GEOLOGICAL SURVEY CIRCULAR 303

STRATIGRAPHIC SECTIONS OF THE PHOSPHORIA FORMATION IN MONTANA

PART 2, 1949–50

Prepared as part of the program of the Department of the Interior for development of the Missouri River Basin and of work done on behalf of the U. S. Atomic Energy Commission. The report is published with the permission of the Commission.

UNITED STATES DEPARTMENT OF THE INTERIOR
Douglas McKay, Secretary

GEOLOGICAL SURVEY
W. E. Wrather, Director

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Washington, D. C., 1953

Free on application to the Geological Survey, Washington 25, D. C.

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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, are published as preliminary reports as they are assembled. This report, which contains abstracts of many of the sections in southwestern Montana (fig. 1), is one of this series and is the fourth Montana report; it includes the second half of the data gathered in Montana during 1949 and 1950. The field and laboratory procedures adopted in these investigations are described rather fully in a previous 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. L. Elliott, W. J. Garmoe, R. F. Gosman, C. W. Tandy, and W. H. Wilson participated in the description of strata and the collection of samples referred to in this report. Crushing and splitting of the samples in the field was done by T. K. Rigby. The laboratory preparation of samples for chemical analysis was done in Denver, Colo., under the direction of W. P. Huleatt.

The P_2O_5 and acid-insoluble 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 Al_2O_3, Fe_2O_3, and loss-on-ignition analyses were made in the Trace Elements Section laboratory of the Survey in Washington, D. C., under the direction of J. C. Rabbitt by chemists H. Alberty, I. Barlow, T. Farley, C. Hoy, and M. Landers.

Compilation of the data has been by K. S. Bergman. Organization of the tabular data has been largely by Anita Wise.

ACKNOWLEDGMENTS

Special thanks are due A. E. Weissenborn and M. R. Klepper, who gave much advice and help in carrying out the field program. The field and laboratory investigations have been conducted as part of the program of the Department of the Interior for the development of the Missouri River Basin and on behalf of the Division of Raw Materials of the Atomic Energy Commission.

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.

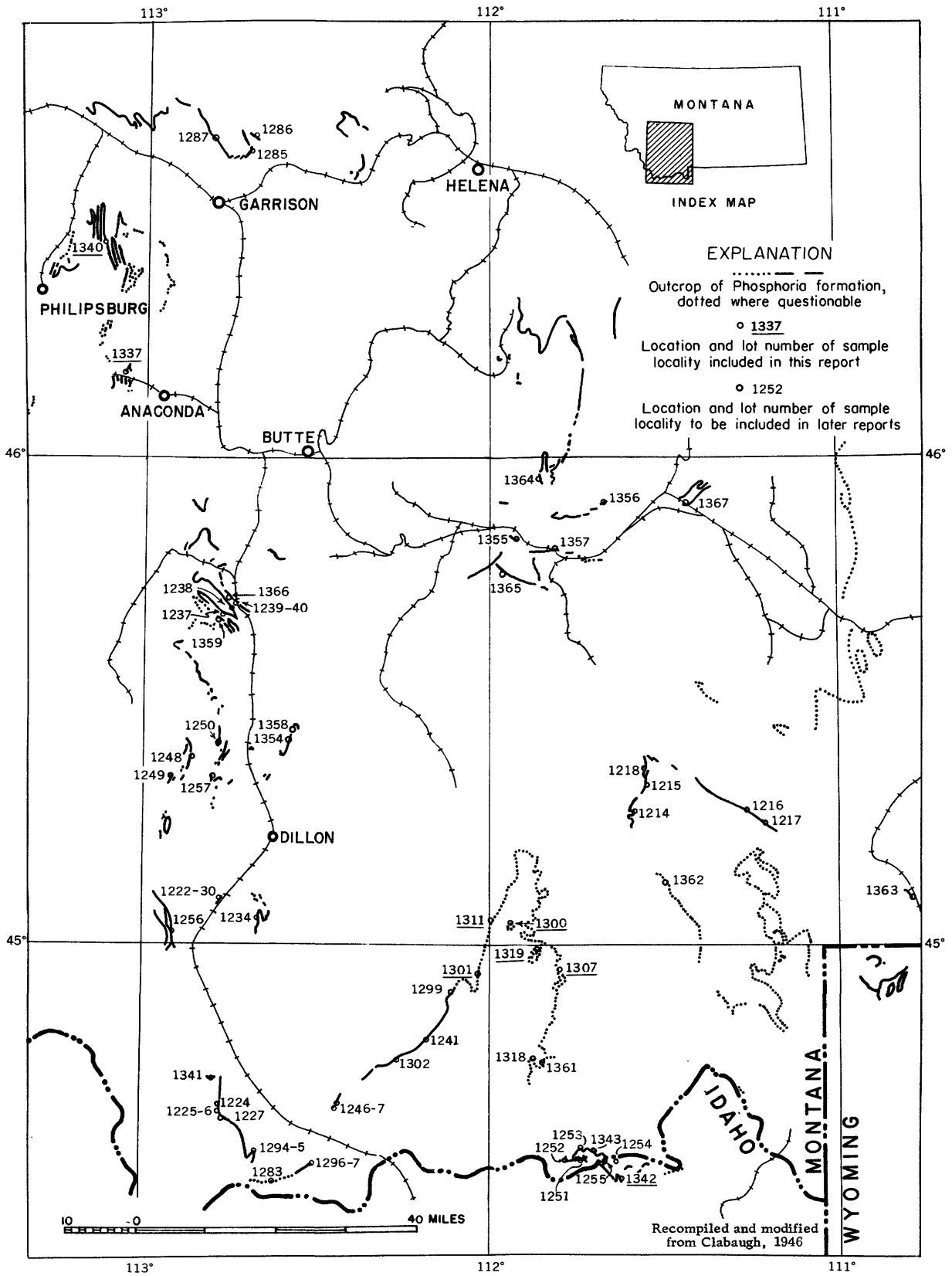

Figure 1.—Outcrops of the Phosphoria formation in Montana and localities sampled.

