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Contents

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Middle and Upper Cambrian Stratigraphy in the Autochthon and Allochthon of Northern Utah*

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ABSTRACT.—Middle and Upper Cambrian stratigraphy in the autochthon of Ogden Canyon, Utah, includes, from oldest to youngest, Ophir Formation, Maxfield Limestone, Calls Fort Shale Member of the Bloomington Formation, Nounan Dolomite, and St. Charles Formation. Four important fossil collections from the autochthon confirm assignment of formational names and allow regional correlation from western Utah to southwestern Wyoming. Cambrian rocks in the autochthon of Ogden Canyon are overlain conformably by Ordovician rocks, which have not been previously recognized.

Middle and Upper Cambrian stratigraphy in the allochthon of the Blacksmith Fork area consists of, from oldest to youngest, Langston Formation, Ute Formation, Blacksmith Dolomite, Bloomington Formation, Nounan Dolomite, and St. Charles Formation. Three measured sections south of Blacksmith Fork indicate facies changes, which differ from those north of Blacksmith Fork. The Langston Formation is thickest at Blacksmith Fork Canyon and thins to the north, east, and south therefrom. The Ute Formation rapidly thickens in the Wolf Creek-Browns Hole area indicating the presence of a southwest trending trough. The Blacksmith Dolomite is fairly uniform throughout the allochthon. The Hodges Shale Member, the middle limestone member, and the Calls Fort Shale Member of the Bloomington Formation form persistent units in the allochthon, except in the East Fork-Wolf Creek area, where the middle limestone member is absent. The East Fork-Wolf Creek area acted as a structural high while carbonates of the middle Bloomington were being deposited in the surrounding area. The Nounan Dolomite and the St. Charles Formation remain fairly uniform in the allochthon. New paleontologic evidence from the allochthon allows regional correlation from western Utah to southwestern Wyoming. Seven major eastward transgressions and six major westward regressions occurred during the Cambrian Period in northern Utah.

The root zone of the allochthon of northern Utah, according to Cambrian stratigraphy, is in the Promontory Range, Utah, and not in the autochthon of Ogden Canyon, Utah. Thus, the allochthon, whose original position was west of the autochthon, has been thrust eastward over the autochthon. On the basis of rates of thinning of Middle and Upper Cambrian rocks, the allochthon has been displaced about 40 to 60 miles east of its original position.

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*A thesis submitted to the faculty of the Department of Geology, Brigham Young University, in partial fulfillment of the requirements for the degree Master of Science, May 25, 1967.

INTRODUCTION

This report describes and discusses Middle and Upper Cambrian rocks of the autochthon and allochthon of northern Utah (Text-fig. 1). Correlation of Middle and Upper Cambrian stratigraphy from the Blacksmith Fork Canyon southward to the Huntsville area and from the Huntsville area westward to the Ogden Canyon area is considered (Text-fig. 1). Cambrian sections of the House Range, Promontory Range, Salt Lake area, and High Creek area in Utah and the Portneuf Range in Idaho will be used to illustrate regional facies changes.

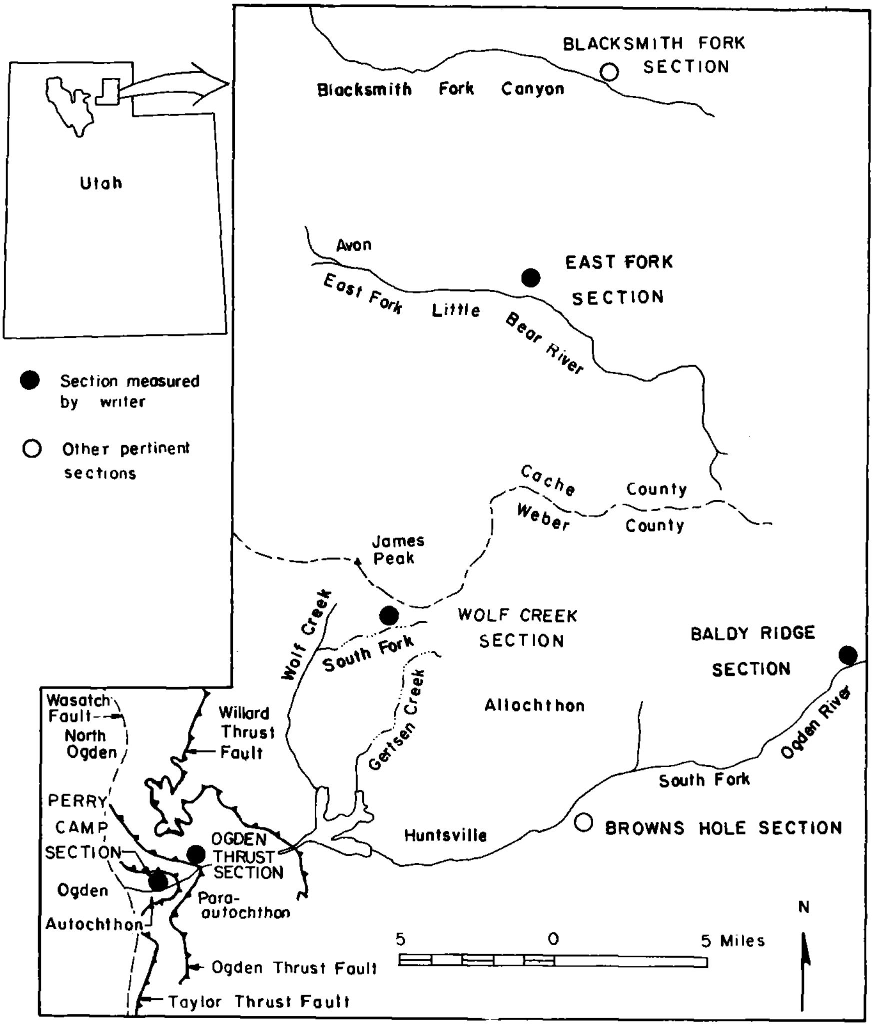
The autochthon is present in the Ogden Canyon area; the allochthon is present in the Huntsville-Blacksmith Fork area (Text-fig. 1). The two sequences are separated by three thrust faults—the Taylor, the Ogden and the Willard, of which the Taylor is the lowest and the Willard is the highest (Eardley, 1944, Plate 1). The Taylor and the Ogden Thrust Faults are imbricate thrust slices that repeat the Cambrian sequence twice over the autochthonous section. These two repetitions of Cambrian rocks are considered to be para-autochthonous since they repeat rocks similar to those of the autochthon. The Willard Thrust plate contains the allochthonous rocks.

Previous Work

In 1878 King, with the 40th Parallel Survey, outlined the general geologic features of the Wasatch Mountains. The first detailed study of the Cambrian stratigraphy was done by Walcott (1908a and 1908b), who named the Cambrian units from the oldest to the youngest as follows: Brigham Quartzite, Langston Limestone, Ute Limestone, Blacksmith Limestone, Bloomington Formation, Nounan Limestone, and St. Charles Limestone. Since much of Walcott's work (1908a and 1908b) was general, Mansfield (1927) and Deiss (1938) found it necessary to amend Walcott's stratigraphy and type localities. Deiss' work (1938) in Blacksmith Fork Canyon proved extremely useful in the current study. In 1941, Williams and Maxey described the Cambrian stratigraphy of the Logan Quadrangle, Utah. A regional study on the Worm Creek Quartzite Member of the St. Charles Formation in the Utah-Idaho vicinity was done by Haynie (1957). Maxey (1958) published a regional study of the Lower and Middle Cambrian rocks in northern Utah and southeastern Idaho.

Present Work

The writer became interested in this problem while employed by the U. S. Geological Survey as a geologic field assistant to M. D. Crittenden, Jr., during the summer of 1965 in the Browns Hole Quadrangle, Utah. The bulk of the fieldwork for this project was done during the fall of 1965. The remainder of the fieldwork was finished during June, 1966.



TEXT-FIGURE 1.—Index map of studied area.

All stratigraphic sections were measured by tape, Brunton compass and Abney hand level. Text-figure 1 shows the location of all sections described in this paper and other pertinent sections.

Acknowledgments

M. D. Crittenden, Jr., of the U. S. Geological Survey and L. F. Hintze of Brigham Young University visited the writer in the field and critically reviewed the manuscript. A. R. Palmer of the U. S. Geological Survey identified the Cambrian fossils and critically reviewed the manuscript. Ordovician fossils were identified by R. J. Ross, Jr., of the U. S. Geological Survey. T. E. Mullens of the U. S. Geological Survey aided the writer with the Baldy Ridge Section. All of the above are gratefully acknowledged.

STRATIGRAPHY OF THE AUTOCHTHON

General Statement

Middle and Upper Cambrian stratigraphy of Ogden Canyon (autochthon) can be matched, in part, with the lithologies of the Salt Lake area (autochthon) and in part, with the lithologies of the Blacksmith Fork area (allochthon) (Text-fig. 1). The Ophir Formation and Maxfield Limestone of the Salt Lake area can be identified in Ogden Canyon along with the Calls Fort Shale Member of the Bloomington Formation, the Nounan Dolomite and the St. Charles Formation of the Blacksmith Fork area. Paleontologic evidence for the age of the autochthonous sections is presented, thus making correlation possible for the first time. Although the upper part of the Tintic Quartzite is known to be of Middle Cambrian age (Crittenden, 1965a), this study is restricted to post-Tintic rocks.

Perry Camp Section

The Perry Camp Section of Ogden Canyon represents the autochthon of northern Utah (Text-fig. 1). Blackwelder (1909) recognized this sequence as Cambrian, and later Eardley (1944, Plate 1) mapped Tintic Quartzite and Ophir Shale along with Cambrian limestones and dolomites here. Detailed work on this section reveals similar lithologies and stratigraphic position with the Cambrian rocks of the Salt Lake area as described by Calkins and Butler (1943, p. 12-20) and by Crittenden (1965a and 1965b).

The Perry Camp Section (Text-fig. 2, and Plate 1, Figs. 1 and 2) was measured on the north slope of Ogden Canyon beginning at the top of the Tintic Quartzite above Perry Camp and ending in the slope cover just below the Taylor Thrust Fault (Sec. 23 and 24, T. 6 N., R. 2 W.). The number of each unit of this section was painted on the outcrop. Fossils were identified by A. R. Palmer (1966, written communication).

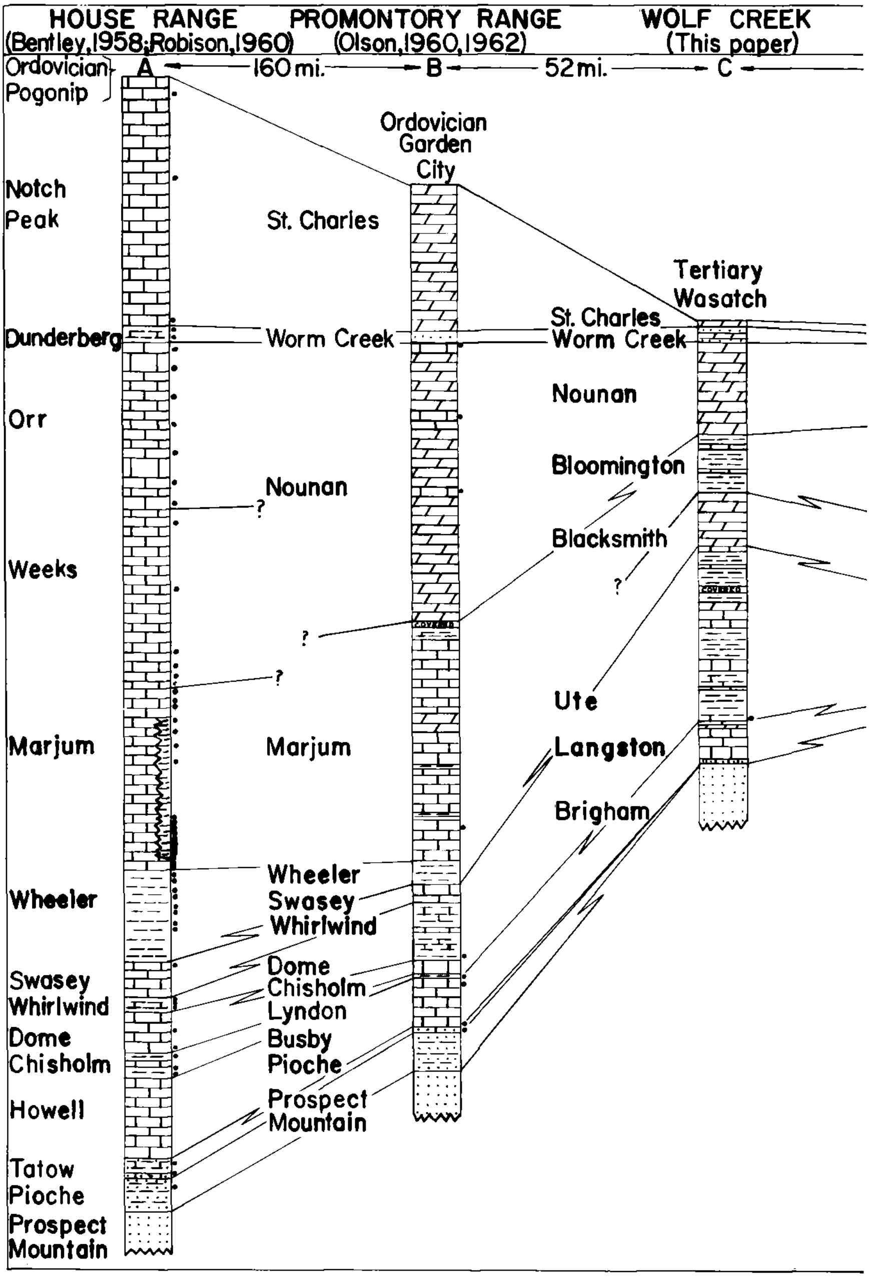
Measured Section 1

Units		Thickness in Feet
	QUATERNARY COVER Continuation of section is questionable due to float from Tintic Quartzite above. About 200 feet northeastward up the slope is the concealed Taylor Thrust Fault.	
	MAXFIELD LIMESTONE	
	Dolomite member	
16	Dolomite like Unit 14.	21
15	Dolomite: medium to dark gray, weathers white to light brown-gray, finely crystalline, thin-bedded, laminated, siliceous, black chert lenses.	10
14	Dolomite: medium to dark gray, weathers same, finely crystalline, thick-bedded, cliff-forming, light gray silt lenses; upper part is oolitic and contains white twiggy bodies and *Girvanella*.	163
13	Covered.	40
12	Dolomite: dark gray, weathers medium gray, finely crystalline, thin- to medium-bedded, cliff-forming, highly fractured; contains calcite veinlets and white twiggy bodies.	103
	Total thickness of dolomite member.	337

