CONTRIBUTIONS TO ECONOMIC GEOLOGY, 1925

PART I. METALS AND NONMETALS EXCEPT FUELS

THE MELROSE PHOSPHATE FIELD, MONTANA

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SUMMARY

The areas described in this report comprise four townships in the vicinity of Melrose, Mont., and two townships that lie a short distance to the southeast and include part of McCarthy Mountain. Both areas are in the drainage basin of Big Hole River and are readily accessible from points on the Oregon Short Line Railroad. (See fig. 1.)

Stratified rocks ranging in age from Algonkian to Cretaceous occur in both areas. They include thick layers of limestone, much shale and sandstone, and a valuable bed of rock phosphate. In both areas granitic rocks of late Cretaceous or early Tertiary age have intruded and metamorphosed the sediments. Unconsolidated deposits described as Tertiary "lake beds" and terrace gravel occupy considerable areas. The older sediments are closely folded and extensively broken by overthrust faults. In the Melrose area four synclines are mapped, all of which hold large segments of the phosphate bed. The richer parts of the phosphate bed range from 2 to 6 feet or more in thickness and contain from 60 to 66 per cent of "bone phosphate." In the McCarthy Mountain area a large overthrust fault block carries part of the phosphate bed, which in at least one place is 6 feet thick and averages 61 per cent of "bone phosphate."

Deposits valuable for gold, silver, lead, and copper are found in both areas near the contacts of the sedimentary rocks with intrusive granite.

AUTHORSHIP

The following report has been put together by J. T. Pardee, chiefly from unpublished data filed with the United States Geological Survey by R. W. Richards and H. S. Gale in 1913 and 1914. Richards's data consist of a geologic map of the four townships constituting the Melrose area and a descriptive text that was nearly completed for publication. Gale's material includes a map of the two townships here referred to as the McCarthy Mountain area and reports prepared for use by the Survey in the administration of the public lands. To these sources Pardee has contributed the information gained in brief examinations of parts of the Melrose area made in 1911 and in July, 1923. During the later visit he collected the Triassic fossils mentioned in the description of the Woodside formation. As published herewith the map of the Melrose area is the work of Richards except for a patch about 3 miles square west and north of Divide in T. 1 S., Rs. 9 and 10 W., and the naming of the strip mapped as Triassic (Woodside formation), for which Pardee is responsible. The geologic mapping of the McCarthy Mountain

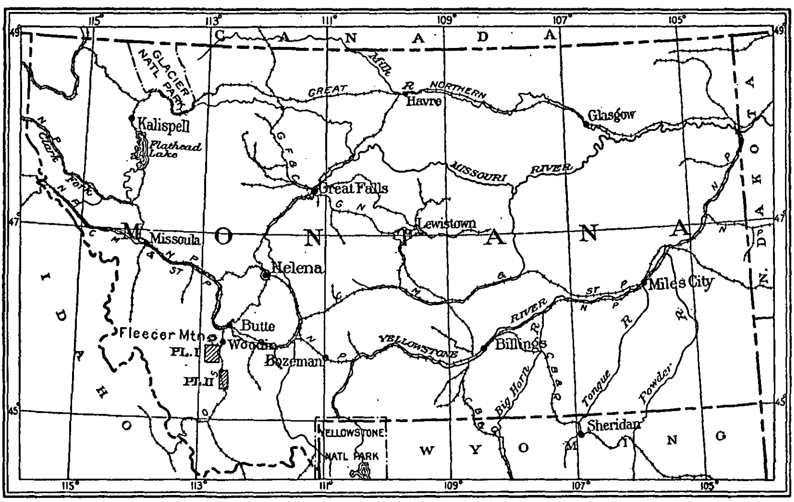

FIGURE 1.—Index map showing location of Melrose phosphate field, Mont.

area is to be credited wholly to Gale. The text describing the Melrose area is the work of Richards except the bibliography and the descriptions of the Woodside formation, the unconformity above the Woodside, the Tertiary "lake beds," the terrace gravel, and the contact-metamorphosed rocks, which were written by Pardee. The description of the McCarthy Mountain area, except for being rearranged by Pardee, is practically as written by Gale.

FIELD WORK

The discovery of rock phosphate in the vicinity of Melrose in 1910 by H. S. Gale [1] led to the segregation of certain lands in that vicinity

[1] Gale, H. S., Rock phosphate near Melrose, Mont.: U. S. Geol. Survey Bull. 370, p. 440, 1911.

as Phosphate Reserve No. 7, by order of the President dated January 12, 1911. A detailed examination of part of the lands thus reserved had already been called for by an act providing for such classification of certain lands included in the Northern Pacific Railway grant. This provision and the added interest in the further delimitation and study of these new phosphate fields led to its prompt and careful consideration. R. H. Reineck, of the Geological Survey, was accordingly detailed to make a topographic survey of the area on a scale of 1:31,680, to serve as a base for geologic work, and this map was made with a 50-foot contour interval during the summer of 1911. In the following field season R. W. Richards was assigned to make a detailed geologic survey of the lands, which he did during the months of September and October. This work was materially interfered with by the unusually early snows of that season, and the examination of the entire area was not completed. The present report is a preliminary statement of the results that were obtained in four contiguous townships, Tps. 1 and 2 S., Rs. 9 and 10 W., in Beaverhead and Silver Bow counties. Richards was assisted during October by J. W. Clark. A. R. Schultz, chairman of the phosphate section of the Survey's land-classification board, made a brief visit to the area.

The area was reviewed in part in 1910 by H. S. Gale, for the classification as to mineral character of certain lands selected by the Northern Pacific Railway under the terms of its land grant, and similar work was continued in 1911 by J. T. Pardee.

The details of the stratigraphy of the region as worked out by Gale have been used in the course of the present work without material modification, and Pardee's results have been drawn on largely in the description of the northwestern township of the group, the higher portions of which were early covered with snow and could not be further examined to advantage.

The geologic conditions are essentially similar to those found in the Three Forks quadrangle, which has been described by Peale,[2] and the igneous rocks are practically identical with those of the Butte district, which has been described in a more recent publication by Weed,[3] although in the present report attention is naturally directed principally to the sedimentary rocks.

The economic deposit which it is the special purpose of this paper to describe is rock phosphate in bedded form, similar to that found elsewhere in western Montana and extensively distributed in southeastern Idaho and the adjoining portions of Wyoming and Utah.

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[2] Peale, A. C., U. S. Geol. Survey Geol. Atlas, Three Forks folio (No. 24), p. 3, 1896.

[3] Weed, W. H., Geology and ore deposits of Butte district, Mont.; U. S. Geol. Survey, Prof. Paper 74, 1912.

BIBLIOGRAPHY

The principal reports that describe the phosphate deposits of these areas are listed below in the order of their publication. Some of the earlier reports are out of print, but those for which a price is stated may be purchased from the Superintendent of Documents, Government Printing Office, Washington, D. C.

Gale, H. S., and Richards, R. W., Preliminary report on the phosphate deposits in southeastern Idaho and adjacent parts of Wyoming and Utah: U. S. Geol. Survey Bull. 430, pp. 457–535, 1910.

Blackwelder, Eliot, Phosphate deposits east of Ogden, Utah: U. S. Geol. Survey Bull. 430, pp. 536–551, 1910.

Girty, G. H., The fauna of the phosphate beds of the Park City formation of Idaho, Utah, and Wyoming: U. S. Geol. Survey Bull. 436, 1910. 20c.

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Richards, R. W., and Mansfield, G. R., Preliminary report on a portion of the Idaho phosphate reserve: U. S. Geol. Survey Bull. 470, pp. 371–439, 1911.

Gale, H. S., Rock phosphate near Melrose, Mont.: U. S. Geol. Survey Bull. 470, pp. 440–451, 1911.

Schultz, A. R., and Richards, R. W., Geologic reconnaissance in southeastern Idaho: U. S. Geol. Survey Bull. 530, pp. 267–284, 1913.

Richards, R. W., and Mansfield, G. R., Geology and phosphate deposits of an area northeast of Georgetown, Idaho: U. S. Geol. Survey Bull. 577, 1914. 30c.

Stone, R. W., and Bonine, C. A., The Elliston phosphate field, Mont.: U. S. Geol. Survey Bull. 580, pp. 373–383, 1915. 40c.

Mansfield, G. R., A reconnaissance for phosphate in the Salt River Range, Wyo.: U. S. Geol. Survey Bull. 620, pp. 331–349, 1916. 15c. (Bull. 620–O).

Pardee, J. T., The Garrison and Philipsburg phosphate fields, Mont.: U. S. Geol. Survey Bull. 640, pp. 195–228, 1917. 30c.

Schultz, A. R., A geologic reconnaissance for phosphate and coal in southeastern Idaho and western Wyoming: U. S. Geol. Survey Bull. 680, 1918. 10c.

Schultz, A. R., A geologic reconnaissance of the Uinta Mountains, northern Utah, with special reference to phosphate: U. S. Geol. Survey Bull. 690, pp. 31–94, 1919. 25c.

Mansfield, G. R., Geography, geology, and mineral resources of the Fort Hall Indian Reservation, Idaho: U. S. Geol. Survey Bull. 713, 1920. 50c.

Pardee, J. T., Phosphate rock near Maxville, Granite County, Mont.: U. S. Geol. Survey Bull. 715, pp. 141–145, 1921. 40c.

GEOGRAPHY

The Melrose area comprises a block of four townships in the north-west-central part of the Dillon quadrangle, about 20 miles southwest of Butte, Mont., immediately south of the Continental Divide. It is characteristically made up of broad, well-rounded mountain masses separated by V-shaped canyons, except where these canyons have been locally widened by glacial action and the long-continued erosional activity of trunk streams. Big Hole River crosses the area from northwest to southeast, roughly paralleling the general trend of the geologic structure and swinging around the northeast side of the compound anticlinal mountain mass. The course of the river through the area presents an interesting alternation of stretches of canyon and broad, open valley. The more open portions appear to represent parts of an earlier drainage system now covered by Tertiary and Quaternary deposits; the canyon portions parallel the structure developed in the older sediments prior to the intrusion of the great masses of granitic rocks upon which the present drainage system is clearly superimposed.

