	Chert	WRL-201-47	2.2	1.5	--	--	--	--	--	76.7	102.00
E-11	Chert and limestone	WRL-200-47	2.5	0.9	--	--	--	--	--	75.5	104.25
E-10	Chert	WRL-199-47	2.7	1.4	--	--	--	--	--	80.4	108.03
E-9	Mudstone	WRL-107-47	5.0	1.2	--	--	--	--	--	78.4	114.03
E-8	Chert	WRL-106-47	5.0	1.6	--	--	--	--	--	8.9	122.03
E-7	Mudstone	WRL-105-47	5.0	1.6	--	--	--	--	--	80.2	130.03
E-6	Mudstone	WRL-104-47	5.0	1.3	--	--	--	--	--	77.4	136.53
E-5	Mudstone	WRL-103-47	5.0	1.3	--	--	--	--	--	80.3	143.03

Bed no.	Rock description	Sample no.	Thickness (feet)	Chemical analyses (percent)						Cumulative thickness (feet)	Thickness x percent P_2O_5 (cumulative)
				P_2O_5	Al_2O_3	Fe_2O_3	V_2O_5	F	Loss on ignition		
E-4	Mudstone	WRL-102-47	5.0	1.3	--	--	--	--	--	79.4	149.53
E-3	Mudstone	WRL-101-47	4.2	1.4	--	--	--	--	--	82.6	155.41
E-2	Mudstone	WRL-100-47	5.0	1.3	--	--	--	--	--	81.1	161.91
E-1	Mudstone	WRL-99-47	3.3	3.5	--	--	--	--	--	66.1	173.46
D member of Phosphoria formation, lot no. 1224											
D-51	Mudstone	WRL-98-47	5.0	5.8	--	--	--	0.47	--	50.3	19.00
D-50	Mudstone	WRL-97-47	5.0	5.6	--	--	--	--	--	50.5	57.00
D-49	Mudstone	WRL-96-47	5.0	7.8	--	--	--	--	--	46.3	96.00
D-48	Limestone, argillaceous	WRL-95-47	1.3	6.8	--	--	--	--	--	40.8	104.84
D-47	Limestone	WRL-94-47	4.1	1.8	--	--	--	--	--	19.2	112.22
D-46	Limestone, argillaceous	WRL-93-47	5.0	5.7	--	--	--	--	--	36.7	140.72
D-45	Limestone, argillaceous	WRL-92-47	1.2	6.8	--	--	--	--	--	38.1	148.88
D-44	Phosphate rock	WRL-91-47	2.5	26.8	--	--	--	2.72	--	12.3	215.88
D-43	Mudstone, calcareous and phosphate rock	WRL-90-47	0.7	8.8	--	--	--	--	--	49.4	222.04
D-42	Phosphate rock, calcareous	WRL-89-47	1.5	22.5	--	--	--	--	--	41.7	255.79
D-41	Mudstone	WRL-88-47	3.0	6.9	--	--	--	--	--	56.9	276.49
D-40	Phosphate rock, calcareous, argillaceous	WRL-87-47	2.3	16.7	--	--	--	--	--	23.7	314.90
D-39	Phosphate rock and argillaceous limestone	WRL-86-47	1.1	21.7	--	--	--	--	--	13.5	338.77
D-38	Limestone, phosphatic, argillaceous	WRL-85-47	0.6	12.9	--	--	--	--	--	32.3	346.51
D-37	Dolomite, argillaceous	WRL-84-47	0.7	5.4	--	--	--	--	--	34.1	350.29
D-36	Phosphate rock, argillaceous, calcareous	WRL-83-47	1.7	13.8	--	--	--	--	--	33.2	373.75
D-35	Limestone, argillaceous	WRL-82-47	0.5	5.1	--	--	--	0.47	--	39.9	376.30
D-34	Phosphate rock, argillaceous and limestone	WRL-81-47	2.9	14.9	--	--	--	1.55	--	33.7	419.51
D-33	Limestone, argillaceous	WRL-80-47	2.9	4.9	--	--	--	--	--	26.3	433.72
D-32	Mudstone, calcareous, phosphatic	WRL-79-47	1.3	8.5	--	--	--	--	--	41.9	444.77
D-31	Limestone and phosphate rock	WRL-78-47	1.8	5.3	--	--	--	0.75	--	15.2	454.31
D-30	Mudstone, calcareous, phosphatic	WRL-77-47	1.2	9.1	--	--	--	--	--	46.0	465.23
D-29	Limestone	WRL-76-47	1.6	6.6	--	--	--	--	--	18.3	475.79
D-28	Mudstone, calcareous, phosphatic	WRL-75-47	0.6	10.0	--	--	--	--	--	42.6	481.79
D-27	Limestone	WRL-74-47	0.7	3.8	--	--	--	--	--	15.2	484.45
D-26	Mudstone, calcareous, phosphatic	WRL-73-47	1.4	9.2	--	--	--	--	--	46.1	497.33
D-25	Limestone, argillaceous	WRL-72-47	1.2	4.0	--	--	--	--	--	22.6	502.13