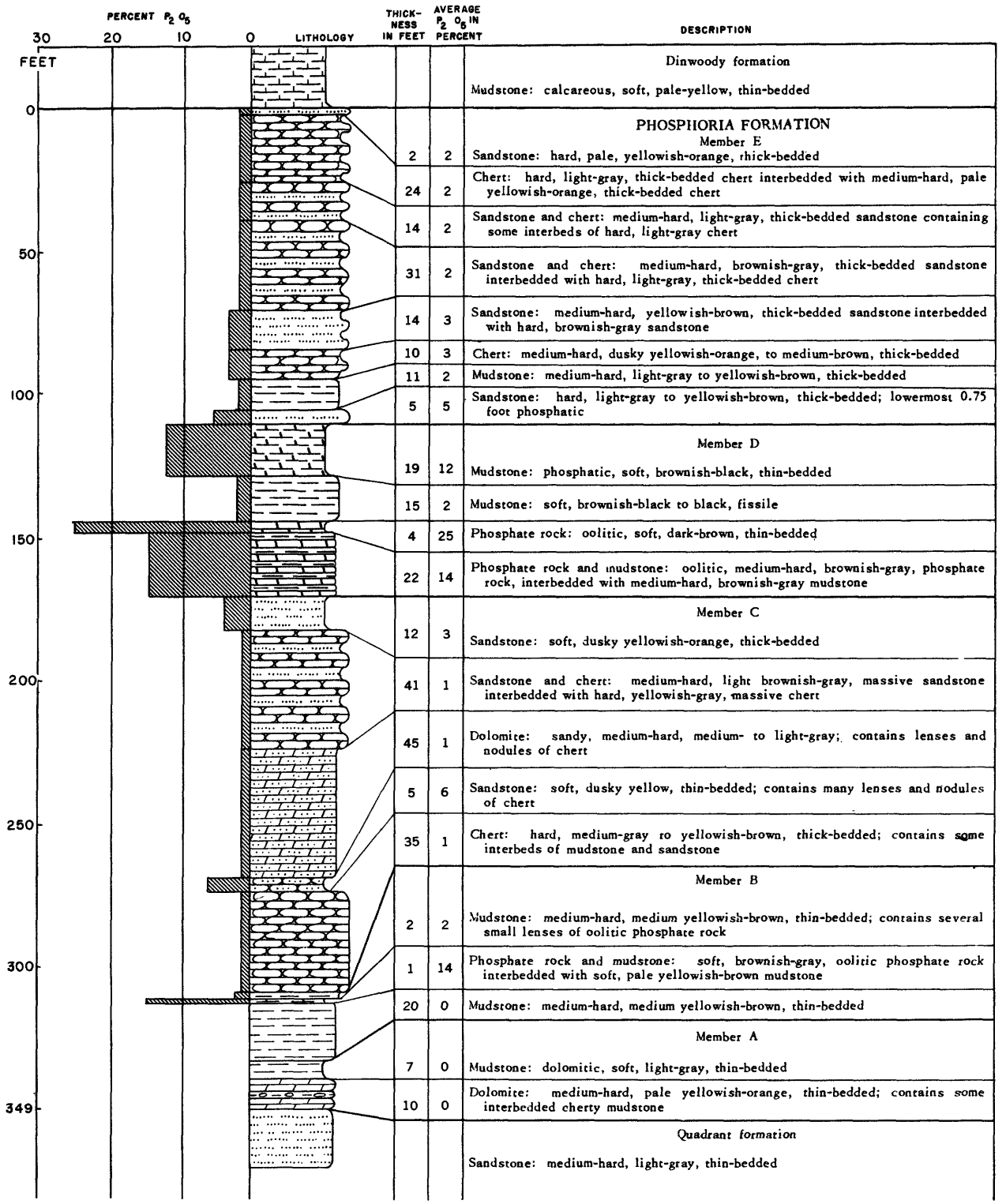

Figure 2.—Generalized section of the Phosphoria formation at Sheep Creek, Montana, lot no. 1234.

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. 2). The lower two hard members are dominated by limestone and the top hard member 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 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.

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 previously reported (Swanson and others, 1953, Klepper and others, 1953, and Cressman and others, 1953) and sections to be reported later are shown in figure 1.

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Moonlight Adit, Mont., lot. 1340

D member of Phosphoria formation sampled in Moonlight adit of Sunlight Mining Company, NW¼ sec. 29, T. 8 N., R. 12 W., Granite, County, Mont. Samples 5903-5907 cut from top of stope above main drift of adit, samples 5908-5914 cut from south end of drift on phosphatic shale member, and samples 5915-5916 cut from same drift at junction with crosscut. Beds strike N. 30° W. and dip 40° NE. Samples analyzed for P_2O_5 and acid insoluble by U. S. Bureau of Mines laboratory, Albany, Oreg., and for other constituents by Trace Elements Section laboratory, Washington, D. C.

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	Loss on ignition	Acid insoluble		
	E member of Phosphoria formation—basal bed only									
E- 1	Chert	--	0.5	--	--	--	--	--	0.5	--
	D member of Phosphoria formation									
D-13	Phosphate rock	5907-RWS	1.9	35.4	0.78	1.69	1.17	7.7	1.9	67.26
D-12	Phosphate rock and mudstone	5906-RWS	.5	22.3	5.66	5.16	2.68	28.5	2.4	78.41
D-11	Phosphate rock	5905-RWS	.7	37.0	1.29	1.25	1.22	3.8	3.1	104.31
D-10	Phosphate rock and mudstone	5904-RWS	.4	26.7	4.86	5.01	2.85	18.2	3.5	114.99
D- 9	Phosphate rock	5908-RWS	1.4	33.6	2.47	1.35	1.67	9.8	4.9	162.03
D- 8	Phosphate rock and mudstone	5909-RWS	.3	26.2	5.54	2.25	3.56	21.8	5.2	169.89
--	Phosphate rock	5903-RWS	(1.1)	32.8	3.11	2.27	2.29	10.4	--	--
	Sample 5903-RWS represents same beds as samples 5908-RWS and 5909-RWS.									
D- 7	Mudstone, phosphatic	5910-RWS	1.3	13.0	9.52	4.06	4.51	49.4	6.5	186.79
D- 6	Mudstone, phosphatic	5911-RWS	.3	8.4	10.3	5.59	5.11	57.3	6.8	189.31
D- 5	Mudstone	5912-RWS	1.6	6.4	10.6	4.03	3.52	66.2	8.4	199.55
D- 4	Mudstone	5913-RWS	.4	1.4	11.4	5.83	4.47	79.7	8.8	200.11
D- 3	Phosphate rock, argillaceous	5914-RWS	1.0	21.4	7.10	4.39	3.95	29.7	9.8	221.51
D- 2	Phosphate rock	5915-RWS	.8	34.2	2.39	1.38	1.97	7.7	10.6	248.87
D- 1	Phosphate rock	5916-RWS	.6	31.0	2.63	1.58	2.19	13.0	11.2	267.47
	C member of Phosphoria formation—upper part only									
C- 2	Chert and quartzite	--	1.3	--	--	--	--	--	1.3	--
C- 1	Breccia, phosphatic sandstone, and limestone	--	2.0	--	--	--	--	--	3.3	--

Lower part of Phosphoria formation measured in outcrop and hand trenches on north side of Little Gold Creek, SW¼ sec. 29, T. 8 N., R. 12 W., Granite County, Mont. This locality is nearly 1 mile SE of Moonlight adit portal. Beds strike N. 40° W. and dip 25° NE. Strata are metamorphosed and D member is sheared and not well enough exposed to sample.

