Art. XXXIX.—*The Paleozoic Section in Northern Utah;* by G. B. Richardson.*

Introduction.—One of the most complete Paleozoic sections known in the entire Cordilleran region is exposed in the vicinity of Bear Lake, northern Utah. This section embraces more than 14,000 feet of strata and includes seven Cambrian, three Ordovician, one Silurian, two Devonian and four Carboniferous formations. The entire sequence is well exposed in the Randolph quadrangle, which was studied in the summer of 1912 by the writer, assisted by Paul V. Roundy, to whom he is indebted for measuring a number of sections and collecting many of the fossils. G. H. Girty visited the party during the progress of field work and, in addition to identifying the Carboniferous fossils, was of great help in making collections. The writer also acknowledges his indebtedness to Messrs. E. O. Ulrich, E. M. Kindle, L. D. Burling and Edwin Kirk for examining the fossils.

The table on page 407 summarizes the Paleozoic rocks of northern Utah.

Cambrian.

The Cambrian section in the Randolph quadrangle is essentially that described by Walcott† as occurring in Blacksmith Fork, Utah, and in the vicinity of Liberty, Idaho, and need not be described here. This section is finely exposed on the eastern flank of Bear River Range west of Garden City, where the thicknesses recorded in the table were measured. There the formations named by Walcott were recognized by their lithology, stratigraphic position and fossils, which latter were examined by L. D. Burling, who assisted Walcott in the study of the type section. In the preparation of the geologic map of the Randolph quadrangle it was found desirable to differentiate the Hodges shale member at the base of the Bloomington formation and the Worm Creek quartzite member at the base of the St. Charles limestone.

The Hodges shale member of the Bloomington formation is a persistent zone of drab clay shale about 350 feet thick, occurring at the base of the formation. It lies apparently conformably on the massive Blacksmith limestone, and is overlain by thin-bedded limestone of the Bloomington formation. The name is derived from Hodges Creek, which crosses the shale and enters Bear Lake 1½ miles south of Garden City.

* Published by permission of the Director, U. S. Geological Survey.

† Walcott, C. D.: Cambrian Geology and Paleontology, Smithsonian Miscellaneous Collections, vol. liii, pp. 5–9 and 190–200, 1908; also Mon. U. S. Geol. Survey, No. 51, pp. 148–153, 1912.

Paleozoic formations in Northern Utah.

System.	Series or fauna.	Formation.	Approximate thickness in feet.	General character.
Carboniferous	Permian ?	Phosphoria formation	400	Chert and siliceous limestone overlying shale, thin limestone and oolitic phosphate rock.
	Pennsylvanian	Wells formation	less than 300 to 600	Massive gray quartzite overlain and underlain by thinner bedded quartzite and limestone.
	Mississippian	Brazer limestone	800 to 1400	Massive to thin-bedded light gray siliceous limestone and sandstone.
		Madison limestone	600 to 1600	Medium to thin-bedded dark limestone rich in fossils.
Devonian	Upper	Threeforks limestone	200	Soft reddish rocks poorly exposed in Randolph quadrangle.
	Middle and Lower	Jefferson dolomite	1200	Massive, fine-grained dark dolomite, weathers a characteristic brown tint.
Silurian		Laketown dolomite	1000	Massive light gray dolomite.
Ordovician	Richmond fauna	Fish Haven dolomite	500	Medium-bedded bluish dolomite.
	Chazy ? fauna	Swan Peak quartzite	500	Fine textured gray quartzite.
	Beekmantown fauna	Garden City limestone	1000	Thick- and thin-bedded gray limestone.
Cambrian	Upper	St. Charles limestone Worm Creek quartzite member	1300 to less than 500	Massive gray limestone with 300 ft. of massive gray quartzite at the base.
	Middle	Nounan limestone	950	Massive to medium-bedded gray limestone.
		Bloomington formation Hodges shale member	1250	Thin-bedded limestone and shale, Hodges shale member at the base.
		Blacksmith limestone	700	Massive fine-grained gray to bluish limestone.
		Ute limestone Spence shale member	480 to 585	Thin limestone, interbedded with shale.
		Langston limestone	375	Massive crystalline blue to gray limestone.
	Middle and Lower	Brigham quartzite	1600 +	Massive fine-grained gray quartzite locally conglomerate.
		Base not exposed		

The Worm Creek quartzite member of the St. Charles limestone is a massive gray quartzite occurring at the base of the formation. It is of variable thickness, having a maximum of 300 feet in the Randolph quadrangle. The Worm Creek quartzite directly overlies the Nounan limestone and is succeeded by the massive gray fossiliferous Upper Cambrian limestone which forms the bulk of the St. Charles limestone. The name is derived from Worm Creek, in the Bear River Range, 10 miles north of the Randolph quadrangle.