D-24	Mudstone, calcareous	WRL- 71-47	0.6	7.1	--	--	--	--	--	50.6	57.4	506.39
D-23	Phosphate rock, argillaceous, calcareous	WRL- 70-47	1.5	18.0	--	--	--	--	--	26.5	58.9	533.39
D-22	Mudstone, phosphatic, calcareous	WRL- 69-47	0.7	12.2	--	--	--	--	--	41.2	59.6	541.93
D-21	Mudstone, calcareous	WRL- 68-47	1.7	3.3	--	--	--	--	--	64.8	61.3	547.54
D-20	Mudstone, phosphatic, calcareous	WRL- 67-47	0.3	12.7	--	--	--	--	--	40.0	61.6	551.35
D-19	Mudstone	WRL- 66-47	0.8	3.4	--	--	--	--	--	69.7	62.4	554.07
D-18	Mudstone and phosphate rock	WRL- 65-47	1.3	5.2	--	--	--	--	--	61.8	63.7	560.83
D-17	Phosphate rock, argillaceous, calcareous	WRL- 64-47	0.5	15.3	--	--	--	1.29	--	36.0	64.2	568.48
D-16	Mudstone	WRL- 63-47	2.5	2.3	--	--	--	--	--	72.3	66.7	574.23
D-15	Mudstone, phosphatic	WRL- 62-47	0.5	14.5	--	--	--	--	--	41.7	67.2	581.48
D-14	Mudstone, phosphatic	WRL- 61-47	0.9	8.1	--	--	--	--	--	53.9	68.1	588.77
D-13	Phosphate rock	WRL- 60-47	0.9	24.0	--	--	--	2.74	--	18.3	69.0	610.37
D-12	Mudstone, calcareous	WRL- 59-47	0.4	0.9	--	--	--	--	--	59.7	69.4	610.73
D-11	Phosphate rock, argillaceous, calcareous	WRL- 58-47	0.4	15.0	--	--	--	1.70	--	36.4	69.8	616.73
D-10	Mudstone	WRL- 57-47	1.4	1.9	--	--	--	--	--	75.9	71.2	619.39
D-9	Mudstone, calcareous, phosphatic	WRL- 56-47	1.7	10.5	--	--	--	--	--	44.9	72.9	637.24
D-8	Phosphate rock, argillaceous, calcareous	WRL- 55-47	1.5	15.7	--	--	--	--	--	30.6	74.4	660.79
D-7	Phosphate rock, calcareous, argillaceous	WRL- 54-47	1.3	16.0	--	--	--	--	--	34.3	75.7	681.59
D-6	Limestone	WRL- 53-47	1.2	0.9	--	--	--	--	--	17.9	76.9	682.67
D-5	Phosphate rock, argillaceous, calcareous	WRL- 52-47	1.3	14.6	--	--	--	--	--	32.7	78.2	701.65
D-4	Phosphate rock, argillaceous, calcareous	WRL- 51-47	1.5	15.9	--	--	--	--	--	29.1	79.7	725.50
D-3	Mudstone, phosphatic, calcareous	WRL- 50-47	0.6	11.2	--	--	--	--	--	43.9	80.3	722.22
D-2	Limestone	WRL- 49-47	0.8	0.8	--	--	--	--	--	19.5	81.1	732.86
D-1	Mudstone, calcareous, phosphatic	WRL- 48-47	1.8	8.8	--	--	--	--	--	42.7	82.9	748.70
C member of Phosphoria formation, lot no. 1224—top bed only												
C-1	Sandstone, phosphatic	WRL- 47-47	(1.7)	13.3	--	--	--	--	--	55.4	--	--
WRL-47-47, lot no. 1224, logged as equivalent to upper 1.7 feet of WRL-198-47, lot no. 1225.												
C member of Phosphoria formation, lot no. 1225												
C-36	Limestone, sandy	WRL-198-47	12.0	1.0	0.5	1.1	0.01	--	26.5	32.6	12.0	12.00
C-35	Sandstone, calcareous	WRL-197-47	8.3	1.0	3.5	2.2	0.01	--	8.4	73.1	20.3	20.30
C-34	Chert, calcareous	WRL-196-47	7.4	0.7	3.5	2.5	0.01	--	9.6	73.1	27.7	25.48
C-33	Chert, calcareous	WRL-195-47	9.9	0.5	4.3	3.7	0.01	--	8.0	75.1	37.6	30.43