	E member of Phosphoria formation—basal part only									
E- 2	Quartzite	--	3.0	--	--	--	--	--	3.0	--
E- 1	Limestone, sandy	--	1.0	--	--	--	--	--	4.0	--

Moonlight Adit—Continued

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	Loss on ignition	Acid insoluble		
	D member of Phosphoria formation									
D- 2	Phosphatic muds one and phosphate rock--	--	5.3	--	--	--	--	--	5.3	--
D- 1	Phosphate rock and mudstone----------	--	1.7	--	--	--	--	--	7.0	--
	Bed D-1 probably equivalent to beds D-1 and D-2 of Moonlight adit.									
	C member of Phosphoria formation									
C-20	Sandstone, quartzitic ----------	--	2.4	--	--	--	--	--	2.4	--
C-19	Limestone, cherty, recrystallized -------	--	13.0	--	--	--	--	--	15.4	--
C-18	Limestone, cherty----------	--	4.0	--	--	--	--	--	19.4	--
C-17	Covered----------	--	1.2	--	--	--	--	--	20.6	--
C-16	Limestone, recrystallized, contains sulfides----------	--	1.9	--	--	--	--	--	22.5	--
C-15	Marble----------	--	5.3	--	--	--	--	--	27.8	--
C-14	Covered----------	--	2.5	--	--	--	--	--	30.3	--
C-13	Marble, cherty----------	--	5.3	--	--	--	--	--	35.6	--
C-12	Marble and chert----------	--	9.1	--	--	--	--	--	44.7	--
C-11	Marble, cherty----------	--	3.0	--	--	--	--	--	47.7	--
C-10	Quartzite----------	--	1.8	--	--	--	--	--	49.5	--
C- 9	Marble, cherty----------	--	2.0	--	--	--	--	--	51.5	--
C- 8	Marble, cherty----------	--	9.8	--	--	--	--	--	61.3	--
C- 7	Marble, cherty----------	--	1.3	--	--	--	--	--	62.6	--
C- 6	Quartzite----------	--	3.7	--	--	--	--	--	66.3	--
C- 5	Marble----------	--	5.3	--	--	--	--	--	71.6	--
C- 4	Quartzite----------	--	.2	--	--	--	--	--	71.8	--
C- 3	Marble----------	--	1.0	--	--	--	--	--	72.8	--
C- 2	Marble----------	--	3.8	--	--	--	--	--	76.6	--
C- 1	Sandstone, conglomerate, and silt--------	--	.7	--	--	--	--	--	77.3	--
	Possibly glacial debris forced between beds at Quadrant-Phosphoria contact.									
	Quadrant formation—top bed only									
Cq-1	Quartzite----------	--	5.	--	--	--	--	--	5.	--

Anaconda Quarry, Mont., lot 1337

Part of Phosphoria formation measured and sampled in outcrop and hand trench in bluff about $\frac{1}{4}$ mile east of limestone quarry of Anaconda Copper Mining Company, north side of Warm Spring Creek, sec. 23, T. 5 N., R. 12 W., Deerlodge County, Mont. Beds in lower half of D member much sheared and graphitic, correlations uncertain. Beds strike N. 75° E. and dip 25° N. Section measured by R. W. Swanson and sampled by R. A. Zeller in August 1950. Samples analyzed for P_2O_5 and acid insoluble by U. S. Bureau of Mines laboratory, Albany, Oreg., 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_2O_5 (cumulative)
				P_2O_5	Al_2O_3	Fe_2O_3	Loss on ignition	Acid insoluble		
	E member of Phosphoria formation—top not exposed									
E- 3	Quartzite	--	3.8	--	--	--	--	--	3.8	--
E- 2	Quartzite	--	28.7	--	--	--	--	--	32.5	--
E- 1	Quartzite	--	7.7	--	--	--	--	--	40.2	--
	D member of Phosphoria formation									
D-12	Quartzite, phosphatic	5902-RWS	0.8	18.9	1.48	1.41	0.94	4.8	0.8	15.12
D-11	Phosphate rock	5901-RWS	.9	29.0	1.87	2.23	2.55	6.3	1.7	41.22
D-10	Phosphate rock	5900-RWS	.9	26.6	4.68	1.02	6.79	20.1	2.6	65.16
D- 9	Phosphate rock	5899-RWS	.6	32.8	1.28	.68	4.96	10.5	3.2	84.84
D- 8	Phosphate rock	5896-RWS	1.8	30.2	3.25	1.25	7.79	11.1	5.0	139.20
D- 7	Mudstone, phosphatic	5898-RWS	.9	11.8	9.12	1.23	12.66	45.7	5.9	149.82
--	Phosphate rock, argillaceous (appears to be same bed as D-7)	5895-RWS	(.5)	19.2	7.30	2.80	16.52	24.7	--	--
D- 6	Mudstone and phosphate rock	5897-RWS	.4	14.0	9.96	7.93	13.68	30.1	6.3	155.42
D- 5	Phosphate rock	5894-RWS	1.2	30.6	3.60	1.45	10.72	10.8	7.5	192.14
D- 4	Phosphate rock, argillaceous	5893-RWS	1.2	19.3	7.92	3.35	16.36	25.6	8.7	215.30
D- 3	Mudstone, phosphatic	5892-RWS	1.0	10.0	10.9	4.54	20.08	44.1	9.7	225.30
D- 2	Mudstone	5891-RWS	.6	3.9	14.8	7.52	20.54	46.7	10.3	227.64
D- 1	Mudstone, phosphatic	5890-RWS	.6	7.2	11.6	12.1	25.16	39.1	10.9	231.96
	C member of Phosphoria formation—top bed only									
C- 1	Quartzite	--	2.	--	--	--	--	--	2.	--

Canyon Camp, Mont., lot 1311

Phosphoria formation measured and B and D members sampled at Canyon Camp, Ruby River Canyon, NE¼ sec. 18, T. 9 S., R. 3 W., Madison County, Mont., on overturned west limb of Ruby Valley syncline. Beds strike N. 10° W. and dip 50° W. Beds A-1 through C-8 are from natural exposures on north side of canyon 300 feet above river; rest of section from south side of canyon, beds C-10 through C-25 and E-7 through E-23 from natural exposures and beds D-1 through E-6 from prospect trench. Section measured by C. W. Tandy, R. S. Jones, E. R. Cressman, R. F. Gosman, and W. J. Garmoe and sampled by Gosman and Garmoe in August 1949. Samples analyzed by U. S. Bureau of Mines laboratory, Albany, Oreg.

