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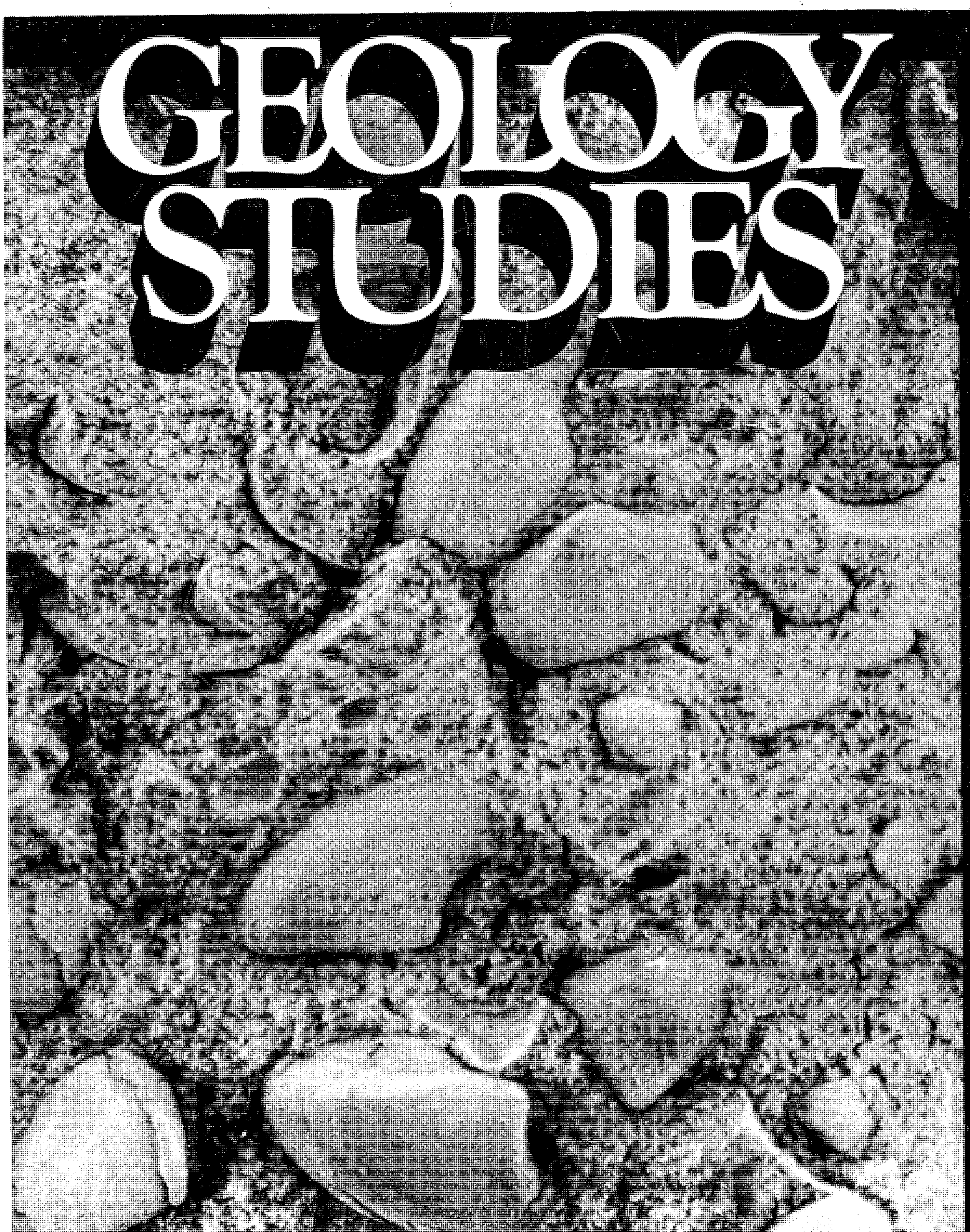

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Cover: Slab of bivalves showing Myalina-Pleuroma *suite, from Torrey section, Sinbad Limestone Member, Moenkopi Formation in the Teasdale Dome Area, Wayne County, Utah. Photo courtesy James Scott Dean.*

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CONTENTS

Biostratigraphy of the Great Blue Formation*

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ABSTRACT.–Six measured sections of Upper Mississippian Great Blue Formation in the Basin and Range Province of northwestern Utah contain Meramecian conodonts at the base of the formation and Chesterian ammonoids in the middle of the formation. Terrestrial plants, as well as marine organisms, are found in the formation. Except for the Ochre Mountain section, east-west correlation of measured sections shows clastics thickening and becoming more coarse to the west, suggesting a westward source. Fossils concentrated in several horizons of shaly limestone in and below shale units in the Oquirrh Mountain section suggest that the organisms were controlled by facies during Great Blue time.

INTRODUCTION

Location and Purpose

This study is concerned with fossil occurrences in six sections of Great Blue Formation measured in the Oquirrh, Onaqui, Ochre, East Tintic, Wasatch, and Wellsville Mountains (fig. 1). The study area encompasses 30,000 km^2 of the Basin and Range Province in northwestern Utah where Mississippian rocks, including the Great Blue Formation, are exposed. Establishment of floral and faunal occurrences and local range zones in the formation aids correlation of the Great Blue Formation within the study area and with established North American zones.

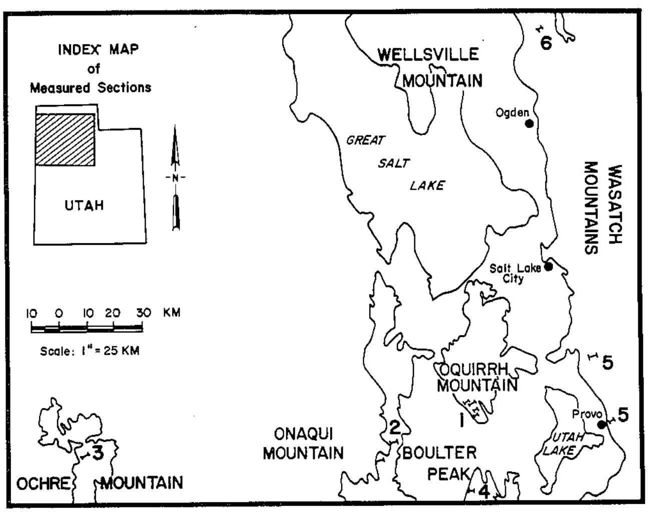

FIGURE 1.–Index map.