Bed no.	Rock description	Sample no.	Thickness (feet)	Chemical analyses (percent)						Loss on ignition	Acid insoluble	Cumulative thickness (feet)	Thickness x percent P_2O_5 (cumulative)
				P_2O_5	Al_2O_3	Fe_2O_3	V_2O_5	F					
C-32	Chert and limestone	WRL-194-47	11.0	0.5	1.3	5.1	0.01	--		12.1	63.2	48.6	35.93
C-31	Chert and limestone	WRL-193-47	7.2	0.3	3.2	2.6	0.01	--		13.8	62.3	55.8	38.09
C-30	Mudstone, calcareous	WRL-192-47	5.0	1.1	6.2	2.4	0.01	--		14.1	59.0	60.8	43.59
C-29	Limestone, cherty	WRL-191-47	4.4	0.5	0.3	3.5	0.01	--		17.6	52.9	65.2	45.79
C-28	Limestone, sandy	WRL-190-47	4.3	0.4	4.1	1.7	0.01	--		22.8	43.2	69.5	47.51
C-27	Sandstone, calcareous	WRL-189-47	3.1	0.6	1.1	2.7	0.01	--		14.5	62.7	72.6	49.37
C-26	Limestone, sandy	WRL-188-47	3.2	0.7	0.5	1.1	0.01	--		27.4	36.0	75.8	51.61
C-25	Sandstone and limestone	WRL-187-47	7.8	0.6	0.6	1.6	0.01	--		19.9	51.3	83.6	56.29
C-24	Limestone, sandy	WRL-186-47	2.5	0.8	0.6	1.7	0.01	--		23.2	44.6	86.1	58.29
C-23	Limestone, sandy	WRL-185-47	2.7	0.6	0.8	1.2	0.01	--		35.0	20.5	88.8	59.91
C-22	Sandstone, calcareous	WRL-184-47	5.8	1.8	0.2	1.3	0.01	--		16.1	58.6	94.6	70.35
C-21	Limestone, sandy	WRL-183-47	7.3	0.8	0.7	1.6	0.01	--		26.3	37.0	101.9	76.19
C-20	Limestone, cherty	WRL-182-47	7.8	0.3	0.5	2.6	0.01	--		22.2	43.1	109.7	78.53
C-19	Chert, calcareous	WRL-181-47	3.7	0.3	1.3	3.2	0.02	--		13.5	63.8	113.4	79.64
C-18	Limestone, sandy	WRL-180-47	1.4	0.8	0.6	2.04	0.02	--		21.5	47.4	114.8	80.76
C-17	Limestone, sandy	WRL-179-47	4.5	0.7	0.6	1.6	0.02	--		25.4	40.6	119.3	83.91
C-16	Sandstone and limestone	WRL-178-47	12.3	0.7	0.2	1.9	0.02	--		18.5	55.4	131.6	92.52
C-15	Limestone, sandy	WRL-177-47	2.4	0.6	0.9	1.2	0.01	--		34.5	21.3	134.0	93.96
C-14	Sandstone, calcareous	WRL-176-47	5.4	1.5	0.4	0.9	0.02	--		14.7	62.2	139.4	102.86
C-13	Limestone	WRL-175-47	1.3	0.2	0.5	1.1	0.01	--		40.7	9.1	140.7	102.32
C-12	Limestone	WRL-174-47	6.2	1.9	0.3	0.7	0.01	--		37.5	10.4	146.9	114.10
C-11	Sandstone, calcareous	WRL-173-47	9.5	1.4	0.6	1.7	0.01	--		12.4	67.2	156.4	127.40
C-10	Chert, sandy	WRL-172-47	4.2	0.5	0.3	2.9	0.01	--		0.3	94.3	160.6	129.50
C-9	Chert	WRL-171-47	2.0	0.3	1.0	2.9	0.01	--		1.0	92.8	162.6	130.10
C-8	Chert	WRL-170-47	3.2	0.4	1.3	4.7	0.02	--		2.2	88.1	165.8	131.38
C-7	Chert	WRL-169-47	5.0	0.3	1.1	2.9	0.01	--		2.6	89.4	170.8	132.88
C-6	Chert	WRL-168-47	5.0	0.4	1.6	4.4	0.02	--		3.4	85.9	175.8	134.88
C-5	Chert	WRL-167-47	5.0	0.5	1.9	4.9	0.01	--		5.7	79.7	180.8	137.38
C-4	Chert	WRL-166-47	5.0	0.4	2.1	4.8	0.01	--		6.9	78.2	185.8	139.38
C-3	Chert	WRL-165-47	5.0	0.5	1.7	4.7	0.02	--		7.2	77.1	190.8	141.88
C-2	Chert, calcareous	WRL-164-47	5.0	0.4	1.8	4.0	0.01	--		13.9	63.4	195.8	143.88
C-1	Chert	WRL-163-47	4.0	0.5	2.0	3.2	0.02	--		2.2	89.7	199.8	145.88