This area merits further study in quest of information concerning the age of the erosion surface or peneplain upon which the dominant drainage features were developed and its relation to the age of the monzonitic intrusion. The problem appears to be closely related to that discussed by Umpleby[4] and Blackwelder.[5] The tributaries of Big Hole River within the area practically without exception flow in valleys which run transverse to the dominant structural trend of the area and which must therefore have been determined by such a peneplain.

The area is crossed by the Butte and Salt Lake division of the Oregon Short Line and contains two towns. Melrose, in T. 2 S., R. 9 W., near the corner of Silver Bow, Madison, and Beaverhead counties, has long been the outfitting and shipping point for the surrounding mining camps, Hecla, Rochester, Soap Gulch, Wickeyup, Camp Creek, and numerous other less extensive workings. Divide, in T. 1 S., R. 9 W., is the terminus of the stage line into the Big Hole Basin country and the shipping point for a portion of the agricultural and mineral products of the same region. Dewey, a post office on Big Hole River in the northwestern part of the area, is variously known as Dewey, Dewey Flat, or locally as The Flat. This is the first stage station on the road from Divide to the Big Hole Basin and at one time was the site of a mill for treating ores from Quartz Hill and the Vipond Park district. The remnant of the old smelter town of Glendale stands on Trapper Creek near the point where it is crossed by the west line of T. 2 S., R. 9 W.

Stock raising and mining are the principal industries of the area, but the valley bottoms and some of the lower bench lands are successfully farmed. The principal crops are oats and winter wheat. The higher benches are utilized extensively for summer or winter grazing according to their exposure and altitude.

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[4] Umpleby, J. B., An old erosion surface in Idaho; its age and value as a datum plane: Jour. Geology, vol. 20, pp. 139–147, 1912.

[5] Blackwelder, Eliot, The old erosion surface in Idaho; a criticism: Jour. Geology, vol. 20, pp. 410–414, 1912.

GEOLOGY

The areal and structural geology of the Melrose district is recorded on the geologic map (Pl. I). The following discussion is intended to supplement and assist in the interpretation of the map.

The rocks of the area can be divided into two main classes—older consolidated rocks and younger unconsolidated deposits. The rocks may be further divided into three groups—(1) stratified or bedded rocks, such as sandstone, shale, limestone, and chert; (2) igneous or massive rocks, such as quartz monzonite (commonly called granite), andesite (variously known as basalt or trap), a light-gray rhyolite, and a light-green porphyry; and (3) metamorphic rocks, such as quartzite and schist.

The unconsolidated deposits are made up of the gravel, sand, and soil of the bottom lands on Big Hole River and tributary streams and the Tertiary "lake beds," which form the bench lands lying between the valley bottoms and the more rugged hill and mountain portions. The Tertiary "lake beds" consist chiefly of light-colored clay and in part of arkosic sand, gravel (in places somewhat cemented by a calcareous matrix), and papery shale. Their thickness is at least 500 feet. Locally a thin cover of terrace gravel overlies them. On the upper portions of Canyon and Trapper creeks, in T. 2 S., R. 10 W., are well-developed glacial boulder moraines. The boulders are mainly monzonite.

The stratified rocks range in age from Algonkian to Cretaceous. Their lithology and sequence are represented graphically in the columnar section accompanying Plate I, and a more detailed description of the rock formations follows.

ALGONKIAN SYSTEM

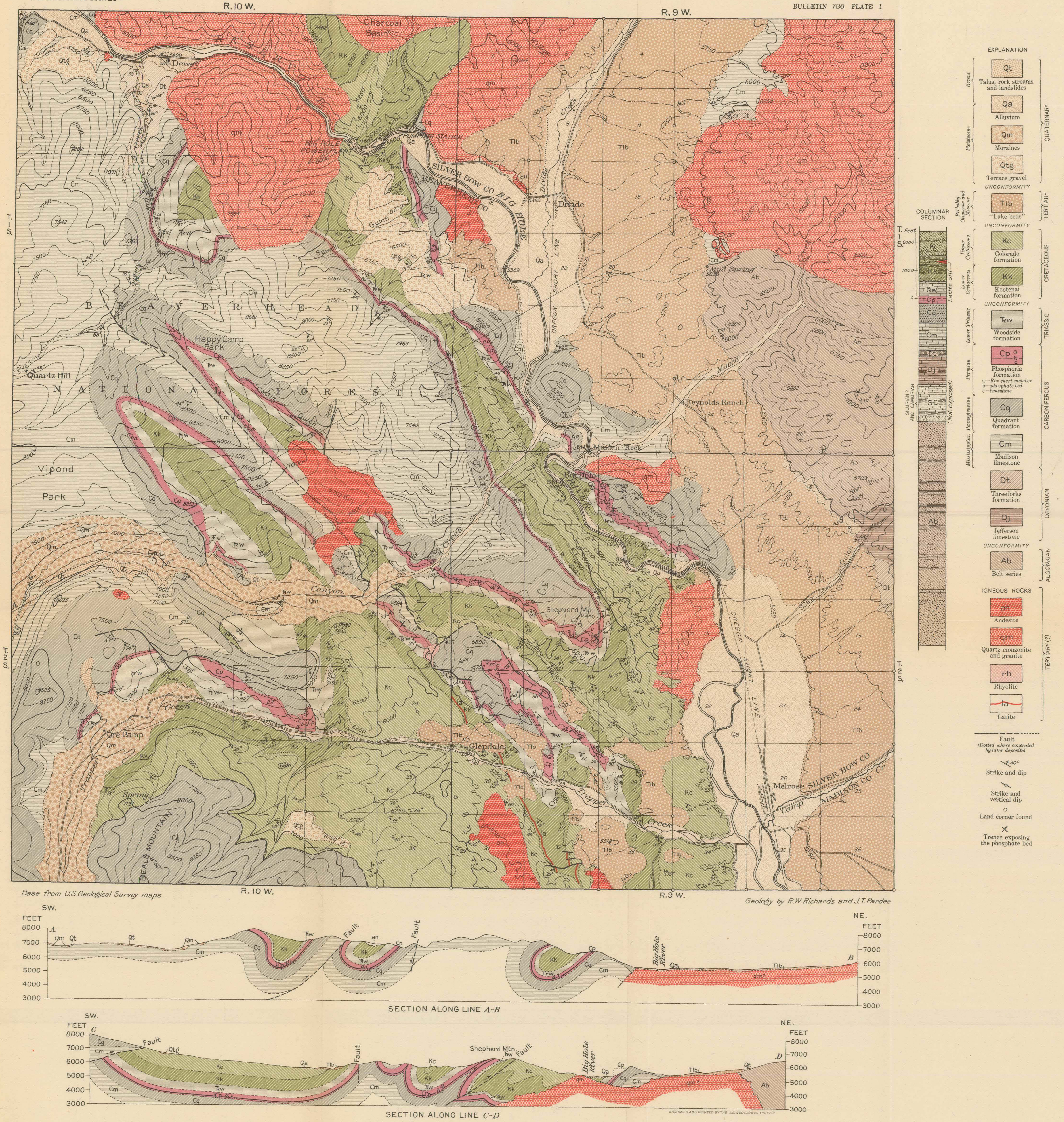
The oldest rocks exposed in the region belong to the Belt series. They consist of arkosic sandstone, dark olive-green argillite, and steel-gray siliceous limestone and arkosic sandstone alternating with conglomerate.

CAMBRIAN SYSTEM

The Belt series is normally overlain by rocks of Cambrian age, which include some 1,300 feet of quartzite, shale, and limestone, the last two highly fossiliferous. No Cambrian rocks were recognized in the area examined, and the absence of exposures is believed to be due to a fault which causes limestone regarded as of Devonian age to overlie the rocks of the Belt series.

ORDOVICIAN AND SILURIAN SYSTEMS (?)

No Ordovician or Silurian rocks are known to be present in this part of Montana. The Maywood formation of the Philipsburg



GEOLOGIC MAP AND SECTIONS OF THE MELROSE PHOSPHATE FIELD, BEAVERHEAD AND SILVERBOW COUNTIES, MONT.

Scale $\frac{1}{62,500}$

0 1 2 3 MILES

Contour interval 250 feet

Datum is mean sea level

1925

region, which may possibly be present but not exposed in the Melrose area, is tentatively classified as Silurian(?), but it may be of Ordovician or even Upper Cambrian age.

DEVONIAN SYSTEM

Jefferson limestone.—The Jefferson limestone, according to Peale,[6] consists of 700 to 1,000 feet of massive black or mud-colored limestone with bands of laminated magnesian limestone. No detailed section of this limestone was measured in the course of the present investigation. Beds of lithologically similar limestone were observed in Soap Gulch in secs. 2 and 12, T. 2 S., R. 9 W. These rest, presumably in fault contact, against rocks of the Belt series. The limestone in the vicinity of this contact is in places highly mineralized, and shallow workings in it have yielded ores of gold, silver, and lead. The metalliferous deposits that occur within the Melrose area and in the neighboring mountains are described by A. N. Winchell.[7]

Threeforks formation.—The Jefferson limestone is conformably overlain by a series of beds composed of about 50 feet of orange-colored shale, 20 feet of grayish-brown argillaceous limestone, 50 feet of green and black shale which is crowded with Devonian fossils, and 25 feet of yellow laminated sandstone. These rocks, which constitute the Threeforks formation, underlie the Madison limestone.

CARBONIFEROUS SYSTEM

Madison limestone.—The sandstone of the Threeforks formation is overlain conformably by 1,300 feet of bluish-gray limestone that has been identified, from fossil collections made by Gale[8] in sec. 18, T. 2 S., R. 8 W., as Madison. The lower fourth of the formation consists of thinly bedded or shaly limestone; the rest is massively bedded. Many nodules of jasper are found near the top. The fossils in this limestone indicate that it is of lower Mississippian age.

Quadrant formation.—Immediately and apparently conformably overlying the Madison limestone are about 700 feet of siliceous beds, including near the base a few thin bands of gray limestone, which are here grouped as the Quadrant formation. This formation was named from Quadrant Mountain, in Yellowstone National Park, where it consists mostly of white quartzite with interbedded layers of sandstone and limestone.

In the Melrose district the greater part of the Quadrant is made up of sandstone. The upper half of the formation contains much vitreous white quartzite, and the lower half has a decidedly reddish tinge.

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[6] Peale, A. C., U. S. Geol. Survey Geol. Atlas, Three Forks folio (No. 24), p. 3, 1896.