Previous Work

Spurr (1894), in his review of the Mississippian strata of the Mercur District, used a miner's term, *Great Blue,* to describe the thick sequence of Upper Mississippian blue-gray limestone. Gilluly (1932) used the term "Great Blue" Limestone throughout his study of the southern Oquirrh Mountains. Bissell and others (1959) dropped the quotation marks on Great Blue and suggested that Great Blue Limestone be the formal name for the limestone between the Humbug Formation and the Manning Canyon Shale. Morris and Lovering (1961) divided the Great Blue into four members in the East Tintic Mountains and named a thick clastic unit the Chiulos Member.

Gilluly (1932) suggested the use of the Long Trail Shale as a useful mappable member in the Great Blue Formation. Zeller (1958) did the first comprehensive work on the Long Trail Shale, working out its paleoecology by studying its fauna. Bissell and others (1959) mention an "unnamed shale" in the Upper Great Blue Formation between the Long Trail Shale and the Manning Canyon Shale. Fieldwork by the writer and Michael Metcalf in 1976 indicated there were at least three mappable shale units between the Long Trail Shale and the Manning Canyon Shale in the southern Oquirrh Mountains.

Fieldwork

A primary reference section was measured in the southern Oquirrh Mountain type locality after carefully mapping the area at a scale of 1:6,000 to insure accuracy. Five additional sections were measured at Ochre Mountain, southern Onaqui Mountains, Wasatch Mountains (Rock Canyon and Box Elder Peak), Wellsville Mountain, and Boulter Peak to compare with the reference Oquirrh Mountain section. Sections were measured using standard methods, and fossils were collected wherever found. Stratigraphic occurrences of all fossils were carefully recorded.

Laboratory Work

Samples were collected for conodonts from almost every measured unit. The samples were digested in 10 percent acetic acid, sieved with a 120-mesh screen and concentrated with tetrabromoethane. The collected specimens were identified by comparing photographs and descriptions of conodonts found in the Upper Mississippi River Valley.

Coral specimens were cut transversely and etched for 20 seconds in hydrochloric acid in preparation for examination under a binocular microscope. They were identified to genera by comparing specimens to descriptions and photographs of corals of similar age. Other fossils were cleaned, etched, and separated from matrix.

Depositional Environment of the Great Blue Formation

Two schools of thought exist on the source of clastics and depositional environments of the Great Blue Formation. On one hand, Rose (1976) and his associates advocate an eastern source for the clastics which were trapped behind a constructional barrier located on the upper shelf margin which restricted circulation of marine waters. Supporting evidence includes apparent basinward thinning of the formation, skeletal lime-

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stone changing facies to dark silty carbonates to the west, and presence of dolomites indicating restricted circulation.

Contrasting with the carbonate shelf margin theory is the possibility that the clastics in the Great Blue are derived from the Antler orogeny. Poole (1974) suggests that westerly derived clastics filled the foreland trough and spread eastward across the limestone shelf onto the craton resulting in an estuarine environment. Evidences for Antler-derived clastics found during this study include thickening and coarsening of clastics to the west (except the Ochre Mountain section) and terrestrial plants found in several horizons within the Great Blue Formation.

Acknowledgments

The writer wishes to acknowledge the assistance of Dr. Morris Petersen and Dr. H. J. Bissell for supervision of the problem and aid in preparing the manuscript.

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STRATIGRAPHIC SECTIONS

Oquirrh Mountain Section (1)

Two partial sections combined into a single 1,010-m section were measured in the southern Oquirrh Mountains. A partial section of 150 m of limestone between the Humbug Formation and the Long Trail Shale measured near Mercur Canyon, NW¼ NW¼, section 18, T. 6 S, R. 3 W, and NE¼, section 13, T. 6 S, R. 4 W, was combined with another section of the remaining 860 m between the Long Trail Shale in Sunshine Canyon and the Manning Canyon Shale in Manning Canyon, NW½, section 21, SE¼, section 16, and SW¼ section 15, T. 6 S, R. 3 W. Other partial sections were measured in NW¼, section 22, and SE¼, section 27, T. 6 S, R. 3 W, to insure completeness of the fossil collection.

As seen in figure 2, there are three zones of fossiliferous material in the Oquirrh Mountain section, each occurring immediately beneath and within a major shale unit. Invertebrates dominating the limestone facies were replaced by terrestrial plants in the shale. The unfossiliferous limestone immediately above each of the shale units gradually becomes fossiliferous near the top where the shale-limestone-shale sequence is repeated, as well as the fossiliferous-unfossiliferous-fossiliferous sequence, suggesting strong facies controls on the organisms.

The gradual increase in clastics and fossils suggests there were periods of shoaling or sea retreat, which controlled the organisms' migratory patterns. The sudden change to unfossiliferous limestone with intraformational conglomerates suggests rapid advance of the sea and periods of unfavorable habitats for life. The cyclic nature of the repeated beds suggests unstable tectonic conditions during Upper Mississippian time.