Ordovician.

Overlying this great thickness of Cambrian rocks the Ordovician system likewise is well developed in the Bear River Range, notably adjacent to the Idaho-Utah state boundary, where it is represented by a continuous exposure of 2,000 feet of strata. These beds are separated into the following formations: the Garden City limestone containing a Beekmantown fauna, the Swan Peak quartzite containing a Chazy ? fauna, and the Fish Haven limestone characterized by a Richmond fauna. Although the succession is apparently conformable, there is nevertheless evidence of erosional unconformity at the base of the lowermost and uppermost Ordovician formations. These unconformities are inferred from the facts that the Garden City limestone and the Fish Haven dolomite, respectively, rest on such different horizons in different parts of the Randolph quadrangle that considerable erosion apparently preceded their deposition. Details will be given in the Randolph folio.

Garden City Limestone.

The Garden City limestone, named from Garden City Canyon, a tributary of Bear Lake, consists of a succession of thick and thin bedded gray limestone approximately 1,000 feet thick. A characteristic feature is the presence throughout the formation of a conglomerate or breccia consisting of elongated bits of limestone up to 2 or 3 inches in length, irregularly imbedded in a matrix of similar composition.

The following fossils, identified by Edwin Kirk of the U. S. Geological Survey, were obtained from the Garden City limestone in the Bear River Range, Randolph quadrangle, at the horizons indicated:

From the eastern flank of Bear River Range 4 miles northwest of Garden City, Utah—

From the base of the Garden City limestone, within 25 feet of St. Charles limestone:

Dalmanella sp.
Syntrophia near *calcifera* Billings
Raphistoma acuta H. & W.
Hormotoma sp.
Eccyliopterus sp.

From 187 feet above the base of the Garden City limestone:

Lingula sp.
Asaphoid

From 337 feet above the base of the Garden City limestone:

Streptorhynchus minor Walcott
Asaphus ?

A new genus of trilobites allied to Bumastus

From 375 feet above the base of the Garden City limestone:

Dalmanella sp.
Raphistoma sp.
Maclurea subannulata Walcott
Asaphus sp.
Ribeiria sp.

From 675 feet above the base of the Garden City limestone:

Strophomena fontinalis White
Dalmanella pogonipensis H. and W.
Streptorhynchus minor Walcott
Eostrophomena n. sp.
Raphistoma ? near *trohiscus* Meek
Raphistoma acuta H. and W.
Maclurea subannulata Walcott
Hormotoma sp.
Eccyliopterus sp.
Asaphus ? curiosus Billings
Asaphus sp.
Bathyurus sp.
Receptaculites sp.

From the top of the Garden City limestone:

Dalmanella pogonipensis H. and W.
Strophomena fontinalis White
Hormotoma sp.
Echinoencrinus ? sp.
Leperditella sp.

The fauna of the Garden City limestone is represented in part by that of certain portions of the Pogonip limestone of the Eureka district, Nevada. It is equivalent to the Beekmantown fauna of the East.

Swan Peak Quartzite.

The Swan Peak quartzite, named from Swan Peak in the Bear River Range, Utah, 1½ miles south of the Idaho boundary, is a fine-textured massive to thin-bedded white to gray quartzite about 500 feet thick which lies apparently conformably on the Garden City limestone. The following fossils, identified by Edwin Kirk, were obtained from this quartzite in the NE¼ sec. 9, T. 14 N., R. 4 E., *Orthis* n. sp. near *tricenaria* Conrad, *Eccyliomphalus* sp., *Endoceras* sp. *Ampyx ?*, *Symphysurus ? golfussi* Walcott, *Bathyurus congeneris* Walcott, *Leperditia* sp., *Leperditella* sp. This fauna, which is related to that occurring in the lower part of the Simpson formation in Oklahoma, is referred tentatively to the Chazy by Ulrich and Kirk.

Fish Haven Dolomite.

In the Bear River Range near the Utah-Idaho boundary the Swan Peak quartzite is immediately overlain by the Fish

Haven dolomite, which is a fine-textured medium-bedded dark gray to blue-black, locally cherty, dolomite about 500 feet thick containing a Richmond fauna. The name is derived from Fish Haven Creek, which enters Bear Lake, Idaho, about 2 miles north of the Utah State Line. A sample from the head of Fish Haven Creek, analyzed by Walter C. Wheeler of the U. S. Geological Survey, showed 21·35 per cent of magnesia.