[7] The mining districts of the Dillon quadrangle, Mont., and adjacent areas: U. S. Geol. Survey Bull. 574, pp. 78–96, 1914.

[8] Unpublished data filed with U. S. Geol. Survey.

The age of the Quadrant formation has not been positively determined; fossil collections from one place have yielded Mississippian forms, from another place Pennsylvanian. No fossils were collected from the Quadrant in the present investigation, and its correlation therefore rests solely upon its stratigraphic relations to the underlying Madison limestone (Mississippian) and to overlying limestone, phosphate beds, and chert which are here assumed to be properly correlated with the Phosphoria formation of southeastern Idaho. The Quadrant formation in this region is tentatively regarded as of Pennsylvanian age, and its correlation with the Wells formation of Idaho is suggested.

Phosphoria formation.—The Phosphoria formation in this area ranges from about 100 to about 300 feet in thickness and includes one or several beds of rock phosphate. Where the section is complete the phosphate-bearing portion of the formation lies between limestone and chert, as in the phosphate districts of Idaho, Wyoming, and Utah, although there appears to be a slight difference in the age relations of the "underlying limestone." In this district the fossils that have so far been collected from this limestone suggest that it is more closely related to the phosphate beds than to the underlying Quadrant formation. In places in the Melrose district the "underlying limestone" is absent and the phosphate bed rests unconformably upon the quartzites of the Quadrant formation. The upper portion of the Phosphoria formation is very persistent throughout the area and consists of a red, yellow, or in many places gray massively bedded chert, which locally is with difficulty distinguished from a quartzite. However, careful inspection with a hand lens will usually fail to show the granularity that is characteristic of quartzite.

The overlying chert can, on lithologic and stratigraphic evidence, be correlated with the Rex chert member of the Phosphoria formation of Idaho, but owing to the narrowness of outcrop of the whole formation and the necessity of publishing the accompanying geologic map without the distinctions afforded by colors, it is not considered wise to represent the member by a separate pattern.

The only fossils that have been collected from the underlying limestone have been referred tentatively by G. H. Girty to the Phosphoria formation. Neither the phosphate beds, the associated shales, nor the overlying chert have yielded fossils.

TRIASSIC SYSTEM

Woodside formation.—Directly above the cherty part of the Phosphoria formation and in apparent conformity with it are about 500 feet of shale, limestone, and sandstone that are characterized by prevailingly brown weathered surfaces and the presence of the phosphatic pelecypod *Lingula.* When freshly broken these rocks range in color from buff to bluish gray and greenish gray. At least half of the thickness is composed of shale. Limestone is next in order of abundance. All the rocks are thin bedded, and locally fossils are moderately plentiful and well distributed vertically. As mapped the series shows variations in thickness from place to place that are mostly to be explained as the result of pre-Kootenai erosion. Fossils collected from the beds are determined by Girty to belong to the Lower Triassic horizon of Idaho and to agree in faunal facies especially well with some of the collections from the Woodside formation. Moreover, the stratigraphic position and thickness of the section appear to be in harmony with such an assignment. In southeastern Idaho bedded rocks assigned to the Lower Triassic aggregate more than 4,000 feet in thickness.[9] The upper part of the Triassic section there, which comprises the Thaynes group, consists largely of gray and gray-weathering limestone with variegated shale and sandstone. The lower part, known as the Woodside shale, is chiefly sandstone and shale with some interbedded limestone.

Sections measured in Montpelier Canyon, Idaho, by C. L. Breger[10] and in the Henry quadrangle, Idaho, about 40 miles north of Montpelier, by P. V. Roundy[11] are, respectively, 1,000 and 2,000 feet thick but otherwise similar. At the bottom of both are brown-weathering shale and limestone containing *Lingula*. Above these are sandstone, shale, and limestone with *Myalina*. Thus the Idaho section both in lithology and in characteristic fossils corresponds closely with the Melrose section as given below. The reduced thickness of the Melrose section is partly due, as explained farther on, to erosion before the Kootenai beds were laid down.

In western Wyoming the Dinwoody formation, described by Condit[12] as composing the upper part of the Embar formation of Darton, consists of brown-weathering shale and limestone regarded as equivalent in age to the beds at Melrose. The Dinwoody, as exposed in Dinwoody Canyon, is only 180 feet thick, and it is overlain conformably by Chugwater red beds that are probably Lower Triassic and equivalent to the Thaynes. Brown-weathering beds containing *Lingula* and referred by Condit[13] to the Triassic occur in Quadrant Mountain, in Yellowstone Park. They are part of the formation previously described as "Teton."[14]

In Montana Condit[15] found on Indian Creek, in the southern part of the Three Forks quadrangle, brown-weathering shale and lime-

[9] Mansfield, G. R., The geography, geology, and mineral resources of part of southeastern Idaho: U. S. Geol. Survey Prof. Paper — (in preparation).

[10] Gale, H. S., and Richards, R. W., U. S. Geol. Survey Bull. 430, p. 473, 1909.

[11] Mansfield, G. R., op. cit.

[12] Condit, D. D., U. S. Geol. Survey Prof. Paper 120, p. 119, 1918.

[13] Condit, D. D., op. cit., p. 117.

[14] U. S. Geol. Survey Geol. Atlas, Yellowstone National Park folio (No. 30), 1896.

[15] Condit, D. D., op. cit., p. 116.

stone containing *Lingula*. The beds aggregate 102 feet in thickness, and their upper limit is marked by an unconformity. This exposure is 60 miles southeast of Melrose.

The sections of Lower Triassic rocks measured in the Melrose area are given below.

Section about 9 miles west of Melrose, north of Trapper Creek, near the west line of sec. 22, T. 2 S., R. 10 W.

Character of beds	Thickness (feet)	Fossils
Conglomerate (Kootenai).		
Unconformity.		
9. Buff shale and bluish-gray limestone. Weathers brown. (Top of Woodside formation.)	50	*Terebratula* n. sp., *Myacites inconspicuus?*, *Modiomorpha?*, *Pseudomonotis?* n. sp., *Pteria?* n. sp., *Astartella?* sp.
8. Bluish-green sandstone and shale. Weathers yellow to brown. Contains thin beds of limestone.	50	*Aviculipecten* aff. *A. thaynesianus*, *Myalina?* sp.
7. Brown-weathering shale and sandstone grading into blue limestone in lower part.	60	*Pseudomonotis?* n. sp., *Aviculipecten curticardinalis*, *Aviculipecten* aff. *A. occidentalis*.
6. Brown sandy shale	50	
5. Lead-gray brittle limestone. Grooved on weathered surfaces. Weathers pale brown.	10	*Aviculipecten* aff. *A. thaynesianus*.
4. Sandy shale. Weathers dark brown	50	
3. Alternating beds of shale and bluish-gray, brown-weathering limestone.	40	*Aviculipecten curticardinalis*, *Pseudomonotis?* n. sp.
2. Brown shale and limestone with sandy layers	75	*Lingula* n. sp., *Sedgwickia concava?*, *Pseudomonotis?* n. sp., *Pteria* n. sp., *Astartella?* sp.
1. No exposures of rock in place. Fragments in the surface mantle indicate the presence of soft yellow and gray shale.	100	
Total Woodside formation (Triassic)	485	
Cherty-appearing quartzite (Rex chert member of Phosphoria formation).		

The beds described above strike N. 60° W. and dip 45°–60° SW., lying on the southwest limb of an anticline. No evidences of faulting were observed, and the exposure apparently gives a true measure of the thickness of the formation in that area.

Section about 2 miles west of Melrose and north of Trapper Creek, in sec. 28, T. 2 S., R. 9 W.

Character of beds	Thickness (feet)	Fossils
Conglomerate (Kootenai).		
Unconformity.		
4. Soft yellow to brown shale. Poor exposures. (Top of Woodside formation.)	150	Fossiliferous.
3. Hard brown-weathering shale. Ripple marked. Includes a few thin beds of limestone.	50	Do.
2. Chiefly brown-weathering shale and limestone. Poorly exposed.	300	*Lingula* n. sp., Pelecypoda indet.
1. Mostly soft buff to lead-colored shale and sandstone with calcareous layers. Weathers brown. Poorly exposed.	200	
Total Woodside formation, Triassic	700	
Cherty quartzite (Rex).		

Here the beds dip steeply northeast, being brought to the surface on the east limb of an anticline that trends northwest. The lowest bed of this section has probably been increased in apparent thickness by faulting. In support of this inference is the fact that the adjoining Rex chert, which here occupies the crest of the anticline, is partly repeated in outcrop because of a strike fault on which the arch of the anticline has dropped.

The rest of the section is fossiliferous, but the material is poorly preserved. The only determinable specimens found consist of a new *Lingula* at a horizon about 210 feet above the base.

The erosional unconformity at the top of the section is well illustrated in this locality. A continuous exposure for a quarter of a mile shows the uppermost bed (No. 4) cut down from 150 feet to a thickness of 50 feet.

Section on east side of Big Hole River at mouth of canyon, 2½ miles north of Melrose

Conglomerate (Kootenai).	
Unconformity.	Feet.
Brown-weathering shale and limestone, poorly exposed (upper part of Woodside formation)	200
Rocks concealed. Fragments in the surface mantle indicate the presence of soft buff and gray shale	75
Total Woodside formation	275
Cherty quartzite (Rex chert).	

These beds are exposed on the steeply dipping southwest flank of an anticline. They are somewhat altered as the result of intrusive igneous rocks, and apparently no fossils are preserved. No evidences of faulting were observed, the reduced thickness of the formation being due to erosion before the deposition of the conglomerate forming the base of the Kootenai.

Unconformity above the Woodside formation.—In the Melrose area, as already described, a bed of conglomerate assigned to the Kootenai lies directly upon a surface eroded in the Woodside formation. In southeastern Idaho[16] beds of Triassic and Jurassic age that aggregate 10,000 feet in thickness intervene between the Woodside and Gannett group (Lower Cretaceous), which probably corresponds to part of the Kootenai. In southern Montana, at Indian Creek,[17] nearly 600 feet of sediments belonging to the Jurassic Ellis formation lie between beds corresponding to the Woodside and the Kootenai. In the Philipsburg quadrangle,[18] 60 miles to the

[16] Mansfield, G. R., op. cit.
[17] Condit, D. D., op. cit., p. 115.
[18] Calkins, F. C., U. S. Geol. Survey Geol. Atlas, Philipsburg folio (No. 196), 1915.

northwest; at Garrison,[19] 70 miles to the north; and near Cardwell,[20] 40 miles northeast of Melrose, Triassic strata are wanting and Ellis beds rest upon the Phosphoria or its equivalent. Thus, so far as known, Melrose is the northermost occurrence of Triassic rocks in the region considered, and, on the other hand, it is the only place showing a complete sedimentary section wherein the Jurassic is missing.