Onaqui Mountain Section (2)

Two partial sections were measured at the south end of the Onaqui Mountains. One partial section was measured below the Chiulos Member and the other was above the same mem-

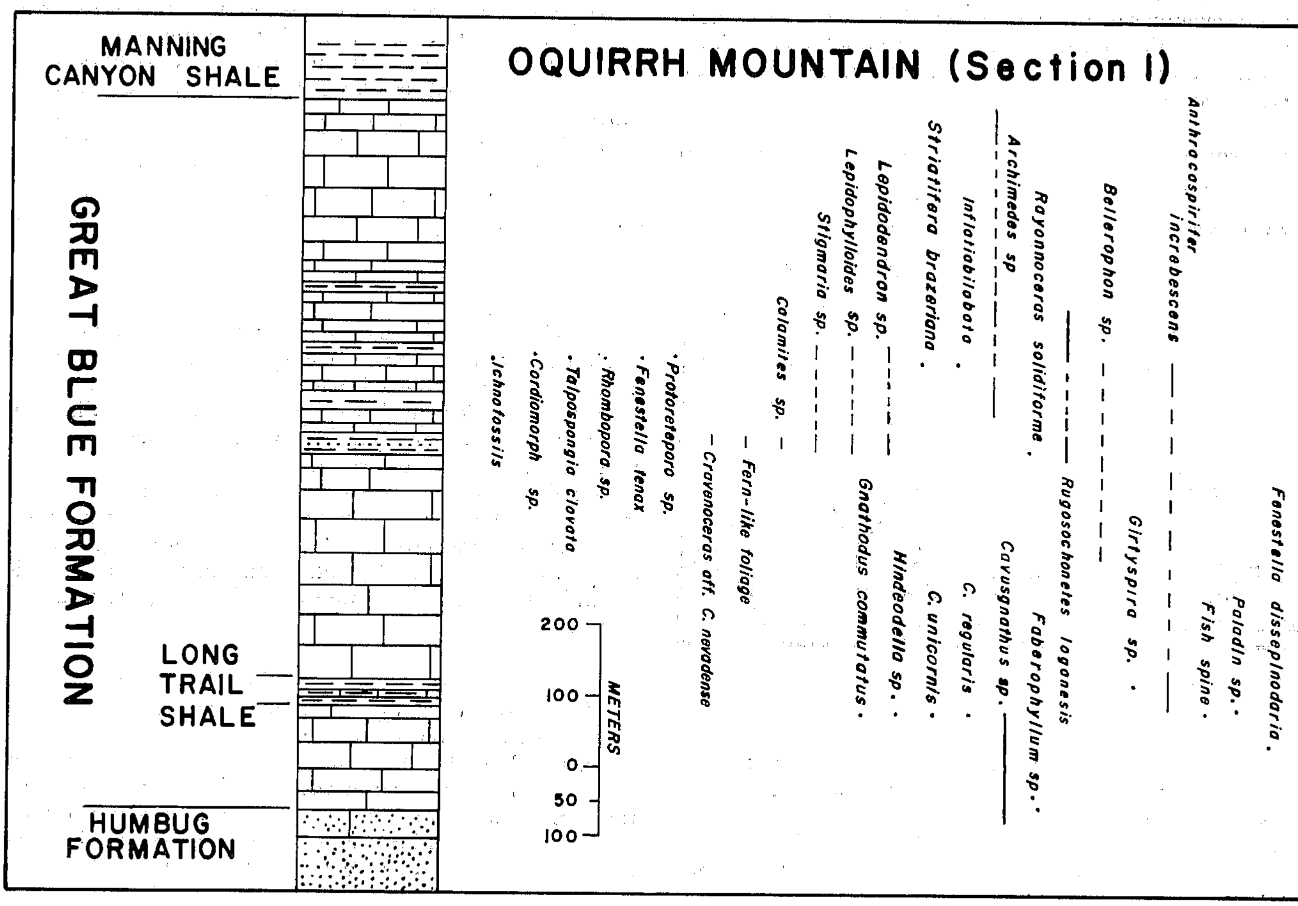

FIGURE 2.–Oquirrh Mountain (section 1).

ber. The two were combined with Cohenour's (1959) measurements of the Chiulos Member to make the 1,300-m Onaqui Mountain section. The partial section of the limestone below the Chiulos Member, south of the Pony Express Road through Lookout Pass, SE¼, section 11, T. 8 S, R. 7 W, was 330 m thick. The partial measured section of Great Blue Limestone above the Chiulos Member, north of the Pony Express Road, NW¼, section 18, T. 8 S, R. 6 W, was 420 m thick.

Somewhat different from section 1, section 2 (fig. 3) has a single thick medial shale unit with interbedded orthoquartzites called the Chiulos Member. Also contrasting with section 1 is the abundance of corals found above the clastic unit. The limestone-shale-orthoquartzite-shale-limestone sequence suggests a single major regression followed by a transgression of the sea. As with several of the shale units in section 1, the clastic unit in section 2 has remains of *Stigmaria* sp. and pith casts suggesting a period of swamp development. The presence of abundant corals below and above the clastic unit in section 2 suggests that the waters were favorable for those organisms. In section 1, however, it appears that with each transgression of the sea the waters were generally inhospitable to life, temporarily inhibiting organisms from migrating into the area.

Ochre Mountain Section (3)

Only 400 m of lowermost Ochre Limestone were measured at Ochre Mountain, SE¼, section 16, NE¼, section 21, T. 8 S, R. 19 W, because of faulting, repeated beds, and lack of a complete section. The limestone appears similar in color, texture, and bedding to the lower Great Blue Formation in section 1. Nolan (1935) measured the blue-gray Ochre Limestone by combining thicknesses of several outcrops of limestone scaled from a geologic map. The partial section of this report replaces the lower 400 m of Nolan's 1,372-m section in figures 4 and 8; however, his section may be greatly exaggerated because of intense faulting in the district.

Only two brachiopods, several corals, crinoid stems, and a conodont were found in the lower part of this section. The occurrence of *Faberophyllum* sp. and *Spathognathodus unicornis* in the lower part of the Ochre Limestone seemingly correlates with the lower Great Blue to the east.

