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THE BANNOCK OVERTHRUST

A MAJOR FAULT IN SOUTHEASTERN IDAHO AND NORTHEASTERN UTAH

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INTRODUCTION

In the course of a detailed geologic examination of portions of the Phosphate Reserve in southeastern Idaho during 1911 and 1912, the writers have had an opportunity to study an overthrust fault which appears to be of unusual extent and magnitude. The purpose of this paper is to summarize the stratigraphy of the region and describe a portion of the great fault.

EARLIER WORK

The first geologic report on the general region is that of Peale (18) of the Hayden Survey.[1] The stratigraphy of the region has been modified only to the extent naturally incident to a more detailed study, but the newly described structural feature is scarcely of the same character. It appears that the stratigraphic discordance produced by the great thrust was recognized by the relations shown between the Jura Trias and the Carboniferous on Peale's map. The accompanying text, however, does not make reference to it. The 1909 report on the phosphate deposits by Gale and Richards (**10**) noted the existence of major thrusts in the Montpelier and Georgetown districts, but not enough of the surrounding country had been mapped at that time to suggest the relationship between the two. C. L. Breger (6a) in the same year noted the existence of a similar thrust along the valley of Crow Creek east of Preuss Range. The 1911 report (19a) on a portion of the Phosphate Reserve described a thrust fault which extended through the region west of Bear Lake and north into Nounan Valley. It remained, however, for the 1911 fieldwork in adjoining areas to develop sufficient data for a clearer understanding of the character of the thrust faulting.

STRATIGRAPHY

The rock formations of southeastern Idaho, and the adjoining portion of Utah, comprise a stratigraphic section in which every system from Middle Cambrian to Upper Jurassic or possibly basal Cretaceous is present unconformably overlain by Tertiary and Quaternary deposits. The latter rocks toward the south are sedimentary, but toward the north include extensive basaltic flows which are probably in part as late as the early Quaternary.

In the vicinity of Ogden, Blackwelder (**1**) has noted the presence of the Algonkian and Archean, while to the east of the Wyoming border Veatch (**24**) and Schultz (**20**) have described additional

[1] The blackface figures in parentheses following a name refer to the Bibliography at the end of this paper.

members of the Cretaceous system. These portions of the geologic column do not outcrop within the area with which this paper especially deals and are not included in the generalized section which follows.

GENERALIZED SECTION IN THE REGION OF THE BANNOCK THRUST

	FEET
Quaternary: Alluvium, travertine, basalt flows	
Tertiary (Pliocene?): Marls, marly limestone, and calcareous conglomerates	
Tertiary (Eocene): Sandstones, conglomerates, and limestones	
Unconformity.	
Cretaceous and Jurassic:	
Beckwith formation (24h) (6a), red shales, sandstones, and conglomerates	4,650
Jurassic: Twin Creek limestone (24i) (shaly limestone)	3,500
Jurassic or Triassic: Nugget sandstone (dark red to white sandstone and quartzite)	1,900
Triassic: (4) (22) (23)	
Ankareh shale (a red-bed horizon) shales and mottled limestone	670
Thaynes limestone, thin-bedded sandy limestone with heavy limestones (and locally conglomerate at top?)	2,000
Woodside shale, iron-stained calcareous shale with heavy limestones at top	1,000
Carboniferous:	
Permian?	
Phosphoria formation, 75 to 627 ft., averages	350
Rex chert member, 0 to 450 ft	
Pennsylvanian:	
Wells formation	2,400
Mississippian:	
Limestone, upper Mississippian, light gray, thick-bedded	1,300
Madison limestone, lower Mississippian, thin-bedded, dark gray to bluish-gray	1,000
Devonian: Jefferson limestone (14a) (19b)	750
Silurian: Limestone (13) (19c) (1a)	400
Ordovician: (1c) (19c) Quartzite and limestone	1,450
Upper Cambrian: (25) (26) St. Charles limestone (bluish-gray to gray arenaceous limestones, with some cherty and concretionary layers, passing at the base into thin-bedded gray to brown sandstone	1,197
Middle Cambrian:	
Nounan limestone (light gray to dark lead-colored arenaceous limestones)	814

	Feet
Bloomington formation (bluish-gray, more or less thin-bedded limestones and argillaceous shales; small rounded nodules of calcite are scattered irregularly through many of the layers of limestone)	1,162
Blacksmith limestone (gray arenaceous limestones in massive layers)	23
Ute limestone:	
Blue to bluish-gray thin-bedded fine-grained limestones and shales, with some oolitic, concretionary, and interformational conglomerate layers	731
Spence shale member (argillaceous shales)	30
Langston limestone (massive-bedded bluish-gray limestone with many rounded concretions)	30
Brigham quartzite (massive quartzitic sandstones)	1,000

Two of the formation names, those of the Wells and Phosphoria formations, and the name of one subordinate member, the Rex chert, appear for the first time in the above table. A discussion of the application of these names and detailed descriptions of the beds to which they are applied follow.

PHOSPHORIA FORMATION

The name of the Phosphoria formation is derived from Phosphoria Gulch, which joins Georgetown Canyon at a distance of 2.5 miles N. 16° W. of Meade Peak, Idaho, in which the formation is typically exposed.

The name of the Rex chert member is derived from Rex Peak in the Crawford Mountains, Rich County, Utah, where the chert forms an anticlinal cap. This locality has been described by Gale (10a) and the selection of the name for the member was originally made by him.

The following section is complete and representative of the formation as exposed in the region about Phosphoria Gulch, Idaho.

Complete Section of Phosphoria Formation, Including the Rex Chert Member, Measured in Section 12, T. 10 S., R. 44 E., and Phosphate Shales in Prospect Pit in Section 7 of T. 10 S., R. 45 E.

Description	Thickness Ft.	In.
Shale, black, cherty, weathers red-brown to purple	80	
Chert, in heavily iron-stained ledges	60	