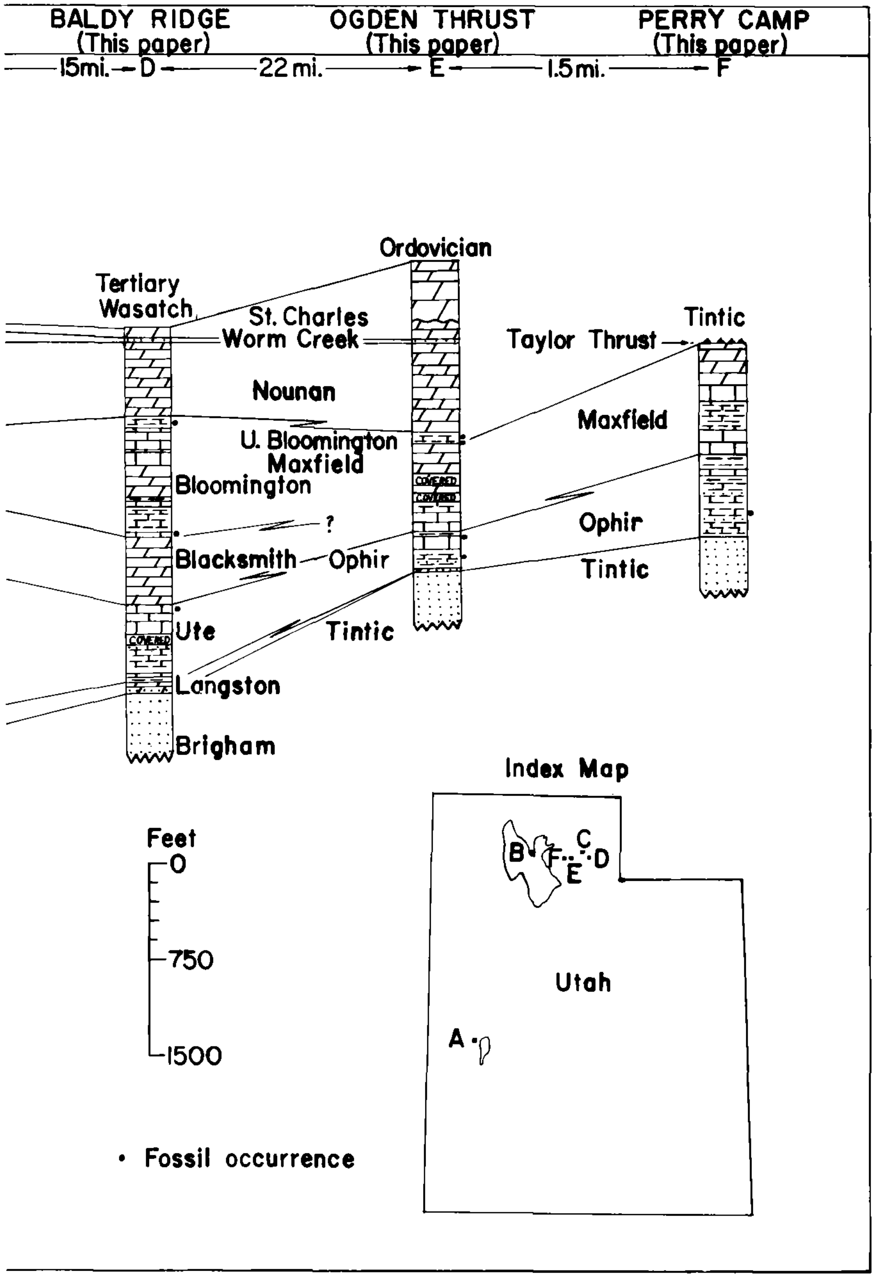
	Upper Limestone member	
11	Limestone: light to medium gray, weathers light gray, medium oolitic, medium-bedded to massive, cliff-forming, partly dolomitic, siliceous.	60
10	Limestone: light blue-gray, weathers same finely crystalline, medium-bedded to massive, cliff-forming, *Girvanella,* wavy lenses of tan to white-gray silty limestone.	78
	Total thickness of upper limestone member.	138
	Shale and nodular limestone member	
9	Shale and Limestone: Shale olive drab to dark gray, micaceous; limestone: like that of Unit 8, forms thin layers, ribbons, and nodules. Unit forms rounded ledges and slopes. Grades into Unit 10.	214
	Offset to southeast of diagonal normal fault.	
	Lower Limestone member	
8	Limestone: dark gray, weathers medium to light gray, finely crystalline, thin-bedded (wavy), cliff-forming, highly fractured, grades into Unit 9; contains layers and lenses of cream to buff calcareous silt up to one inch thick and thick, white calcite veins.	194
	Total thickness of Maxfield Limestone.	883
OPHIR SHALE		
	Upper Shale member	
7.	Covered: float of medium gray limestone and dark gray siliceous shale.	123
	Medial limestone member	
6	Limestone: medium gray, weathers light gray, finely crystalline, thin-bedded (wavy), cliff-forming, partly siliceous, layers and lenses of tan silty limestone.	49
	Lower shale member	
5	Shale, sandstone and limestone: Shale olive drab, micaceous, abundant linguloid brachiopods, 60% of unit; Sandstone and Quartzite: red-brown, weathers rusty brown, fine-grained, thin-bedded, calcareous, 20% of unit; Limestone: medium gray, weathers light rusty brown, medium crystalline, thin-bedded, siliceous, fossiliferous, 20% of unit. Entire unit is slope-forming. Fossil Collection 8-1 (USGS No. 5951-CO): *Alokistocare* sp., *Zacanthoides* sp.	369
4	Quartzitic dolomite: light gray, weathers rusty brown, medium crystalline, ledge-forming.	1
3	Shale: olive drab, micaceous, slope-forming, slightly metamorphosed.	25
2	Covered: float of quartzite, shale and limestone.	48
1	Shale and quartzite: Shale: olive drab, micaceous, slope-former; Quartzite: olive drab, fine-grained, thin-bedded (one to six inches), slope-forming.	36
	Total thickness of lower shale member.	479
	Total thickness of Ophir Shale.	651
Gradational Contact:		
TINTIC QUARTZITE:	white to reddish tan, weathers same, fine- to medium-grained, thin- to medium-bedded, cliff-forming. approximately	1000

Ogden Thrust Section

The Ogden Thrust Section of Ogden Canyon (Text-fig. 1) combines the lithologies of the Salt Lake area (autochthon) and the Blacksmith Fork area (allochthon). However, since the lower part of this section more closely re-



TEXT-FIGURE 2.—Palinspastic Middle and Upper Cambrian columnar sections from western and northern Utah.


BALDY RIDGE
(This paper)
OGDEN THRUST
(This paper)
PERRY CAMP
(This paper)
15mi. D 22 mi. E 1.5mi. F
Ordovician
Tertiary
Wasatch
St. Charles
Worm Creek
Taylor Thrust
Tintic
Nounan
Maxfield
U. Bloomington
Maxfield
Bloomington
?
Ophir
Blacksmith
Ophir
Tintic
Ute
Tintic
Langston
Brigham
Index Map
Feet
0
750
1500
B
C
F
E
D
Utah
A
• Fossil occurrence

sembles that of the structurally lower Perry Camp section and of the Salt Lake area (Crittenden, 1965a and 1965b), it is considered para-autochthonous.

A complete Cambrian section is present in the Ogden Thrust Section. The sequence of formations, from oldest to youngest, is as follows: Tintic Quartzite, Ophir Formation, Maxfield Limestone, Calls Fort Shale Member of the Bloomington Formation, Nounan Dolomite, and St. Charles Formation (Text-fig. 2 and Plate 2, Fig. 1). Eardley (1944, Plate 1) recognized Tintic Quartzite and Ophir Shale in the Ogden Thrust Section, but he referred to the remainder of the section as "Cambrian limestone and dolomite." The terms Maxfield Limestone, Calls Fort Shale Member of the Bloomington Formation, Nounan Dolomite, and St. Charles Formation are used in the Ogden Thrust Section for the first time in the present paper and correspond to Eardley's "Cambrian limestone and dolomite." The uppermost portion of Eardley's "Cambrian limestone and dolomite" also includes Ordovician rocks, as shown in the measured section. The Bloomington Formation, the Nounan Dolomite, and the St. Charles Formation were named and described in general by Walcott (1908a, p. 6-7). Later, Mansfield (1927, p. 55-56) amended these formations. Richardson (1913, p. 406-408) established the Hodges Shale Member of the Bloomington Formation and the Worm Creek Quartzite Member of the St. Charles Formation. In 1942, Denson (p. 24-25) named the Calls Fort Shale Member of the Bloomington Formation.

The Ogden Thrust Section was measured on the north side of Ogden Canyon along the east rim of Johnson Draw, northwest of The Hermitage (Sec. 13, T. 6 N., R. 1 W. and Sec. 18, T. 6 N., R. 1 E.). The number of each unit of this section was painted on the outcrop. A. R. Palmer (1966, written communication) identified the Cambrian fossil collections. R. J. Ross, Jr., (1966, written communication) identified the Ordovician fossils.

Measured Section 2

Units		Thickness in Feet
	ORDOVICIAN ROCKS	
43	Limestone and sandstone: Limestone: dark gray, weathers light blue-gray, finely crystalline, thin-bedded, tan and red silty limestone layers lenses, siliceous, fossiliferous, few beds of intraformational flat-pebble conglomerate are present, few thin black shale layers are found in the upper part; Sandstone: brown-gray, weathers tan, fine-grained, thin-bedded (1 inch thick). Fossil Collection 10-6: trilobite genal spines, gastropods, and crinoid stems. .... approximately	50
42	Covered: float of medium gray fossiliferous limestone, intraformational limestone conglomerate and tan siltstone. Fossil Collection 10-5 (USGS No. D1744 CO) *Hystricurus oculilunatus* Ross, syntrophid brachiopod. .... approximately	75
41	Dolomite: light gray to light tan-gray, weathers same, medium crystalline, thin-bedded, slope-forming.	22
	ST. CHARLES FORMATION	
	Dolomite member	
40	Dolomite: medium gray, weathers light to white gray, finely crystalline, thin- to medium-bedded, cliff-forming, highly fractured and breciated, sharp contact with Unit 41.	92
39	Dolomite: light gray, weathers dull brown-gray, finely crystalline, thick-bedded, cliff-forming, white dolomitic twiggy bodies, sharp contact with Unit 40.	66

38	Dolomite: light to dark gray, weathers light gray, finely crystalline, massive, cliff-forming, upper part is thin- to thick-bedded.	295
37	Dolomite: dark gray, weathers medium gray, finely crystalline, thin-bedded, cliff-forming, light gray mottles, small white chert bodies, middle part is light gray, contact with Unit 38 is disconformity.	100
36	Dolomite: light gray, weathers light gray to light tan-gray, finely crystalline, thin- to medium-bedded, cliff-forming, large white dolomite bodies and lenses.	69
35	Dolomite: light gray, weathers white-gray, medium to coarsely crystalline, thin- to medium-bedded, slope-forming.	15
	Total thickness of dolomite member	637

Worm Creek Quartzite Member

34	Shale: tan, weathers same, slope-forming, gradational contact with Unit 35.	5
33	Quartzite: medium to dark gray, weathers brown, fine-grained, thin-bedded, dolomitic, ledge-forming.	18
	Total thickness of Worm Creek Quartzite Member	23
	Total thickness of St. Charles Formation	660

NOUNAN DOLOMITE

32	Dolomite: medium gray, weathers dull brown-gray, finely crystalline, thin-bedded, ledge-forming, siliceous, white dolomitic twiggy bodies, white quartz veinlets.	71
31	Dolomite like that of Unit 28: thick-bedded, cliff-forming, wavy bedding planes; contact with Unit 32 is a disconformity.	50
30	Dolomite like that of Unit 28: thin-bedded, slope-forming.	108
29	Dolomite like that of Unit 28: no cross-bedding or oolites, contains large white dolomitic twiggy bodies, many disconformities with relief up to 10 inches in the upper part of this unit.	247
28	Dolomite: light gray, weathers white-gray to light tan-gray, finely crystalline, thin- to thick-bedded, cliff-forming, siliceous, small cross-beds, partly oolitic.	142
27	Dolomite: medium gray, weathers dull brown-gray, finely crystalline, medium-bedded to massive, cliff-forming, siliceous, white quartz twiggy bodies and veinlets.	59
26	Mudstone: brown-black, weathers muddy brown, fine-grained, thin-bedded, blocky, grades into Unit 27.	5
25	Dolomite: light gray, weathers cream to tan, medium to coarsely crystalline, thin-bedded, siliceous.	7
24	Dolomite: dark gray, weathers tan-gray, finely crystalline, thick-bedded, ledge forming, siliceous.	5
	Total thickness of Nounan Dolomite	693

CALLS FORT SHALE MEMBER OF THE BLOOMINGTON FORMATION

23	Shale and Limestone: Shale: olive drab; Limestone: medium gray, red-gray and rusty brown, weathers tan to light gray, very finely crystalline, nodular, siliceous, fossiliferous, few beds of intraformational limestone conglomerate. Contact with Unit 24 concealed. Fossil Collection 10-4 (USGS No. 5949-CO): *Eldoradia* sp.	51
21	Shale: olive drab, micaceous fissile.	5
20	Limestone: medium gray, weathers same, fine to medium oolitic, thin-bedded, wavy tan silty limestone layers and lenses.	9
19	Shale and Limestone: Shale: olive drab; Limestone: medium gray, weathers same, finely crystalline, thin-bedded, tan and red *Girvanella*.	8
	Total thickness of Calls Fort Shale Member of the Bloomington Formation	88

MAXFIELD LIMESTONE

	Dolomite member	
18	Dolomite: medium gray, weathers same, finely oolitic, thin-bedded, ledge-forming.	12
17	Dolomite of Unit 15.	12
16	Covered.	14
15	Dolomite: light gray to black, weathers light gray to white, finely crystalline, thin-bedded, partly laminated, ledge-forming, few lenses of black chert.	42
14	Dolomite: light gray, weathers same, finely crystalline, thin-bedded; interbedded with Unit 13.	37
13	Dolomite: dark gray, weathers same, finely crystalline, thin- to medium-bedded, cliff-forming, lower part contains white calcite veinlets and twiggy bodies, sharp wavy contact with Unit 14, small white chert bodies one to three inches below the contact.	46
12	Covered: float from Units 13 and 14.	92
11	Dolomite: medium gray, weathers same, finely oolitic, massive, quartz grains present, highly fractured and faulted, gossan present along fault planes.	60
	Total thickness of dolomite member	315
	Upper limestone member	
10	Covered: float of medium gray limestone.	65
	Shale and nodular limestone member	
9	Shale and limestone: Shale: olive drab; Limestone like that of Unit 6 forms nodules, ribbons, and layers. Few beds of intraformational limestone conglomerate.	87
	Lower limestone member	
8	Limestone like that of Unit 6: lower half slope-forming, upper half cliff-forming, grades into Unit 9.	54
7	Limestone: medium gray, weathers same, medium oolitic, thin-bedded to massive, rounded cliff-forming, highly fractured and faulted.	64
6	Limestone: dark gray, weathers medium blue-gray, finely crystalline, thin-bedded, lenses and layers of tan silty limestone, wavy bedding, grades into Unit 5.	33
	Total thickness of lower limestone member	151
	Total thickness of Maxfield Limestone	618

Due to faulting and folding, the section was offset and continued immediately northeast of The Hermitage.