Boulter Peak Section (4)

Boulter Peak Quadrangle (section 4) in the northeast Tintic Mountains, is more like section 2 than any other section. It has a thick shale with interbedded orthoquartzites between two

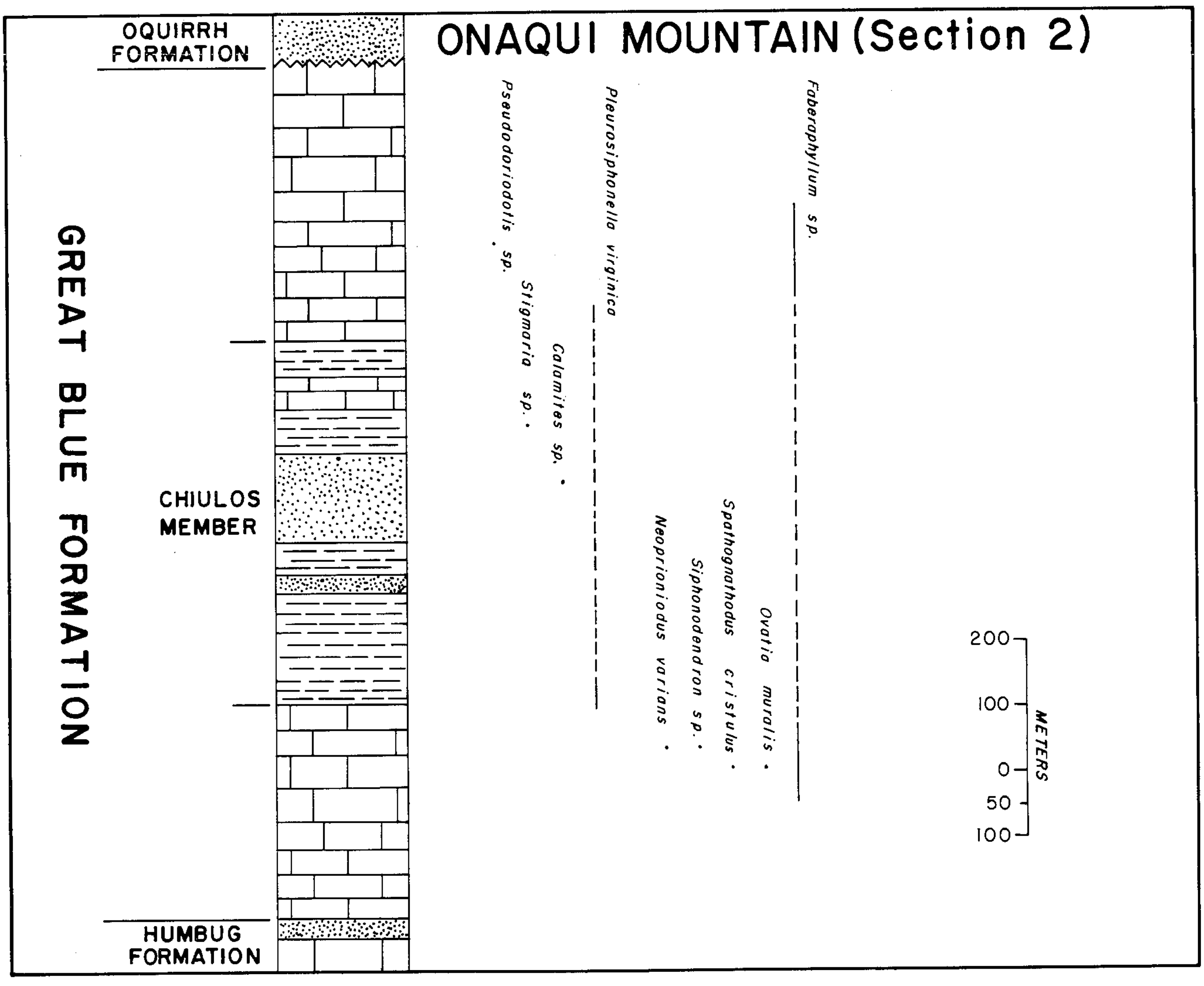

FIGURE 3.—Onaqui Mountain (section 2).