The unconformity indicated by these facts is discussed by Condit,[21] who concludes that it is due to erosion in Jurassic time which may have removed as much as 2,000 feet of strata from northern Montana. Evidently the Triassic and subjacent rocks were elevated above the sea in his region without being very noticeably tilted or folded. So far as observed there appears to be no angular discordance between the beds that were laid down before the erosion took place and the beds that were laid down after the erosion. At Melrose, in addition to cutting away whatever had been deposited above the Woodside, the erosion cut more or less deeply into that formation. At Philipsburg, Garrison, and Cardwell, as already mentioned, the Triassic was removed entirely, and farther north, in the Great Falls region, where the Ellis formation in places rests upon the Quadrant and in places upon the Madison,[22] still deeper beds were cut away. Sedimentation began again during the Jurassic as the result of submergence, the sea advancing from the north. Although the sediments deposited at this time are found on all sides of Melrose, none occur in that area at present. Either the Jurassic sediments were completely removed by reelevation and erosion just prior to the Kootenai epoch, or, more probably, the Melrose area remained during all of Jurassic time as an island above the sea.

CRETACEOUS SYSTEM

Kootenai formation.—Above the Woodside formation there is a series of some 700 feet of beds, including at the base a heavy brown quartzitic conglomerate about 100 feet thick, which locally loses its conglomeratic character and is represented by a true quartzite or sandstone. The conglomerate is succeeded by a series of maroon, green, and yellow sandy shale and buff sandstone, and these in turn are capped by a series of one to three beds of bluish-gray limestone, which locally is very dark blue to black and contains abundant gastropod fossils. The uppermost fossiliferous limestone will be called the "gastropod limestone," to distinguish it from a somewhat less prominent but similar limestone that occurs some 250 feet below

[19] Pardee, J. T., U. S. Geol. Survey Bull. 640, p. 203, 1916.
[20] Condit, D. D., op. cit., pl. 10.
[21] Condit, D. D., op. cit., p. 120.
[22] Fisher, C. A., Geology of the Great Falls coal field, Mont.: U. S. Geol. Survey Bull. 356, p. 27, 1909.

the top of the series and contains numerous traces of very minute unidentified fossils. In the southwest corner of T. 2 S., R. 9 W., a sill of quartz dacite, 5 to 15 feet thick, is intruded between the limestone beds near the top of the series, at about the same place in the section as an intrusion in the Three Forks region noted by Peale.[23]

The group of beds described constitutes a convenient mapping unit and is here correlated with the Kootenai formation, which was described by George M. Dawson[24] from beds in the southern Canadian Rocky Mountains. The name was later applied by Fisher,[25] Calvert,[26] and Calkins[27] in the Great Falls, Lewistown, and Philipsburg districts of Montana. The unit corresponds roughly to the Dakota formation of the Three Forks folio.

The beds referred to the Kootenai formation in the Melrose district do not, so far as examined, contain carbonaceous or coal-bearing layers, as in the more northern localities.

Colorado formation.—The youngest of the consolidated sedimentary rocks of the Melrose area are regarded as of Colorado age. They are made up of black fissile shale and greenish-gray fine-grained and indistinctly bedded buff sandstone, in part arkosic. Locally there appears at the base of this section about 200 feet of brown variegated shale with thin interbedded tan-colored limestone that in places contains cubes of altered pyrite. Possibly these lower beds represent the Dakota sandstone. The Colorado formation, including the last-mentioned beds, appears to have taken up a large amount of the readjustment incident to the folding. In consequence its beds are in places so involved in minor folds that they cover larger areas than would be expected from their total stratigraphic thickness, which is probably not in excess of 1,000 feet. In the vicinity of the granitic intrusive rock near the south end of Big Hole Canyon, 2½ miles north of Melrose, the shale is metamorphosed into knotted schist.

TERTIARY "LAKE BEDS"

A broad belt of bench land that crosses the eastern part of the area from north to south and several small patches along the lower course of Trapper Creek west of Melrose are underlain by light-colored clay, sand (in part arkosic), papery shale, and gravel that

[23] U. S. Geol. Survey Geol. Atlas, Three Forks folio (No. 24), 1896.

[24] Dawson, G. M., Canada Geol. Survey Rept. Progress, 1882–1884, pp. 10–168C, 1885.

[25] Fisher, C. A., Southern extension of Kootenai and Montana coal-bearing formations in northern Montana: Econ. Geology, vol. 3, pp. 78–80, 1908; Geology of the Great Falls coal field, Mont.: U. S. Geol. Survey Bull. 356, 1909.

[26] Calvert, W. R., Geology of the Lewistown coal field, Mont.: U. S. Geol. Survey Bull. 390, 1909.

[27] Calkins, F. C., U. S. Geol. Survey Geol. Atlas, Philipsburg folio (No. 196), 1915.

are correlated with the so-called Tertiary "lake beds" of the general region. Nearly everywhere a rather thin cover of later gravel conceals these deposits, and as a rule natural exposures of them are to be found only on very steep slopes.

About 3 miles north of Divide, east of the Oregon Short Line Railroad, thick beds of buff clay with interbedded thin layers of gravel or conglomerate are exposed that aggregate 200 feet in thickness. The beds strike N. 15° W. and dip 12° E. In the same neighborhood along a ridge extending eastward are several exposures of the gravel beds, which owing to their comparative hardness project somewhat above the adjoining clay beds. These gravel layers are from 3 to 6 feet thick and consist of subangular cobbles and pebbles in an abundant matrix of sand and clay. In places they contain boulders as large as 3 feet in diameter.

An apparent thickness of at least 500 feet of Tertiary beds is indicated by these exposures. However, the beds may be repeated by faults that are concealed by the superficial cover. This idea is suggested by the fact that the eight or more outcrops of the gravel beds are very much alike. In Townsend Valley, near Toston, Mont., Tertiary beds similar to these in occurrence are observed to be repeated by faulting.[28]

The most abundant varieties of rock in the gravel are granite, quartzite, and metamorphosed sediments such as argillite and hornstone, all of which occur in the neighboring mountains. Locally the gravel is cross-bedded. Evidently it was carried from the mountains and deposited by streams. The clay that composes the bulk of the formation consists of fine volcanic ash with material derived from land waste. Undoubtedly it was deposited in an area that had poor drainage but was not necessarily occupied by a lake.

The beds north of Divide are similar in appearance and composition to beds described by Douglass [29] that crop out north and south of Big Hole River southeast of McCarthy Mountain, about 15 miles south of Melrose. Here Douglass at different times prior to 1907 found fossil remains, chiefly in nodules in the clay, indicating an Oligocene (lower White River) age. Among the forms determined from this locality are lizards, turtles, and several genera of moles and other small mammals, which are associated with a large rhinoceros-like animal (*Titanotherium*) and a very primitive horse.

Along the road that crosses the hills and bench lands between Moose Creek and Divide about 300 feet of gravel with layers of sandy clay is exposed. Most of the pebbles are from 1 to 3 inches in size

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[28] Pardee, J. T., U. S. Geol. Survey Water-Supply Paper 539, p. 32, 1925.

[29] Douglass, Earl, The Tertiary of Montana: Carnegie Mus. Mem., vol. 2, pp. 204–223, pl. 22, 1905; Some Oligocene lizards: Carnegie Mus. Annals, vol. 4, pp. 278–281, 1908.

and smoothly rounded. They consist chiefly of quartzite, with a few of granite and other rocks, all in an abundant light-gray matrix of sand and clay. Overlying the gravel is at least 100 feet of light-colored clay and other fine sediment. Above this layer unconformably is thick coarse gravel described below as terrace gravel of Pleistocene age. Apparently these gravel beds are horizontal or nearly so, and they crop out at a somewhat higher altitude than the beds exposed north of Divide. They are probably to be correlated with beds exposed near Woodin, 6 miles north of the Melrose area, where Douglass found, in gravel and cream-colored sand, the fossil remains of an animal (*Ticholeptus breviceps*) [30] that resembled both a deer and a pig and of a primitive horse (*Altippus taxus*).[31] Both these species indicate Miocene age.

Tertiary beds similar to those of the areas considered are found in all the larger valleys of southwestern Montana, and in the aggregate they occupy a large area. Everywhere they are much the same in composition, and at several places they have yielded fossil remains of numerous vertebrates ranging from an early date in the Oligocene to the middle or later part of the Miocene. Where the relations of the Oligocene and Miocene are shown, as for example near Logan [32] and in Townsend Valley,[33] the two series of deposits are separated by an unconformity.

Before the Oligocene sediments were deposited the broad valley that extends from the south across the eastern part of the Melrose area and northward across the Continental Divide apparently was a cleanly swept drainageway on the surface of the older rocks. In probably the early part of the Oligocene epoch stream and flood-plain deposits began to accumulate in this valley, either because of a change from a wet to a dry climate that reduced the capacity of the streams to carry out the sediments washed down from the adjacent highlands or, more probably, because the drainage was obstructed by warping or other results of deformative earth movements. At first the sediments were derived chiefly from volcanic ash carried by the winds from distant explosive craters. Later they were supplied almost entirely by waste from the adjacent mountains. The increasing coarseness of the later beds indicates higher stream gradients, which in turn suggest growing mountains or a sinking valley. In any event it is evident that deformation again occurred after the Oligocene beds were laid down and before the later Tertiary or at least the Quaternary gravel had come into place.

[30] Douglass, Earl, Some new merycoidodonts: Carnegie Mus. Annals, vol. 4, pp. 107–108, pl. 29, 1907.

[31] Idem, pp. 271–273, pl. 67, figs. 3, 4; pl. 68, figs. 6–8, 1908.

[32] Douglass, Earl, Carnegie Mus. Annals, vol. 2, pl. 2, 1903.

[33] Pardee, J. T., U. S. Geol. Survey Water-Supply Paper 539, p. 29, 1925.