OPHIR FORMATION

	Upper shale member	
5	Shale: medium gray to olive drab, weathers same, tan and red stains.	36
	Middle limestone member	
4	Limestone: medium to dark gray, weathers same, finely crystalline, thin-bedded, cliff-forming, *Girvanella,* layers of buff and red calcareous silt in the lower and middle part. Upper part contains very small pyrite crystals and is fossiliferous. Fossil Collection 10-2 (USGS No. 5948-CO): *Bathyuriscus* sp., *Elrathina* sp., *Peronopsis* sp., *Ptychagnostus* sp.	100

Unit 4 is folded locally into an overturned isoclinal fold. Offset to equivalent bed to the north of the fold.

	Lower shale member	
3	Shale: olive drab, micaceous; few quartzite and fossiliferous limestone beds in upper part. Fossil Collection 10-1 (USGS No. 5947-CO): *Ehmaniella* sp.	69

2	Quartzite, limestone and dolomite: Quartzite: dark gray, weathers light red-brown, very fine-grained, thin-bedded, dolomitic; intertongues laterally with beds of dark gray, oolitic limestone and medium red-brown weathering, dark gray dolomite.	33
1	Quartzite: medium brown to medium gray-brown, weathers same, fine- to very fine-grained, thin-bedded, dolomitic.	74
	Total thickness of lower shale member	176
	Total thickness of Ophir Shale	312

TINTIC QUARTZITE: grayish white, weathers light rusty brown to light gray, thin-bedded, fine-grained, cliff-forming, grades into Unit 1. .... approximately 700

STRATIGRAPHY OF THE ALLOCHTHON

General Statement

The Blacksmith Fork Section (Text-fig. 1) of Deiss (1938, p. 1107-1116) still stands as the standard Cambrian section for the allochthon of northern Utah. Cambrian stratigraphy was originally described by Walcott (1908a, p. 6-7). Later, Mansfield (1927, p. 55-56) and Deiss (1938, p. 1120-1121) emended Walcott's work. The Blacksmith Fork Section was divided into the following formations: Brigham Quartzite, Langston Limestone, Ute Limestone, Blacksmith Dolomite, Bloomington Limestone, Nounan Dolomite, and St. Charles Formation. These same units can be recognized in all other Cambrian sections in the allochthon. Langston Limestone, Ute Limestone, and Bloomington Limestone is herein formally changed to "Formations," since the lithologies of each formation are a mixture of carbonates and clastic rocks.

The three following allochthonous sections serve to illustrate the rapid facies changes occurring in the Middle and Upper Cambrian rocks south of Blacksmith Fork Canyon. These sections also possess important faunas, which are of regional correlation value.

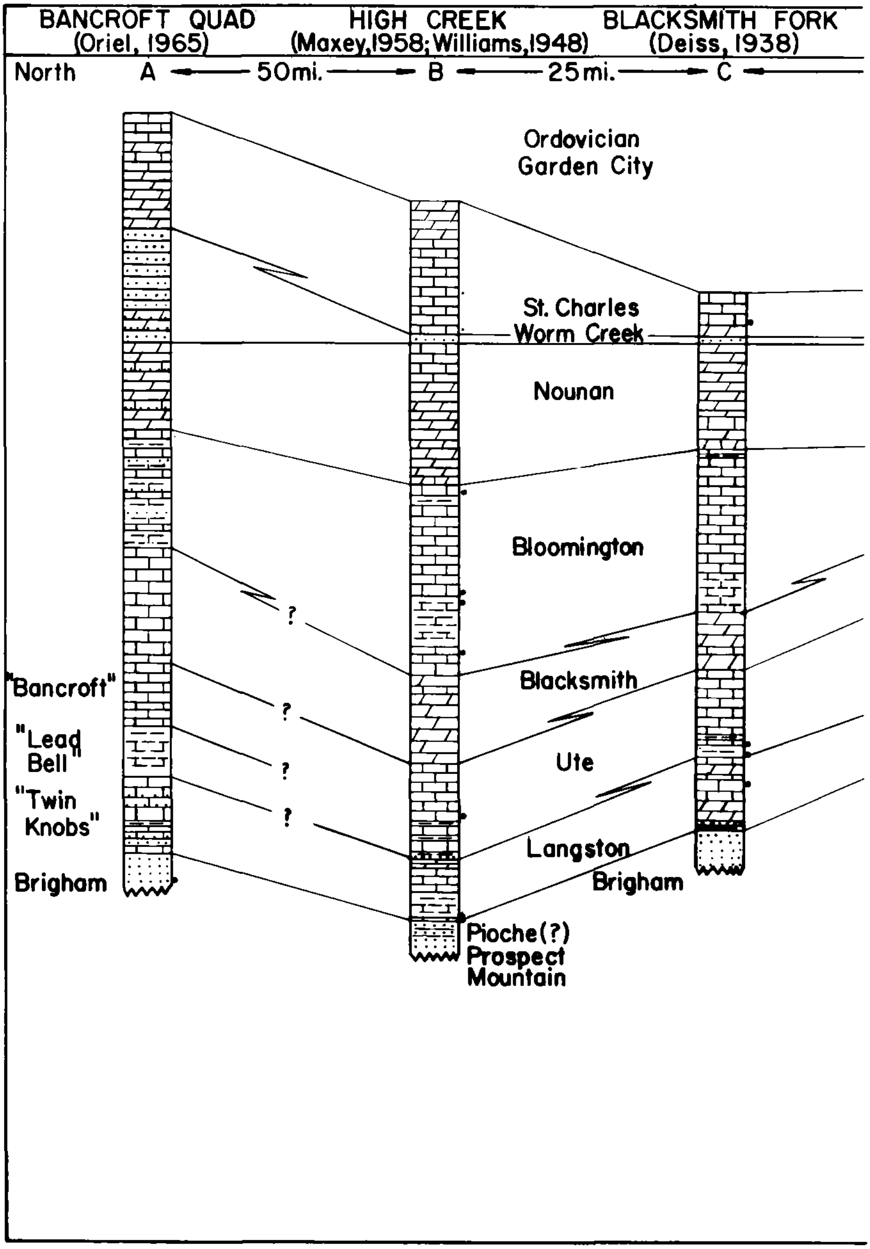
East Fork Section

The East Fork Section (Plate 2, Fig. 2) contains important lithologic variations from the Blacksmith Fork Section of Deiss (1938, p. 1107-1116) (Text-fig. 3). One variation of the East Fork Section from the Blacksmith Fork Section is the intertonguing relationship between the Langston and Ute Formations. Other differences are the rapid thinning of the Bloomington Formation and the thickening of the Ute Formation south of Blacksmith Fork Canyon.

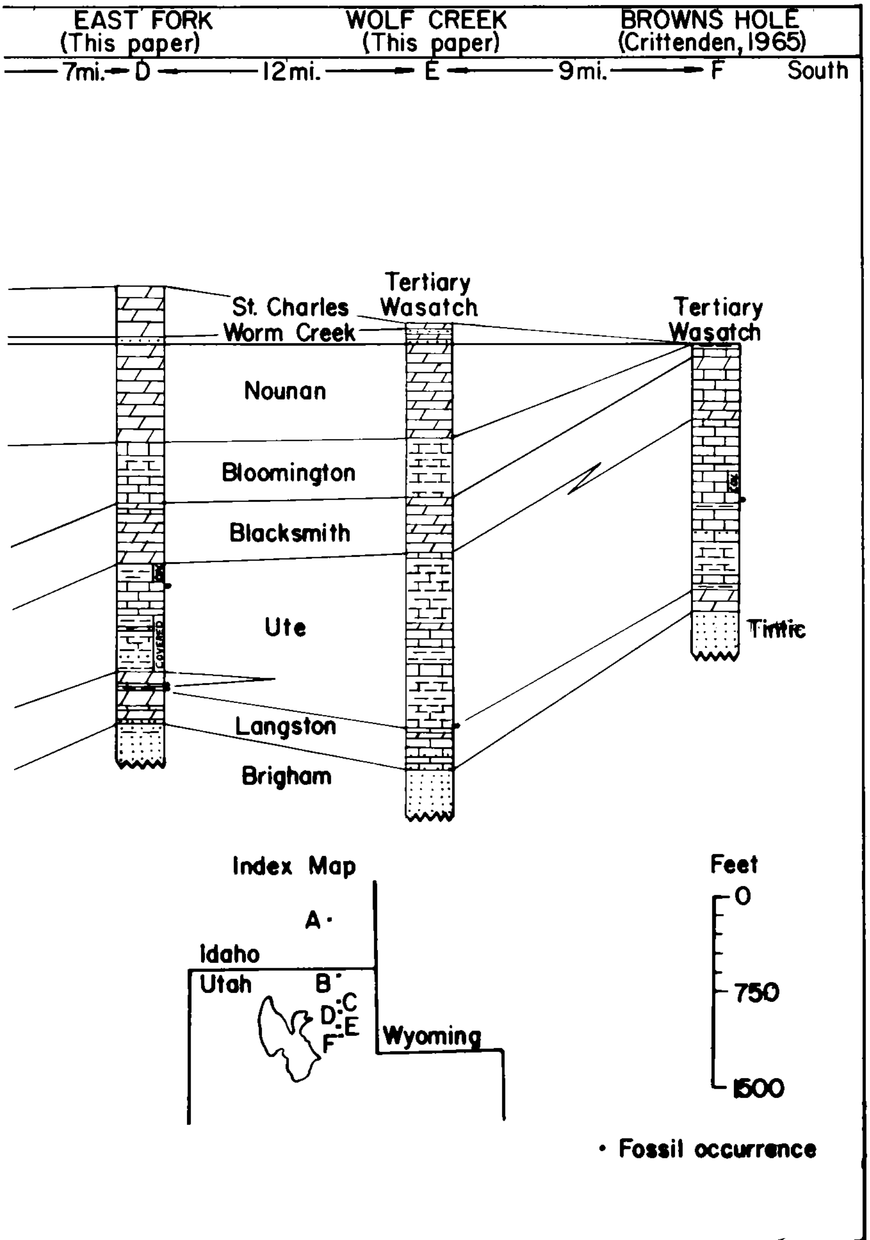
The East Fork Section was measured on the north slope of the East Fork of Little Bear River beginning at the top of the Brigham Quartzite and ending at the base of the Garden City Limestone (Sec. 14, 15, and 16, T. 9 N., R. 2 E.).

Measured Section 3

Units		Thickness in Feet
	ORDOVICIAN GARDEN CITY LIMESTONE	
64	Limestone: medium gray, weathers same, finely crystalline, thin-bedded, yellow-tan to tan silt layers, ledge-forming, fossiliferous (brachiopods, large trilobite genal spines, and corals).	100+
63	Quartzite: tan to white, weathers tan to rusty brown. .... approximately	75
62	Covered: float of medium gray limestone with tan to red silt lenses	



TEXT-FIGURE 3.—Middle and Upper Cambrian columnar sections from southeastern Idaho and northern Utah.


EAST FORK
(This paper)
WOLF CREEK
(This paper)
BROWNS HOLE
(Crittenden, 1965)
7mi. D 12mi. E 9mi. F South
Tertiary
Wasatch
Tertiary
Wasatch
St. Charles
Worm Creek
Nounan
Bloomington
Blacksmith
Ute
Langston
Brigham
Tintic
COVERED
Index Map
A
Idaho
Utah
B
C
D
E
F
Wyoming
Feet
0
750
1500
• Fossil occurrence

	and fossils (large trilobite free cheek, brachiopods, and crinoid stems), and white to tan quartzite.	15
61	Quartzite: tan, weathers same, fine-grained, thin-bedded.	8

ST. CHARLES FORMATION

Dolomite member

60	Dolomite like that of Unit 58.	6
59	Dolomite: light cream to light gray, weathers light tan, coarsely crystalline, medium-bedded, slope-forming.	47
58	Dolomite: light to medium gray, weathers same, finely crystalline, medium-bedded, ledge-forming, partly oolitic, few beds with red-tan and light gray wavy silt layers.	33
57	Limestone: dark gray, weathers medium gray, fine to medium crystalline, thin-bedded, partly siliceous, red and tan silt lenses and layers.	33
56	Covered.	77
55	Dolomite like that of Unit 53.	23
54	Dolomite: medium gray, weathers medium tan-gray, medium crystalline, medium- to thick-bedded, cliff-forming, partly oolitic, white twiggy bodies.	37
53	Dolomite: light tan, weathers same, finely crystalline, thin- to thick-bedded, siliceous, partly oolitic.	56
52	Dolomite: medium gray, weathers light tan-gray, medium crystalline, thin- to thick-bedded, cliff-forming, partly oolitic, siliceous, few chert lenses.	28
	Total thickness of dolomite member	399

Worm Creek Quartzite Member

51	Quartzite and dolomite: Quartzite: tan-gray, weathers tan to buff, fine-grained, thin-bedded, ledge-forming, dolomitic; with interbedded medium gray quartzitic dolomite.	60
	Total thickness of the St. Charles Formation	459