B member of Phosphoria formation, lot no. 1225

B-30	Mudstone and chert	WRL-162-47	1.4	1.0	4.7	3.1	0.01	--		8.2	79.9	1.4	1.40
B-29	Mudstone	WRL-161-47	1.5	1.4	6.4	2.7	0.03	--		9.7	74.3	2.9	3.50
B-28	Limestone, argillaceous	WRL-160-47	0.6	0.4	1.2	0.8	0.02	--		35.1	22.8	3.5	3.74

B-27	Limestone, argillaceous and phosphate rock	WRL-159-47	0.8	7.5	2.2	1.5	0.02	--	24.9	27.3	4.3	9.74
B-26	Mudstone	WRL-158-47	1.8	3.2	6.8	3.1	0.04	--	9.6	68.7	6.1	15.50
B-25	Mudstone, phosphatic, calcareous	WRL-157-47	2.3	11.7	1.8	1.7	0.02	--	11.4	43.0	8.4	42.41
B-24	Chert and mudstone	WRL-156-47	5.4	0.9	2.7	3.5	0.02	--	3.5	83.7	13.8	47.27
B-23	Mudstone, cherty	WRL-155-47	3.2	0.3	5.8	3.9	0.02	--	5.0	79.0	17.0	48.23
B-22	Mudstone, cherty	WRL-154-47	2.8	0.2	6.8	3.5	0.03	--	3.4	86.6	19.8	48.79
B-21	Chert	WRL-153-47	3.3	2.9	2.9	3.6	0.03	--	8.4	70.7	23.1	58.36
B-20	Chert, calcareous and mudstone	WRL-152-47	2.3	2.3	1.7	3.4	0.03	--	15.0	56.3	25.4	63.65
B-19	Phosphate rock, calcareous, argillaceous	WRL-151-47	1.0	18.1	3.4	1.9	0.06	--	11.6	25.6	26.4	81.75
B-18	Mudstone	WRL-150-47	1.3	1.5	7.9	3.6	0.47	--	13.1	66.1	27.7	83.70
B-17	Limestone, argillaceous	WRL-149-47	0.8	0.3	5.8	3.4	0.08	--	19.9	48.0	28.5	88.94
B-16	Mudstone, calcareous, phosphatic	WRL-148-47	1.5	9.5	7.2	2.9	0.12	--	10.6	50.0	30.0	98.19
B-15	Mudstone, calcareous	WRL-147-47	2.4	2.0	6.2	2.7	0.03	--	19.4	45.4	32.4	102.99
B-14	Mudstone, phosphatic	WRL-146-47	0.5	14.6	5.3	2.2	0.03	--	10.0	39.4	32.9	110.29
B-13	Mudstone, calcareous	WRL-145-47	1.7	1.4	6.9	2.8	0.03	--	16.1	54.0	34.6	112.67
B-12	Limestone, argillaceous	WRL-144-47	3.3	5.8	6.0	2.6	0.04	--	26.0	35.7	37.9	131.81
B-11	Phosphate rock, calcareous	WRL-143-47	2.6	19.8	2.3	1.4	0.14	--	20.8	12.0	40.5	183.29
B-10	Limestone, argillaceous	WRL-142-47	1.3	4.8	5.4	2.1	0.09	--	33.8	27.8	41.8	189.53
B-9	Limestone, argillaceous	WRL-141-47	1.0	3.6	5.2	2.3	0.1	--	37.3	27.3	42.8	193.13
B-8	Limestone, argillaceous	WRL-140-47	1.5	3.3	5.2	2.2	0.07	--	36.3	27.9	44.3	198.08
B-7	Limestone, phosphatic, argillaceous	WRL-139-47	1.2	8.0	3.8	1.6	0.1	--	31.0	20.8	45.5	207.68
B-6	Mudstone, calcareous and calcareous phosphate rock	WRL-138-47	1.8	16.6	3.1	1.9	0.11	--	24.7	15.2	47.3	237.56
B-5	Phosphate rock, calcareous	WRL-137-47	1.2	22.1	2.4	1.0	0.07	--	12.5	15.2	48.5	264.08
B-4	Phosphate rock, calcareous and calcareous mudstone	WRL-136-47	1.5	20.5	2.3	1.2	0.09	--	18.3	14.2	50.0	294.83
B-3	Limestone, argillaceous	WRL-135-47	1.2	3.3	4.9	1.8	0.11	--	23.7	41.1	51.2	298.79
B-2	Phosphate rock	WRL-134-47	1.2	16.8	3.6	1.9	0.2	--	22.1	19.3	52.4	318.95
B-1	Phosphate rock	WRL-133-47	2.0	29.4	0.8	0.8	0.008	3.16	6.4	8.8	54.4	377.75