The following fossils, identified by Edwin Kirk, were obtained by R. W. Richards in the Fish Haven dolomite near the crest of the Bear River Range at the head of Fish Haven Creek in the Montpelier quadrangle, Idaho, immediately north of the Randolph quadrangle: *Calapoecia* cf. *Canadensis* Bill., *Streptelasma* sp., *Halysites catenulatus* var. *gracilis* Hall, *Rhynchotrema* cf. *capax* Conrad, *Columnaria thomii* Hall. This represents a widespread western Richmond fauna.

Silurian.

Laketown Dolomite.

The Laketown dolomite, named from Laketown Canyon 4 miles southeast of Laketown in the Randolph quadrangle, is a massive light gray to whitish dolomite, containing lenses of calcareous sandstone, having a thickness of approximately 1000 feet. An analysis of a sample from SE¼ sec. 17, T. 12 N., R. 6 E. showed 21·38 per cent MgO. In the Montpelier quadrangle, Idaho, R. W. Richards reports a few feet of the Laketown dolomite lying above the Fish Haven dolomite apparently conformably, but the most complete section of this formation is in Laketown Canyon. There, however, because of the scarcity of fossils, the lower boundary and consequently the thickness of the Laketown dolomite has not yet been determined. Fossils in general are rare in the Laketown dolomite although locally there occur considerable quantities of a poorly preserved *Pentamerus* cf. *oblongus* Sow. Specific identification is impossible, but they clearly point to the Silurian age of the containing beds. A similar fauna was reported by Kindle* from Green Canyon east of Cache Valley. Some poorly preserved corals, identified provisionally as *Halysites catenulatus?* Linn., *Favosites* sp. and *Cyathophyllum?* sp., were found in the lower part of the dolomite in Laketown Canyon, but it is doubtful whether these fossils, here tentatively referred to the Silurian, may not be Richmond. It is proposed to restrict the name Laketown dolomite to beds of Silurian age.

* Kindle, E. M.: The fauna and stratigraphy of the Jefferson limestone in the northern Rocky Mountain region. Bull. of American Paleontology, No. 20, p. 17, 1908.

DEVONIAN.

Jefferson dolomite.

The Jefferson limestone of Lower and Middle Devonian age, which has a widespread distribution in the northern Rocky Mountain region, is well developed in the Randolph quadrangle, where, however, the name dolomite is applied instead of limestone because of the magnesian content. A sample from Laketown Canyon showed the presence of 19·16 per cent MgO. In the area here considered the Jefferson consists chiefly of massive fine-grained dark-colored dolomite, weathering a characteristic brownish tint, but in places, as in Laketown canyon, the lower strata are thin-bedded. The Jefferson is about 1200 feet thick, and overlies the Laketown dolomite apparently conformably. Fossils are not abundant although two collections were obtained in Laketown Canyon, one from near the top of the dolomite and the other from near its base. Both lots were identified by E. M. Kindle.

Fossils from Jefferson dolomite, Randolph quadrangle.

From East Fork of Laketown Canyon, SE¼ sec. 17, T. 12 N., R. 6 E., about 150 feet above the base of the formation:

Productella sp.
Spirifer englemani
Nuculites sp.
Aviculopecten? sp.
Fish bone fragment.

From East Fork of Laketown Canyon, W½ sec. 17, T. 12 N., R. 6 E., from several beds between 200 and 500 feet below the top of the formation.

Aulopora sp.
Favosites cf. *limitaris*
Zaphrentis sp.

Dr. Kindle reports that "the coral listed here as *Favosites* cf. *limitaris* is one of the characteristic and widely distributed fossils of the Jefferson limestone of the northern Rocky Mountain region. One of the species of the preceding faunule, *Spirifer englemanni*, is also a characteristic fossil of this formation."

Threeforks limestone.

At the type locality, Threeforks, Montana, the Threeforks limestone, there the Threeforks shale, lies conformably between the Madison and Jefferson limestones. But although the Threeforks has not been recognized over so wide an area as have the immediately overlying and underlying formations, in the Randolph quadrangle all three formations are present, the Threeforks being definitely recognized by fossil evidence.

The Threeforks limestone is a soft formation lying between harder ones and in the area here considered usually occupies

talus slopes or debris-covered lowlands so that nowhere was a complete exposure of the formation found and only thin beds of impure reddish-colored limestone were observed, the stratigraphic interval between the underlying Jefferson and overlying Madison limestone being about 200 feet. This soft reddish zone lying between well marked massive limestone is an excellent horizon marker.