Description	Thickness Ft.	In.
Limestone, gray, banded with ashy gray to black chert	100	
(Thickness of Rex chert member 240 feet)		
Shale, dark brown, weathers light brown, not fetid	1	0
Phosphate rock, gray, coarsely oolitic, with large pebbles, fossils, or oolites near base, some up to 2 inches in diameter; phosphoric acid 36.3 per cent	1	0
Shale, brown, finely oolitic	0	5
Phosphate rock, gray, coarsely oolitic pebbles or oolites up to 1 inch in diameter; phosphoric acid 36.7 per cent	0	8½
Shale, brown, weathers gray, in part finely oolitic	0	2½
Clay, yellow, weathered sandy, concretions up to ¼ inch, 3 grades into above shale	0	8
Phosphate rock, brown, medium oolitic, weathers gray; phosphoric acid 35.3 per cent	0	5
Shale, dark brown, phosphatic	0	2
Phosphate rock, dark brown, weathers gray, medium oolitic, single bed; phosphoric acid 29.4 per cent	0	5
Shale, brown, sandy with concretions up to 1 inch	0	5
Phosphate rock, gray, coarsely oolitic; phosphoric acid 35.9 per cent	1	2
Shale, dark brown to black, finely oolitic	0	3
Phosphate rock, coarsely oolitic; phosphoric acid 35.9 per cent	0	4
Shale, brown, sandy	0	1
Phosphate rock, medium oolitic	0	1½
Shale, brown, weathers gray with bluish tinge, finely oolitic	0	5
Phosphate rock, black, soft, medium oolitic	0	2
Shale, brown, calcareous	0	4
Phosphate rock, black, medium oolitic, soft	0	1
Shale, brown, oolitic in thin streaks	0	2
Phosphate rock, gray, coarse to finely oolitic; phosphoric acid 33.2 per cent	0	11
Phosphate rock, brown, finely oolitic, shaly	0	3
Phosphate rock, brown, medium oolitic	0	4
Shale, brown, with ¼-inch streak of oolitic rock near base	0	6
Phosphate rock, dark brown, coarse to finely oolitic, shaly in places; phosphoric acid 33.2 per cent	0	9
Phosphate rock, gray, coarsely oolitic, includes ½ inch of shale near base; phosphoric acid 37 per cent	1	1
Limestone, drab, impure	0	5
Phosphate rock, medium to finely oolitic	0	3

Description	Thickness Ft.	In.
Shale, brown, weathers gray	0	9
Phosphate rock, dark gray, coarsely oolitic, soft	0	2
Shale, brown	0	3
Phosphate rock, dark gray, coarsely oolitic, with several shaly partings less than ⅛ inch thick; phosphoric acid 30 per cent	0	10
Limestone, lenticular	0	10
Phosphate rock, dark brown, medium to finely oolitic; phosphoric acid 26.1 per cent	9	8
Shale, black, in part finely oolitic	3	0
Shale, brown, partly weathered to clay	1	8½
Shale, black, phosphatic, in part finely oolitic	6	6
Shale, brown, with concretions up to 2 inches in diameter	0	10
Shale, rusty brown to yellow, with a few concretions up to 1 inch in diameter	1	8
Shale, dark brown, with thin pebbly or concretionary bed at top, phosphatic in places	16	6
Pebbly or concretionary bed, concretions up to 2 inches in diameter	0	3¼
Shale, brown	1	2
Shale, black to dark brown	0	9
Pebbly or concretionary layer, phosphatic	0	3
Shale, black, slightly oolitic	0	7
Shale, with pebbles or concretions up to 2 inches in diameter	0	6
Shale, brown, weathers to ochreous soil	3	4
Pebbly or concretionary bed	0	4
Shale, brown, weathers to ochreous soil	2	3
Pebbly or concretionary bed, phosphatic	1	0
Shale, brown, phosphatic	2	6
Shale, black, thin-bedded	0	6
Clay, ochreous	0	10
Shale, brown	1	0
Shale, black to light brown, slightly phosphatic	11	0
Limestone, broken, and intermixed with shale	6	0
Shale, broken, and weathered, only slightly phosphatic	21	0
Shale, black, phosphatic, finely oolitic, estimated to contain phosphoric acid 20 per cent	5	6
Shale, brown, weathers yellow, concretionary	1	0
Limestone, purplish-drab, lenticular	0	8
Shales, dark, broken, and weathered	15	0
Phosphate rock, broken, weathered drab	3	0
Soil, black, fetid	9	0

Description	Thickness Ft.	Thickness In.
Shale, black, phosphatic, finely oolitic	5	6
Limestone, dark, fetid	0	6
Shale, brown, somewhat phosphatic, contorted	15	0
Limestone, dark gray, dense ("Cap Lime" fossils)	3	0
Phosphate rock, dark brown, medium oolitic, soft, broken, apparently high grade*	7	0
Shale, brown, contorted, soft	1	0
Sandstone, white, calcareous, weathers buff. Top of Wells formation		
Thickness of phosphate shales	175	2½
Thickness of formation	415	

*Corresponds to bed from which sample 144S was taken. (10c)

The Phosphoria formation is the equivalent of the upper two members of the Park City formation (4a) (10b) as heretofore mapped in the phosphate district of Idaho and Utah, namely, the "overlying chert" and the phosphate shales. These members have also been recognized in the type section (4a) of the Park City in Cottonwood Canyon by H. S. Gale,[1] who reviewed the section in 1909 and noted the presence of phosphate rock. Gale regards the upper 129 feet of Boutwell's section (4a) as approximately equivalent to the chert member, and the underlying 112 feet as representing the phosphatic shale interval.

The remaining 194 feet is predominantly siliceous but contains a number of prominent limestone beds and is evidently comparable to the underlying siliceous limestone or calcareous sandstone of the phosphate districts.

The Park City formation was first referred by Boutwell to the Pennsylvanian, but in his later work on the district (5) has been referred as a whole doubtfully to the Permian. The lower portion contains the bonanzas for which the Park City district is famous and is therefore the essential part of the formation. This member is now upon additional faunal evidence referred to the Pennsylvanian.

The Phosphoria formation is also correlated with the upper portion of the Embar formation of Wyoming (8a) (9a) (3a), and

[1] Personal communication.

the phosphatic beds above the Quadrant formation of certain areas (11) (1) in southwestern Montana.

The Rex chert member is the conspicuous portion of the Phosphoria formation, and because of its superior hardness it stands out in salient topographic features. The phosphate shales on the other hand are comparatively non-resistant and the development of gulches along them is characteristic.

Locally 50 to 75 feet above the base the Rex chert gives way to gray limestone and in other places a dark gray to black or purplish flinty or cherty shale occupies the major portion of the Rex chert interval, but more generally the shaly facies is present near the top of the section and is occasionally with difficulty distinguished from the basal portion of the Woodside shale.

The Rex chert is generally non-fossiliferous but locally contains sponge spicules and casts of crinoid stems. Dr. Girty lists the following as the most characteristic species:

Productus multistriatus
Productus subhorridus
Spirifer aff. cameratus
Spiriferina pulchra
Composita subtilita var.

At a locality on Deer Creek in the Preuss Range Dr. Girty obtained the following fauna from the limestone facies of the Rex chert:

Amphoporella laminaria
Productus nevadensis
Productus eucharis
Productus multistriatus(?)
Camarophoria n. sp.

The basal portion of the Phosphoria formation consists of 75 to 180 feet of yellowish to brown phosphatic sandstones and shales with 1 to 3 economically important beds of rock phosphate and occasional dark fetid limestones in beds and lenses ranging from 3 inches to 2 feet in thickness.