Bed no.	Rock description	Sample no.	Thickness (feet)	Chemical analyses (percent)		Cumulative thickness (feet)	Thickness x percent P_2O_5 (cumulative)
				P_2O_5	Acid insoluble		
	Dinwoody formation—basal bed only						
Trd-1	Carbonate rock, argillaceous	--	1.8	--	--	1.8	--
	E member of Phosphoria formation						
E-23	Covered: Phosphoria-Dinwoody contact arbitrarily placed at top of covered interval.	--	15.0	--	--	15.0	--
E-22	Mudstone, cherty	--	12.3	--	--	27.3	--
E-21	Sandstone, cherty, and dolomitic mudstone	--	.9	--	--	28.2	--
E-20	Chert	--	2.7	--	--	30.9	--
E-19	Chert, sandy	--	4.2	--	--	35.1	--
E-18	Chert	--	12.8	--	--	47.9	--
E-17	Chert, dolomitic	--	6.0	--	--	53.9	--
E-16	Chert, dolomitic and dolomite	--	2.1	--	--	56.0	--
E-15	Sandstone, cherty and mudstone	--	2.0	--	--	58.0	--
E-14	Chert	--	1.6	--	--	59.6	--
E-13	Sandstone, cherty	--	23.3	--	--	82.9	--
E-12	Chert, sandy	--	14.0	--	--	96.9	--
E-11	Chert	--	15.0	--	--	111.9	--
	Faults of unknown but probably small displacement occur within and at base of bed E-11; thickness given is uncertain.						
E-10	Chert	--	1.7	--	--	113.6	---
E- 9	Chert, dolomitic	--	3.0	--	--	116.6	--
	Fault of unknown displacement at base of bed E-9.						
E- 8	Chert, dolomitic	--	1.5	--	--	118.1	--
E- 7	Chert, dolomitic	--	.4	--	--	118.5	--
E- 6	Chert	725- RSJ	.5	0.8	80.5	119.0	0.40
E- 5	Chert	724- RSJ	2.0	.8	81.7	121.0	2.00
E- 4	Chert	723- RSJ	.5	.6	85.1	121.5	2.30

E- 3	Chert	722- RSJ	1.1	.3	84.4	122.6	2.63
E- 2	Chert, calcareous	721- RSJ	1.4	1.8	76.8	124.0	5.15
E- 1	Chert, carbonatic	720- RSJ	1.2	.5	57.3	125.2	5.75**
	D member of Phosphoria formation						
D-20	Mudstone	719- RSJ	2.3	3.0	69.3	2.3	6.90
D-19	Mudstone, carbonatic	718- RSJ	3.2	2.8	60.6	5.5	15.86
D-18	Mudstone	717- RSJ	.9	.3	70.0	6.4	16.13
D-17	Mudstone, carbonatic	716- RSJ	.8	6.9	50.8	7.2	21.65
D-16	Phosphate rock	715- RSJ	1.4	25.5	11.3	8.6	57.35
D-15	Phosphate rock and carbonate rock	714- RSJ	2.0	17.6	5.8	10.6	92.55
D-14	Mudstone and phosphate rock	713- RSJ	3.1	15.5	33.6	13.7	140.60
D-13	Phosphate rock, argillaceous	712-CWT	2.6	15.2	27.2	16.3	180.12
D-12	Mudstone, carbonatic	711-CWT	1.1	5.8	41.2	17.4	186.50
D-11	Mudstone, carbonatic	710-CWT	1.6	7.4	38.8	19.0	198.34
D-10	Mudstone, carbonatic	709-CWT	.6	6.1	44.0	19.6	202.00
	The base of bed D-10 may be a bedding plane fault.						
D- 9	Mudstone, carbonatic	708-CWT	.9	6.4	46.0	20.5	207.76
D- 8	Dolomite	707-CWT	1.6	1.3	8.7	22.1	209.84
D- 7	Mudstone, carbonatic	706-CWT	1.2	6.8	40.7	23.3	218.00
D- 6	Phosphate rock; fos. col. no. 11683[1]	705-CWT	2.0	23.9	11.8	25.3	265.80
D- 5	Mudstone, carbonatic	704-CWT	3.0	1.6	43.2	28.3	270.60
D- 4	Mudstone, phosphatic	703-CWT	.7	10.0	47.0	29.0	277.60
D- 3	Phosphate rock, carbonatic	702-CWT	1.4	22.9	11.6	30.4	309.66
D- 2	Mudstone; fos. col. no. 11683	701-CWT	2.4	2.7	67.8	32.8	316.14
D- 1	Chert	700-CWT	.6	6.5	71.3	33.4	320.04
	C member of Phosphoria formation						
C-25	Chert, sandy	--	1.1	--	--	1.1	--
C-24	Chert, sandy	--	2.0	--	--	3.1	--
C-23	Chert, sandy	--	1.2	--	--	4.3	--
C-22	Chert, sandy	--	2.2	--	--	6.5	--
C-21	Dolomite, sandy	--	1.8	--	--	8.3	--
C-20	Dolomite, argillaceous	--	1.2	--	--	9.6	--
C-19	Dolomite and chert	--	6.4	--	--	16.0	--
C-18	Dolomite	--	14.3	--	--	30.3	--
C-17	Chert, dolomitic, argillaceous	--	1.7	--	--	32.0	--
C-16	Chert	--	.5	--	--	32.5	--
C-15	Dolomite, argillaceous	--	4.3	--	--	36.8	--
C-14	Dolomite	--	2.1	--	--	38.9	--
C-13	Sandstone, dolomitic	--	4.5	--	--	43.4	--
C-12	Dolomite	--	8.2	--	--	51.6	--

[1] Fossil collection made by W. R. Record, Paleontology and Stratigraphy Branch, U. S. Geological Survey.