In the Randolph quadrangle the Threeforks limestone outcrops in two distinct areas in Laketown Canyon and in the Crawford Mountains but fossils were found in it only in the Crawford Mountains, where the following lot, identified by E. M. Kindle, was obtained in S½ sec. 29, T. 11 N., R. 8 E.

Productella coloradensis
Camarotœchia cf. *contracta*
Schizophoria striatula var. *australis*
Spirifer notabils
Syringothyris cf. *carteri*
Spirifer whitneyi var. *anima-sensis*
Cleiothyridina sp. undet.

Dr. Kindle states that this fauna is of Upper Devonian age and includes elements both of the Ouray limestone and Threeforks shale fauna.

It may be observed in passing that reddish beds referred to by Blackwelder as constituting a "non-marine member in the Mississippian limestone"* exposed around the sources of the south fork of Ogden River, Utah, and thought by him to be of continental origin, may prove to be the marine Threeforks.

Carboniferous.

The Carboniferous rocks of the area under consideration outcrop in the Crawford Mountains east of the town of Randolph, where the entire local section is well exposed.

Mississippian Series.

Madison limestone.

The Threeforks limestone is apparently conformably overlain by the well known Madison limestone, which here is a medium to thin-bedded dark limestone of variable thickness ranging from about 600 to 1600 feet thick. It is abundantly fossiliferous. The following small selected list was identified, and in part collected, by G. H. Girty:

Fossils from Madison limestone, Randolph quadrangle:

Menophyllum excavatum
Leptæna analoga
Schuchertella chemungensis
Productella concentrica
P. arcuata
Productus levicosta
P. gallatinensis
Camarotœchia herrickana
Spirifer centronatus
Reticularia Cooperensis
Syringothyris carteri
Euomphalus utahensis

* Blackwelder, Eliot.: New Light on the Geology of the Wasatch Mts., Bull. Geol. Soc. America, vol. xxi, pp. 528, 529, 1910.

Brazer limestone.

The Madison limestone is overlain by the Brazer limestone, of upper Mississippian age, named from Brazer Canyon in the Crawford Mountains, 6 miles east by north of Randolph, where it is well exposed. The Brazer for the most part is a massive light-colored impure limestone, but it varies considerably in composition especially in its lower part. In some places much chert is present, occurring in layers a few inches thick and also in irregular bunches. In other localities chert is not conspicuous, and the lower part of the limestone is thin-bedded to shaly. About a mile east of Laketown a thin bed of phosphate rock, formerly assigned to the Park City (Phosphoria) formation, occurs in the shaly lower part of this limestone. The Brazer limestone is more or less sandy throughout, and locally considerable sandstone is present. In the Randolph quadrangle this limestone ranges from 800 to 1400 feet in thickness, which variation suggests an erosional unconformity separating the upper Mississippian from the overlying Pennsylvanian deposits. Fossils are usually scarce in the Brazer limestone. Their occurrence is characteristically bunched, and collections from different localities often show quite different facies. The following species, identified and in part collected by G. H. Girty, were obtained in the Randolph quadrangle :

Fossils from Brazer limestone, Randolph quadrangle :

From 1½ miles east of Laketown, near center of sec. 32, T. 13 N., R. 6 E., and 1 mile south in N.E. 1/4 sec. 5, T. 12 N., R. 6 E.:

Endothyra Baileyi
Zaphrentis sp.
Productus aff. *pileiformis*
P. Biseriatus ?
P. aff. *giganteus*
Dielasma formosum ?
Girtyella turgida
Spirifer bifurcatus ?
Composita sp.
Cliothyridina hirsuta
Concardium sp.
Aviculipecten sp.
Astartella nucleata ?
Euomphalus sp.
Holopea proutana ?
Griffithides sp.
Kirkbya sp.
Paraparchites carbonarius ?

From 1¼ miles east of Laketown, near center of W. 1/2 sec. 32, T. 13 N., R. 6 E., in shaly limestone near the base of the formation :

Triplophyllum sp.
Michelinia sp.
Rhipidomella sp.
Chonetes illinoisensis var.
Productella hirsutiformis ?
Productus altonensis
Martinia ? sp.
Spirifer moorefieldanus
Platyceras sp.
Paraparchites sp.

Dr. Girty states that the latter fauna is related to that of the Moorefield shale of Arkansas, which is of basal upper Mississippian age.

Pennsylvanian and Permian ? series.