The fauna of the phosphate shales is an extensive one and has been studied by Dr. Girty, who has selected the following characteristic list from his bulletin (12) on the subject:

Lingula carbonaria (?)
Lingulidiscina missouriensis
Chonetes ostiolatus
Productus geniculatus
Productus eucharis
Productus montpelierensis
Productus phosphaticus
Pugnax weeksi
Pugnax osagensis var. occidentalis
Ambocoelia arcuata
Leda obesa
Plagioglypta canna
Omphalotrochus ferrieri
Omphalotrochus conoideus
Hollina emaciata var. occidentalis

The distribution of the Phosphoria formation, so far as at present known, is limited to portions of southeastern Idaho, northeastern Utah, and western Wyoming.

WELLS FORMATION

The Phosphoria formation is normally underlain by 2,400 feet of sandy limestones, calcareous sandstones, and quartzites of somewhat variable character. These beds are here grouped in a formation whose name is derived from Wells Canyon in T. 10 S., R. 45 E., on the north side of which a detailed section was measured. The stratigraphic interval is probably the same as is represented by the Morgan, Weber, and a portion of the Park City formations of northeastern Utah. In the Idaho field, however, these rocks show such variable lithologic features that it has been found impracticable to apply successfully the names Weber and Morgan over a major portion of the area. Furthermore, Dr. Girty comments that there is no faunal assurance that these divisions as recognized are actually the equivalents of the formations in Weber Canyon, Utah. Faunal and structural grounds make it advisable to include in the formation the limestone that normally underlies the phosphate shales and has hitherto been included in the Park City formation (10b) (19d).

The following section was measured at the type locality.

GEOLOGIC SECTION OF BEDS EXPOSED ON NORTH SIDE OF WELLS CANYON, IDAHO

WELLS FORMATION

	FEET
(1)	
Limestone, light brownish-gray, sandy *Squamularia* or *Composita*, possibly *Productus* crinoid stems	5
Chert, bluish-gray	1
Limestone, light brownish-gray, sandy	44
(2)	
Concealed	172
Sandstone, gray, calcareous, fine-grained in loose blocks and thin beds of quartzite or chert	150
Concealed	50
Sandstone, whitish, soft, in loose blocks, weathers like limestone, includes small quartz-lined geodes, poorly exposed, and partly represented by sandy soil and small fragments	350
Limestone, light bluish-gray, earthy with considerable dark chert	230
Sandstone, yellowish to red, in large blocks weathered rounded	100
Sandstone, whitish, rather soft	150
Quartzite, white, weathers pink to red, in large loose slabs, laminated and cross-bedded	200
Limestone, in part clear, in part cherty	200
(3)	
Limestone, dark gray with large chert concretions, fossil collection No. 45	200
Limestone, sandy, alternating with quartzite and clearer limestone	400
Sandstone, whitish, fine-grained, one bed	2
Sandstone, red in part, nearly quartzite, cross-bedded	100
Limestone, sandy, with quartz-lined geodes, one bed	3
Sandstone, white to reddish, soft, bears abundant *Schizophoria;* also represented by fossil collections Nos. 28 and 32 for near-by locality	35
Sandstone, one bed	2
Sandstone, thin-bedded; fossil collection 101c	6
Total thickness, Wells formation	2,400

UPPER MISSISSIPPIAN

	FEET
Limestone, earthy with chert in irregular concretions and streaks parallel to bedding	20
Limestone, light gray to whitish, thin-bedded; fossil collection 101	46
Sandstone, white, calcareous, bears large *Zaphrentoids*	14
Limestone, dark gray crinoidal, includes a *Martinia* horizon, about	100
Shale and reddish quartzite fragments, about	30
Quartzite, whitish, outcrops small and scattered, bears small *Zaphrentoids*	270
Concealed	200
Limestones, gray, in 1- to 3-foot beds, fossil collections	450
Base of upper Mississippian not exposed.	
Thickness of upper Mississippian exposed	1,130
Total thickness of section	3,530

It will be noted that in this section it is possible to subdivide the Wells formation into three portions, an upper calcareous sandstone or siliceous limestone, a middle sandy series, and a lower sandy and cherty limestone series, the lower two of which, however, do not correspond with the Weber and Morgan formations in Weber Canyon, Utah. Dr. Girty has recently reviewed the section at the latter locality and states that the order of lithologic succession is quartzite, calcareous sandstone, and red quartzite.

The variations which occur in the three portions of the Wells formation have been studied throughout the general area under discussion and in brief are as follows:

The upper limestone ranges from a maximum thickness of 75 feet down to a feather edge. It consists of a dense gray calcareous sandstone grading locally to siliceous limestone, which weathers into white massive beds that are topographically conspicuous as cliff makers. Bluish-white chert occurs in it in bands 2 inches to 1 foot thick and locally in ovate nodules. Toward the base the chert becomes more nodular and darker. Silicified fragments of brachiopods project in little crescents from the weathered surfaces of the limestone. This member is usually sparingly fossiliferous but, in the vicinity of Swan Lake, Dr. Girty reports a limited fauna (12*a*).

Local unconformity.—Locally the upper cliff-making limestone (1) is absent from the section and the Phosphoria formation then rests directly upon the more siliceous portion of the Wells formation, which in these places is composed of a breccia of chert and quartzite, similar to that described by Blackwelder (1d) under practically identical conditions, and it appears to the authors that this relationship represents another instance of a brief erosion interval in this part of the geologic section. Dr. Girty says (personal letter):

> The upper part of the Wells formation is usually nearly barren of fossils. Occasionally large *Producti* of the *semi-reticulatus* group are found as at Station 49 (T. 9 S., R. 45 E., sec. 35 SW $\frac{1}{4}$ SE $\frac{1}{4}$); rarely, however, in identifiable condition. Some well preserved examples obtained at this horizon near Swan Lake (Bannock County) show a form closely allied to *Productus Ivesi*. In that region also a small spiriferoid is very abundant, occurring as silicified fragments which project from weathered surfaces like small arched scales. When they can be identified these fossils belong to a species of *Squamularia* related to *S. perplexa*.

The middle portion (2) comprises 1,700 to 1,800 feet of sandy limestone with occasional thin beds of quartzite and sandstones, weathering white, red, or yellow, and forming smooth slopes with few projecting ledges. This portion is sparingly fossiliferous or non-fossiliferous. No fossils have yet been found in it. Locally a siliceous facies becomes strongly developed and this portion is then comparable with the Weber quartzite of Utah.