NOUNAN DOLOMITE

50	Dolomite: medium gray, weathers same, finely crystalline, thin-bedded, tan silt layers.	14
49	Dolomite: cream-colored, weathers same, coarsely crystalline, thin- to to medium-bedded, extremely rough weathered surface.	28
48	Dolomite: light gray to cream, weathers cream to white, finely crystalline, thin-bedded, laminated.	5
47	Dolomite like that of Unit 45 without thick bedding.	136
46	Covered.	28
45	Dolomite: medium to dark gray, weathers same, finely crystalline, medium- to thick-bedded, cliff-forming. Lowest ledge has purple-gray cast. Upper half is light gray.	111
44	Dolomite: medium gray, weathers same, finely crystalline, thin lenses of medium-grained oolites, layers of tan silt.	14
43	Dolomite like that of Unit 44 with white twiggy bodies and few black ledges.	305
42	Covered: float like that of Units 41 and 43.	111
41	Dolomite: light gray, weathers same, finely oolitic, medium-bedded, cliff-forming, layers of *Girvanella,* blocky surface.	10
	Total thickness of Nounan Dolomite	762

BLOOMINGTON FORMATION

Upper limestone member

40	Limestone: medium gray, weathers light gray, thin-bedded, cliff-forming, tan wavy silt layers, thin lenses (1-2" thick) of black chert. Upper half is dolomite.	20

39	Covered: float like that of Units 38 and 40.	10
38	Limestone like that of Unit 34 and finely crystalline limestone beds with tan silt wavy layers and *Girvanella*.	87
	Total thickness of upper limestone member	117

Middle shale and nodular limestone member

37	Shale and limestone like that of Unit 33.	97
36	Limestone like that of Unit 34.	6
35	Shale and limestone like that of Unit 33.	15
34	Limestone: medium gray, weathers same, medium oolitic, medium-bedded, rusty silt lenses.	2
33	Covered: float of shale and limestone: Shale: olive drab, 80% of unit; Limestone: medium brown-gray to dark green-gray, weathers cream to light green-gray, very finely crystalline, nodular, partly siliceous, four inch layers of intraformational flat pebble conglomerate, 20% of unit.	38
	Total thickness of middle shale and nodular limestone member	158

Lower limestone member

32	Limestone: medium gray to dark gray, weathers same, finely crystalline, thin-bedded, buff silt lenses, ledge-forming, cross-bedded, oolitic, intraformational flat-pebble conglomerate.	91
31	Limestone: medium gray, weathers same, medium crystalline, thin-bedded, oolitic, buff silt lenses, ledge-forming.	38
30	Limestone: medium to dark gray, weathers same, finely crystalline, thin- to medium-bedded, partly oolitic, ledge-forming, few white weathering laminated beds.	69
	Covered	9
	Total thickness of lower limestone member	207
	Total thickness of Bloomington Formation	482

BLACKSMITH DOLOMITE

28	Dolomite: light to medium gray, weathers white to light gray, finely crystalline to micritic, thin-bedded, laminated. Black chert bed about 2 inches thick enclosed in dark gray oolitic limestone in middle of unit.	42
27	Limestone: black, weathers dark gray, finely crystalline, thin-bedded, white twiggy bodies, lenses of medium gray and buff silt.	30
26	Dolomite: dark gray, weathers dull gray, finely crystalline, thin-bedded, white twiggy bodies, upper contact gradational.	10
25	Covered: float of medium gray dolomite and black limestone.	57
24	Dolomite: light to medium gray, weathers light gray, medium crystalline, thin- to medium-bedded, white twiggy bodies, cliff-forming.	54
23	Covered: float of medium gray dolomite with twiggy bodies.	44
22	Dolomite: light gray, weathers same, medium oolitic.	84
21	Dolomite: medium gray, weathers dull brown-gray, medium crystalline, thick-bedded, cliff-forming, partly siliceous, becomes lighter gray in upper part.	156
	Total thickness of Blacksmith Dolomite	477

UTE FORMATION

20	Covered: float of medium gray dolomite and whitish gray oolitic dolomite.	141
19	Limestone like Unit 17 plus light red-gray siliceous limestone (beds up to one inch thick) with trilobites. Fossil Collection 6-3 (USGS No. 5963-CO): *Ptychagnostus* cf. *P. gibbus* (Linnarsson), *Ptychagnostus* ? sp., *Peronopsis* sp., *Spencella* sp., *Bolaspidella* (?) sp.	47
18	Limestone like that of Unit 17: thick-bedded and has white calcite lenses coated with brown silica.	4

17	Limestone: black, weathers dark gray, finely crystalline, thin-bedded, partly siliceous, few beds sound like brittle china.	35
16	Limestone: medium gray, weathers same, finely crystalline, medium-bedded, partly siliceous, light tan-gray silty wavy limestone layers up to one inch thick.	172
15	Covered: float of medium gray limestone, tan calcareous sandstone, and olive drab and red shale.	441
	Total thickness of the Ute Formation	840

LANGSTON FORMATION

Upper dolomite member

14	Dolomite like that of Unit 13 except medium brown weathering.	39
13	Dolomite: light gray, light brown weathering, finely to coarsely crystalline, thin-bedded, ledge-forming.	4
12	Covered: float of medium gray *Girvanella* limestone.	34
11	Dolomite: medium gray, weathers medium brown, medium to coarsely crystalline, thin- to thick-bedded, ledge-forming.	38
	Total thickness of upper dolomite member	115

Middle shale and limestone member

10	Limestone: medium gray, weathers same, fine to medium crystalline, thin-bedded, ledge-forming, fossiliferous, grades into Unit 11. Fossil Collection 6-2 (USGS No. 5966-CO): *Athabaskia* sp.	30
9	Covered: float of olive drab fissle shale and medium red-brown sandy fossiliferous limestone. Fossil Collection 6-1 (USGS No. 5962-CO): *Glossopleura* sp.	25
	Total thickness of middle shale and limestone member	55

Lower dolomite member

8	Dolomite like that of Unit 6: thin-bedded and medium brown weathering.	15
7	Dolomite like that of Unit 6: cliff-forming.	51
6	Dolomite: light blue-gray, weathers light brown, medium to coarsely crystalline, medium-bedded, slope-forming.	44
5	Limestone: medium gray, weathers same, finely crystalline, thin- to medium-bedded, layers of light gray silty limestone with wavy bedding. Upper part contains dolomitic *Girvanella* that stands out in relief.	25
4.	Covered.	10
3	Dolomite: medium gray, weathers medium brown, coarsely crystalline, medium-bedded, ledge-forming.	52
2	Covered: float of dolomite like Unit 3.	10
1	Sandstone: cream, weathers medium brown, fine- to medium-grained, thin-bedded, calcareous, poorly exposed.	36
	Total thickness of lower dolomite member	243
	Total thickness of Langston Formation	413

BRIGHAM QUARTZITE: whitish tan, weathers medium gray-brown, fine- to coarse-grained, thin- to medium-bedded, limonite pock marks. Thin beds of olive drab shale with worm burrows or primary structures are present about 35 feet below the top. The Brigham Langston contact is gradational.	2500+

Wolf Creek Section

Compared with other sections in the allochthon, the Wolf Creek Section (Text-figs. 1 and 3) exhibits differences in lithology and thickness of the Langston Formation and a change in thickness of the Ute Formation. The remaining Cambrian formations are similar in lithology and thicknesses.

The Wolf Creek Section was measured on the ridge crest above the north slope of the south fork of Wolf Creek beginning at the top of the Brigham Quartzite and ending at the Cambrian-Tertiary contact (Sec. 12, T. 7 N., R. 1 E., and Sec. 6 and 7, T. 7 N., R. 2 E.).

Measured Section 4

Units		Thickness in Feet
	TERTIARY WASATCH FORMATION	
	Angular Unconformity	
	ST. CHARLES FORMATION	
	Dolomite member	
43	Dolomite: dark gray, weathers light gray, finely crystalline, medium-bedded slightly siliceous.	41
	Worm Creek Quartzite Member	
42	Covered: float of sandstone like Unit 37.	9
41	Dolomite like that of Unit 38 with *Girvanella.*	5
40	Dolomite: light gray, weathers same, medium crystalline, thin-bedded, tan silt lenses up to two inches thick, few red stained areas.	7
39	Covered: float of sandstone like that of Unit 37.	9
38	Dolomite: black, weathers medium gray, medium-grained oolites, white dolomitic twiggy bodies, pink to tan silt lenses in upper two feet.	46
37	Covered: float of tan very fine-grained platy slope-forming sandstone.	46
	Total thickness of Worm Creek Quartzite Member	122
	Total thickness of St. Charles Formation	163
	NOUNAN DOLOMITE	
36	Dolomite like that of Unit 33.	71
35	Covered: float of dolomite like Unit 33.	164
34	Dolomite: dark gray, weathers same, medium crystalline, thin-bedded, small white dolomitic twiggy bodies, medium gray mottles.	18
33	Dolomite: whitish gray, weathers same to light tan-gray, medium crystalline, medium-bedded, ledge-forming, white dolomitic veinlets, upper part forms slope and weathers pinkish gray.	126
32	Dolomite and limestone: Dolomite: light pinkish to whitish yellow, weathers same, medium crystalline, thin-bedded, knobby weathered surface; interbedded with light red medium crystalline limestone.	14
31	Dolomite: white, weathers white to cream, medium crystalline, thin-bedded, rough weathered surface, lower part is interbedded with beds like that of Unit 30, upper part becomes whitish gray with white dolomitic veinlets.	113
30	Dolomite: light gray, weathers same, finely crystalline, oolitic, thin-bedded, slope-forming, white mottles, white dolomitic twiggy bodies, upper part is dark gray and has a rough surface.	139
29	Dolomite: medium to dark gray, weathers medium to light brown-gray, medium crystalline, thin-bedded, ledge-forming, white dolomitic twiggy bodies, upper part contains medium-grained oolites and weathers to a rough surface.	87
	Total thickness of Nounan Dolomite	732
	BLOOMINGTON FORMATION	
28	Shale and limestone: Shale: olive drab, fissile, slope-forming, 80% of unit; interbedded with dark gray finely crystalline thin-bedded ledge-forming limestone with wavy bedding, *Girvanella,* and fine	

	oolites, few beds of flat-pebble limestone conglomerate, upper part has thin, buff, wavy silt layers, 20% of unit.	458
27	Limestone: dark gray, weathers medium gray, finely crystalline, coarsely crystalline, white calcite twiggy bodies.	5
	Total thickness of Bloomington Formation	463

BLACKSMITH DOLOMITE

26	Dolomite: light gray to dark gray, weathers white, thin-bedded, ledge-forming, laminated, siliceous, black chert lenses up to six inches thick, grades into Unit 27.	55
25	Dolomite: medium gray, weathers medium brown-gray, finely crystalline with medium-grained oolites, thin-bedded, cliff-forming, rough weathered surface, upper part has white dolomitic twiggy bodies and black chert lenses (up to six inches thick), grades in Unit 26.	373
	Total thickness of Blacksmith Dolomite	428

UTE FORMATION

24	Limestone: dark gray, weathers medium gray, finely crystalline, thin-bedded, layers of thin wavy bedded light gray limestone, lenses of medium-grained oolites, lower part interbedded with Unit 23.	38
23	Shale and limestone like that of Unit 21.	258
22	Covered.	59
21	Shale and limestone: Shale: olive drab to light red, fissile, 70% of unit; Limestone: medium gray, weathers same, finely crystalline, thin-bedded, lenses of buff to light red silt, 30% of unit.	73
20	Dolomite: light gray, weathers light to medium brown, finely crystalline, thin-bedded, slope-forming, partly siliceous, layers of buff to red medium crystalline dolomite.	59
19	Limestone: medium gray, weathers light gray, finely crystalline, thin-bedded, buff silt lenses and layers, *Girvanella* in upper part, interfingered with Unit 20	139
18	Covered: float of olive drab shale.	243
17	Limestone: medium to dark gray, weathers light gray, finely crystalline, partly silicified, brittle, sounds like china when it breaks, small black oolites, upper part has quartzite limestone layers that weather light brown and stand out in relief on weathered surface.	95
16	Shale and limestone: Shale: olive drab, micaceous, upper part is black, 70% of unit, interbedded with Limestone: medium gray, weathers light gray, finely crystalline, thin-bedded, wavy thin buff silt layers, medium-grained oolites at base, 30% of unit.	116
15	Shale: olive-drab, micaceous, slope-forming, few one inch thick layers of light gray quartzitic limestone.	55
14	Shale and limestone: Shale: olive drab to light red-brown, fissile, 80% of unit; interbedded with Limestone: medium to dark gray, finely crystalline, thin-bedded wavy buff silt layers, few quartz grains	56
13	Limestone: medium to dark gray, weathers light gray, finely crystalline, thin-bedded, lenses of medium-grained oolites	6
12	Limestone: medium to dark gray, weathers light gray, finely crystalline, thin-bedded, wavy buff silt layers, *Girvanella* upper part, grades into Unit 13	5
11	Shale and limestone: Shale like that of Unit 10; interbedded with dark gray, light gray-weathering, thin-bedded limestone with light yellow-brown silt layers and fine oolites	39
10	Shale: olive drab, micaceous, slope-forming.	34
9	Shale and limestone: Shale: olive drab to light red-brown, slope-forming, Limestone: medium gray, weathers same, fine to medium crystalline, ledge-forming, *Girvanella* are replaced by black coarsely crystalline limestone	36
8	Limestone: light gray, weathers same, finely crystalline, thin-bedded to medium-bedded, ledge-forming, *Girvanella*.	29

7	Shale: olive drab to medium red, micaceous, slightly metamorphosed, two inch layer of slightly silicified fossil hash at top. Fossil Collection 5-1 (USGS No. 5964-CO): *Glossopleura* sp.	30
	Total thickness of Ute Formation	1370
	LANGSTON FORMATION	
6	Limestone: very light gray, weathers cream to white, very finely crystalline, laminated, partly siliceous.	20
5	Limestone: medium gray, weathers light gray, finely crystalline, thin- to medium-bedded, ledge-forming, buff to light red silt lenses, few quartz grains, few brown-weathering dolomite and oolitic limestone beds in upper part.	178
4	Covered: float of red-gray calcareous sandstone.	24
3	Limestone: light gray, weathers same, finely crystalline, thin- to medium-bedded, ledge-forming, at places streaked with pink stain, upper half contains one inch thick, wavy, tan sandstone layers that grade laterally into tan, medium crystalline limestone and dolomite.	94
2	Sandy limestone: light gray, weathers yellow-brown to light red-brown, medium to coarsely crystalline, slope-forming, knobby weathered surface, streaks of yellow-brown to red-brown stain, about 40% quartz grains.	5
1	Sandstone: tan, very fine-grained, thin-bedded, calcareous, grades laterally into a brown-weathering dolomitic quartzite.	5
	Total thickness of Langston Formation	326

Gradational Contact:
BRIGHAM QUARTZITE

Baldy Ridge Section

The Baldy Ridge Section illustrates the rapid thinning of the Langston and Ute Formations and the rapid thickening of the Bloomington Formation to the southeast. The Blacksmith Dolomite, the Nounan Dolomite, and the Worm Creek Member of the St. Charles Formation maintain a rather uniform thickness throughout the area.