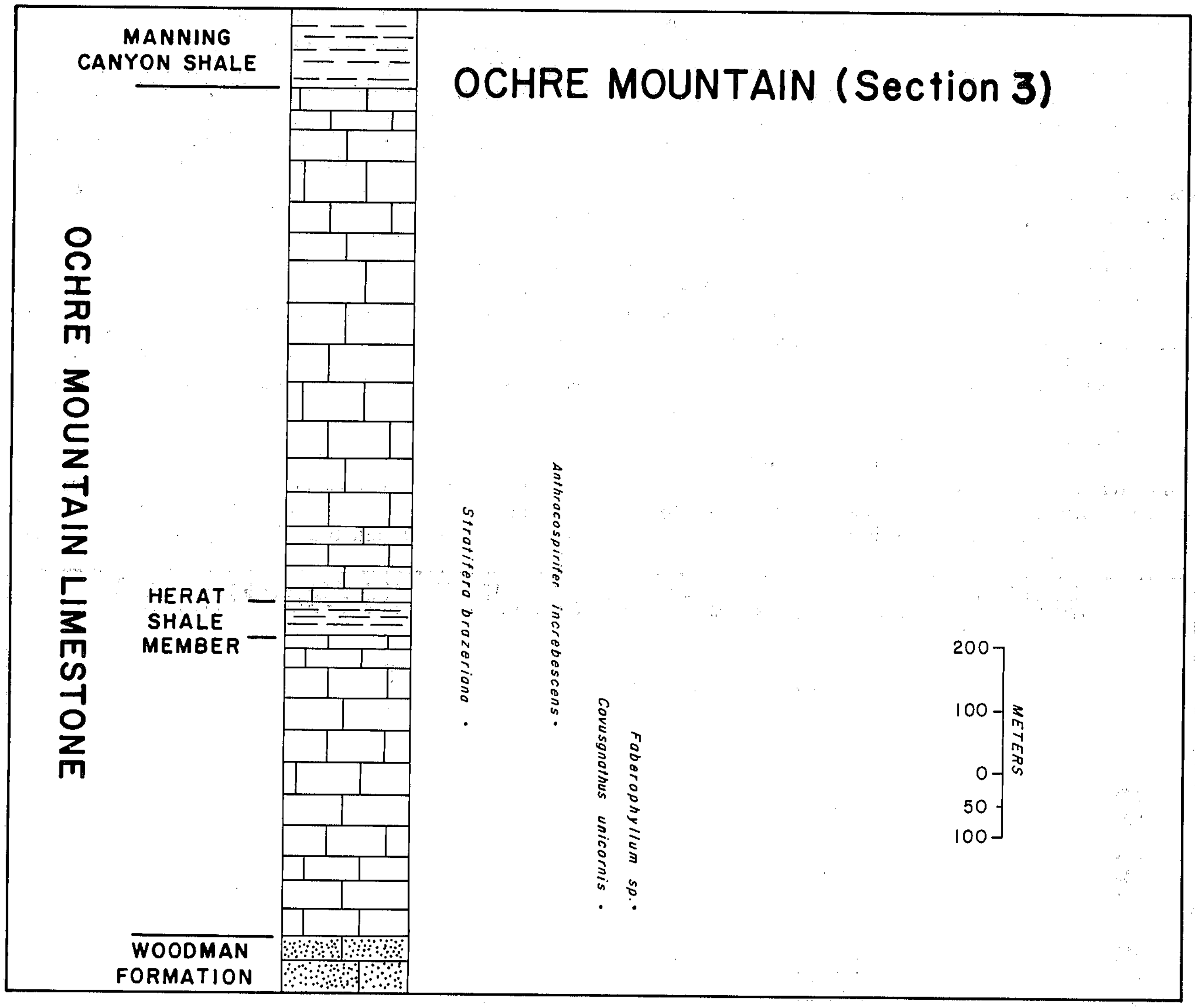

FIGURE 4.—Ochre Mountain (section 3).

thick units of limestone. A 365-m partial section of the lower limestone was measured in section 6, T. 9 S, R. 3 W, and section 31, T. 8 S, R. 3 W. The remaining 475 m of the section were compiled with the use of a measured section by Morris and Lovering (1961).

Characterized by scattered corals, brachiopods, and crinoids, the lower limestone of section 4 appears very similar to the lower limestone in section 2 (figs. 3, 5). The shale and orthoquartzite unit, although somewhat thinner and apparently lacking fossil plants, appears to be similar to the shale and orthoquartzite in section 2. The coral *Pleurosiphonella virginica* occurs in both sections 2 and 4, and it appears 14 m lower in section 4 than in section 2. The first occurrence of *Faberophyllum* sp. is at the same level in both sections. Differing sharply from section 2, the limestone overlying the clastic unit in section 4 lacks corals.

Wasatch Mountain Section (5)

Located in Rock Canyon, NE¼, section 28, NW¼, section 27, T. 6 S, R. 3 E, and accessible from the top of the formation via Squaw Peak Trail, section 5 is measured 890 m thick. Since the base of the formation is poorly exposed at Rock Canyon, another partial section was measured near Alpine, Utah, in section 8, T. 4 S, R. 2 E. It was included in the total thickness of 890 m.

For the most part, section 5 is unfossiliferous limestone. Pinney (1965) reports the following four Chesterian age conodonts from the upper part of the Great Blue Formation: *Cavusgnathus unicornus, Gnathodus(?) antitexanus, G. texanus,* and *Neoprioniodus scitulus,* but fails to give detailed stratigraphic occurrence (fig. 6).

Wellsville Mountain Section (6)

Only the lower 550 m of this section of the Great Blue were measured and collected by Lindsay (1977) in SW¼, section 15, T. 11 N, R. 2 W, on the ridge south of Holdaway Canyon, Wellsville Mountain. Fossils and measurements, given by Lindsay to the writer, are used exclusively for this section. More than 150 samples from this measured section were processed for conodonts. Although they occurred rarely, enough conodonts were found to give a tentative *Apatognathus-Spathognathodus scitulus* Zone for the lower Great Blue Formation