Canyon Camp, Mont., lot 1311

Bed no.	Rock description	Sample no.	Thickness (feet)	Chemical analyses (percent)		Cumulative thickness (feet)	Thickness x percent P_2O_5 (cumulative)
				P_2O_5	Acid insoluble		
C-11	Mudstone	--	3.0	--	--	54.6	--
C-10	Mudstone	--	14.3	--	--	68.9	--
C- 9	Covered; unable to correlate from north to south side of canyon.	--	--	--	--	--	--
C- 8	Chert	--	1.3	--	--	70.2	--
C- 7	Dolomite	--	.6	--	--	70.8	--
C- 6	Chert, sandy	--	1.1	--	--	71.9	--
C- 5	Sandstone	--	.9	--	--	72.8	--
C- 4	Limestone, sandy, cherty	--	1.4	--	--	74.2	--
C- 3	Mudstone and chert	--	1.4	--	--	75.6	--
C- 2	Chert	--	4.7	--	--	80.3	--
C- 1	Chert	732-ERC	5.0	0.9	75.4	85.3	4.50
	B member of Phosphoria formation						
B- 5	Chert, argillaceous	731-ERC	0.7	1.1	85.8	0.7	0.77
B- 4	Phosphate rock; fos. col. no. 11682	730-ERC	.5	27.0	18.7	1.2	14.27
B- 3	Carbonate rock	729-ERC	1.0	3.0	8.8	2.2	17.27
B- 2	Chert	728-ERC	.8	2.5	77.7	3.0	19.27
B- 1	Carbonate rock	727-ERC	.5	5.6	15.8	3.5	22.02
	A member of Phosphoria formation—base not exposed						
A-12	Dolomite, dolomitic chert, and quartzite	726-ERC	2.1	1.2	28.2	2.1	--
A-11	Dolomite	--	1.4	--	--	3.5	--
A-10	Chert, dolomitic	--	.3	--	--	3.8	--
A- 9	Dolomite	--	.6	--	--	4.4	--
A- 8	Chert	--	.25	--	--	4.65	--
A- 7	Dolomite	--	1.3	--	--	5.95	--
A- 6	Chert	--	.2	--	--	6.15	--
A- 5	Dolomite	--	1.7	--	--	7.85	--
A- 4	Chert, dolomitic	--	.25	--	--	8.10	--
A- 3	Dolomite	--	2.4	--	--	10.50	--
A- 2	Dolomite	--	3.5	--	--	14.00	--
A- 1	Mudstone, calcareous	--	5.6	--	--	19.60	--

Warm Springs Creek, Mont., lot 1300

Phosphoria formation measured and B and D members sampled near Warm Springs Creek, NW¼ sec. 22, T. 9 S., R. 3 W., Madison County, Mont., near crest of small anticline. D member measured and sampled in hand trench; rest of formation measured and B member sampled from natural exposures. Beds strike N. 30° E. and dip 2° NW. Section measured by W. H. Wilson, B. K. Replogle, and J. L. Elliott and sampled by Elliott, Replogle, and R. F. Gosman in August 1949. Samples analyzed by U. S. Bureau of Mines laboratory, Albany, Oreg.

Bed no.	Rock description	Sample no.	Thickness (feet)	Chemical analyses (percent)		Cumulative thickness (feet)	Thickness x percent P_2O_5 (cumulative)
				P_2O_5	Acid insoluble		
	E member of Phosphoria formation—top not exposed						
--	Dinwoody-Phosphoria contact covered, approximate thickness of covered interval	--	4.5	--	--	4.5	--
E-13	Sandstone, carbonatic, contains glauconite-	--	4.4	--	--	8.9	--
E-12	Chert	--	1.4	--	--	10.3	--
E-11	Sandstone, contains glauconite	--	5.0	--	--	15.3	--
E-10	Sandstone	--	40.3	--	--	55.6	--
E- 9	Chert	--	.5	--	--	56.1	--
E- 8	Sandstone	--	2.3	--	--	58.4	--
E- 7	Chert, argillaceous	--	6.8	--	--	65.2	--
E- 6	Chert	--	32.1	--	--	97.3	--
E- 5	Chert	--	21.5	--	--	118.8	--
E- 4	Chert	--	5.0	--	--	123.8	--
E- 3	Chert	3385-WHW	1.9	0.5	92.8	125.7	--
E- 2	Chert	3384-WHW	2.5	.4	93.2	128.2	--
E- 1	Chert	3383-WHW	2.0	.7	93.6	130.2	--
	D member of Phosphoria formation						
D- 7	Phosphate rock, argillaceous	3382-WHW	1.7	18.5	41.3	1.7	31.45
D- 6	Phosphate rock, argillaceous	3381-WHW	.9	27.3	23.0	2.6	56.02
D- 5	Phosphate rock, argillaceous	3380-WHW	.7	26.7	20.2	3.3	74.71
D- 4	Phosphate rock	3379-WHW	1.7	31.2	10.5	5.0	127.75
D- 3	Mudstone, phosphatic	3378-WHW	1.1	10.4	43.7	6.1	139.19
D- 2	Mudstone	3377-WHW	1.5	1.8	75.5	7.6	141.89
D- 1	Mudstone, phosphatic, cherty mudstone, and chert	3376-WHW	1.8	3.3	80.5	9.4	147.83
	C member of Phosphoria formation						
C-10	Chert	3375-WHW	1.2	0.4	92.0	1.2	--
C- 9	Chert and sandstone	--	8.!	--	--	9.7	--
C- 8	Sandstone	--	5.	--	--	14.7	--

Warm Springs Creek, Mont., lot 1300

Bed no.	Rock description	Sample no.	Thickness (feet)	Chemical analyses (percent)		Cumulative thickness (feet)	Thickness x percent P_2O_5 (cumulative)
				P_2O_5	Acid insoluble		
C- 7	Sandstone and mudstone	--	10.0	--	--	24.7	--
C- 6	Carbonate rock	--	3.8	--	--	28.3	--
C- 5	Carbonate rock, argillaceous	--	3.4	--	--	31.9	--
C- 4	Sandstone, cherty	--	18.7	--	--	50.6	--
C- 3	Sandstone	--	3.1	--	--	53.7	--
C- 2	Chert	--	3.2	--	--	56.9	--
C- 1	Sandstone	750-WHW	1.3	3.3	78.3	58.2	--
	B member of Phosphoria formation						
B- 2	Sandstone, phosphatic and phosphate rock	743-WHW	1.2	19.4	45.4	0.9	--
B- 1	Phosphate rock, cherty, sandy	743-WHW	1.2	21.9	39.3	2.1	--
	A member of Phosphoria formation—base not exposed						
A- 3	Sandstone	--	2.5	--	--	2.5	--
A- 2	Mudstone, carbonatic	--	9.8	--	--	12.3	--
A- 1	Carbonate rock; fos. col. no. 11681[1]	--	15.0	--	--	27.3	--

[1] Fossil collection made by W. R. Record, Paleontology and Stratigraphy Branch, U. S. Geological Survey.

Lazyman Hill, Mont., lot 1319

Phosphoria formation sampled on Lazyman Hill, sec. 9, T. 10 S., R. 2 W., Madison County, Mont., on east limb of Ruby Valley syncline. Beds D-1 through E-2 exposed in hand trench on east face of hill; E member measured from natural exposure on east face of hill; all other samples taken and rest of formation measured from natural exposures on northeast face of hill. Beds strike N. 10° E. and dip 13° W. Section measured by E. R. Cressman, B. K. Replogle, and W. J. Garmoe and sampled by R. F. Gosman in September 1949. Samples analyzed by U. S. Bureau of Mines laboratory, Albany, Oreg.