A member of Phosphoria formation, lot nos. 1226 and 1227

Lot no. 1226												
A-53	Limestone	WRL-132-47	5.0	0.2	--	--	--	--	--	4.9	5.0	1.00
A-52	Mudstone, calcareous	WRL-131-47	2.3	0.2	--	--	--	--	--	60.7	7.3	1.46
A-51	Limestone	WRL-130-47	4.7	0.2	--	--	--	--	--	17.9	12.0	2.40
A-50	Limestone	WRL-129-47	4.9	1.2	--	--	--	--	--	3.3	16.9	8.28
A-49	Mudstone, calcareous	WRL-128-47	4.8	0.2	--	--	--	--	--	63.3	21.7	9.24
A-48	Mudstone, calcareous	WRL-127-47	5.0	0.3	--	--	--	--	--	62.6	26.7	10.74
A-47	Mudstone, calcareous	WRL-126-47	5.0	0.1	--	--	--	--	--	64.8	31.7	11.24
A-46	Mudstone, calcareous	WRL-125-47	5.0	1.2	--	--	--	--	--	72.9	36.7	17.24

¹ See additional analyses at end of table.

Bed no.	Rock description	Sample no.	Thickness (feet)	Chemical analyses (percent)						Cumulative thickness (feet)	Thickness x percent P ₂ O ₅ (cumulative)
				P ₂ O ₅	Al ₂ O ₃	Fe ₂ O ₃	V ₂ O ₅	F	Loss on ignition		
A-45	Mudstone, calcareous	WRL-124-47	5.0	0.1	--	--	--	--	--	41.7	17.74
A-44	Mudstone, calcareous	WRL-123-47	2.3	0.1	--	--	--	--	--	44.0	17.97
A-43	Mudstone, calcareous	WRL-122-47	5.0	1.3	--	--	--	--	--	49.0	24.47
A-42	Mudstone, calcareous	WRL-121-47	5.0	1.3	--	--	--	--	--	54.0	30.97
A-41	Mudstone, calcareous	WRL-120-47	5.0	1.3	--	--	--	--	--	59.0	37.47
A-40	Mudstone, calcareous	WRL-119-47	5.0	0.1	--	--	--	--	--	64.0	37.97
A-39	Sandstone, calcareous	WRL-118-47	2.5	0.1	--	--	--	--	--	66.5	38.22
A-38	Mudstone, calcareous	WRL-117-47	3.7	0.1	--	--	--	--	--	70.2	38.59
A-37	Mudstone, calcareous	WRL-116-47	5.0	0.1	--	--	--	--	--	75.2	39.09
A-36	Mudstone, calcareous	WRL-115-47	5.0	1.3	--	--	--	--	--	80.2	45.59
A-35	Mudstone, calcareous	WRL-114-47	5.0	0.1	--	--	--	--	--	85.2	46.09
A-34	Mudstone, calcareous	WRL-113-47	5.0	0.1	--	--	--	--	--	90.2	46.59
A-33	Mudstone, calcareous	WRL-112-47	5.0	1.4	--	--	--	--	--	95.2	53.59
A-32	Mudstone, calcareous	WRL-111-47	5.0	1.2	--	--	--	--	--	100.2	59.59
A-31	Mudstone, calcareous and calcareous sandstone	WRL-110-47	4.5	1.2	--	--	--	--	--	104.7	64.99
A-30	Mudstone, calcareous	WRL-109-47	2.8	0.2	--	--	--	--	--	107.5	65.55
A-29	Sandstone, calcareous and mudstone	WRL-108-47	3.6	0.3	--	--	--	--	--	111.1	66.63
A-28	Limestone, cherty	WRL-250-47	2.3	0.5	--	--	--	--	--	113.4	67.78