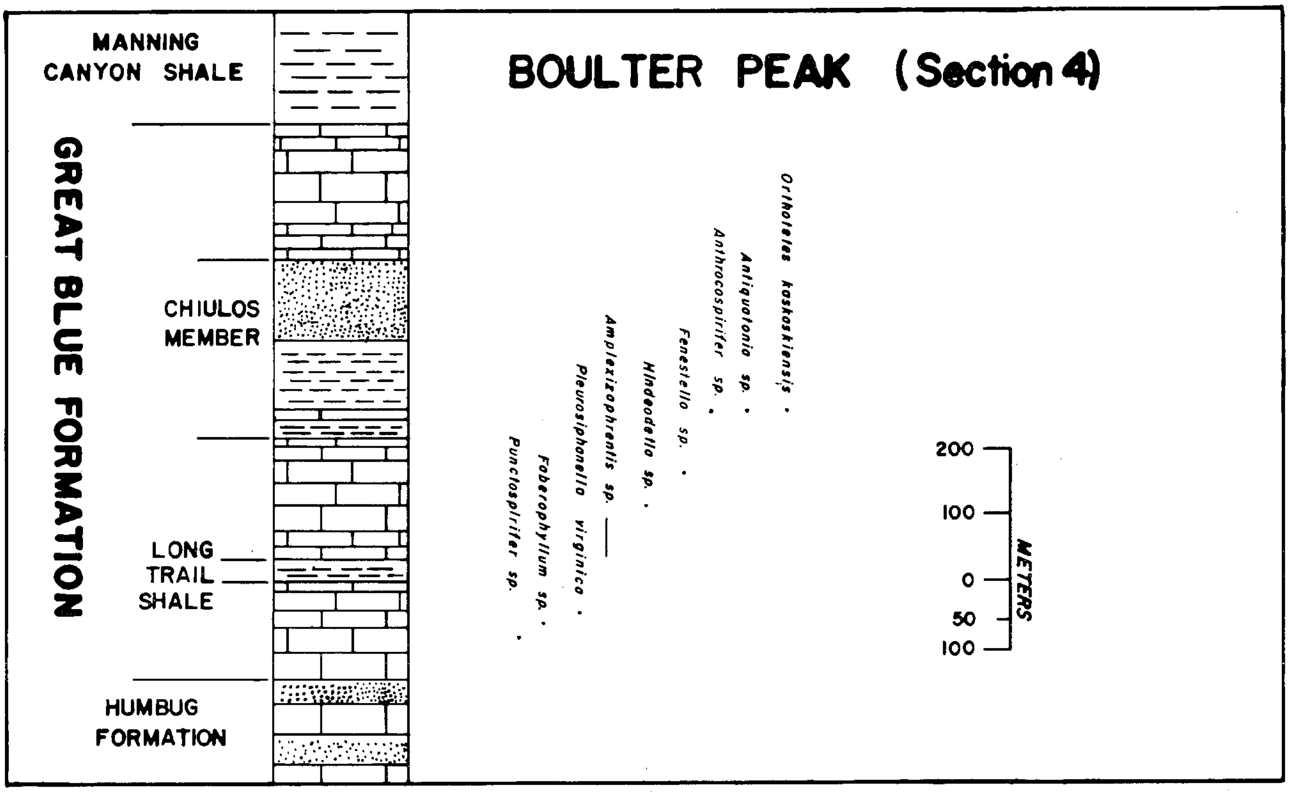

FIGURE 5.—Boulter Peak (section 4).

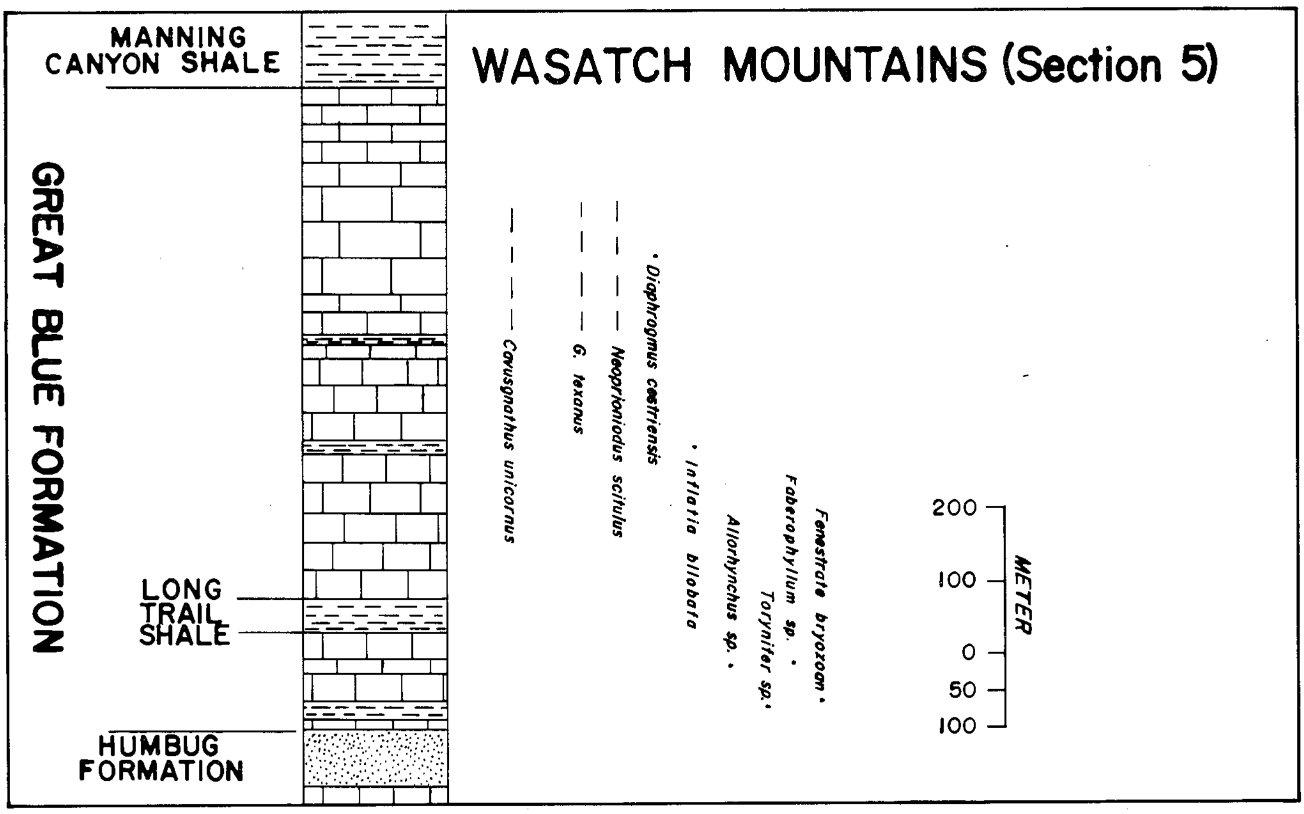

FIGURE 6.—Wasatch Mountains (section 5).