Bed no.	Rock description	Sample no.	Thickness (feet)	Chemical analyses (percent)		Cumulative thickness (feet)	Thickness x percent P_2O_5 (cumulative)
				P_2O_5	Acid insoluble		
	E member of Phosphoria formation—top not exposed						
--	Dinwoody-Phosphoria contact covered, approximate thickness of covered interval--	--	10.0	--	--	10.0	--
E-25	Dolomite, sandy	--	1.0	--	--	11.0	--
E-24	Dolomite	--	.5	--	--	11.5	--
E-23	Sandstone, dolomitic	--	.6	--	--	12.1	--
E-22	Mudstone, dolomitic	--	3.3	--	--	15.4	--
E-21	Mudstone, dolomitic	--	3.8	--	--	19.2	--
E-20	Dolomite, argillaceous	--	7.4	--	--	26.6	--
E-19	Covered interval	--	5.3	--	--	31.9	--
E-18	Sandstone, phosphatic and chert	--	1.4	--	--	33.3	--
E-17	Sandstone, cherty	--	2.3	--	--	35.6	--
E-16	Covered interval	--	2.9	--	--	38.5	--
E-15	Sandstone	--	4.1	--	--	42.6	--
E-14	Sandstone	--	8.5	--	--	51.1	--
E-13	Sandstone	--	4.3	--	--	55.4	--
E-12	Sandstone	--	15.2	--	--	70.6	--
E-11	Sandstone, cherty, and sandy chert	--	8.1	--	--	78.7	--
E-10	Chert, sandy	--	9.0	--	--	87.7	--
E- 9	Chert	--	7.9	--	--	95.6	--
E- 8	Chert	--	8.2	--	--	103.8	--
E- 7	Chert	--	.6	--	--	104.4	--
E- 6	Chert	--	8.5	--	--	112.9	--
E- 5	Chert	--	8.5	--	--	121.4	--
E- 4	Chert	--	3.7	--	--	125.1	--
E- 3	Chert	--	3.2	--	--	128.3	--
E- 2	Chert	742-ERC	3.5	0.7	93.8	131.8	--
E- 1	Chert	741-ERC	1.3	.8	90.4	133.1	--
	D member of Phosphoria formation						
D- 8	Mudstone	740-ERC	1.0	0.5	87.6	1.0	0.50
D- 7	Mudstone	739-ERC	1.3	1.2	86.3	2.3	2.06

Lazyman Hill, Mont., lot 1319

Bed no.	Rock description	Sample no.	Thickness (feet)	Chemical analyses (percent)		Cumulative thickness (feet)	Thickness x percent P_2O_5 (cumulative)
				P_2O_5	Acid insoluble		
D- 6	Carbonate rock	738-ERC	0.9	1.5	17.0	3.2	3.41
D- 5	Phosphate rock, argillaceous	737-ERC	1.2	28.0	19.2	4.4	37.01
D- 4	Phosphate rock	736-ERC	.9	33.7	7.6	5.3	67.34
D- 3	Mudstone, phosphatic	735-ERC	.6	10.4	49.4	5.9	73.58
D- 2	Mudstone, phosphatic, and argillaceous phosphate rock	734-ERC	1.2	6.2	63.4	7.1	81.02
D- 1	Mudstone, phosphatic, phosphate rock, and phosphatic chert	733-ERC	1.4	15.6	42.0	8.5	102.86
	C member of Phosphoria formation						
C-16	Chert	749-WJG	6.1	0.5	93.2	6.1	--
C-15	Chert	--	2.0	--	--	8.1	--
C-14	Quartzite	--	6.1	--	--	14.2	--
C-13	Limestone, dolomitic, argillaceous and calcareous sandstone	--	4.5	--	--	18.7	--
C-12	Sandstone, calcareous	--	8.5	--	--	27.2	--
C-11	Sandstone, calcareous	--	6.2	--	--	33.4	--
C-10	Sandstone, calcareous	--	7.7	--	--	41.1	--
C- 9	Dolomite and cherty sandstone	--	2.7	--	--	43.8	--
C- 8	Sandstone, cherty and dolomite	--	2.8	--	--	46.6	--
C- 7	Sandstone	--	2.0	--	--	48.6	--
C- 6	Dolomite	--	1.2	--	--	49.8	--
C- 5	Quartzite, calcareous	--	2.3	--	--	52.1	--
C- 4	Chert, dolomitic	--	3.9	--	--	56.0	--
C- 3	Dolomite and calcareous sandstone	--	3.6	--	--	59.6	--
C- 2	Sandstone, cherty, sandstone, and sandy phosphate rock	--	3.5	--	--	63.1	--
C- 1	Chert	748-BKR	4.2	0.6	91.0	67.3	--
	B member of Phosphoria formation						
B- 2	Mudstone, phosphatic and chert	747-BKR	1.2	8.5	61.8	1.2	--
B- 1	Phosphate rock	746-BKR	1.5	27.9	19.3	2.7	--
	A member of Phosphoria formation						
A-26	Carbonate rock, argillaceous	745-BKR	0.7	1.7	20.3	0.7	--
A-25	Carbonate rock	--	6.5	--	--	7.2	--
A-24	Carbonate rock	--	8.2	--	--	15.4	--
A-23	Carbonate rock	--	3.2	--	--	18.6	--
A-22	Carbonate rock	--	8.6	--	--	27.2	--

A-21	Carbonate rock	--	4.6	--	--	31.8	--
A-20	Sandstone, carbonatic	--	11.2	--	--	43.0	--
A-19	Carbonate rock	--	1.5	--	--	44.5	--
A-18	Carbonate rock	--	2.5	--	--	47.0	--
A-17	Carbonate rock	--	3.7	--	--	50.7	--
A-16	Carbonate rock	--	4.7	--	--	55.4	--
A-15	Carbonate rock	--	3.7	--	--	59.1	--
A-14	Sandstone, carbonatic	--	2.6	--	--	61.7	--
A-13	Mudstone	--	4.8	--	--	66.5	--
A-12	Sandstone, carbonatic	--	7.0	--	--	73.5	--
A-11	Sandstone	--	2.5	--	--	76.0	--
A-10	Mudstone	--	3.3	--	--	79.3	--
A- 9	Sandstone, carbonatic	--	12.0	--	--	91.3	--
A- 8	Sandstone, carbonatic	--	16.1	--	--	107.4	--
A- 7	Carbonate rock	--	1.0	--	--	108.4	--
A- 6	Covered interval	--	2.3	--	--	110.7	--
A- 5	Sandstone, carbonatic	--	3.7	--	--	114.4	--
A- 4	Covered interval	--	4.5	--	--	118.9	--
A- 3	Carbonate rock	--	5.5	--	--	124.4	--
A- 2	Covered interval	--	4.3	--	--	128.7	--
A- 1	Sandstone, carbonatic	--	7.9	--	--	136.6	--
	Quadrant formation—top bed only						
Cq-1	Sandstone breccia	--	24.0	--	--	24.0	--

Alpine Creek, Mont., lot 1307

B and D members of Phosphoria formation sampled and A, C, and most of E members described in southeast-facing slope at head of Alpine Creek, N½ sec. 26, T. 10 S., R. 2 W., Madison County, Mont., on gently dipping east limb of Ruby Valley syncline. Beds C-10 through E-1 measured and sampled in hand trench, all others from natural exposure. Beds strike N. 5° E. and dip 8° W. Section measured by E. R. Cressman, W. H. Wilson, and R. L. Jones and sampled by W. J. Garmoe and J. L. Elliott in August 1949. Samples analyzed by U. S. Bureau of Mines laboratory, Albany, Oreg.