QUATERNARY DEPOSITS

Terrace gravel.—The areas mapped as Tertiary "lake beds" contain also a mantle of loose or unconsolidated gravel. In places this gravel overlaps adjoining areas, and on the slope west of Big Hole River opposite Divide it is so thick as to conceal most of the details of the underlying rocks.

This gravel lies upon a surface eroded across the Tertiary and older rocks and evidently was deposited by streams from the adjacent mountains. Northeast of the road between Moose Creek and Divide it caps several hills that rise to altitudes between 5,800 and 6,100 feet and appears to range from 40 or 50 to as much as 200 feet in thickness. Part of the material is well-washed gravel that, so far as its composition shows, may have been derived from the underlying Tertiary beds. There is in addition, however, much rather coarse subangular material that appears to have been brought directly from the mountains. Boulders as large as 3 or 4 feet in diameter are not uncommon. In the gravel, as in the Tertiary beds, the rocks most abundantly represented are the more resistant varieties, such as quartzite, hornstone, and dense fine-grained igneous rocks. Most of the granite fragments observed were badly decomposed, as if they had lain a long time after they were transported from their parent ledges.

The possibility that this gravel or some of it may have been transported by early Pleistocene glaciers should not be overlooked, though no evidence of such an origin was found in this area. Near Silverbow, about 20 miles to the north, is an early deposit of glacial material mentioned by Atwood.[34] This deposit extends 4 or 5 miles southward and in its relations to the Tertiary beds and the adjacent mountain is similar to the gravel considered.

East of Melrose and north and south of Camp Creek the bench lands are covered with a rather coarse gravel containing boulders as much as 3 feet in size, of quartzite, conglomerate, and other rocks that crop out in the adjoining mountains. In the neighborhood of Divide the gravel is thinner and somewhat patchy. The deposit on the slope across the river from Divide is thick, subangular, and coarse textured. No good exposure of it was observed.

The gravel described is of similar occurrence to gravel that mantles terraces in neighboring valleys, in some of which it appears to be chiefly of early Pleistocene age.[35]

Moraines.—Moraines that closely mark the former extent of the valley glaciers are present in the valleys of Canyon and Trapper

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[34] Atwood, W. W., Physiographic conditions at Butte, Mont.: Econ. Geology, vol. 11, p. 717, pl. 30A, 1916.

[35] Pardee, J. T., Geology and ground water in Townsend Valley, Mont.: U. S. Geol. Survey Water-Supply Paper 539, p. 36, 1925; Glaciation of the Pioneer district, Mont.; U. S. Geol. Survey Prof. Paper — (in preparation).

creeks. The one in the Canyon Creek valley extends down to an altitude of 5,650 feet; that in the Trapper Creek valley ends at 6,250 feet. The boulders that make up these moraines consist mainly of granite or quartz monzonite and have been transported a maximum distance of 10 or 12 miles from their points of origin, near the heads of the canyons. A few boulders of quartzite and limestone are included in the morainal débris.[36]

Alluvium.—The valleys of Big Hole River, Camp Creek, and Trapper Creek include sand, gravel, and soil that have been deposited mainly by the present streams but in part during Pleistocene time.

Talus.—A small area in sec. 28, T. 2 S., R. 9 W., of loose rock fragments, derived mainly from the Phosphoria and Woodside formations, has been mapped as talus. Other areas in T. 2 S., R. 9 W., and T. 1 S., R. 8 W., of loose fragmentary material derived from several formations have been similarly mapped, and still other areas could doubtless be shown by more detailed areal mapping in places where the boundaries shown on the present map have been inferred between the points at which observations have been made—as, for example, along the northeast front of Shepherd Mountain.

CONTACT-METAMORPHOSED ROCKS

Near their contact with the masses of intrusive monzonite the sedimentary rocks show the changes called contact metamorphism. These changes are most noticeable and extensive north of Big Hole River, west of Divide. Here the sediments are so extensively altered that their correlation is difficult, and though, as indicated on the map, they appear to belong chiefly to the Kootenai and Colorado, parts of them may belong to the Woodside and other formations. The bulk of these rocks may be described as hornstone and argillite. These are hard, tough, and fine grained and range in color from light gray to dark green and black, including purple. As a rule they are distinctly banded with different colors or different shades of the same color. Brown mica, epidote, and garnet appear to be common and widespread constituents. A specimen examined microscopically by F. C. Calkins is chiefly a fine granular mixture of quartz, muscovite, and biotite with a little tourmaline. Apparently these rocks are the altered equivalents of the fine-grained beds such as shale described on pages 12–13.

Interbedded with the hornstone are rocks that are considerably altered but still recognizable as sandstone and limestone, and the features and relations of these beds serve to indicate the proper place of the whole in the stratigraphic section.

[36] This drift is fresh-looking and was deposited by glaciers that flowed down the present valleys, evidently in late Pleistocene time, probably at the Wisconsin stage.—J. T. P.

The intense metamorphism of the rocks described is due to the fact that they form part of the cover that lay directly above the intrusive granitic mass and were thus most favorably exposed to its heat and other emanations.

IGNEOUS ROCKS

Quartz monzonite or granite.—Areas of granitic igneous rocks are prominent in secs. 4 and 15, T. 2 S., R. 9 W. These massive intrusions are supposed to represent portions of the Boulder batholith, with which the extensive monzonite areas near Butte have been correlated. The rocks themselves are grayish, medium grained, and made up mainly of quartz, decomposed orthoclase, biotite, magnetite, and plagioclase having the composition of an albite oligoclase. In this township the rock seems to have more nearly the composition of quartz diorite than that of a monzonite, but for the purpose of this report all the granitic rocks are grouped under quartz monzonite as a mapping unit. In the eastern part of sec. 16, along the contact with sediments of probable Colorado age, this rock appears to have more nearly the composition of a gabbro, simulating the basic facies common near contacts with sediments in the Butte district.[37]

Andesite.—Several areas of dark-colored igneous rocks which range in lithologic character from aphanitic amygdaloid to porphyry containing phenocrysts of decomposed olivine but which so far as examined in thin section also contain augite have been mapped as andesite. They have the appearance of being fairly recent rocks, probably Tertiary. It is possible, however, that a more thorough study would show that they are in part basaltic and in part represent older flows. Weed[38] describes andesites in the Butte district that are older than the monzonitic batholith; in the Melrose district, however, it appears that the andesites observed are distinctly younger.

Rhyolite.—A small area in sec. 13, T. 2 S., R. 10 W., is covered by a flow of light-gray rhyolite. In this rock phenocrysts of smoky quartz and glassy andesite are prominent, and flecks of biotite are sparsely distributed through a devitrified groundmass. In thin section a small amount of soda feldspar is found to be present, and the rock doubtless may well be called a sodic rhyolite. This rock weathers into plates half an inch to 2 inches in thickness. In this and in many other respects this rock corresponds rather closely with the rhyolitic dike rocks of the Butte district described by Weed.

Latite.—A sill of light greenish-gray altered porphyrite is intruded between limestone beds near the top of the Kootenai formation

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[37] Weed, W. H., Geology and ore deposits of the Butte district, Mont.: U. S. Geol. Survey Prof. Paper 74, p. 28, 1912.
[38] Idem, p. 27.

in the southwestern part of T. 2 S., R. 9 W. This rock was examined microscopically in thin section by the late J. Fred Hunter, of the Geological Survey, who reported that the phenocrysts consist of altered hornblende and plagioclase feldspar, which is probably oligioclase. In the alteration of the rock much secondary calcite, apatite, magnetite, muscovite, and chlorite has developed. Mr. Hunter suggested that the rock when fresh may have been a quartz latite. The field relations indicate that it bears a close relation to the rhyolite occurring in T. 2 S., R. 10 W., although no surficial connection has been observed.

STRUCTURE

The area includes three distinct structural units—the folded sedimentary rocks, the intrusive igneous rocks, and the extrusive igneous rocks and younger unconsolidated deposits.

The sedimentary rocks are compressed in a series of folds that have a northwesterly trend and plunge toward the southeast. The compressive forces were apparently directed from the southwest, as the anticlines are generally overturned toward the east. The synclines form narrow belts including the phosphate-bearing rocks and are separated from one another by anticlines in which prephosphate limestone and quartzite are exposed by erosion, except in the southeastern part of the area, where even the anticlines include uneroded phosphate.

The synclinal folds may be conveniently named, from places situated near their axes, the Ore Camp syncline, Glendale syncline, Dry Hollow syncline, and Big Hole syncline.

The synclines possess certain common characteristics—for example, the southwestern flank of each one is overridden to some extent by overthrust portions of the adjoining anticline.

Big Hole River enters the Big Hole syncline in sec. 5, T. 2 S., R. 9 W., and leaves it approximately in sec. 10 of the same township. This fold extends continuously to the contact of the sediments with the monzonite mass south of the power plant in T. 1 S., R. 10 W., and a portion of what may represent the continuation of the same fold is found in the hills south of Dewey. The same syncline is cut off toward the southeast by a portion of the batholith.

The Dry Hollow syncline is parallel with Dry Hollow in T. 2 S., R. 9 W., and extends to the northwest. The phosphate beds persist to the vicinity of Happy Camp Park. A portion of the eastern limb of this fold is interrupted by faulting near the township line.

The Glendale syncline is named after the old smelter town of Glendale, which is somewhat east of the axis of the fold. This syncline is broader than either of the others so far described. Its western margin is complicated by faulting in the divide between Canyon and Trapper creeks.

The Ore Camp syncline lies in the southwestern part of the area. It is a broad basin-like fold, and its southwestern margin is concealed by an overthrust mass of quartzite of the Quadrant formation. The field studies were not carried far enough outside of the area to determine the origin of this mass, but it is supposed to represent the top or flank of an anticlinal fold.

The intrusive granitic rocks, the quartz monzonite and granite of the area, form a portion of a large batholith which is known in this region as the Boulder batholith. The effects of this intrusion are more evident in the northern third of the area, but in the vicinity of the Big Hole River valley the intrusive rocks are present within 2 miles of Melrose, and it is possible that the sedimentary rocks have been entirely cut out in portions of the area that is now covered by alluvium and Tertiary "lake beds."

The andesitic flows have a vertical range of about a thousand feet, and the portions now left in the area are so scattered that it is difficult to regard them as remnants of a single extrusive sheet. It appears more probable to the writer that they represent more or less local outpourings from fault fissures.