In the section under discussion sandy and cherty limestones with thin interbedded sandstones are conspicuous in the lower portion (3) of the Wells formation. The maximum observed interval of beds included in this facies is about 750 feet. Within a distance of 2 miles to the north the same interval was found on careful study to comprise only about 100 feet of beds. The cherty limestones are topographically important as ledge-makers and carry a fauna which, according to Dr. Girty, is probably similar in age to, although not specifically identical with, that found in the Morgan formation of Utah. Blackwelder (1e) has described the Morgan formation as composed of red sandstone, shale, and thin intercalated limestones, so that, lithologically, it is wholly distinct from the cherty limestones described above. Dr. Girty has contributed the following faunal lists of collections from the Wells formation together with the following comments:

At the very base of the Wells formation a *Schizophoria* is often very abundant, apparently the same species as White identified in New Mexico as *S. resupinoides?* (Lot 101c). A short distance above a more varied fauna is usually found in which a large variety of *Spirifer rockymontanus*, the same which I identified in Colorado as *S. boonensis*, is specially abundant (Stations 28 and 32). Large branching *Stenoporas* related to *S. carbonaria* are also a feature of this fauna. Another phase of the lower Wells fauna is shown in Lot 33. In this assemblage of species *Marginifera splendens* is extremely common and large branching *Stenoporas* are also plentiful.

Lot 33

T. 9 S., R. 45 E., sec. 22, SW corner. From beds about 500 feet above base of Wells formation.

Stenopora Wellsiana	Productus Cora
Stenopora gracilis	Productus Nebraskensis
Stenopora Idahoensis	Productus semireticulatus
Stenopora ? sp.	Marginifera splendens
Derbya sp.	Spirifera rockymontanus

Lot 45

See section.

Zaphrentis Gibsoni	Productus semireticulatus
Monilipora Prosseri	Spirifer cameratus
Rhombopora lepidodendroides	Composita subtilita
Productus Cora	Euconospira n. sp.

Lot 28

T. 9 S., R. 45 E., sec. 35, SE ¼.

Spirifer rockymontanus
Myalina aff. Kansasensis
Aviculopecten sp.

Lot 32

Same locality as Lot 28 but from beds about 150 feet lower in the section.

Stenopora Idahoensis	Productus Cora
Stenopora ? sp.	Spirifer rockymontanus
Batostomella ? sp.	Composita subtilita
Derbya sp.	Myalina sp.

Lot 101c

See section.

Schizophoria resupinoides ?

UPPER MISSISSIPPIAN LIMESTONE

The Wells formation in southeastern Idaho rests in apparent conformity upon limestone of upper Mississippian age. In Utah, however, Blackwelder (1f) has observed an unconformity at this position in the section. These limestones represent an unnamed formation comprising about 1,130 feet of beds. Lithologically they are massive gray, light to dark colored, weathering white to light gray. Locally a dark shale zone is developed near the top about 15 feet thick. In places also chert nodules with concentric and irregular forms and streaks of chert are present. The limestones are sometimes specked with siderite and seamed with calcite or aragonite, and are abundantly fossiliferous in some horizons. The fauna includes large cup corals with many fine septa, *Syringopora*, *Lithostrotion*, *Martinia*, and *Productus giganteus*. The Martinias are found in a bed near the top of the formation. A fauna collected at Ross Fork–Lincoln Creek (Idaho) by Meek (17) and later by Girty (19e) at Swan Lake which is comparable to that of the Spergen limestone of the central basin region of the United States is included at the Swan Lake locality in the upper Mississippian limestone interval.

The formation constitutes much of the Preuss Range and is well exposed in Meade Peak, the culminating point of that range. No complete section has been measured because of structural interruptions, but it is expected that future studies in the Ross Fork locality may afford a more favorable opportunity to obtain this, and the selection of a type locality for the formation is deferred for the present.

The authors are also indebted to Dr. Girty for the following faunal list and comments:

An interesting and varied fauna has in places been obtained from the upper part of the upper Mississippian. It is shown by the list of forms collected at Station 101. A short distance below this collection a new species of *Martinia* was found in countless numbers constituting a bed a foot thick. Very abundant also in local occurrences is a small variety of *Productus giganteus*. Large Zaphrentoid corals are likewise a feature of the upper Mississippian, often occurring associated with *Syringopora* and one or more species of *Lithostrotion*. These colonies are sometimes of great size. Here too is sometimes found an assemblage of small forms more or less related to the "Spergen" fauna reported by Meek from Ross Fork. The horizon of all these rather strikingly different facies appears to be below that of Station 101.

101

Zaphrentis sp.	Edmondia ? sp.
Stenopora sp. a	Conocardium sp.
Stenopora sp. b	Schizodus sp.
Stenopora ? sp.	Sphenotus sp.
Batostomella ? sp.	Myalina aff. Sanctiludovici
Rhombopora ? sp.	Leptodesma aff. Spergenense
Productus semireticulatus	Sulcatipinna Ludlowi ?
Productus semireticulatus var.	Parallelodou ? sp.
Productus pileiformis	Cypricardinia ? sp.
Productus punctatus var.	Aviculipecten sp. a
Productus aff. longispinus	Aviculipecten sp. b
Diaphragmus elegans	Aviculipecten sp. c
Camarophoria Wortheni	Pseudomonotis ? sp.
Dielasma sp.	Laevidentalium venustum ?
Spirifer striatus ?	Naticopsis sp.
Spirifer increbescens ?	Straparollus similis var.
Spiriferina sp.	Bulimorpha aff. elongata
Composita trinuclea ?	Griffithides sp.
Edmondia sp.	Phillipsia sp.

THE BANNOCK FAULT

The field seasons of 1909 and 1910 led to the recognition by members of the U.S. Geological Survey of important thrust faults in southeast Idaho (10d, e) and adjacent parts of Utah (10f, g). In 1911 the study of the great fault east of Georgetown, Idaho, led to the view that several of these faults, formerly considered distinct, are in reality parts of one great overthrust, for which the name Bannock is proposed, from Bannock County, Idaho, where the fault is strikingly developed. The individual faults which have been thus united and the facts upon which the interpretation rests are described below (Fig. 1).