The Baldy Ridge Section was measured along the southeast slope of Baldy Ridge and the north slope of Knighton Ridge beginning at the top of the Brigham Quartzite and ending at the Cambrian-Tertiary contact (Sec. 21 and 22, T. 7 N., R. 4 E.).

Measured Section 5

Units		Thickness in Feet
	TERTIARY WASATCH FORMATION	
	Angular unconformity	
	ST. CHARLES FORMATION	
	Dolomite member	
59	Dolomite like that of Unit 57.	5
58	Limestone: light gray-tan, weathers same, fine to medium crystalline, thin-bedded, light gray-tan and red wavy silt layers.	10
57	Dolomite: light gray, weathers dull brown-gray, finely oolitic, thin-bedded, siliceous, rough weathered surface.	36
	Total thickness of dolomite member	51
	Worm Creek Quartzite Member	
56	Covered.	26
55	Quartzite and dolomite: Quartzite: light tan-gray, weathers tan to rusty brown, fine-grained, thin-bedded (one-fourth to one inch	

	thick), dolomitic, 50% of unit; Dolomite: light to medium gray, weathers dull brown-gray, finely crystalline, thin-bedded, layers of light gray, tan and red silt, 50% of unit.	21
54	Dolomite and quartzite: Dolomite: cream to light gray, weathers cream to tan, fine to medium crystalline, thin-bedded (two to three inches thick), 70% of unit; Quartzite: tan-gray, weathers tan, fine-grained, thin-bedded (one fourth to one-half inch thick), 30% of unit.	5
	Total thickness of Worm Creek Quartzite Member	52
	Total thickness of St. Charles Formation	103

NOUNAN DOLOMITE

53	Dolomite like that of Unit 49.	50
52	Dolomite like that of Unit 46.	15
51	Dolomite like that of Unit 46: slope-forming and weathers slightly darker.	86
50	Dolomite like that of Unit 49: slope-forming.	40
49	Dolomite: tan to cream, weathers same, medium crystalline, massive, cliff-forming, blocky weathered surface.	202
48	Dolomite like that of Unit 46.	16
47	Covered.	16
46	Dolomite: dull brown-gray, weathers same, finely crystalline, medium- to thick-bedded, cliff-forming, small white dolomitic bodies.	88
45	Dolomite: medium brown-gray, weathers cream to tan, finely crystalline, thin- to medium-bedded, one inch thick lenses of tan weathering micritic dolomite.	57
	Total thickness of Nounan Dolomite	571

BLOOMINGTON FORMATION

Calls Fort Shale Member

44	Covered: float of olive drab shale and dolomite like that of Unit 45.	41
43	Shale and limestone like that of Unit 41.	15
42	Limestone: medium gray, weathers light gray, fine to medium crystalline, thin-bedded, ledge-forming, tan silt lenses, oolitic, fossiliferous. Fossil Collection 2-3 (USGS No. 5965-CO): *Bolaspidella* sp.	12
41	Shale and limestone: Shale: olive drab, slope-forming, 90% of unit; Limestone: nodules of light cream, light gray and light red-gray, very finely crystalline, 10% of unit.	21
	Total thickness of Calls Fort Shale Member	89

Middle limestone member

40	Limestone: dark gray, weathers medium gray, fine to medium crystalline, thin-bedded, ledge-forming.	37
39	Limestone: dark gray, weathers white, finely crystalline, thin-bedded, laminated, partly dolomitic.	26
38	Limestone like that of Unit 30 with white dolomitic twiggy bodies.	45
37	Covered: float like limestone of Units 38 and 39.	19

Offset to west side of valley

36	Limestone like that of Unit 30.	19
35	Covered: float of light cream to tan dolomite.	24
34	Limestone like that of Unit 30.	5
33	Dolomite: medium gray, weathers dull brown-gray, fine to medium oolitic, medium-bedded, slope-forming, partially dolomitized bed of Unit 32.	24
32	Limestone like that of Unit 30: upper part contains tan silt lenses.	14
31	Dolomite like that of Unit 25.	10
30	Limestone: dark gray, weathers medium gray, finely crystalline, medium-bedded, cliff-forming, light gray dolomitic mottles, rough weathered surface.	29

29	Covered: float of medium gray mottled limestone.	39
28	Dolomite like that of Unit 25.	24
27	Dolomite: light tan-gray, weathers light blue-gray with white laminations, finely crystalline, thin-bedded.	2
26	Covered: float of white laminated dolomite.	40
25	Dolomite: dull brown-gray, weathers same, fine to medium crystalline, thin-bedded, ledge-forming, white dolomitic twiggy bodies.	190
	Total thickness of middle limestone member	548
	Hodges Shale Member	
24	Covered.	10
23	Limestone: medium gray, weathers same, finely to coarsely oolitic, medium-bedded, ledge-forming.	40
22	Shale and limestone: Shale: olive drab, fissile, 60% of unit; Limestone: light gray to medium brown-gray, weathers same, fine to medium crystalline, thin-bedded, red to tan silt layers, few beds of flat-pebble limestone conglomerate, 40% of unit.	144
21	Covered: float of tan and black shale, flat-pebble limestone conglomerate, nodular limestone that is light gray, red-gray and tan-gray, light green-gray and cream.	60
20	Limestone like that of Unit 18 with abundant oolites, pyrite crystals present, fossiliferous. Fossil Collection 2-2 (USGS No. 5961-CO): *Ehmania* sp., other indet. ptychoparioids.	15
19	Limestone: yellow-brown, weathers same, finely to coarsely crystalline, medium-bedded, layers of white calcite.	2
18	Limestone: dark gray, weathers light gray, finely crystalline, thin-bedded, wavy layers and lenses of tan silt, few oolitic and *Girvanella* beds.	10
	Total thickness of Hodges Shale Member	281
	Total thickness of Bloomington Formation	918
	BLACKSMITH DOLOMITE	
17	Dolomite like that of Units 15 and 16 interbedded.	314
16	Dolomite like Unit 15: light gray and not siliceous.	39
15	Dolomite: dark gray, weathers light to medium brown-gray, fine to medium crystalline, massive, cliff-forming, siliceous, vuggy and knobby weathered surface, white dolomitic twiggy bodies.	177
	Total thickness of Blacksmith Dolomite	530
	UTE FORMATION	
14	Limestone: dark gray, weathers to medium red- to purple-gray, micritic to finely crystalline, thin-bedded, cliff-forming, partly siliceous, fossiliferous, upper half is dolomite. Fossil Collection 2-1 (USGS No. 5960-CO): *Zacanthoides* sp., *Kootenia* cf. *K. serrata* (Meek), *Ehmania* (?) sp., *Bathyuriscus* sp., *Peronopsis* sp.	105
13	Limestone: medium to dark gray, weathers medium gray, finely crystalline, thin- to medium-bedded, cream silt lenses and layers.	43
	Offset to west side of creek.	
12	Limestone: medium gray, weathers light gray, finely crystalline, thin-bedded, cream silt lenses, *Girvanella* filled with tan and red calcite crystals, locally folded.	87
11	Covered: float of limestone like Unit 12.	92
10	Shale, limestone and sandstone: Shale: olive drab, red and dark gray, fissile, 50% of unit; Limestone: light to dark gray, weathers light gray, finely crystalline, thin-bedded, platy, *Girvanella,* buff and red wavy silt lenses, few siliceous beds that sound like china when broken, few twiggy bodies, 40% of unit; Sandstone: rusty brown, weathers same, fine-grained, thin-bedded (one-fourth inch thick), calcareous, 10% of unit. Entire unit is locally folded.	100

9	Limestone like that of Unit 5 without *Girvanella.*	19
8	Covered: float of olive drab shale.	8
7	Limestone like that of Unit 5, without silt lenses and with many white calcite veinlets.	4
6	Covered.	20
5	Limestone: dark gray, weathers light to medium gray, finely crystalline, thin- to medium-bedded, buff and red wavy silt lenses, *Girvanella*	25
4	Covered: float of olive drab micaceous shale and dark gray platy limestone.	12
	Total thickness of the Ute Formation	515

LANGSTON FORMATION

3	Dolomite: light tan to light pinkish tan, weathers medium brown, medium to coarsely crystalline, medium-bedded, partly siliceous, poorly exposed.	16
2	Covered: float of dark gray *Girvanella* limestone with tan lenses, olive drab shale and red- to yellow-brown sandstone.	12
1	Quartzite: light gray, weathers medium brown to red-brown, thin- to medium-bedded, very fine-grained, dolomitic, poorly exposed.	57
	Total thickness of Langston Formation	85

Gradational contact

BRIGHAM QUARTZITE .... about 2500

CORRELATION AND NOMENCLATURE

Autochthon

Ever since the work of the Fortieth Parallel Survey in the 1870's, age assignments of Cambrian rocks in the autochthon of Ogden Canyon have been unresolved due to the lack of fossils. In 1944, Eardley (Plate 1) mapped Tintic Quartzite, Ophir Shale, and Cambrian limestone and dolomite in Ogden Canyon but reported no fossils. Maxey (1958, p. 664) carried the names Pioche Shale and Langston Formation into Ogden Canyon via his Willard Peak Section but again without paleontologic evidence. The fossils found during this study allow age assignment to the Cambrian rocks of the autochthon (para-autochthon) of Ogden Canyon (Text-fig. 1).

Ophir Formation

Ehmaniella, collected from the lower shale member of the Ophir Formation in the Ogden Thrust Section, indicates that this shale member is the time equivalent of the upper shale member of the Ophir Formation in the Tintic district (Morris and Lovering, 1961, p. 22; Robison, 1960, Fig. 3), of the Whirlwind Formation in the House Range (Robison, 1960, p. 51), and of the middle Ute Formation in Blacksmith Fork Canyon (Deiss, 1938, p. 1114). Since *Ehmaniella* may have ranged in time enough to have existed throughout deposition of the Ophir Formation, the upper shale member of the Ophir Formation in the Tintic District may not be the exact time equivalent of the lower shale member of the Ophir in Ogden Canyon. The lower shale member of the Ophir in the Perry Camp Section contains *Alokistocare* and *Zacanthoides,* which are of little detailed correlation value since they range from the *Glossopleura* through the *Bathyuriscus-Elrathina* zones (Lochman-Balk and Wilson, 1958, Text-fig. 1).

The medial limestone member of the Ophir Formation in the Ogden Thrust Section contains *Bathyuriscus, Elrathina, Peronopsis,* and *Ptychagnostus.* These fossils represent the middle and late *Bathyuriscus-Elrathina zone* (Lochman-Balk and Wilson, 1958, Text-fig. 2). A *Bathyuriscus-Elrathina* age of the middle limestone member in the Ogden Thrust Section is younger than the age assigned to the middle limestone member of the Ophir in the Tintic district by Robison (1960, Fig. 3). No fossils were reported from this member in the Tintic district by Morris and Lovering (1961, p. 22). The middle limestone member of the Ophir in the Ogden Thrust Section is equivalent in time to the Swasey Limestone in the House Range (Robison, 1964, Table 1), and to the uppermost Ute Formation in the Baldy Ridge and East Fork Sections of this paper.

No fossils were found in the upper shale member of the Ophir in the Perry Camp and Ogden Thrust Sections, thus creating a correlation problem. The upper shale member of Ophir may be equivalent to the uppermost Ute Formation, the Blacksmith Dolomite, or the Hodges Shale Member of the Bloomington Formation in the allochthon. The writer favors correlation with the uppermost Ute Formation.

On the basis of the above mentioned fossils, Eardley's correlation (1944, p. 828) of the Ophir Formation to Ogden Canyon is correct. Maxey's assignment of Pioche Shale (1958, p. 664) to the shales overlying the Tintic Quartzite in Ogden Canyon is erroneous, since these shales contain fossils equivalent to those of the Whirlwind Formation and the Swasey Limestone of the Promontory and House Ranges (Text-fig. 2). Thus, Pioche Shale should not be used as a formational name in Ogden Canyon. Similarly, Maxey's use of Langston Formation (1958, p. 664) in Ogden Canyon is incorrect, since the fossils found in the Ophir Formation are equivalent to those of the Ute Formation, which overlies the Langston. Thus, Langston Formation is equivalent to the uppermost Tintic Quartzite and possibly the lowermost Ophir Shale, for which another formational name is not necessary.

Maxfield Limestone

The sequence of carbonates and clastics that overlie the Ophir Formation and underlie the Calls Fort Shale Member of the Bloomington Formation in Ogden Canyon is here assigned to the Maxfield Limestone.

The description of the Maxfield Limestone given by Calkins and Butler (1943, p. 14-18) and Crittenden (1965a and 1965b) match the Maxfield in this paper. No fossils were found in the Maxfield Limestone at its type locality and in Ogden Canyon; however, occurrence of the Maxfield immediately below the Calls Fort Shale Member of the Bloomington Formation indicates a correlation with the middle limestone member of the Bloomington. Lithologies of the middle limestone member of the Bloomington Formation in the Baldy Ridge Section are similar to those of the upper limestone and dolomite members of the Maxfield Limestone in the Ogden Thrust Section. Thus, the upper limestone and dolomite members of the Maxfield Limestone are tentatively correlated with the middle limestone member of the Bloomington Formation. On the basis of paleontologic evidence, Palmer (in Morris and Lovering, 1961, p. 38) correlates the Bluebird Dolomite of the Tintic district with the upper Maxfield Limestone of the central Wasatch region. The lower Cole Canyon Dolomite at Tintic (Morris and Lovering, 1961, p. 42) is equivalent to the dolomite member of the Maxfield in the Ogden Thrust Section as indicated by identical fossils found above each of the above mentioned units.

The middle shale and nodular limestone member of the Maxfield is tentatively correlated with the Hodges Shale Member of the Bloomington in the allochthon, and with the lower and middle members of the Herkimer Limestone at Tintic (Morris and Lovering, 1961, p. 33).