The structure of the Quaternary and Tertiary deposits differs only locally from that acquired during sedimentation. Nowhere were dips of more than 15° or 20° noted, and the highest dips are interpreted, in part at least, as the result of inclined deposition. The structure of the Tertiary "lake beds" is further discussed on page 14.

PHOSPHATE DEPOSITS

CHARACTER

The phosphate of the Melrose district is a dark-colored granular rock which resembles somewhat a black limestone or even, on casual examination, a fine-grained basalt. When examined closely most of it is found to have an oolitic texture—that is, it is made up of small oval grains. These in general are darker colored than the matrix, and many of them have shiny surfaces. The color of the freshly broken phosphate rock ranges from dark gray to brownish black or black, but the weathered surfaces are either lighter colored or streaked with a net of pale-bluish to white lines of "phosphate bloom." In places this light coating almost completely covers the rock with a translucent veil, so that the whole somewhat resembles silicified fossil bone in appearance.

The phosphate of the Melrose district closely resembles that of southeastern Idaho, which, however, is in general of somewhat lighter color and more characteristically yields a fetid odor when freshly broken.

The mineral composition of the rock phosphate has not been thoroughly investigated, but so far as studied it appears to represent a mixture of the several lime phosphates described by Lacroix,[39] with minor variable amounts of calcite.

The phosphoric acid content is set forth in the chemical analyses included in the following detailed sections.

The phosphate is found in one or more beds included in Carboniferous sedimentary rocks, specifically in the Phosphoria formation of Permian age. The phosphate beds are normally underlain by a series of light-gray slightly cherty limestones and overlain by the massively bedded chert constituting the Rex chert member of the Phosphoria formation, which locally closely resembles quartzite. The materials composing this series of rock beds were originally deposited in a nearly horizontal position but have since been consolidated in beds that have been subjected to great lateral pressure and compressed into a series of close and in part overturned folds.

The folds consist of four major anticlines and one subordinate anticline and a corresponding number of synclines. The anticlines appear on the whole to have been the sharper folds, and in one of them the limit of folding endurance of the strata was reached and an overthrust fault was produced, the maximum exposed throw of which brings quartzite of the Quadrant formation out over sandstone and shale of the Colorado formation in sec. 18, T. 2 S., R. 9 W. The occurrence affords an example of the abnormal presence of phosphate in an area where the surface rocks are older than the phosphate bed. In the other places in this area where the surface rocks belong to the Madison limestone or the Quadrant formation or the older formations phosphate deposits are presumably absent.

Postphosphate igneous rocks may occur at the surface overlying phosphate deposits, as in the southwestern part of the area, where andesitic flows cover postphosphate sediments, or they may cut out the rocks overlying and presumably the rocks including the phosphate, as the granite does in secs. 9, 10, 15, 16, 21, and 22, T. 2 S., R. 9 W.

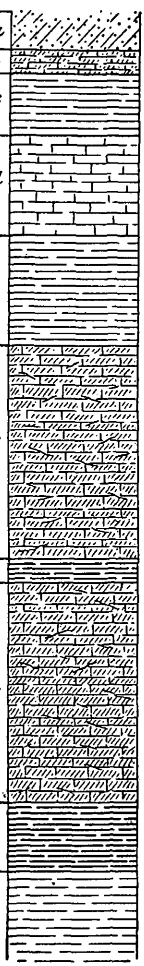
THICKNESS AND QUALITY

The first detailed section of the phosphate beds of the Phosphoria formation in this area was measured and sampled by E. L. Jones, jr., of the Geological Survey, in May, 1911, and the chemical tests were made by J. G. Fairchild in the laboratory of the Geological Survey. This section [40] is reproduced in Figure 2.

[39] Lacroix, A., Sur la constitution minéralogique des phosphorites français: Compt. Rend., vol. 150, p. 1913, 1910; Minéralogie de la France, vol. 4, pt. 2, p. 555, 1910.
[40] U. S. Geol. Survey Bull. 470, fig. 50, 1911.

The following is an abstract from Jones's notes:

The phosphate-bearing section was trenched at a point 430 feet S. 10° W. from the quarter corner on the east side of sec. 17, T. 2 S., R. 9 W. The excavation is 14 feet long, 18 inches wide, and 4 feet deep. It trends N. 85° W., nearly at right angles to the strike of the phosphate beds. The phosphate occupies,



Specimen			Thickness Ft.	Thickness in.	Phosphorus pentoxide P_2O_5 Per cent.	Equivalent to tricalcium phosphate ($Ca_3(PO_4)_2$) Per cent.
No. 1	a	Chert or vitreous quartzite			None.	
No. 2	b	Brecciated phosphate rock		4	23	50.1
	c	Cream-colored argillite		11		
No. 3	d	Solid bed of phosphate rock	1	7	24.3	53.0
No. 4	e	Mottled reddish and cream-colored argillite.	1	8	None.	
No. 5	f	Brecciated phosphate containing veinlets of calcite	3	3	30.6	66.8
No. 6	g	Dark-colored argillite		4	.7	15.3
No. 7	h	Brecciated phosphate containing veinlets of calcite	3	4	29.8	65.1
	i	Dark-colored argillite	1			

FIGURE 2.—Section across phosphate deposit near Melrose, Mont.

together with the shale, a depression between two rather prominent ledges, a chert or quartzite on the east and a light-blue limestone on the west side. The average distance between these outcropping ledges was found to be about 50 feet. The strike of the phosphate bed at the point where the trench was dug is N. 8° E., with a dip of 81° W. The structure is apparently that of an overturned fold, as described in the report of Mr. Gale.

The phosphate beds *f* and *h* are fractured and brecciated, veins of calcite being common, and specimens showing cementation of argillaceous fragments torn from the walls are included in the samples mailed to you. In these beds the phosphate rock is in loose slabs which dip in the same general direction as that of the undisturbed ledge. This evidence, taken together with the similarity of the beds *f* and *h* separated by a thin bed of argillite, suggests a strike fault, and thus bed *h* may be a repetition of bed *f*.

Representative samples of the different beds were taken in the places indicated in the section. From phosphate bed *d* the sample was taken at the surface, but from beds *f* and *h* the samples were taken at depths of 3 to 4 feet.

This section was also examined in 1912 by A. R. Schultz and the writer, both of whom are inclined to interpret beds *f* and *h* as separate beds rather than the same bed repeated by faulting. Further prospecting is necessary, however, to remove doubt concerning the proper interpretation of the section.

About 10 feet west of the base of this section is a shallow pit in gray phosphatic shale similar to material known to contain about 38 per cent of tricalcium phosphate. This shale rests apparently on the "underlying limestone."

Float phosphate collected at three localities on the more eastern outcrop of the phosphate bed, analyzed by Walter C. Wheeler in the laboratory of the Geological Survey, was found to average 62 per cent in tricalcium phosphate.

In 1912 a trench was dug about 2¾ miles west of the Jones prospect. This trench, which is in sec. 13, T. 2 S., R. 10 W., is about 25 feet long and extends from the base of the chert to the top of the "underlying limestone." Here the dip ranges from 43° SW. in the chert to about 30° SW. in the limestone. The details of the exposures are as follows:

Section of part of the Phosphoria formation in the SW. ¼ NW. ¼ sec. 13, T. 2 S., R. 10 W., Montana

[Analyses by W. C. Wheeler]

Field No. of sample		Phosphorus pentoxide (P_2O_5)	Equivalent to tricalcium phosphate ($Ca_3(PO_4)_2$)	Thickness
	Chert, black, base of Rex chert member.	Per cent	Per cent	Ft. in.
R 157-1	Phosphate, dark bluish gray, finely oolitic	30.46	66.6	10
2	Phosphate rock, yellow to brown, broken calcite filling	16.78	33.0	2
3	Shale, dark gray, massive, 8 inches; Shale, yellow, sandy, 2 inches; Shale, light gray, papery, 2 inches	Trace.		1
4	Phosphate, dark bluish gray, massive	27.54	60.1	11
	Shale, brown, in ⅛ to ¼ inch beds			2
5	Phosphate rock, dark bluish gray, broken	20.04	44.0	6
6	Shale, brown, gray, and yellow	12.80	22.0	4
7	Shale, gray	12.53	22.0	5
8	Shale, yellowish brown to gray	9.18	20.0±	2
9	Phosphate rock, reddish	13.79	27.0±	6
	Limestone, reddish gray, dense.			
				15 1

In this section beds 1 and 4 may represent the equivalents of *a* and *d* of the Jones section. However, beds *f* and *h* are apparently absent, as the lower part of the section is made up of low-grade phosphatic shale.

Another prospect was opened about 3½ miles slightly west of north of the Jones prospect, and the following section was measured:

Section of part of the Phosphoria formation in sec. 31, T. 1 S., R. 9 W., Montana

[Analyses by W. C. Wheeler]

Field No. of sample		Phosphorus pentoxide (P_2O_5)	Equivalent to tricalcium phosphate ($Ca_3(PO_4)_2$)	Thickness	
	Chert, black, lower 3 inches pebbly, base of Rex chert member.	*Per cent*	*Per cent*	*Ft.*	*in*
R 329-1	Shale, dark gray; weathers light gray	4.38	10.0		3
2	Phosphate, dark gray, medium oolitic, 7 inches Sand ocher, lens, maximum thickness ½ inch Phosphate, brownish gray, medium oolitic, 5 inches	28.34	61.8	1	
3	Shale, brownish gray, sandy	19.12	43 0±		3
4	Phosphate, yellowishto gray	28.81	62.9		5
5	Phosphatic rock, iron stained	17.22	37.6	1	4
6	Shale, gray	Trace.	----	1	4
7	Phosphatic rock, dense, brecciated	13.41	29.3	1	5
	Limestone, dark gray, dense	----	----		5
8	Phosphate, gray, medium oolitic; includes 1 inch of brown phosphate	27.18	59.4	1	
9	Clay, gray, soft, plastic	19.54	43.0	7	
10	Shale, olive-green	22.93	49.0	6	
11	Phosphatic rock, thin bedded, finely oolitic	22.68	47.8	1	2
12	Shale	4.31	10.0	1	4
13	Phosphate, 10 inches Sand, 2 inches	12.91	----	1	
14	Phosphatic rock, dark gray, hard, pebbly	25.24	55.0		6
	Limestone, gray; top of "underlying limestone."				
				24	5

In this section only three beds approach 60 per cent in their content of tricalcium phosphate, and their total thickness is 2 feet 6 inches. The upper two, with an intervening 3-inch parting that runs 43 per cent in tricalcium phosphate, together amount to 1 foot 8 inches.