GEORGETOWN FAULT

In 1909 a thrust fault involving the superposition of Mississippian limestones upon rocks of Jurassic or Cretaceous age was recognized by Gale (10d) in Georgetown Canyon about 5 miles

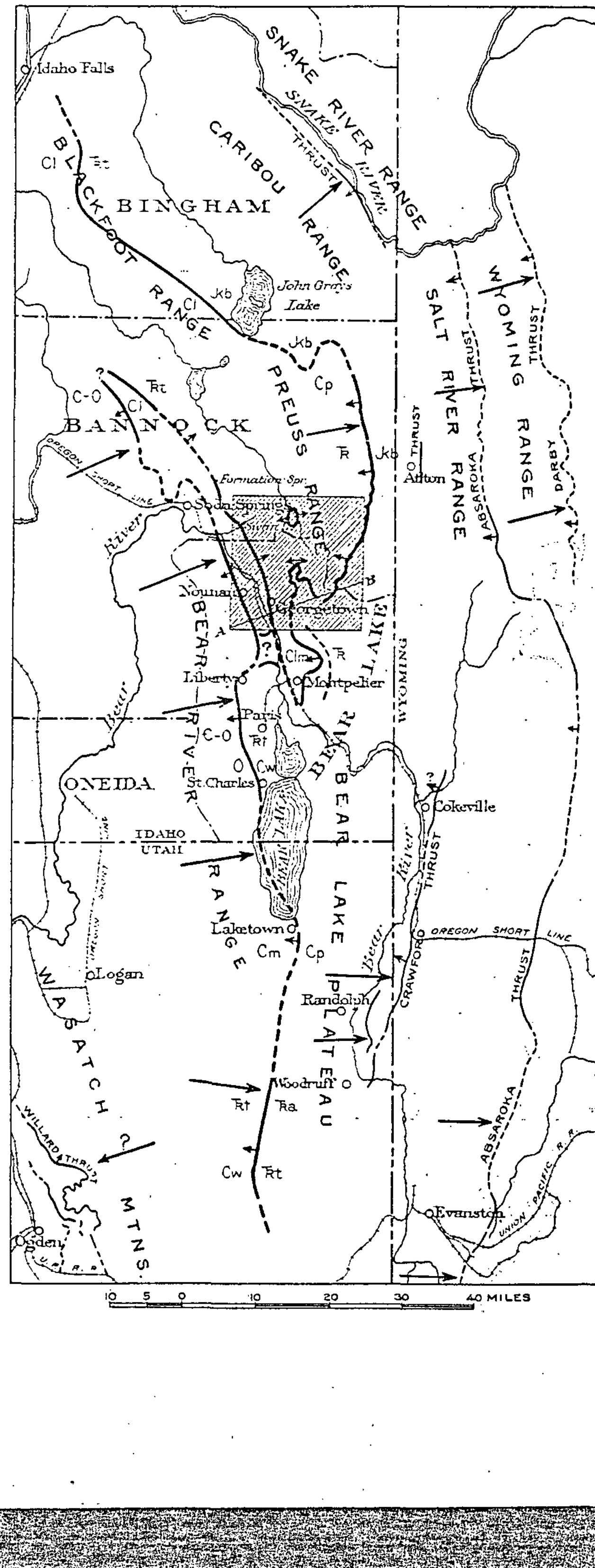

FIG. 1.—Sketch map of southeastern Idaho and portions of adjacent states.

Explanatory notes.—The trace of the Bannock thrust is shown by the heavy broken line. The shaded area is more fully illustrated by the stereogram, Fig. 2, and the geologic structure along the line *A–B* is represented by Fig. 5. The letter symbols signify as follows: *Jkb*, Beckwith formation; *Jtc*, Twin Creek limestone; *Tr*, Triassic undifferentiated; *Trn*, Nugget sandstone; *Tra*, Ankareh shale; *Trt*, Thaynes limestone; *Cp*, Phosphoria formation; *Cw*, Wells formation; *Cl*, Upper Mississippian limestone; *Cm*, Lower Mississippian (Madison) limestone; *Clm*, Mississippian undifferentiated; *O*, Ordovician; *C*, Cambrian.

northeast of ıe village of Georgetown (see map). In 1911 this district was ›ited by the writers and the fault was studied and mapped in gı ater detail. From the north fork of Georgetown Canyon, wher the fault emerges from beneath the late conglomerates, its .nuous course was followed across the Preuss Range into Crow Cre ς as far as the mouth of Sage Creek (Fig. 2), a distance of appr ›ximately 30 miles, and here it appeared to continue northward.

The sinuos· of the fault trace is due not only to erosion but to deform· ›on as well. In the north fork of Georgetown Canyon an anticlinal axis has arched the thrust surface or plane so that it has been partly removed and the underlying Nugget and Twin Creek formations are exposed in the valley, while long strips of heavy Mississippian limestone reach down the spurs of the ridges like the fingers of some giant hand (see Figs. 1 and 2). A synclinal axis depresses the thrust surface where it passes beneath the Preuss Range in the headwaters of Montpelier Creek. In this region there is a marked contrast between the massive and castellated limestones of the Mississippian that constitute the upper part of the ridge and the chippy and shaly limestones of the Twin Creek formation that are exposed along the lower slopes of the valley side.

In Georgetown Canyon and southeast across the Preuss Range (Fig. 3) the same relations obtain. The underlying Twin Creek beds are folded so that the stratigraphic throw cannot be obtained with accuracy, but the missing formations, including Pennsylvanian to Triassic (?) rocks (Nugget), represent a minimum vertical displacement of about 8,500 feet. Eastward the throw apparently diminishes partly by the agency of branching faults and partly on account of the folded structure of the rocks in the upper block.

The general trend of the trace of the fault appears to be a few degrees to the west of north and the direction of thrust a little to the north of east. The dip of the fault surface gives little aid in determining the direction of movement because of its present deformed condition. The older rocks, however, lie to the west and the thickness of the thrust block appears to increase in that direction.