The lower limestone member of the Maxfield is questionably correlated with the Blacksmith Dolomite of the allochthon and with the upper part of the Teutonic Limestone and the Dagmar Dolomite of the Tintic district (Morris and Lovering, 1961, p. 26-30). Morris and Lovering (1961, p. 30) reached the same conclusion.

Calls Fort Shale Member of the Bloomington Formation

The Calls Fort Shale Member of the Bloomington Formation in the Ogden Thrust Section contains *Eldoradia,* which heretofore has not been reported from Bloomington beds. Of the occurrence of *Eldoradia* in the upper part of the Cole Canyon Dolomite at Tintic, Palmer (in Morris and Lovering, 1961, p. 43) states that

> *Eldoradia* is characteristic of rocks of late Middle Cambrian age, and the Middle-Upper Cambrian boundary, therefore, is probably at or near the Opex-Cole Canyon contact as you have defined it.

Thus, occurrence of *Eldoradia* from the Ogden Thrust Section is considered to be near the Middle-Upper Cambrian boundary, which corresponds to the Bloomington-Nounan contact in the allochthon (Williams and Maxey, 1941, p. 284). Lithology and stratigraphic position of the rocks assigned to the Calls Fort Shale Member in the Ogden Thrust Section resembles that of the Calls Fort Shale Member at its type locality near Calls Fort (Maxey, 1958, p. 660) and in the Baldy Ridge Section. In fact, lithology and thickness of the Calls Fort Shale Member in the Ogden Thrust and Baldy Ridge Sections are almost identical, thus providing an important stratigraphic tie from the allochthon to the autochthon. Regionally, this shale member is correlated with the upper Cole Canyon Dolomite at Tintic (Morris and Lovering, 1961, p. 43), with the upper Marjum Limestone in the Promontory Range (Olson, 1962, p. 3), with the lower Weeks Limestone in the House Range (Robison, 1960, p. 49), and with part of the Park Shale of the Gros Ventre Formation, and the Buck Spring Formation in southwestern Wyoming (Shaw and DeLand, 1955, Fig. 1).

Nounan Dolomite

The Nounan Dolomite is correlated from the allochthon to Ogden Canyon on the basis of lithology and stratigraphic position. No fossils were found in the Nounan Dolomite in Ogden Canyon. Williams and Maxey (1941, p. 284) assigned an early *Cedaria* age to the Nounan in the Logan Quadrangle on the basis of fossils. Olson (1962, p. 4) found fossils from the *Cedaria* through the *Dunderbergia* zones in the Nounan of the Promontory Range. The Nounan Dolomite is the time equivalent of the lower Opex Formation at Tintic (Morris and Lovering, 1961, p. 46), of the upper Weeks Limestone and the Orr Formation in the House Range (Bentley, 1958, p. 39-42), and of the upper Park Shale, the DuNoir Limestone, and the lower Dry Creek Shale Member of the Open Door Limestone of southwestern Wyoming (Shaw and DeLand, 1955, Fig. 1).

St. Charles Formation

Correlation of the St. Charles Formation from the allochthon to the autochthon of this paper is made on the basis of similar lithology and stratigraphic position. Presence of the Worm Creek Quartzite Member in the Ogden Thrust Section substantiates this assignment. The St. Charles is unfossiliferous in Ogden Canyon, but is fossiliferous in the Logan Quadrangle, where Williams and Maxey (1941, p. 284) assigned a late Late Cambrian age to it. The Worm Creek Quartzite Member represents the lower *Elvinia* zone (Williams and Maxey, 1941, p. 284) and is equivalent to the Dunderberg Shale of western Utah (Bentley, 1958, p. 21) and to the upper Dry Creek Shale Member of the Open Door Limestone of Wyoming (Shaw and DeLand, 1955, Fig. 1). The unnamed dolomite member of the St. Charles is correlated with the Upper Opex Formation and the Ajax Dolomite at Tintic (Morris and Lovering, 1961, p. 46-51), with the Notch Peak Limestone of the House Range (Bentley, 1958, p. 24), and with the Open Door Limestone of southwestern Wyoming (Shaw and DeLand, 1955, p. 41).

Ordovician Rocks

Fossil Collections 10-5 and 10-6, found above the St. Charles Formation in the Ogden Thrust Section and tentatively identified by R. J. Ross, Jr. (1966, written communication) as Ordovician, establish the upper age limit of the underlying formation. These fossils, also, present evidence for the existence of Ordovician rocks in Ogden Canyon for the first time.

Allochthon

Middle and Upper Cambrian stratigraphic nomenclature of the allochthon (Text-fig. 1) of northern Utah is well established and is comprised of the Langston Formation, Ute Formation, Blacksmith Dolomite, Bloomington Formation, Nounan Dolomite, and St. Charles Formation. This sequence was proposed by Walcott (1908a, p. 6-8), redefined by Mansfield (1927, p. 53-56) and Deiss (1938, p. 1119-1121), and continued to the present by subsequent workers. Richardson (1913, p. 408) proposed the Hodges Shale Member of the Bloomington Formation and the Worm Creek Quartzite Member of the St. Charles Formation. The Calls Fort Shale Member of the Bloomington was proposed by Denson (1942, p. 24-25).

In 1958, Maxey (p. 668-669) proposed that the term "Pioche Shale" be used for interbedded quartzite and shale, which underlie the Langston Formation and overlie the Brigham (Prospect Mountain) Quartzite in northern Utah. The writer's observation fail to show that the interbedded quartzite and shale at the top of the Brigham Quartzite constitutes a laterally continuous formation south of Blacksmith Fork Canyon, which Maxey (1958, p. 668) also observed. Hafen (1961, Plate 1) used the term Pioche Shale just south of the East Fork Section of this paper. Pioche Shale was not mapped in the Logan Quadrangle by Williams (1948, Plate 1) or in the Browns Hole Quadrangle by Crittenden (1965, oral communication). In this paper, the Pioche Shale of Maxey (1958, p. 668-669) is considered to be the upper part of the Brigham Quartzite as accepted by previous workers.

Langston Formation

The Langston Formation of the allochthon was extended south of Blacksmith Fork Canyon on the basis of lithology, stratigraphic position, and paleontology. The East Fork Section contains a middle shale and limestone member, which is stratigraphically and paleontologically equivalent to the upper Spence Shale Member of the Langston Formation in the High Creek Section (Maxey, 1958, p. 654). However, the Spence Shale Member and the unnamed shale and limestone member are not laterally continuous through Blacksmith Fork Canyon (Text-fig. 3). *Glossopleura* and *Athabaskia* characterize the middle shale and limestone member of the Langston at East Fork. The Langston Formation can be regionally correlated with the Lyndon Limestone and the Busby Quartzite equivalent of the Promontory Range (Olson, 1962, p. 2), with the lower shale member of the Ophir Formation at Tintic (Morris and Lovering, 1961, p. 22) but questionably not in the Ogden Thrust Section (this paper), with the Tatow Formation, the Howell Limestone, and the lower Chisholm Shale in the House Range (Robison, 1960, Fig. 4), and questionably with all or part of the "Twin Knobs" unit of the Bancroft Quadrangle, Idaho (Oriel, 1965) (Text-figs. 2 and 3).

Ute Formation

Lithology, stratigraphic position, and paleontology confirm the extension of the Ute Formation from Blacksmith Fork to the headwaters of the Ogden River. Basal beds of the Ute Formation are characterized by *Glossopleura, Kootenia, Zacanthoides, Acrotreta, Acrothele, Ipidella, Alokistocare, Elrathina* (?), *Kochina, Micromitra,* and *Hyolithes* (Deiss, 1938, p. 1114; Maxey, 1958, p. 661; and this paper). Thus, the basal beds are correlated with the Chisholm Shale of the Promontory Range (Olson, 1962, p. 2), with the upper Chisholm Shale of the House Range (Robison, 1960, p. 49), and questionably with the "Lead Bell" unit of the Bancroft Quadrangle (Oriel, 1965) (Text-fig. 2 and 3).

The middle Ute Formation at Calls Fort contains *Alokistocare, Ehmaniella* (?), *Olenoides,* and *Obolus* (Maxey, 1958, p. 661), which allows tentative correlation with the Dome Limestone and the Whirlwind Formation in the Promontory Range and the House Range (Olson, 1962, p. 2, and Robison, 1960, p. 51) and with the lower shale member of the Ophir Formation in the Ogden Thrust Section (this paper).

Fossils of the upper Ute were reported by A. R. Palmer (1966, written communication) and Maxey (1958, p. 653 and 657) to include *Ptychagnostus cf. P. gibbus* (Linnarsson), *Peronopsis, Spencella, Bolaspidella* (?), *Bathyuriscus, Ehmania* (?), *Kootenia* cf. *K. serrata* (Meek), *Zacanthoides, Alokistocare, Olenoides,* and *Acrotetra.* Thus, the upper Ute rocks can definitely be correlated with the Swasey Limestone of western Utah (Robison, 1964, Table 1), with the middle limestone member of the Ophir Formation in the Ogden Thrust Section (this paper), and questionably with the "Bancroft" unit of the Bancroft Quadrangle, Idaho (Oriel, 1965) (Text-fig. 2 and 3).

Blacksmith Dolomite

Blacksmith Dolomite is extended southward of Blacksmith Fork Canyon on the basis of lithology and stratigraphic position. The Ute-Blacksmith contact is arbitrarily placed at the first limestone-dolomite contact above the shales and limestones of the Ute and below the cliff-forming dolomite of the Blacksmith Dolomite. As a result, the Blacksmith Dolomite varies in thickness, and the Ute Formation may locally include some rocks equivalent to lower Blacksmith beds elsewhere. The Blacksmith-Bloomington contact is arbitrarily placed at the uppermost dolomite-limestone contact, above the cliff-forming Blacksmith Dolomite and below the shales and limestones of the Hodges Shale Member of the Bloomington Formation. Denson (Maxey, 1958, p. 676) reported *Anomocare* and *Palella* from the Blacksmith. The Blacksmith Dolomite is tentatively correlated with the lower limestone member of the Maxfield Limestone in the Ogden Thrust Section, with the upper Teutonic Limestone and the Dagmar Dolomite at Tintic (Morris and Lovering, 1961, p. 26-30), with the Wheeler Shale of the House Range (Robison, 1960, p. 49), and with part or all of the Blacksmith Limestone in the Bancroft Quadrangle, Idaho (Oriel, 1965) (Text-figs. 2 and 3).

Bloomington Formation

Lithology, paleontology, and stratigraphic position confirm the extension of the Bloomington Formation south of Blacksmith Fork. The Hodges Shale Member of the Bloomington contains *Ehmania, Bolaspidella, Blainia* cf. *gregaria* Walcott, *Olenoides, Solenopleura,* and *Helcionella* (Maxey, 1958, p. 676; and this paper). Regionally, the Hodges Shale Member can be correlated with the lower Marjum Limestone of the Promontory Range and the House Range (Olson, 1962, p. 3; Robison, 1964, Fig. 5), with the lower and middle members of the Herkimer Limestone at Tintic (Morris and Lovering, 1961, p. 33), with the middle shale and nodular limestone member of the Maxfield Limestone in Ogden Canyon (this paper), and questionably with all or part of the Wolsey Shale of southwestern Wyoming (Shaw and DeLand, 1955, p. 38-39).

The middle limestone member of the Bloomington Formation contains only *Olenoides,* as reported by Maxey, 1958, p. 676). This member is tentatively correlated with the upper limestone and dolomite members of the Maxfield Limestone in the Ogden Thrust Section, with the Bluebird Dolomite and the lower Cole Canyon Dolomite at Tintic (Morris and Lovering, 1961, p. 38-42), and with the Death Canyon Limestone of southwestern Wyoming (Shaw and DeLand, 1955, Fig. 1).

Fossils of the Calls Fort Shale Member of the Bloomington consist of *Bolaspidella, Asaphiscus, Pachyrhachis oweni* Walcott, *Parehmania, Bolaspis* (?), *Howellaspis* (?), *Acrocephalops* (?), *Elrathia,* and *Homagnostus* cf. *pisiformis pater* (Holm and Westergaard) (Maxey, 1958, p. 676; and Rigo, this paper). Regional correlation of the Calls Fort Shale Member is discussed earlier in this paper under "Autochthon."

Nounan Dolomite

The Nounan Dolomite is extended south of Blacksmith Fork Canyon on the basis of lithology and stratigraphic position. No fossils were found in these rocks in the study area. Williams and Maxey (1941, p. 284) and Olson (1962, p. 4) found the Nounan Dolomite to be fossiliferous and assigned an early Late Cambrian age to it. Correlation of the Nounan Dolomite is discussed in an earlier part of this paper under "Autochthon."

St. Charles Formation

No fossils were found in the St. Charles Formation south of Blacksmith Fork. T. E. Mullens (1966, oral communication) found brachiopods in the dolomite member of the formation a few miles west of the Baldy Ridge Section of this paper. An early *Elvinia* age is assigned to the Worm Creek Quartzite Member of the St. Charles and a late *Elvinia* through *Saukia* age is assigned to the dolomite member (Williams and Maxey, 1941, p. 284). See section on "Autochthon" for regional correlation.

LITHOFACIES

Lithofacies of the Cambrian System of the western U.S. have been divided into three belts: inner detrital, middle carbonate, and outer detrital belts (Palmer, 1960, p. 53). The inner and outer detrital belts are dominated by clastic rocks; the middle carbonate belt is dominated by carbonate rocks. The inner detrital belt derived its sediments from the East (eastern Utah, Colorado, and Wyoming), while the outer detrital belt received its sediments, most likely, from the West (central and western Nevada) (Palmer, 1960, p. 53-58; Robison, 1960, p. 43-47). The middle carbonate belt oscillated across Nevada and Utah, depending on the position of sea level (Palmer, 1960, Figs. 2 and 3; Robison, 1960, Fig. 1).

McKee's documentation (1945, p. 37-39 and 59-79) of the lithofacies of Cambrian rocks of Grand Canyon has been extended to the eastern Great Basin by Robison (1960, p. 43-47). A similar extension of McKee's work to northern Utah is done in this paper.

McKee (1945, p. 37-39) indicated that changes in lithofacies occurred by rapid advances and retreats of the Cambrian sea. Relatively long periods of stability existed after each movement of the sea, allowing time for an individual lithofacies to establish itself. McKee (1945, p. 37-39) stated that certain lithofacies were formed during periods of transgression, while others were formed during periods of regression. The following discussion will briefly summarize Cambrian lithofacies along the lines suggested by McKee (1945).