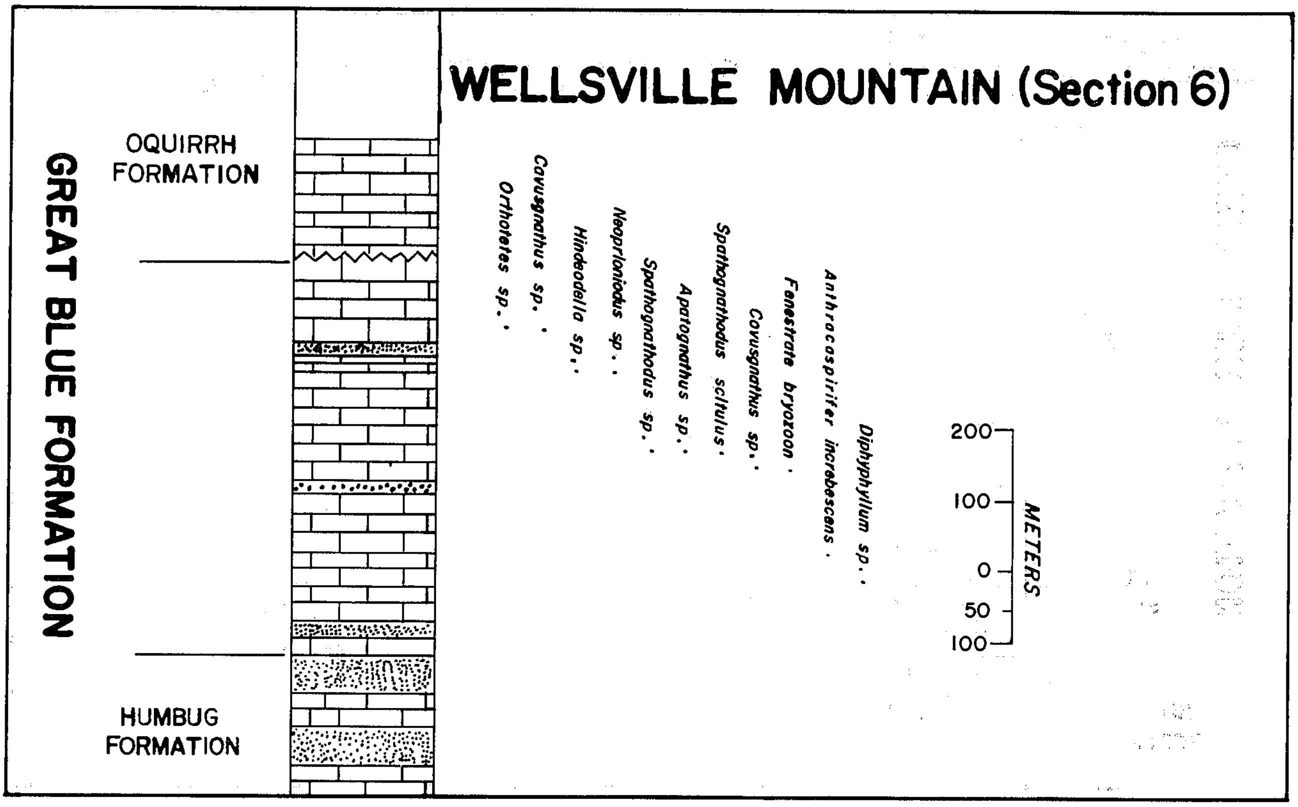

FIGURE 7.—Wellsville Mountain (section 6).

(Clark and others 1969). Other fossils found include brachiopods, bryozoans, and corals (fig. 7).

FOSSILS

Conodonts

More than 200 samples (approximately 500 kg) were processed for conodonts. A conodont assemblage yielding forms from the *Apatognathus-Spathognathodus scitulus* Zone suggests a Meramecian age for the Great Blue below the Long Trail Shale. Clark and others (1969) reported conodonts of the same zone from the Great Blue in central Utah but never published specific information on the occurrences. Pinney (1965) reports occurrences of upper Meramecian conodonts from the lower Great Blue at Stansbury Mountain and occurrence of Chesterian conodonts in the Upper Great Blue in Rock Canyon (fig. 6).

Conodonts found in the Great Blue sections are dark gray to black and sometimes cracked and fractured. Nowhere were they found in abundance, and commonly samples completely lacked conodonts. The yield was approximately one conodont per 10 kg of rock.

Corals

Large colonies of *Pseudodoriodotia* sp. are especially abundant in the upper Great Blue of section 2, the southern Onaqui Mountains, and contrast sharply with the lack of corals in the upper Great Blue of other sections. No corals were found in sections 1, 4, or 5 above the clastic horizons, suggesting local differences in environments of deposition. It is interesting to note that coral occurrences in the upper Great Blue change from very abundant in section 2 to a total absence of coral in section 1 within 32 km. Characteristic of Sando's (Sando and others 1969) zone and supported by the occurrence of *Spathognathodus scitulus,* the corals in the lower Great Blue are probably equivalent to corals in the upper St. Louis or upper Meramecian age.

Brachiopods

Every section is characterized by the occurrence of brachiopods. Several horizons of fossiliferous limestone in section 1, composed almost wholly of brachiopod shells occur in the Long Trail Shale and just below the shale 650 m above the Humbug Formation.

The presence of *Striatifera brazeriana* in the middle and lower Great Blue suggests an upper Meramecian-lower Chesterian age for the middle and lower Great Blue.

Bryozoans

Every section contains bryozoans which may become useful in development of fossil zones with future study (see table 1). They are present when many other forms are absent, and at times they may be especially abundant, as those found at about 646 m above the Humbug Formation in section 1.

Sponge

The occurrence of *Talpaspongia clavata* King 650 m above the base of the Great Blue in section 1 may be the earliest known occurrence of this species in western North America (Rigby personal communication 1977). This sponge, rather abundant at the 650 m horizon, occurs in many shapes and sizes as distinct black silicic masses in dark gray limestone.

TABLE 1
FIRST AND LAST OCCURRENCES OF ORGANISMS IN THE GREAT BLUE FORMATION
MEASURED IN METERS FROM THE BASE OF THE FORMATION