The distance, perpendicular to the general trend, between the

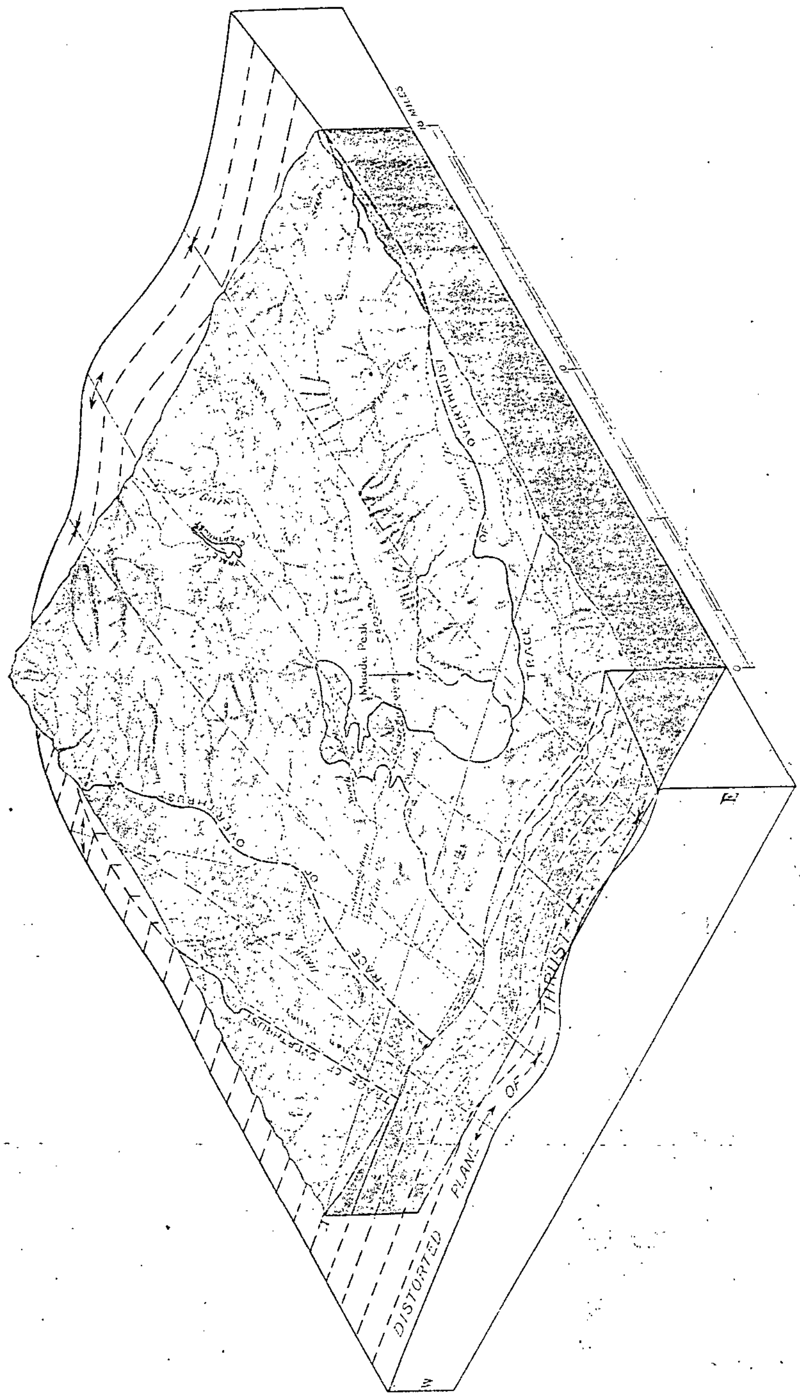

FIG. 2.—Stereogram of a portion of the region including the trace of the Bannock thrust. The location of the area is shown on Fig. 1. The direction of movement was in general from west to east and approximately parallel to the line of the structure section A–B.

Fig. 2.—Stereogram of a portion of the region including the trace of the Bannock thrust. The location of the area is shown on Fig. 1. The direction of movement was in general from west to east and approximately parallel to the line of the structure section *A–B*.

westernmost observed portion of the fault trace in Georgetown Canyon and the easternmost portion of that trace in Crow Creek is about 12 miles. It appears, therefore, that the heave may be equal at least to that distance.

In the ridge west of Slug Creek (Fig. 2) an elongate area apparently surrounded by a fault boundary is interpreted as an anticlinal portion of the main thrust, or of a subordinate thrust, unroofed by erosion so that the underlying block is exposed through a "window" or "fenster." The position of this window with reference to the anticline in the north fork of Georgetown Canyon is favorable to this interpretation.

JOHN GRAYS LAKE AND BLACKFOOT FAULTS

Reconnaissance by the senior author and Dr. A. R. Schultz of the U.S. Geological Survey northward from the area above described and in the vicinity of John Grays Lake developed the presence of a thrust fault of similar magnitude in that region. While this fault has not been traced directly into the Georgetown fault, from the position of the thrust and its general relations it is interpreted as a continuation of that fault. The northwestward extension of the John Grays Lake fault is concealed by flows of basalt. A similar thrust was recognized in the same reconnaissance in the Blackfoot Range. The alignment and the

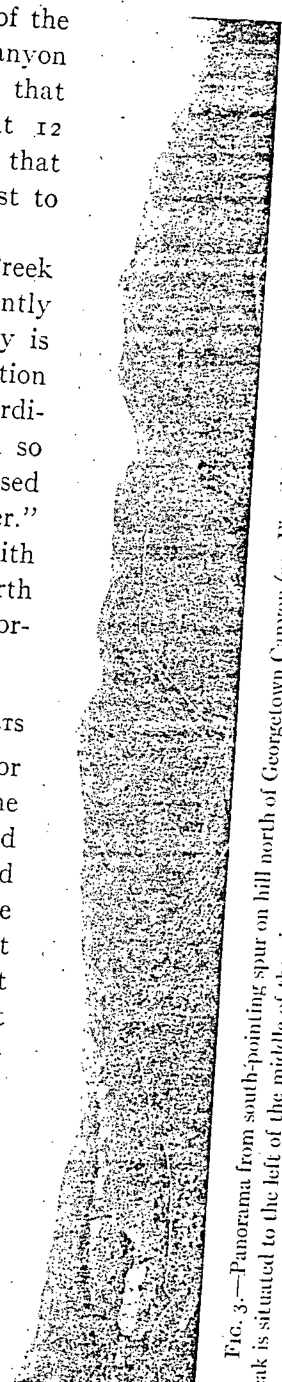

Fig. 3.—Panorama from south-pointing spur on hill north of Georgetown Canyon (see Fig. 2) looking northeast to nearly due south. Meade Peak is situated to the left of the middle of the picture. The trace of the Bannock thrust and a sharp drag fold in the overthrust Mississippian limestone is shown in the left foreground. The trace of the Bannock fault is also indicated on the divides between Georgetown and South Canyons, the latter and Dunn's Canyon; thence to the head of the latter where it crosses to the head of Montpelier Creek where it appears in Fig. 4. For explanation of letter symbols, see Fig. 1.

effects of the two are practically identical and they clearly may represent the same crustal break.

MONTPELIER FAULT

The work of Gale and Girty in 1909 (10e) in the Montpelier district demonstrated the existence near Montpelier of a great thrust fault in which heavy Mississippian limestones from the west were overthrust upon Lower Triassic formations, the Woodside, Thaynes, and Ankareh. Northward, southward, and westward the fault trace passes beneath the cover of late deposits. To the south no further indication of thrust faulting has been recognized on the east side of Bear Lake Valley, though a normal fault of considerable importance lies along the east shore of Bear Lake. To the north, however, at no great distance lies the Georgetown thrust fault, in which the structural relations of older and younger rocks are closely similar to those of the Montpelier district. There seems therefore good reason for the supposition that the two faults are continuous beneath the covering of alluvium and Tertiary deposits.