The inner detrital belt is characterized by a clean, pure orthoquartzite of a near-shore environment. Such rocks are typically developed in the Prospect Mountain and Tintic Quartzites (Robison, 1960, p. 43-44). Brigham Quarzite is the equivalent of the near-shore environment in northern Utah. Robison (1960, p. 44) stated that the off-shore environment of the inner detrital belt consists of red, green, and brown shale typical of the Pioche and Ophir Shales. Parts of the Ute Formation and the Hodges and Calls Fort Shale Members of the Bloomington Formation represent the off-shore environment of the inner detrital belt of northern Utah. Shale over quartzite characterizes a transgressive marine movement in the inner detrital belt.

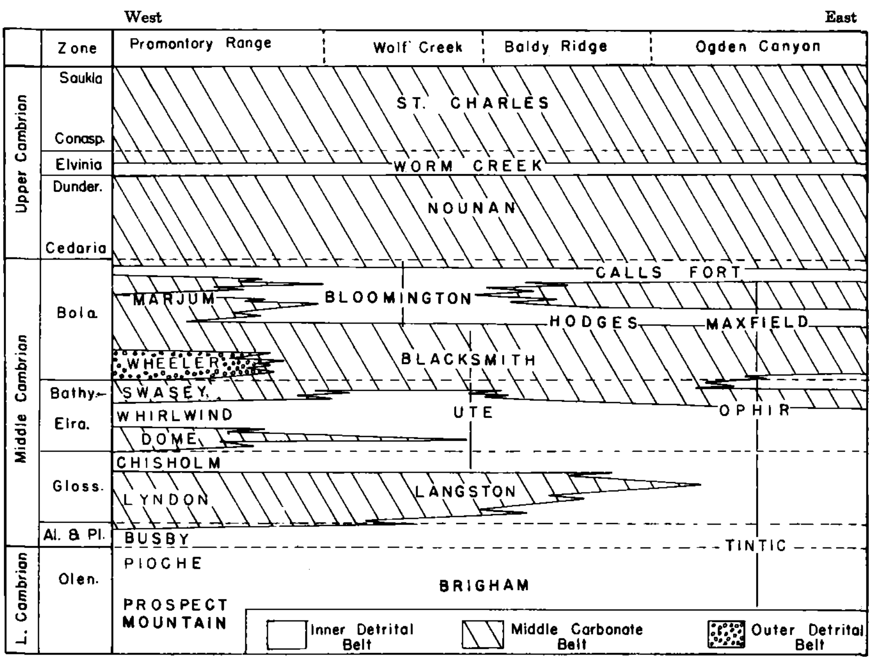
The middle carbonate belt consists of *Girvanella* limestone, rusty brown dolomite or limestone, mottled limestone, massive limestone and dolomite, laminated dolomitic limestone, intraformational flat-pebble conglomerate, and undifferentiated limestone and dolomite (McKee, 1945, p. 59-79; Robison, 1960, p. 44). McKee (1945, p. 59-62) and Robison (1960, p. 44) conclude that *Girvanella* limestone and rusty brown dolomite represent a transgressive facies. They indicate that laminated dolomitic limestone and intraformational flat-pebble conglomerate are common in regressive facies. The remaining rock types of the middle carbonate belt represent central and outer facies of this belt (Robison, 1960, p. 44).

The outer detrital belt is not completely understood. Robison (1960, p. 44 and 47) lists a few common rock types from this belt. He indicates that the Wheeler and Marjum Formations are characteristic of this belt. The eastern extension of the Marjum Formation in northern Utah represents the middle carbonate belt.

TRANSGRESSION AND REGRESSION

Transgressive and regressive movements of the Cambrian sea are reflected by changes in lithofacies. Such movements in northern Utah are illustrated by north-south and east-west lithofacies sketches in Text-figures 4 and 5. Both lithofacies and paleontology, listed below, indicate that the rocks of the allochthon, now found to the east of Ogden, were orginally deposited to the west of Ogden (Text-fig. 1). Thus, in Text-figure 4, the Wolf Creek and Baldy Ridge Sections of the allochthon are placed to the west of Ogden Canyon in order to illustrate the original depositional position. Cambrian zones of Text-figures 4 and 5 are taken from Lochman-Balk and Wilson (1958, Text-figs. 1 and 2). Fossil zonation of various formations or of part of various formations is inadequately known in northern Utah; thus, this study forms an outline of the major movements of the Cambrian sea, whose detail will be improved with further paleontologic studies.

Lower Cambrian sedimentation of northern Utah includes deposition of the Prospect Mountain Quartzite and the Pioche Shale in the Promontory

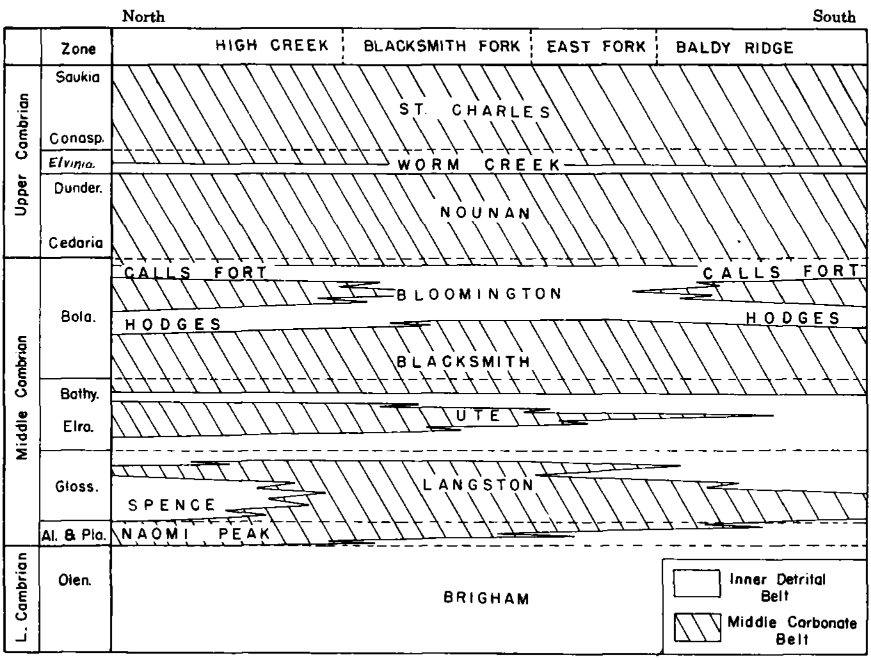


TEXT-FIGURE 4.—East-west palinspastic diagrammatic sketch across northern Utah indicating Cambrian lithofacies changes. Rock thickness ranges from about 10,000 feet on the west to about 3,100 feet on the east. For locations, see Text-figure 2.

Range, Utah, (Olson, 1962, p. 1) and deposition of the upper part of the Brigham Quartzite in southeastern Idaho and northern Utah (Oriel, 1965; and Williams and Maxey, 1941, p. 277). As the sea transgressed eastward, Tintic Quartzite was deposited in the Ogden Canyon area during the late Early Cambrian time and early Middle Cambrian time.

During *Albertella* time, the sea continued to move eastward depositing the Busby Quartzite equivalent, the lower part of the Lyndon Limestone of Promontory Range (Olson, 1962, p. 2) (Text-fig. 4), and the Naomi Peak Limestone Member of the Langston Formation of High Creek (Maxey, 1958, p. 671) (Text-fig. 5).

Eastward transgression from the Promontory Range to Baldy Ridge continued through middle *Glossopleura* time, as illustrated by the Lyndon Limestone and the Langston Formation in Text-figure 4. This transgression is also shown by the Langston Formation with small regressive tongues (the Spence Shale Member from the north and the unnamed shale member from the south) (Text-fig. 5). Convergence of the inner detrital belt towards Blacksmith Fork during *Glossopleura* time (Text-fig. 5) indicates the presence of an east-northeast trending carbonate trough, in which the Langston Formation was deposited (Text-fig. 5). The Langston Formation is thickest and contains no shale at Blacksmith Fork, while to the north, east, and south of Blacksmith Fork, the Langston thins and at places contains shale tongues (Text-figs. 3 and 5). The writer measured 217 feet of Langston near the intersection of the



TEXT-FIGURE 5.—North-south diagrammatic sketch across northern Utah indicating Cambrian lithofacies changes. Rock thickness ranges from about 5,200 feet on the north to about 2,100 feet on the south. For locations, see Text-figure 3.

Bannock Thrust and Utah Highway 39, just west of Woodruff. Thinning of the Langston to the east is thus verified. To the west the Langston thickens to form the Lyndon Limestone and changes from a dolomite to a limestone in the vicinity of Wolf Creek (Text-figs. 2 and 4).

The first major westward regressive movement occurred in late *Glossopleura* time, as recorded by the basal Ute Formation, and the Chisholm equivalent of Promontory Range (Olson, 1962, p. 2) (Text-fig. 4).

The second eastward transgressive movement occurred in early *Bathyuriscus-Elrathina* time, which is recorded by the Dome Limestone equivalent of Promontory Range (Olson, 1962, p. 2) (Text-fig. 4). The Dome transgression probably reached the area between Promontory Range and Wolf Creek as an eastern limit. At this time, the basal Ophir was deposited (Text-fig. 4).

During middle *Bathyuriscus-Elrathina* time, the second regression took place when clastics of the inner detrital belt swept westward across the middle carbonate belt depositing the lower shale member of the Ophir Formation, the middle Ute Formation, and the Whirlwind equivalent (Olson, 1962, p. 2) (Text-fig. 4). At this time, the middle carbonate belt retreated to northern Utah where the middle Ute was deposited (Text-fig. 5).

In late *Bathyuriscus-Elrathina* time, the middle carbonate belt (Swasey Limestone) transgressed eastward to Wolf Creek where it intertongues with a southwest trending trough of the inner detrital belt (upper Ute Formation) (Text-fig. 4). The middle limestone member of the Ophir Formation and the upper Ute Formation also intertongue with the southwest trending trough of the inner detrital belt at Wolf Creek (Text-fig. 4). The upper shale member of the Ophir represents a minor regression questionably during latest *Bathyuriscus-Elrathina* time.

A major eastward transgression occurred in early *Bolaspidella* time. The sea deposited the Blacksmith Dolomite throughout most of northern Utah (Text-figs. 4 and 5). Wheeler Shale of the outer detrital belt reached Promontory Range during the *Bolaspidella* transgression (Text-fig. 4), the only time in which the outer detrital belt covered part of northern Utah.

During middle *Bolaspidella* time, the westward Hodges regression occurred, ending in the vicinity of the Promontory Range. Eastward transgression by the middle carbonate belt followed, but did not completely cover the East Fork-Wolf Creek area (Text-figs. 4 and 5), which acted as a high during middle Bloomington time. The Calls Fort regression occurred during late *Bolaspidella* time and extended to the west of Promontory Range (Text-fig. 4).

Major eastward transgression occurred from *Cedaria* to *Dunderbergia* times, so that the central part of the middle carbonate belt occupied northern Utah. The Nounan Dolomite was deposited at this time.

During early *Elvina* time (Williams and Maxey, 1941, Fig. 2), clastics of the inner detrital belt from Idaho formed the persistent Worm Creek Quartzite Member of the St. Charles Formation (Text-figs. 4 and 5). Text-figure 3 indicates that the source area of the Worm Creek Quartzite is to the north in the vicinity of the Bancroft Quadrangle, Idaho, a conclusion which Haynie (1957, p. 24) also reached.

In late *Elvinia* time, a major eastward transgression extended across northern Utah, where the middle carbonate belt persisted throughout the remainder of Late Cambrian time (Text-figs. 4 and 5).

STRUCTURAL IMPLICATIONS

Stratigraphic study of Middle and Upper Cambrian rocks indicates that the allochthon of northern Utah has its root zone in the region near the Promontory Range of Utah and not in the autochthon of Ogden Canyon, Utah, for the following reasons:

(1) Presence of a thick *Glossopleura* zone in post-Brigham or equivalent beds in the allochthon of northern Utah and in the Promontory Range, Utah.

(2) Questionable absence or at most a thin *Glossopleura* zone in post-Tintic beds in the autochthon of Ogden Canyon, Utah.

(3) Progressive thinning of Middle and Upper Cambrian formations from 6,900 feet in the Promontory Range to 3,400 feet in the allochthon and from 3,400 feet in the allochthon to 2,200 feet in autochthon (Text-fig. 6).

(4) Disconformities in the Upper Cambrian rocks of the autochthon, which are characteristic of an unstable shelf deposit.