The last two detailed sections of the phosphate beds demonstrate that the deposits are not everywhere thick enough for commercial development, but the section measured by Jones in sec. 16, T. 2 S., R. 9 W., shows that they are locally of sufficient thickness, and a number of sections measured by Pardee[41] in other portions of Montana show beds of adequate thickness and quality. The two sections recently measured show, however, that it is important in the study of the Montana fields that the beds be thoroughly prospected along the outcrop in order to differentiate clearly the richer from the leaner and less valuable portions, and that such thorough prospecting precede attempts at utilization.

[41] Pardee, J. T., Some further discoveries of rock phosphate in Montana: U. S. Geol. Survey Bull. 530, pp. 285–291, 1912.

RELATIVE VALUE

In general, it appears that the phosphate deposits in the vicinity of Melrose are not as good as the beds in many parts of the Idaho fields. The beds of higher grade are split by shale, and even the thickness and quality of the rock in this district vary so greatly that, with the information at hand, it is impossible to formulate estimates of the available tonnage, such as have been made for the phosphate fields of southeastern Idaho. The deposits of this district that are thick enough for economical development probably have some advantage over the Idaho deposits in that they are close to a potential supply of cheap acid—namely, the smelting centers at Anaconda, Butte, and Great Falls. Thorough prospecting of these deposits will doubtless disclose other places where the beds are thicker and richer. The fact that the deposits are thin in some places should stimulate the search for the richer deposits and enhance their value when found.

LOCATION AND STRUCTURE

The phosphate deposits of the Melrose district underlie the portions of the area where the surface rocks are those of the Phosphoria formation or the later sedimentary rocks. (See Pl. I.) The greater part of the area underlain by phosphate is in the southern half of T. 2 S., Rs. 9 and 10 W., but three strips half a mile to 1 mile wide extend in a northwesterly direction into T. 1 S., R. 10 W. These strips represent synclinal folds, which are more fully treated in the section on structure (p. 19). The northeastern part of the Big Hole syncline is traversed for about 3 miles by the Oregon Short Line Railroad, and the deposits included in this fold are therefore the most favorably situated for development.[42]

McCARTHY MOUNTAIN AREA

By J. T. Pardee

INTRODUCTION

The following description and accompanying map of Tps. 4 and 5 S., R. 8 W., which may be referred to as the McCarthy Mountain area, are taken from unpublished data filed with the United States Geological Survey by H. S. Gale. The map (Pl. II) is copied from Gale's records without changes except the following, for which the writer assumes responsibility.

Certain areas in the eastern and western parts of T. 4 S., R. 8 W., mapped by Gale as "boulder covered" and "outwash covered," respectively, and a large part of T. 5 S., R. 8 W., called "older alluvium

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[42] Since 1913 the Anaconda Copper Mining Co. has done considerable development work on the phosphate bed along Big Hole River north of Melrose, the results of which have not been obtained for publication in this report.—J. T. P.

or lake beds," are all here designated Tertiary "lake beds" and Pleistocene terrace gravel. The change in designation is made in order to indicate the probable correlation of the deposits of these areas with those of the Melrose area and other parts of Montana. In addition, these designations have been applied to several small patches in T. 4 S., R. 8 W., one of which was originally mapped as "tuff" and the others as "andesite and tuff." The patch of "tuff" is near the southeast corner of the township, and the "andesite and tuff" are in the western part north of Big Hole River. One of the last-mentioned patches east of Behrs Gulch includes the place at which Douglass, as mentioned farther on, found Oligocene vertebrate fossils. Because tuffs are not uncommon in the so-called Tertiary "lake beds" all these patches have been included under that designation. Areas in both townships consisting mainly of lowlands along the rivers and mapped as "Recent alluvium" by Gale have been designated by the writer Quaternary alluvium, for the reason that in the neighboring Melrose area similar deposits are regarded as chiefly of Pleistocene age.

In preparing the text the writer has followed closely Gale's notes and reports.

FIELD WORK

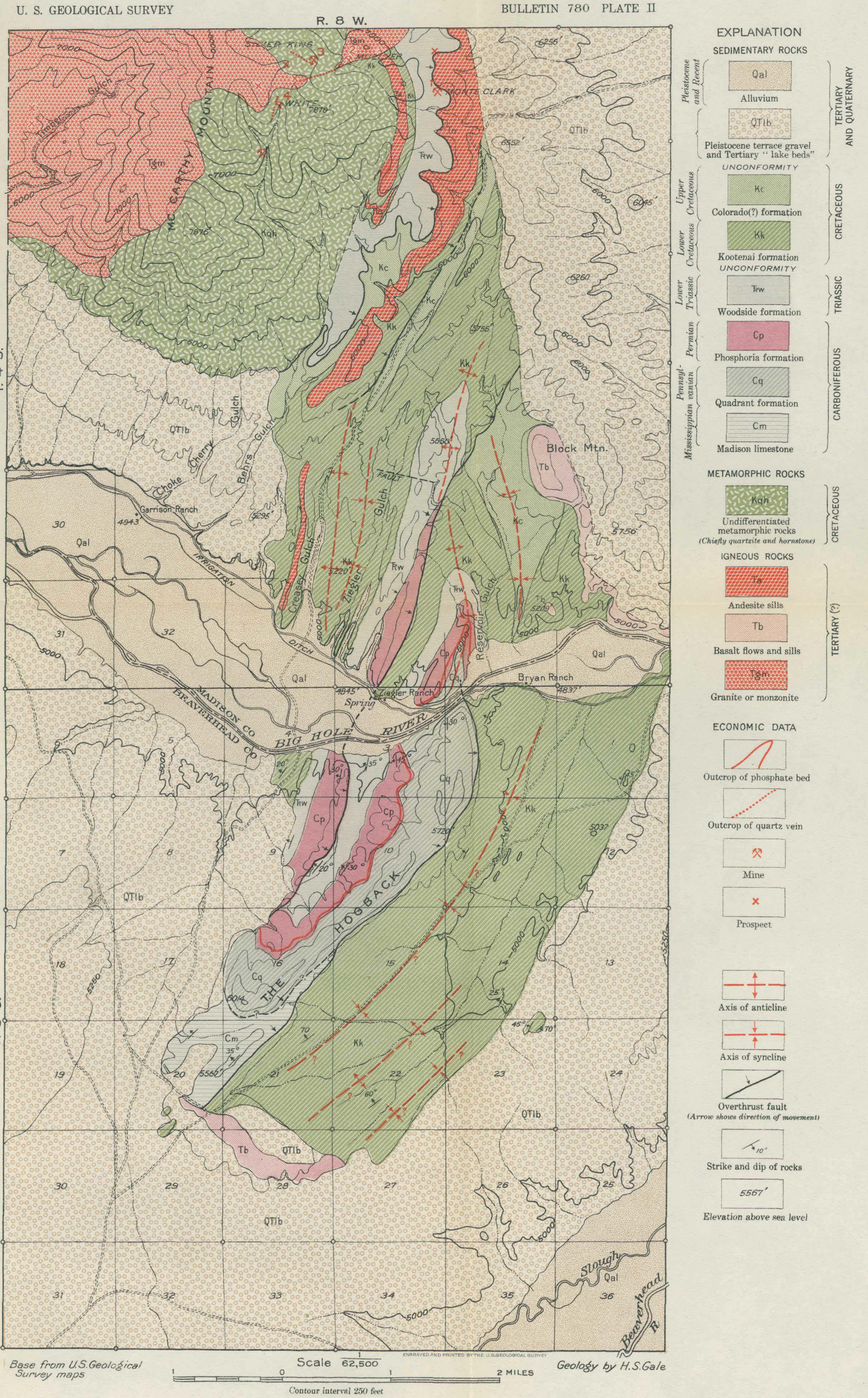
T. 4 S., R. 8 W., was examined briefly in 1910 by H. S. Gale. In 1912 part of its area was studied in somewhat more detail by R. W. Richards, who late in the fall visited T. 5 S., R. 8 W., also but was prevented by unfavorable weather from doing any geologic mapping. In 1913 both townships were reexamined and their geology mapped by Gale.

Many years before this work was begun land surveys of T. 5 S. and part of T. 4 S. had been made by the General Land Office. In 1911 a topographic survey of both townships was made by R. H. Reineck, of the United States Geological Survey, and the resulting manuscript maps, which are drawn on a scale of 2 inches to a mile, with a 50-foot contour interval, were available for use in 1912. These maps form the base of Plate II.

SEDIMENTARY ROCKS

Rocks ranging in age from early Carboniferous (Madison limestone) to Cretaceous (Colorado (?) formation) are exceptionally well exposed in an area that occupies large parts of both townships and extends north and south of Big Hole River. In this area cleanly washed slopes of the hills and ravines almost completely reveal the softer as well as the harder beds. It would be difficult to find a more interesting area in which to study details of both the structure and the stratigraphy characteristic of this part of Montana.

Of the rock section described in the following table, that part extending from the Quadrant to the Woodside very closely corresponds



GEOLOGIC MAP OF THE McCARTHY MOUNTAIN AREA, MONTANA

1925

to the section in southeastern Idaho. In the McCarthy Mountain area, however, the apparently consecutive sequence is terminated somewhere within the Woodside, for a profound unconformity marks the top of the Woodside and separates it from a heavy conglomerate that forms the base of the Kootenai. Above the section as given in the table is a thick series of beds thought to belong to the Colorado, the details of which are obscured by folding, faulting, and metamorphic changes due to the intrusion of igneous rocks.

Section of bedded rocks in the vicinity of the lower canyon of Big Hole River in T. 4 S., R. 8 W.