There has been some confusion in the naming of the Pennsylvanian and Permian ? rocks of northern Utah and southern Idaho. The 40th Parallel Survey introduced the term Weber quartzite, taken from a great development of gray quartzite in Weber canyon, for the beds lying between what was called "Wasatch limestone" and the "Upper Coal Measure limestone." Since then down to comparatively recently the name Weber quartzite, without being clearly defined, has been in current usage, but lately somewhat conflicting terms have been introduced for what is thought to be in part the equivalent of the original Weber, although detailed work has not yet been done in the type locality. Boutwell in his report on the Park City District included in the Park City formation beds which may be the equivalent of the upper part of the original Weber quartzite; and Blackwelder, following Weeks, applied the name Morgan formation to a mass of red sandstone and shale with intercalated thin limestone that apparently was included in the lower part of the original Weber quartzite. Gale and Richards, in their Preliminary Report on the Phosphate Deposits in Southeastern Idaho and adjacent parts of Wyoming and Utah, extended the terms Weber quartzite and Park City formation to that region. But as the work in the phosphate reserves of southeastern Idaho was extended, the introduction of new names became necessary because satisfactory correlation with the Weber Canyon section could not be established. Accordingly, Richards and Mansfield introduced the names Wells and Phosphoria formations defined below.

Wells Formation.

The Wells formation,* named from Wells Canyon in T. 10 S., R. 45 E., Idaho, includes the beds of Pennsylvanian age lying between the Brazer limestone and the overlying Phosphoria formation. At the type locality the Wells formation is 2400 feet thick and is divisible into three portions, an upper calcareous sandstone or siliceous limestone series, a middle sandy series and a lower sandy and cherty limestone series. In the Randolph quadrangle, the Wells formation outcrops in only two areas, in the canyon 1½ miles east of Laketown and in the Crawford Mountains. In the former area, where exposures

*Richards and Mansfield: The Bannock Overthrust, Journal of Geology, vol. xx, pp. 689-693, 1912.

are poor, the Wells appears to be less than 300 feet thick, while in the latter area this formation measures 600 feet. Approximately the lower third of the formation is composed of alternating layers of thin-bedded quartzite and limestone, the middle third of massive quartzite, and the remaining upper part of the formation consists of calcareous sandstone and sandy limestone. An unconformity at the base of the Wells formation is indicated by the varying thickness of the underlying Brazer limestone, by the apparent absence in the Randolph quadrangle of a richly fossiliferous horizon near the top of the Brazer limestone, present in the Montpelier quadrangle, and by the absence of the red sandstone, Morgan formation, which occurs at the base of the Pennsylvanian section in Weber Canyon. It should be noted that the thickness of rocks of Pennsylvanian age varies greatly in this general region. In Weber Canyon, Utah, although exact measurements have not been made, there are several thousand feet of beds of that age. This great mass of rocks is reported by Blackwelder* to have disappeared about seven miles north of Weber River. As stated above, in the Randolph quadrangle the rocks of Pennsylvanian age range from less than 300 to about 600 feet in thickness, and in southern Idaho, Richards and Mansfield report the Wells formation to be 2400 feet thick.

Phosphoria Formation.

The Phosphoria formation, named by Richards and Mansfield† from Phosphoria Gulch, a branch of Georgetown Canyon, Bear Lake County, Idaho, includes the phosphate deposits and associated beds of Permian ? age which lie between the Pennsylvanian Wells formation and the Woodside shale of Triassic age. In northern Utah (Randolph quadrangle) the Phosphoria formation is about 400 feet thick. The upper part of the formation consists of chert, cherty limestone, and some intercalated shales from 125 to 200 feet thick, and the lower part is composed of a sequence about 200 feet thick of brown and gray clay shale, subordinate limestone, and layers up to 5 feet thick of oölitic phosphate rock.

At several widely separated localities (noted by Blackwelder‡ north of Weber Canyon, by Richards and Mansfield,§ in Idaho, and exposed in the Randolph quadrangle, a mile north of Brazer Canyon), a zone of breccia-conglomerate is present at or near the base of the Phosphoria formation. This is

* Bulletin, Geological Society of America, vol. xxi, p. 531, 1910.

† Richards and Mansfield: The Bannock Overthrust, Journal of Geology, vol. xx, pp. 684–689, 1912.

‡ Bulletin, Geological Society of America, vol. xxi, pp. 530–533, 1910.

§ Journal of Geology, vol. xx, p. 692, 1912.

marked by angular to semi-rounded bits of chert and quartzite, resembling that of the underlying Wells formation, irregularly scattered through a bed of limestone. That this horizon marks an unconformity separating the Phosphoria and Wells formations is suggested by the varying thickness of the underlying Pennsylvanian beds.

The Phosphoria formation carries an abundant fauna, part of which has been described by Girty.* This is distinctly different from the fauna of the underlying Wells formation and serves as a means of separating the two. The Phosphoria formation is tentatively assigned to the Permian.