Bed no.	Rock description	Sample no.	Thickness (feet)	Chemical analyses (percent)		Cumulative thickness (feet)	Thickness x percent P_2O_5 (cumulative)
				P_2O_5	Acid insoluble		
	E member of Phosphoria formation—top not exposed						
--	Dinwoody-Phosphoria contact covered, estimated thickness of covered interval --	--	10.	--	--	10.0	--
E-12	Sandstone, dolomitic; fos. col. no. 11689[1] --	--	4.9	--	--	14.9	--
E-11	Dolomite; fos. col. no. 11688 ----------	--	4.2	--	--	19.1	--
E-10	Covered interval----------	--	2.0	--	--	21.1	--
E- 9	Sandstone, dolomitic; fos. col. no. 11687 --	--	3.0	--	--	24.1	--
E- 8	Sandstone ----------	--	14.0	--	--	38.1	--
E- 7	Sandstone ----------	--	4.8	--	--	42.9	--
E- 6	Sandstone and sandy chert ----------	--	8.0	--	--	50.9	--
E- 5	Chert, argillaceous ----------	--	36.5	--	--	87.4	--
E- 4	Chert----------	--	11.5	--	--	98.9	--
E- 3	Covered interval ----------	--	9.5	--	--	108.4	--
E- 2	Chert----------	--	5.9	--	--	114.3	--
E- 1	Chert----------	3394-WHW	2.4	0.9	90.6	116.7	--
	D member of Phosphoria formation						
D- 4	Phosphate rock, argillaceous and phosphate rock ----------	3393-WHW	1.1	30.5	13.7	1.1	33.55
D- 3	Mudstone ----------	3392-WHW	1.8	4.6	64.6	2.9	41.83
D- 2	Carbonate rock, argillaceous ----------	3391-WHW	1.0	2.6	29.4	3.9	44.43
D- 1	Mudstone, phosphatic ----------	3390-WHW	.5	12.1	52.5	4.4	50.48
	C member of Phosphoria formation						
C-10	Chert----------	3389-WHW	1.0	5.6	79.9	1.0	--
C- 9	Chert and sandstone ----------	--	4.3	--	--	5.3	--
C- 8	Sandstone, dolomitic----------	--	6.7	--	--	12.0	--
C- 7	Dolomite ----------	--	3.0	--	--	15.0	--
C- 6	Dolomite, sandy----------	--	5.2	--	--	20.2	--
C- 5	Dolomite ----------	--	3.6	--	--	23.8	--
C- 4	Sandstone, dolomitic----------	--	6.8	--	--	30.6	--

C- 3	Chert	--	3.2	--	--	33.8	--
C- 2	Sandstone, dolomitic	--	2.2	--	--	36.0	--
C- 1	Sandstone, dolomitic and dolomite	--	1.7	--	--	37.7	--
	B member of Phosphoria formation						
B- 3	Sandstone	3388-WHW	2.3	1.4	90.0	2.3	3.22
B- 2	Sandstone, phosphatic and conglomerate; fos. col. no. 11686	3387-WHW	.9	8.3	53.7	3.2	10.69
B- 1	Phosphate rock, sandy, conglomeratic; fos. col. no. 11685	3386-WHW	1.1	26.6	19.1	4.3	39.95
	A member of Phosphoria formation						
A-16	Dolomite	--	2.9	--	--	2.9	--
A-15	Dolomite	--	2.9	--	--	5.8	--
A-14	Dolomite	--	3.3	--	--	9.1	--
A-13	Dolomite	--	3.8	--	--	12.9	--
A-12	Dolomite	--	0.8	--	--	13.7	--
A-11	Dolomite	--	2.2	--	--	15.9	--
A-10	Dolomite, argillaceous	--	2.8	--	--	18.7	--
A- 9	Sandstone, dolomitic	--	0.8	--	--	19.5	--
A- 8	Dolomite, sandy	--	0.9	--	--	20.4	--
A- 7	Dolomite, argillaceous	--	1.7	--	--	22.1	--
A- 6	Sandstone, dolomitic	--	2.4	--	--	24.5	--
A- 5	Dolomite breccia	--	2.0	--	--	26.5	--
A- 4	Dolomite	--	2.8	--	--	29.3	--
A- 3	Dolomite breccia, sandy	--	2.6	--	--	31.9	--
A- 2	Dolomite	--	15.5	--	--	47.4	--
A- 1	Dolomite, sandy	--	0.3	--	--	47.7	--
	Quadrant formation—top bed only						
Cq-1	Sandstone	--	5.4	--	--	5.4	--

[1] Fossil collection made by W. R. Record, Paleontology and Stratigraphy Branch, U. S. Geological Survey.

Sliderock Mountain, Mont., lot 1301

Phosphoria formation measured and B and D members sampled on Sliderock Mountain, N½ sec. 25, T. 10 S., R. 4 W., Madison County, Mont., on overturned west limb of Ruby Valley syncline. Thrust-faulting was recognized in lower formations up slope from the Phosphoria outcrop. Average strike is about N-S and dip about 40° W. A and C members measured from natural exposure and B and D members sampled from hand trenches on spur between heads of South and Middle Forks of Fawn Creek. E member measured from natural exposure in gully at head of Middle Fork of Fawn Creek. Section measured by C. W. Tandy and E. R. Cressman and sampled by R. F. Gosman and W. J. Garmoe in August 1949. Samples analysed by U. S. Bureau of Mines laboratory, Albany, Oreg.