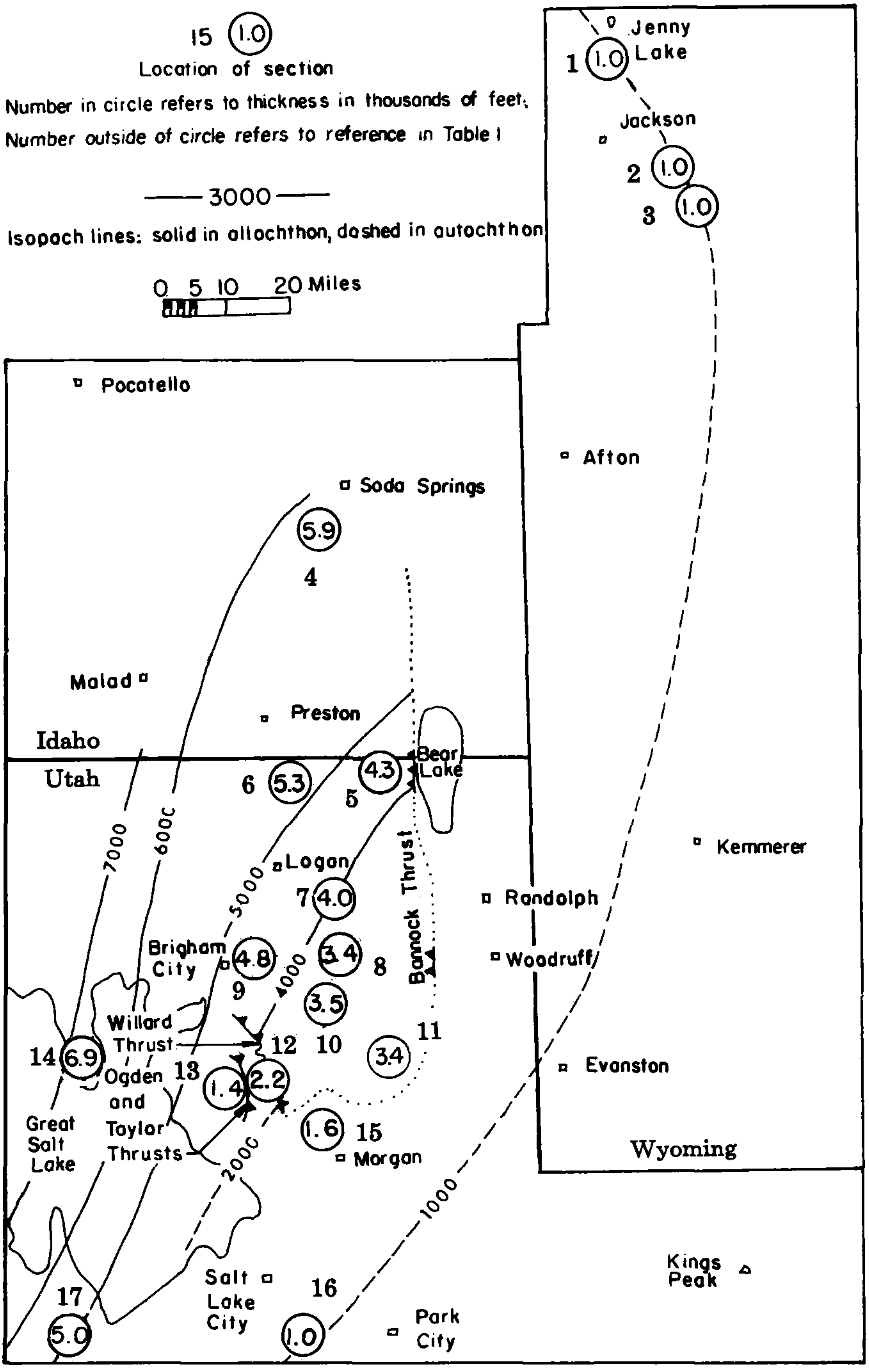
(5) Absence of disconformities in the Upper Cambrian rocks of the Promontory Range and of the allochthon of the Blacksmith Fork-Huntsville area.

Thus, the allochthon of northern Utah (Text-fig. 1) appears to belong between the Promontory Range on the west and Ogden Canyon on the east, rather than to the east of Ogden Canyon.

An isopach map of Middle and Upper Cambrian rocks of northern Utah and adjacent areas indicates an incongruous pattern (Text-fig. 6). Isopach lines of Text-figure 6 indicate a progressive thinning of the Middle and Upper Cambrian rocks in the allochthon to the southeast and in the autochthon to the east-southeast. The direction of thinning, in general, is not greatly different for the two structural blocks. However, the incongruity appears in matching

TABLE 1
REFERENCES TO SECTIONS IN TEXT-FIGURE 6

No. on Map	Reference
1	Miller, 1936, p. 128
2	Miller, 1936, p. 130
3	Blackwelder, 1918, in Miller, 1936, Fig. 2
4	Oriel, 1965
5	Richardson, 1941, plate 6
6	Williams, 1948, p. 1134-1135; and Maxey, 1958, p. 651-655
7	Deiss, 1938, p. 1107-1116; and Williams, 1948, p. 1135
8	Rigo, this paper
9	Maxey, 1941, p. 17-24
10	Rigo, this paper
11	Rigo, this paper
12	Rigo, this paper; and Mullens, 1966, oral communication
13	Rigo, this paper
14	Olson, 1962, p. 1-6
15	Eardley, 1944, p. 828-829
16	Calkins and Butler, 1943, plate 5
17	Rigby, 1958, Figures 3 and 4



TEXT-FIGURE 6.—Middle and Upper Cambrian isopach map of northern Utah and vicinity.

equivalent isopachs between the allochthon and autochon, which indicates that the allochthon has been displaced to the east over the autochthon. This statement supports Eardley's theory on thrusting of the allochthon to the east (1944, p. 869-871), which is also supported by Crittenden (1961, p. 128-311). Eardley (1951, p. 330) has suggested that eastward movement of the allochthon may be as much as 75 miles. On the basis of stratigraphic thinning of Precambrian and Paleozoic rocks, Crittenden (1961, p. 128-131) states that a minimum eastward displacement of 40 miles is necessary for the allochthon.

The amount of eastward displacement of the allochthon in northern Utah may be estimated in various ways from Text-figure 6. Moving the Bannock Thrust Fault to the west of the autochthon at Ogden indicates about 33 miles of movement. However, this represents a bare minimum, inasmuch as it does not allow for stratigraphic thinning of the Middle and Upper Cambrian rocks from the allochthon to the autochthon. A more accurate method of calculating displacement of the allochthon is on the basis of rates of stratigraphic thinning. Providing that the Promontory Range (Section 14, Text-fig. 6) has moved the same with respect to Baldy Ridge (Section 11, Text-fig. 6), Middle and Upper Cambrian rocks thin at the average of 66 feet per mile between these two sections. This rate of thinning is extremely steep when compared with 6 feet per mile for the thinning of equivalent rocks from the House Range to the Promontory Range (Text-fig. 2) and with 35 feet per mile from the Ogden Thrust Section (Section 12, Text-fig. 6) to the 1,000-foot isopach. The rapid rate of thinning between sections 11 and 14 is attributed to the tectonic hinge belt that separates the miogeosyncline on the west from the shelf on the east. At the rate of 66 feet per mile, section 11 (Text-fig. 6) would thin to 2,000 feet in 21 miles. Thus, section 11 should be about 21 miles west of the 2,000-foot isopach in the autochthon or about 42 miles west of its present position. On the other hand, if the rate of thinning decreased to that of 35 feet per mile, which sections 7, 8, and 10, and 11 (Text-fig. 6) seem to indicate, section 11 would thin to 2,000 feet in 40 miles. This would place section 11 about 40 miles west of the 2,000-foot isopach in the autochthon or about 60 miles west of its present position. The rates of thinning of Middle and Upper Cambrian rocks of northern Utah thus indicate that the displacement between the allochthon and autochthon lies between 42 and 60 miles.

CONCLUSIONS

Middle and Upper Cambrian stratigraphy of the allochthon in northern Utah consists of Langston through St. Charles Formations. The Langston, Ute, and Bloomington Formations undergo lithofacies and thickness changes. The Blacksmith, Nounan, and St. Charles Formations remain fairly uniform throughout the allochthon.

The autochthon in Ogden Canyon, Utah, contains a well-exposed section of middle and Upper Cambrian rocks. The lower two formations are the Ophir Shale and the Maxfield Limestone. The remainder of the sequence includes the Calls Fort Shale Member of the Bloomington Formation, the Nounan Dolomite, and the St. Charles Formation. Use of Pioche Shale and Langston Formation are not recommended in Ogden Canyon for paleontologic and lithologic reasons. Ordovocian rocks, recognized for the first time in the present paper, conformably overlie the St. Charles Formation in Ogden Canyon.

Explanation of Plate 1
PERRY CAMP SECTION

Fig. 1.—Panoramic view of the Perry Camp Section from the south side of Ogden Canyon. Ct, Tintic Quartzite; Co, Ophir Formation; Cm, Maxfield Limestone.

Fig. 2.—Close-up of the middle shale and nodular limestone member of the Maxfield Limestone in the Perry Camp Section.

Explanation of Plate 2
OGDEN THRUST AND EAST FORK SECTIONS

Fig. 1.—Panoramic view of the Ogden Thrust Section from the south side of Ogden Canyon, just south of the Hermitage. Ct, Tintic Quartzite; Co, Ophir Formation; Cm, Maxfield Limestone; Cbo, Calls Fort Shale Member of the Bloomington Formation; Csw, Worm Creek Quartzite Member of the St. Charles Formation; Csc, St. Charles Formtaion.

Fig. 2.—Panoramic view of the East Fork Section from the south side of the East Fork of the Little Bear River, just west of Mineral Point. Cbr, Brigham Quartzite; Cl. **Langston Formation; Cu, Ute Formation; Cbl,** Blacksmith Dolomite; Cbo, Bloomington Formation; Cn, Nounan Dolomite; Csc, St. Charles Formation; Ogc, Garden City Limestone.

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Seven major eastward transgressions and six major westward regressions of the Cambrian sea in northern Utah are illustrated in Text-figures 4 and 5.

Cambrian rocks of the allochthon of the Blacksmith Fork-Huntsville area have their root zone in the vicinity of the Promontory Range, Utah, and not in Ogden Canyon. Lithology, paleontology, and isopach changes of Cambrian rocks indicate that the allochthon has been thrust eastward over the autochthon. Rates of thinning of Middle and Upper Cambrian rocks indicate that the allochthon has been displaced some 42 to 60 miles eastward of its original position.

REFERENCES CITED

Bentley, C., 1958, Upper Cambrian stratigraphy of western Utah: Brigham Young University Research Studies, Geol. Ser., v. 5, no. 6, 70 p.

Blackwelder, Eliot, 1909, New light on the geology of the Wasatch Mountains, Utah: Geol. Soc. America Bull., v. 21, p. 517-542.

Calkins, F. C., and Butler, B. S. 1943, Geology and Ore Deposits of the Cottonwood-American Fork Area, Utah: U. S. Geol. Survey Prof. Paper 201, p. 1-147.

Crittenden, M. D., Jr., 1961, Magnitude of thrust faulting in northern Utah: U. S. Geol. Survey Prof. Paper 424-D, p. 128-131.

———, 1965a, Geology of the Mount Aire Quadrangle, Salt Lake County, Utah: U. S. Geol. Survey, Geol. Quadrangle Map GQ-379.

———, 1965b, Geology of the Sugarhouse Quadrangle, Salt Lake County, Utah: U. S. Geol. Survey, Geol. Quadrangle Map GQ-380.

Deiss, C. F., 1938, Cambrian formations and sections in part of the Cordilleran Trough: Geol. Soc. America Bull., v. 49, p. 1067-1168.

Denson, N. M., 1942, Late Middle Cambrian trilobite faunas and stratigraphy of Alberta, Montana, Wyoming, and Utah: unpub. Ph.D. dissertation, Princeton University, 76 p.

Eardley, A. J., 1944, Geology of the north-central Wasatch Mountains, Utah: Geol. Soc. America Bull., v. 55, p. 819-894.

———, 1951, Structural Geology of North America: Harper and Row, Publishers, New York, 624 p.

Hafen, P. L., 1961, Geology of the Sharp Mountain area, southern part of the Bear River Range, Utah: unpub. M. S. thesis, Utah State University, 72 p.

Haynie, A. V., Jr., 1957, The Worm Creek Quartzite Member of the St. Charles Formation, Utah-Idaho: unpub. M. S. thesis, Utah State University, 39 p.

King, Clarence, 1878, Systematic geology: U. S. Geol. Explor. 40th Parallel, v. 1, p. 127-227.

Lochman-Balk, Christina, and Wilson, J. L., 1958, Cambrian biostratigraphy in North America: Jour. Paleont., v. 32, no. 2, p. 312-350.

Mansfield, G. R., 1927, Geography, geology and mineral resources of part of southeastern Idaho: U. S. Geol. Survey Prof. Paper 152, 409 p.

Maxey, G. B., 1941, Cambrian stratigraphy in the northern Wasatch region: unpub. M.S. thesis, Utah State Agriculture College, 83 p.

———, 1958, Lower and middle Cambrian stratigraphy in northern Utah and southeastern Idaho: Geol. Soc. America Bull., v. 69, p. 647-688.

McKee, E. D., 1945, Stratigraphy and ecology of the Grand Canyon Cambrian, part 1 of the Cambrian History of the Grand Canyon Region: Carnegie Inst. Washington Pub. 563, p. 5-168.

Miller, B. M., 1936, Cambrian stratigraphy of northwestern Wyoming: Jour. Geology, v. 44, p. 113-144.

Morris, H. T., and Lovering, T. S., 1961, Stratigraphy of the East Tintic Mountains, Utah: U. S. Geol. Survey Prof. Paper 361, 145 p.

Olson, R. H., 1962, Geology of the Promontory Range, Box Elder County, Utah: unpub. Ph.D. dissertation, University of Utah, 341 p.

———, 1964, Cambrian stratigraphy at Promontory Point, Box Elder County, Utah (abstract). Geol. Soc. Amer. Special Paper 76, p. 287-288.

Oriel, S. S., 1965, Preliminary Geologic Map of the SW¼ of the Bancroft Quadrangle, Bannock and Caribou Counties, Idaho: U. S. Geol. Survey, Mineral Investigations Field Studies Map MF-299.

Palmer, A. R., 1960, Some aspects of the early Upper Cambrian stratigraphy of White Pine County, Nevada and vicinity: Intermountain Assoc. Petrol. Geol. Eleventh Ann. Field Conf., p. 53-58.

Richardson, C. B., 1913, The Paleozoic section in northern Utah: Am. Jour. Sci., 4th Ser., v. 36, p. 406-416.

———, 1941, Geology and mineral resources of the Randolph Quadrangle, Utah-Idaho: U. S. Geol. Survey Bull. 923, 54 p.

Rigby, J. K., 1958, Geology of the Stansbury Mountains, Tooele County, Utah; in Guidebook to the Geology of Utah: Utah Geol. Soc., no. 13, 175 p.

Robison, R. A., 1960, Lower and Middle Cambrian stratigraphy of eastern Great Basin: Intermountain Assoc. Petrol. Geol. Eleventh Ann. Field Conf., p. 43-52.

———, 1964, Upper Middle Cambrian stratigraphy of western Utah: Geol. Soc. America Bull., v. 75, p. 995-1010.

Shaw, A. B., and DeLand, C. R., 1955, Cambrian of southwestern Wyoming: Wyoming Geol. Assoc. Guidebook, Tenth Ann. Field Conf., Green River Basin, p. 38-42.

Walcott, C. D., 1908a, Nomenclature of some Cambrian Cordilleran formations: Smithson. Misc. Coll., v. 53, no. 1, p. 1-12.

———, 1908b, Cambrian sections of the Cordilleran area: Smithson. Misc. Coll., v. 53, no. 5, p. 167-230.

Williams, J. S., 1948, Geology of the Paleozoic rocks, Logan quadrangle, Utah: Geol. Soc. America Bull., v. 59, p. 1121-1164.

———, and Maxey, G. B., 1941, The Cambrian section in the Logan Quadrangle, Utah and vicinity: Am. Jour. Sci., v. 239, p. 276-285.

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