SWAN LAKE FAULT

In 1910 the writers found a thrust fault along the west base of the Aspen Range east of Bear Lake Valley, particularly well developed near Swan Lake, about 7 miles southeast of Soda Springs (Fig. 1). Here similar conditions hold and Carboniferous limestones lie upon Triassic rocks. The dip of the fault plane here appears to be eastward but this feature may, as in the Georgetown block, be due to deformation of the fault plane, for the source of the older rocks appears to be to the west as in the Georgetown fault. The trace of the Swan Lake fault is marked by the occurrence of sulphur and calcareous springs and also by great deposits of travertine, of which Formation Spring, 3 miles northeast of Soda Springs, with its basins and terraces is a beautiful example. In the 1910 report (19f) it was argued that these springs marked the trace of a normal fault that cut the Carboniferous thrust block along the west base of the Aspen Range. In the light of the later studies in the Georgetown region it seems probable that all the features ascribed to the normal fault can be better explained by the deformation of the thrust fault surface here described. Southward deposits of travertine occur at intervals along the base of the range to a point opposite the mouth of Three Mile Creek, about 3 miles south of Georgetown. It seems probable therefore that the Swan Lake fault is closely related to the Georgetown fault and may represent a part of the same thrust plane so deformed as to constitute the west limb of a gentle syncline. This interpretation is shown on the map and stereogram (Figs. 1 and 2).

WEST BEAR LAKE FAULT

In 1910 the writers encountered a great thrust fault on the west side of Bear Lake near Paris. This fault was followed southward beyond St. Charles, and northward beyond Soda Springs, a distance of over 45 miles (Fig. 1). The fault surface or plane appears to dip gently west. The upper block comprises rocks of Cambrian to Devonian age, while the underlying rocks are Pennsylvanian Lower Triassic (Upper Wells to Thaynes). Hence the structural relations here are similar to those of the Georgetown–Swan Lake fault except that the range of the formations involved and the magnitude of the throw are somewhat greater. The presence of two such great and similar overthrusts upon opposite sides of Bear River Valley, together with the known fact of deformation in the eastern fault, leads to the interpretation that the West Bear Lake fault and the Georgetown–Swan Lake fault are parts of the same great thrust fault, and that they have been separated by the partial erosion of an anticlinal fold in the thrust plane (see map and stereogram, Figs. 1 and 2).

FAULTS NEAR LAKETOWN AND WOODRUFF, UTAH

In 1909 Gale and Richards reported the existence of thrust faults at Laketown (10f) and near Woodruff (10g), Utah. These faults also represent movements from the west and bring rocks of Mississippian or greater age over younger formations. It is not possible to follow these faults and to trace their connection with each other and with the West Bear Lake fault to the north because of the extensive development of Tertiary beds (Eocene) in the intervening area. Their position and structural relations lend support to the view that they represent the southern continuation of the great thrust fault to the north. This interpretation is tentatively shown on the map (Fig. 1).

MAGNITUDE OF THE BANNOCK FAULT

The trace of the Bannock fault as above constituted with its major sinuosities as represented on the map (Fig. 1) extends approximately 270 miles from the vicinity of Woodruff, Utah, to the region north of John Grays Lake. The general trend of the fault trace is slightly west of north and the direction of movement must have been perpendicular to that trend and, as indicated in the above discussion, was probably from the west.

The structure of the underlying block, as shown in the mountainous portion of the region, comprises a series of folds, for the most part close and overturned toward the east. Figs. 4 and 5 (photo and cross-section) show folds in the overridden Twin Creek limestone in the upper waters of Montpelier Creek. The large alluvial area at the north end of Bear Lake Valley and extensive areas masked by Tertiary detrital deposits render the structure of the underlying rocks problematical. This structure must, however, be determined before the place of origin and the amount of displacement effected by the thrust can be satisfactorily determined. It has been pointed out that in the Georgetown Canyon region the missing formations indicate a minimum vertical displacement in that locality of about 8,500 feet. On the west side of Bear Lake where Cambrian or Ordovician quartzites overlie Woodside and Thaynes formations the minimum throw on the same basis would probably be at least 12,000 feet.

The structure section (Fig. 5) along the line *A–B* contains one of the best exposures of the underlying block and a minimum amount of cover. The section represents the supposed attitude of the deformed fault plane.

Cambrian rocks nowhere rise to the level of the fault surface in the region traversed by the section. It therefore follows that the Cambrian portion of the overthrust block at the extreme west end of the section must have been derived from a fold lying to the west of this point, the structure of which is concealed by the overthrust block.

A clue to the minimum horizontal displacement is suggested by the possibility that the Mississippian limestones of the western fold of the structure section may represent the source of the overthrust mass of these formations that lies some 12 miles to the east. The source can certainly not be nearer, for the Mississippian limestones do not rise to the level of the fault plane in any of the folds farther east in this district. Furthermore, the size of the Mississippian limestone mass, as inferred from known conditions north and south of the line of the section, suggests that either the westernmost fold of the section has not been made large enough, or that the source was a more westerly fold. These considerations make it apparent that the amount of horizontal displacement is not less than 12 miles.

Another measurement of the horizontal displacement may be expressed by a line drawn perpendicular to the general trend of the fault trace and extending from the westernmost point on the trace

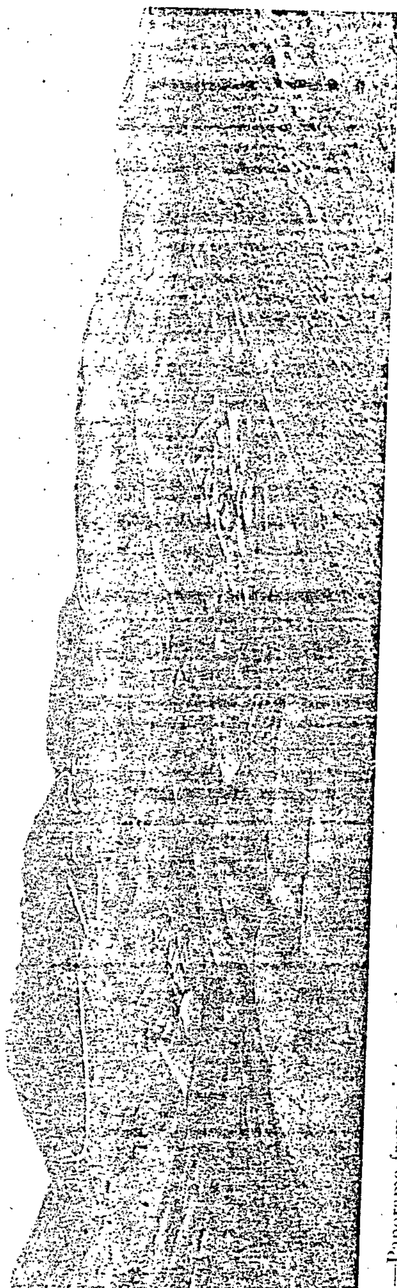

FIG. 4.—Panorama from point near the southeast corner of area shown in Fig. 2. The direction of view is northwesterly. The southern tip of the uneroded portion of the overthrust block and the position of the subordinate branch fault, together with the approximate character of geologic discordance is indicated. A syncline and parallel anticlines are visible in the foreground (in the Twin Creek limestone). For meaning of letter symbols see Fig. 1.

to the easternmost point on the east margin of the fault block. The length of such a line is about 35 miles. This, however, neglects the recession produced by erosion along the east margin of the fault block.