A-27	Limestone and sandstone	WRL-249-47	2.4	0.3	--	--	--	--	--	115.8	68.50
A-26	Phosphate rock	WRL-248-47	1.0	31.4	--	--	--	--	--	116.8	99.90
A-25	Limestone, cherty	WRL-247-47	2.6	0.5	--	--	--	--	--	119.4	101.20
A-24	Limestone and chert	WRL-246-47	3.5	0.3	--	--	--	--	--	122.9	102.25
A-23	Limestone	WRL-245-47	1.8	0.1	--	--	--	--	--	124.7	102.43
Lot no. 1227											
A-22	Limestone, sandy	WRL-244-47	5.6	0.0	--	--	--	--	--	130.3	102.43
A-21	Limestone and sandstone, calcareous	WRL-243-47	19.2	0.1	--	--	--	--	--	149.5	104.35
A-20	Limestone, sandy	WRL-242-47	7.7	0.1	--	--	--	--	--	157.2	105.12
A-19	Limestone	WRL-241-47	25.6	1.3	--	--	--	--	--	182.8	138.40
A-18	Chert and limestone	WRL-240-47	5.8	0.4	--	--	--	--	--	188.6	140.72
A-17	Limestone	WRL-239-47	12.4	0.2	--	--	--	--	--	201.0	143.20
A-16	Limestone, argillaceous	WRL-238-47	4.2	0.4	--	--	--	--	--	205.2	144.88
A-15	Limestone, argillaceous	WRL-237-47	4.0	0.4	--	--	--	--	--	209.2	146.48
A-14	Mudstone	WRL-236-47	2.3	0.5	--	--	--	--	--	211.5	147.63
A-13	Sandstone	WRL-235-47	17.8	0.2	--	--	--	--	--	229.3	151.19
A-12	Limestone, sandy, cherty	WRL-234-47	11.0	0.3	--	--	--	--	--	240.3	154.49
A-11	Sandstone, calcareous	WRL-233-47	7.5	0.1	--	--	--	--	--	247.8	155.24
A-10	Mudstone, calcareous	WRL-232-47	2.3	0.4	--	--	--	--	--	250.1	156.16

Bed no.	Sample no.	P ₂ O ₅	V ₂ O ₅	F	SiO ₂	TiO ₂	CaO	MgO	Na ₂ O	K ₂ O	159.58
A-9	Limestone, argillaceous										
A-8	Chert and limestone float, bedrock not exposed										
A-7	Chert, calcareous, sandy										
A-6	Chert and limestone										
A-5	Chert, calcareous, and limestone										
A-4	Sandstone, calcareous										
A-3	Limestone, cherty, sandy										
A-2	Limestone										
A-1	Limestone										

* Cumulative data incomplete due to missing information. Computations start from zero after interruption.
 ** Note incompleteness of cumulative data.

Additional analyses of sample WRL-150-47²

Bed no.	Sample no.	P ₂ O ₅	V ₂ O ₅	F	SiO ₂	TiO ₂	CaO	MgO	Na ₂ O	K ₂ O	MnO
B-18	WRL-150-47	2.81	0.56	0.31	60.60	0.48	4.02	2.34	0.17	3.15	0.028
		NI	Cr ₂ O ₃	Co	Zn	Cu	Pb	Ag	MnO ₃	W	Organic matter
		0.022	0.02	0.004	0.003	0.011	0.006	0.0001	0.006	<0.005	6.66 ³

² Analyses made by the U. S. Geological Survey, Geochemistry and Petrology Branch.
³ CO₂ and S reported present.