		Feet.
Colorado (?) formation:		
Top, shale (unmeasured thickness).		
Sandstone, greenish yellow, thin bedded, separated into slabs by weathering; forms the crest of a hogback ridge	100	
Shale, sandy, with coal-black fissile layers and beds of slab-forming sandstone. Yellow and sandy shale near the bottom	200	
Total Colorado (?) formation		300
Kootenai formation:		
Sandstone, rusty, coarse, weathering dark	85	
Shale	75	
Sill of porphyritic lava (andesite ?) 10 feet thick.		
Shale	45	
Limestone, massive beds with shaly partings	70	
Limestone, massive, bluish gray, with fossil gastropods[43] (the "gastropod limestone")	40	
Shale, brick-red, soft, poorly exposed	250	
Sandstone, coarse, brown and green tints on weathered surface	30	
Shale, sandy	110	
Limestone containing fossil gastropods and pelecypods	35	
Shale	30	
Limestone, blue; weathers muddy yellowish brown	25	
Shale, rather soft, green and dark purple	100	
Limestone, blue, broken and mixed with deep-red soil	3	
Shale, dark maroon and green	30	
Sandstone, compact, dark green; weathers black; cross-bedded	50	
Shale, mostly dark red, with coarse layers of dark sandstone	320	
Conglomerate; massive stratum composed of hard rounded pebbles in a coarse sandy matrix	20	
Total Kootenai formation		1,318

[43] A collection (No. 592) from this bed was determined by T. W. Stanton to contain internal casts of a species of *Goniobasis*?

		Feet.
Woodside formation: Sandstone, sandy shale, and argillaceous limestone, brown or rusty, weathering red; contains fossils characteristic of the Woodside of southeastern Idaho section. Not measured in detail		600
Phosphoria formation:		
Chert, massive stratum (the principal hogback maker)	100±	
Interval, no exposures	50	
Chert and cherty limestone, rusty weathering	25	
Limestone, very cherty, white; a distinct stratum	35	
Interval, no exposures	20	
Chert, solid	2	
Interval, no exposures; loose fragments of phosphate rock on the surface (the phosphate horizon)	8	
Chert, very dense, dark and persistent	2	
Interval, no exposures	6	
Limestone, white, cherty, iron stained	30	
Chert, dark, fractured; contains nodules and obscure fossils [44]	1	
Limestone, white, siliceous	2	
Interval, no exposures; shaly beds indicated by character of surface mantle	60	
Limestone, white, massive, cherty	10	
Interval, no exposures	15	
Limestone, rough, siliceous, iron stained	15	
Total Phosphoria formation		381
Quadrant formation: Quartzite, massive, white and reddish, not measured or examined in detail. A thickness of 500 feet, more or less, exposed by a cliff on the south side of the lower canyon of Big Hole River. Approximate total thickness		700
Total thickness of the sedimentary section to probable base of Quadrant formation		3, 299
Madison limestone not exposed.		

A large aggregate area, most of which is south of Big Hole River, is covered by loose boulders and cobbles beneath which are beds of slightly consolidated gravel and sand. Such beds have been generally regarded as belonging to the so-called Tertiary "lake beds" of this part of Montana.

METAMORPHIC ROCKS

In the northwest corner of the McCarthy Mountain area Gale's map shows a large area of metamorphic rocks, which he describes

[44] Material from this bed (lot 546) was determined by G. H. Girty to consist of "concretions, on the exterior of a few of which are remains of several brachiopods (*Spiriferina*?) and possibly of Bryozoa. This paleontologic evidence suggests a comparison with the *Spiriferina pulchra* zone of the Phosphoria formation, though it does not furnish any criteria that are reliable."

as consisting chiefly of quartzite and hornstone. Probably most of these metamorphic rocks are of Kootenai and Colorado age.

IGNEOUS ROCKS

A coarse-grained gray biotite granite or monzonite occupies 3 or 4 square miles in the northwest quarter of T. 4 S., R. 8 W., and extends into adjoining areas on the north and west. The rock forms some of the highest points in the township. Presumably it forms the summit of McCarthy Mountain, half a mile north of the township. Most of the granite area is timbered. The granite was not intruded before late Cretaceous time, as shown by the fact that it has extensively metamorphosed the Colorado(?) rocks. On the other hand, the granite had come to place and had been exposed by erosion before the Tertiary "lake beds" accumulated.

South of Big Hole River a small area of coarse granitic rock extends into T. 5 S. from the west. This exposure is surrounded by later sediments, which presumably are not older than Oligocene.

Basalt occupies an area that includes Block Mountain, in the southeastern part of T. 4 S., and a small tract in the southwestern part of T. 5 S., south of the Hogback. The Block Mountain mass exhibits columnar jointing on a large scale and appears to be the remnant of a formerly extensive flow. It is accompanied by beds of white volcanic ash whose relations are not defined. This ash has been included in the area shown as Tertiary "lake beds", (Pl. II). The basalt, as suggested by the association mentioned, is probably Tertiary also.

The basalt south of the Hogback evidently is the remnant of a flow or sill.

A porphyritic gray to brown rock provisionally determined as andesite extends through the middle of T. 4 S. from north to south. Most of it was probably intruded as sills, though possibly some was extruded, forming flows that were interbedded with the sedimentary rocks. An occurrence of slag and tuff southwest of Behrs Gulch indicates that part of the andesite may have been extruded through the sediments after they had been deformed as at present. It was in this area of tuff that Douglass (p. 14) collected remains of Oligocene (lower White River) vertebrates.

STRUCTURE

Throughout the area the bedded rocks from Madison limestone to Colorado(?) formation have been closely folded and broken and displaced by overthrust faults. As a rule the folds (Pl. II) strike northeastward, and most of them tend to be overturned toward the east.

North of Big Hole River, west of Reservoir Gulch, an anticline that elevates the phosphate bed to the surface leans to the east. South of the river the large area of Kootenai rocks east of the Hogback shows a succession of closely compressed folds overturned to the east that cause the "gastropod limestone" beds to crop out repeatedly. Here the dip ranges from 40° W. to the vertical.

Overthrust faults are prominent features of the structure. South of the river the trace of one appears at the base of the cliff that forms the east side of the Hogback. On this fault Quadrant quartzite has been thrust eastward and upward over Kootenai rocks.

The overthrust block probably is the west limit of an anticline that represents the southward extension of the anticline west of Reservoir Gulch, north of the river—an inference suggested by the fact that the thrust plane coincides at the north with the axis of the anticline. If this inference is correct the rocks, during their folding, broke along the crest of the anticline from Big Hole River southward. Evidently the amount of overthrusting increased southward also.

West of the Hogback an overthrust causes the Phosphoria formation to overlie the Woodside. In T. 4 S., north of the river, other faults cause the Phosphoria to override the Kootenai in sec. 34, and the Kootenai and Woodside to rest upon beds regarded as Colorado east of McCarthy Mountain.

ROCK PHOSPHATE

A bed of rock phosphate that occurs in the Phosphoria formation about 140 feet stratigraphically above its base crops out north of Big Hole River in secs. 34 and 35, T. 4 S. In sec. 35 the phosphate and its inclosing rocks are involved in the compressed and overturned anticline west of Reservoir Gulch, as a result of which the outcrop of the phosphate bed traces a "hairpin" curve around the north end of the plunging arch (Pl. II). At the south end of the long hogback which terminates near the middle of the south line of sec. 34 the phosphate bed is exposed for a short distance in the lower part of an overthrust block which rests upon the Kootenai. North of this point no outcrop could be found, the phosphate bed apparently being cut out by the fault.

South of Big Hole River, in T. 5 S., the phosphate bed is elevated to the surface as a part of the large overthrust block that forms the Hogback. The outcrop lies about half a mile west of the ridge. By means of loose fragments or "float" it may be traced from the river southwestward for about 3 miles. In depth this bed probably is cut out by an overthrust fault which comes to the surface about half a mile farther west.

At the south end of the ridge in sec. 34, north of the river, a section measured by R. W. Richards in 1912 shows 6 feet of phosphate beds the upper and lower halves of which contain, respectively, 26.54 and 29.66 per cent of phosphorus pentoxide (P_2O_5), equivalent to 57.9 and 64.6 per cent of tricalcium phosphate ($Ca_3(PO_4)_2$).

"Float" from the outcrop near the southeast corner of sec. 34 contained 25.07 per cent of phosphorus pentoxide, equivalent to 54.78 per cent of tricalcium phosphate. The beds in the locality were not exposed sufficiently to be measured.

South of the river "float" collected along the outcrop near the southwest corner of sec. 10 contained 37.84 per cent of phosphorus pentoxide, equivalent to 82.68 per cent of tricalcium phosphate.

The presence of a bed of high-grade rock phosphate is indicated by these samples. Its thickness and persistence are not known, but apparently they could be determined by a small amount of digging along the outcrop.

SILVER, LEAD, AND GOLD

Several metalliferous deposits in T. 4 S., on the flanks of McCarthy Mountain, have yielded considerable ore, chiefly from the Mueller and Monte Clark mines, situated along a southeast spur 2 miles and 3 miles, respectively, from the summit of the mountain (Pl. II).

The Mueller mine comprises the Jay Gould and Silver Cliff claims, which are said to have been worked for the last 20 years by Edward Mueller & Sons. The principal working is an adit level 800 feet long, above which are extensive stopes. A well-defined vein is exposed that strikes N. 10°–60° E. and cuts porphyritic granite near the contact with metamorphosed Cretaceous beds. The ore is silver-bearing galena, of which the oxidized products near the surface are said to have been very rich.

The Silver King lode, a short distance west of the Mueller mine, strikes northwest and is inclosed between sedimentary beds. The ore consists of drusy quartz and limonite and is said to be rich in silver in places.

The Monte Clark mine is a shaft near the contact of sedimentary rocks with intrusive andesite. It is reported to have produced considerable ore, but no details of the ore body are available.

About three-quarters of a mile southwest of the Mueller mine a shaft was being sunk in 1913 by Ira White on an ore body in metamorphosed sedimentary rock near the granite contact. Up to the time of visit about 40 tons of shipping ore consisting chiefly of galena had been produced. Assays of samples said to represent this ore show about 38 ounces of silver and from \$3 to \$7 in gold to a ton and from 16 to 76 per cent of lead.

In the upper part of Timber Gulch, on the western slope of McCarthy Mountain, are several prospects in granite which are said to have produced good ore. Details concerning them are not available.

COAL

A thin bed of coal is reported half a mile southwest of Block Mountain, near the axis of the syncline in Colorado (?) shale. Several years ago some development work was done, and some of the coal is said to have been burned in a forge. Since then interest in the deposit has waned.