AGE OF THE THRUST

The youngest rocks involved in the faulting are sandstones of the Beckwith formation, which may in part be of early Cretaceous age. The oldest rocks which have been found concealing its trace are the conglomerates of the Almy formation (24a) which represents the basal portion of the Wasatch group as defined by Veatch.

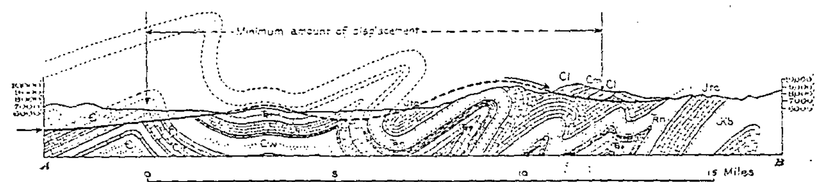

FIG. 5.—Geologic structure section along the line *A–B* in Figs. 1 and 2. The meaning of the letter symbols is explained under Fig. 1 with the exception of *Trw*, which represents Woodside shale.

The possible range of age is then from late Cretaceous to early Eocene, and it is probable that the faulting may have occurred during the interval represented by the unconformity between the Adaville (24b) and Evanston (24e) formations of Veatch.

DEFORMATION OF FAULT PLANE

The arrow points distributed along the fault trace on the map (Fig. 1) indicate in a general way the present attitudes of the fault plane. The stereogram (Fig. 2) shows the nature of these folds as present and reconstructed for a block 18 miles square. The location of Fig. 2 is indicated by the shaded area on the map, Fig. 1. The plications comprise two anticlines, two synclines, and portions of the adjoining folds. The trend of these folds is slightly west of north. Erosion has completely unroofed the western anticline and has made a considerable start on the second. The exposure of a closed area of the underlying block through a "window" or "fenster" in the overthrust has already been mentioned.

Deformation of fault planes is usually attributed to a renewal of the compressive forces and the folding tends to continue along the lines formerly developed. In the vicinity of Meade Peak near the south end of the Preuss Range, where the best opportunity has been found to study the character of the deformation, a well defined syncline has been developed almost directly under a sharp anticline in the overlying beds. The question is raised as to whether or not the deformation of the plane of the thrust may be due to the load of the overlying anticlinal mass rather than lateral pressure. The dip of the fault plane that branches from the main fault and extends under the east flank of Meade Peak (Fig. 4) is steep and in places appears to be inclined westward. These facts are regarded as unfavorable to the latter view.

PARALLEL ASSOCIATED THRUSTS

Extensive overthrust faults are by no means a novel feature of the region, and faults have been previously described immediately east and west of the trace of the Bannock. The position of these faults has been shown upon Fig. 1.

Western Wyoming.—Peale (18a), Veatch (24d), and Schultz (10a) have described portions of the great Absaroka thrust, the trace of which lies about 8–25 miles east of the state boundary.

The throw in two localities (24e) described by Veatch is over 15,000 and 20,000 feet respectively. In the latter place rocks of Triassic age rest upon rocks of middle Cretaceous age—specifically, the Thaynes limestone upon the Oyster Ridge sandstone member of the Frontier (24f) formation.

North of these areas Schultz reports that the throw is of the same amount. The Darby, another overthrust which has been mapped by Schultz (20b), has a maximum exposed horizontal displacement of 3 miles. Labarge Mountain, which is a part of the overthrust block overlying the plane of the Darby fault, is composed in part of rocks of Cambrian age. This is, according to Schultz,[1] the easternmost exposure of the Cambrian rocks which make up the greater part of the Bear River Range in Utah and Idaho, a distance of over 50 miles to the west. It is possible, then, that the rocks present in Labarge Mountain may have been derived from the region of the Bear River Range.

[1] Personal communication.

Between the Absaroka and Bannock thrusts there appears to be at least one extensive parallel thrust zone. The Crawford thrust (24g) or the parallel fault (10h) immediately to the west may represent the southern end, while the faults reported in the vicinity of Cokeville (10i), Afton (18b), and observed by the senior author and A. R. Schultz in the Snake River region, represent the northward continuation.

These overthrusts are held by Veatch (24) and Schultz (20) to have occurred near the close of the Cretaceous period.

Ogden, Utah.—In the vicinity of Ogden, Blackwelder (1) has recently described several overthrusts. The major of these, the Williard thrust, causes lower Algonkian slates and graywackes to overlie Cambrian and Carboniferous sediments. The thrust plane has an average easterly dip of 15° but locally is as high as 50°. Blackwelder holds that subsequent deformation of the plane has been slight and that the apparent distortion is mainly due to original undulation. The maximum exposed horizontal displacement of 4 miles is probably only a small fraction of the total heave. The direction of movement is naturally inferred to be westward from the inclination of the thrust plane. The writers suggest that broader regional studies are necessary before a westward direction of movement can be regarded as proved. It may well be that the present eastward inclination of the fault plane is the result of deformation, as is clearly the case in many places along the trace of the Bannock thrust.

Blackwelder described two other thrusts in the Ogden region, one which produces discordant relations within the Cambrian, and another which causes Carboniferous limestone to overlie Cambrian shales and quartzites.

Blackwelder concludes that the Ogden thrusts "are of Cretaceo-Eocene age."

RELATION OF BANNOCK THRUST TO PARALLEL THRUSTS

The fact that the several portions of the Bannock thrust as described have been isolated by erosion and disguised by subsequent deformation makes it possible that future study will show that outliers of the overthrust block lie to the east of the margin of the Bannock thrust as at present defined.

The additional possibility should not be overlooked that the known thrusts of probably identical age lying to the east and to the west may in reality bound portions of the same overthrust mass which have been isolated by erosion.

North of the region of the Bannock thrust and in what appears to be the same zone of crustal readjustment, faults of great magnitude are known to exist. One in Montana, on the east side of the Bitterroot Mountains, has been described by Lindgren (15), another in the vicinity of Philipsburg, Montana, by Calkins (7), and the Lewis thrust in northern Montana and southern British Columbia which has been described by McConnell (16), Willis (27), and more recently studied by Campbell.

The last two are clearly thrusts the planes of which have been deformed, and all three may eventually prove features of the same tectonic event as the Bannock and the parallel faults toward the south, although it appears that if Willis' age determination of the Lewis thrust is correct, the Bannock overthrust occurred at an earlier geologic date.

It is apparent, however, that a close approximation of the actual and relative ages of the several faults awaits more extended geologic studies in the Rocky Mountain region.

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