Bed no.	Rock description	Sample no.	Thickness (feet)	Chemical analyses (percent)		Cumulative thickness (feet)	Thickness x percent P_2O_5 (cumulative)
				P_2O_5	Acid insoluble		
	Dinwoody formation—basal bed only						
Td-1	Mudstone, calcareous	--	22.0	--	--	22.0	--
	E member of Phosphoria formation						
E- 7	Sandstone, contains glauconite	--	2.7	--	--	2.7	--
E- 6	Chert, sandy, calcareous	--	30.2	--	--	32.9	--
E- 5	Sandstone	--	2.9	--	--	35.8	---
E- 4	Chert and dolomitic chert	--	7.2	--	--	43.0	--
E- 3	Sandstone, cherty	--	3.5	--	--	46.5	--
E- 2	Chert	--	4.8	--	--	51.3	--
E- 1	Chert and mudstone	--	60.0	--	--	111.3	--
	D member of Phosphoria formation—base not exposed						
D-12	Chert	692-CWT	6.0	1.0	87.5	6.0	6.00
D-11	Mudstone and phosphate rock	691-CWT	3.8	7.3	51.7	9.8	33.74
D-10	Phosphate rock, argillaceous dolomitic	690-CWT	.5	12.0	22.5	10.3	39.74
D- 9	Mudstone, carbonatic	689-CWT	.6	2.9	53.3	10.9	41.48
D- 8	Phosphate rock, dolomitic	688-CWT	.9	22.6	18.3	11.8	61.82
D- 7	Dolomite	687-CWT	.6	4.8	8.3	12.4	64.70
D- 6	Mudstone and phosphate rock	686-ERC	1.0	12.2	37.1	13.4	76.90
D- 5	Phosphate rock, calcareous	685-ERC	2.4	23.4	14.5	15.8	133.06
D- 4	Phosphate rock and argillaceous phosphate rock	684-ERC	.7	21.6	20.4	16.5	148.18
D- 3	Dolomite; fos. col. no. 11672[1]	683-ERC	2.4	.8	12.7	18.9	150.10
D- 2	Mudstone, phosphatic	682-ERC	1.5	10.2	42.0	20.4	165.40
D- 1	Mudstone, phosphate rock, and phosphatic mudstone	681-ERC	1.6	13.6	40.7	22.0	187.16
	Fault and shear zones, especially at the base of beds D-2, 5, 6, and 12 make thickness and stratigraphic sequence questionable.						

C member of Phosphoria formation— top not exposed

	D-C contact not exposed, covered interval of about five feet may include faults.						
--	Covered interval	--	5.0	--	--	5.0	--
C-19	Sandstone, dolomitic	--	2.6	--	--	7.6	--
C-18	Sandstone	--	12.5	--	--	20.1	--
C-17	Chert	--	2.2	--	--	22.3	--
C-16	Dolomite	--	5.0	--	--	27.3	--
C-15	Dolomite	--	6.0	--	--	33.3	--
C-14	Dolomite	--	2.4	--	--	35.7	--
C-13	Dolomite	--	5.8	--	--	41.5	--
C-12	Dolomite	--	14.2	--	--	55.7	--
C-11	Dolomite	--	8.7	--	--	64.4	--
C-10	Covered interval	--	5.5	--	--	69.9	--
C- 9	Chert and sandstone	--	2.7	--	--	72.6	--
C- 8	Sandstone, cherty	--	2.4	--	--	75.0	--
C- 7	Chert and sandstone	--	1.5	--	--	76.5	--
C- 6	Sandstone, cherty	--	1.1	--	--	77.6	--
C- 5	Chert	--	8.7	--	--	86.3	--
C- 4	Sandstone	--	3.0	--	--	89.3	--
C- 3	Sandstone	--	.3	--	--	89.6	--
C- 2	Chert	--	11.8	--	--	101.4	--
C- 1	Chert	--	1.6	--	--	103.0	--

B member of Phosphoria formation—base not exposed

B- 7	Phosphate rock, argillaceous and mudstone	699-CWT	0.7	14.3	53.0	0.7	10.01
B- 6	Mudstone and phosphatic mudstone	698-CWT	.8	5.7	72.7	1.5	14.57
B- 5	Sandstone and phosphate rock	697-CWT	1.1	18.0	45.5	2.6	34.37
B- 4	Phosphate rock, argillaceous	696-CWT	1.3	26.7	20.2	3.9	69.08
B- 3	Sandstone and phosphate rock	695-CWT	.7	14.2	60.0	4.6	79.02
B- 2	Phosphate rock, sandy	694-CWT	.5	26.2	26.0	5.1	92.12
B- 1	Phosphate rock	693-CWT	1.0	34.6	5.0	6.1	126.72

A member of Phosphoria formation—top not exposed

--	Covered interval	--	35.0	--	--	35.0	--
A-14	Dolomite	--	17.0	--	--	52.0	--
	Bed A-14 is highly fractured and brecciated.						
A-13	Mudstone, calcareous, dolomitic	--	.8	--	--	52.8	--
A-12	Dolomite	--	2.0	--	--	54.8	--
A-11	Sandstone, calcareous, dolomitic	--	1.7	--	--	56.5	--

[1] Fossil collection made by W. R. Record, Paleontology and Stratigraphy Branch, U. S. Geological Survey.

Sliderock Mountain—Continued

Bed no.	Rock description	Sample no.	Thickness (feet)	Chemical analyses (percent)		Cumulative thickness (feet)	Thickness x percent P_2O_5 (cumulative)
				P_2O_5	Acid insoluble		
A-10	Dolomite, calcareous	--	4.7	--	--	56.5	--
A- 9	Limestone	--	1.0	--	--	62.2	--
A- 8	Dolomite; fos. col. no. 11671	--	12.0	--	--	74.2	--
A- 7	Dolomite	--	4.4	--	--	78.6	--
A- 6	Sandstone, calcareous	--	5.2	--	--	83.8	--
A- 5	Dolomite	--	1.2	--	--	85.0	--
A- 4	Dolomite, calcareous	--	1.2	--	--	86.2	--
A- 3	Sandstone, calcareous	--	5.8	--	--	92.0	--
A- 2	Dolomite	--	6.7	--	--	98.7	--
A- 1	Dolomite	--	6.8	--	--	105.5	--
	Quadrant formation—top bed only						
Cq-1	Sandstone, calcareous	--	--	--	--	--	--

Taylor Creek, Idaho, lot 1342

B member of Phosphoria formation measured and sampled from natural exposure on the east side of Taylor Creek valley, NE$\frac{1}{4}$ sec. 19, T. 14 N., R. 41 E., Clark County, Idaho, by R. F. Gosman in September 1950. Beds strike N. 80° W. and dip 11° S. Samples analyzed for P_2O_5 and acid insoluble by U. S. Bureau of Mines laboratory, Albany, Oreg., 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_2O_5 (cumulative)
				P_2O_5	Al_2O_3	Fe_2O_3	Loss on ignition	Acid insoluble		
	B member of Phosphoria formation									
B-3	Phosphate rock	5562-RFG	3.5	30.2	0.68	0.77	5.39	11.4	3.5	105.70
B-2	Phosphate rock, calcareous	5563-RFG	.75	17.0	.62	1.35	1.97	13.6	4.25	118.45
B-1	Phosphate rock	5564-RFG	1.5	31.3	.73	.83	3.31	12.6	5.75	165.40
	A member of Phosphoria formation—top beds only									
A-2	Sandstone	5565-RFG	1.6	4.5	--	--	--	85.5	1.6	--
A-1	Chert	--	--	--	--	--	--	--	--	--

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