FOSSILS	SECTIONS											
	1		2		3		4		5		6	
	Base	Top	Base	Top	Base	Top	Base	Top	Base	Top	Base	Top
Conodonts												
Apatognathus sp.	–	–	–	–	–	–	–	–	–	–	310	310
Cavusgnathus unicornis	140	140			30	30			?600	700?	–	–
C. regularis	140	140	–	–	–	–	–	–	–	–	–	–
Cavusgnathus sp.	0	140	–	–	–	–	–	–	–	–	305	460
Gnathodus texanus	–	–	–	–	–	–	–	–	?600	700?	–	–
G. commutatus	140	140	–	–	–	–	–	–	–	–	–	–
Hindeodella sp.	140	140	–	–	–	–	265	265	–	–	400	400
Neoprioniodus varians	–	–	260	260	–	–	–	–	–	–	–	–
N. scitulus	–	–	–	–	–	–	–	–	?600700?	–		–
Neoprioniodus sp.	–	–	–	–	–	–	–	–	–	–	400	400
Spathognathodus cristulus	–	–	220	220	–	–	–	–	–	–	–	–
S. scitulus	–	–	–	–	–	–	–	–	–	–	310	310
Spathognathus sp.	–	–	–	–	–	–	–	–	–	–	310	310
Corals												
Diphyphyllum sp.	–	–	–	–	–	–	–	–	–	–	100	100
Faberophyllum sp.	20	20	170	1085	40	40	–	–	84	84	–	–
Pleurosiphonella virginica	–	–	320	930	–	–	106	106	–	–	–	–
Amplexizaphrentis sp.	–	–	–	–	–	–	200	248	–	–	–	–
Pseudodoriodotis sp.	–	–	255	255	–	–	–	–	–	–	–	–
Brachiopods												
Torynifer sp.	–	–	–	–	–	–	–	–	30	30	–	–
Striatifera brazeriana (Girty)	640	640	–	–	345	345	–	–	–	–	–	–
Diaphragmus cestriensis (Worthen)	–	–	–	–	–	–	–	–	656	656	–	–
Ovatia muralis Gordon	–	–	230	230	–	–	–	–	–	–	–	–
Orthotetes kaskaskiensis (McChesney)	–	–	–	–	–	–	450	450	–	–	–	–
Orthotetes sp.	–	–	–	–	–	–	–	–	–	–	460	460
Antiquatonia sp. (Martin)	–	–	–	–	–	–	450	450	–	–	–	–
Inflatia bilobata Sadlick	640	640	–	–	–	–	–	–	385	385	–	–
Punctospirifer sp.	–	–	–	–	–	–	64	64	–	–	–	–
Anthracospirifer increbescens (Hall)	149	640	–	–	345	345	450	450	–	–	120	120
Rugosochonetes loganensis (Hall and Whitfield)	500	717	–	–	–	–	–	–	–	–	–	–
Bryozoans												
Fenestella sp.	–	–	–	–	–	–	315	315	–	–	–	–
F. tenax Ulrich	645	645	–	–	–	–	–	–	–	–	–	–
Protoretepora sp.	645	645	–	–	–	–	–	–	–	–	–	–
Rhombopora tenuirama Ulrich	645	645	–	–	–	–	–	–	–	–	–	–
Archimedes sp.	560	1003	–	–	–	–	–	–	–	–	–	–
Fenestella dissepinodaria Burkle	97	97	–	–	–	–	–	–	–	–	–	–
Fenestrate bryozoan	–	–	–	–	–	–	–	–	45	45	250	250
Sponge												
Talpaspongia clavata (King)	645	645	–	–	–	–	–	–	–	–	–	–
Plants												
Lepidodendron sp.	510	663	–	–	–	–	–	–	–	–	–	–
Lepidophylloides sp.	510	663	–	–	–	–	–	–	–	–	–	–
Stigmaria sp.	510	666	750	750	–	–	–	–	–	–	–	–
Calamites sp.	510	538	660	660	–	–	–	–	–	–	–	–
Cephalopods												
Rayonnoceras solidiforme (Croneis)	510	663	–	–	–	–	–	–	–	–	–	–
Cravenoceras aff. C. nevadense (Miller & Furnish)	510	663	–	–	–	–	–	–	–	–	–	–
Gastropods												
Bellerophon sp.	360	640	–	–	–	–	–	–	–	–	–	–
Girtyspira sp.	183	183	–	–	–	–	–	–	–	–	–	–
Bivalves												
Cardiomorpha sp.	655	655	–	–	–	–	–	–	–	–	–	–
Allorynchus sp.	–	–	–	–	–	–	–	–	84	84	–	–
Trilobite												
Paladin sp.	145	145	–	–	–	–	–	–	–	–	–	–
Fish												
Fish spine	145	145	–	–	–	–	–	–	–	–	–	–
Ichnofossils	645	645	–	–	–	–	–	–	–	–	–	–

Cephalopods

Several poorly preserved *Cravenoceras aff. C. nevadense* Miller and Furnish and one large *Rayonnoceras solidiforme* Croneis were found in the shale 510 m above the Humbug Formation in section 1. Since lycopods found in the same shale unit are in place, it may be assumed that the ammonoids were washed in.

Plants

Abundant *Lepidodendron* debris in two shale horizons of the Great Blue Formation may be one of the earliest lycopod occurrences in the Basin and Range Province (fig. 2). Lycopod rhizomorphs (*Stigmaria* sp.), leaf cushions (*Lepidodendron* sp.), and branches and leaves (*Eyperites* sp.), found in abundance near the top of the shale units and commonly found in place, strongly suggest periods of lagoonal deposition during Great Blue time. Pith casts and fernlike foliage were found associated with the lycopods in the 510-m shale unit of section 1. *Stigmaria* sp., found 750 m above the Humbug Formation in section 2, suggests that the lagoonal or swamp environment may have been regional rather than local. Perhaps the presence of terrestrial plants in the Great Blue may cause stimulus needed for more detailed studies of Great Blue depositional environments.

Other Fossils

Bivalves are especially abundant in a siltstone of the shale unit 650 m above the Humbug Formation in section 1. Scattered through the sections are several forms of gastropods (table 1). One of the earliest occurrences of the trilobite *Paladin* sp. in the Great Blue was found to occur in a crinoidal limestone just below the Long Trail Shale in section 1. A fish spine 8 mm in length, collected near the Long Trail Shale in section 1, and numerous small fish teeth approximately 1 mm long, collected from nearly every section, give evidence of vertebrates in the Great Blue seas.

CONCLUSION

Study of six measured sections of Upper Mississippian Great Blue Formation has resulted in (1) discovery of terrestrial plants in shale units of the formation in its type region; (2) indication that the Meramecian-Chesterian boundary must lie somewhere between the Meramecian fossils in the lower 150 m of the formation and the Chesterian fossils near the middle; (3) the first record of *Talpaspongia clavata* King and *Paladin* sp. of the type area; (4) correlation of measured sections at six widely spaced localities in the proto-Oquirrh Basin; and (5) documen-

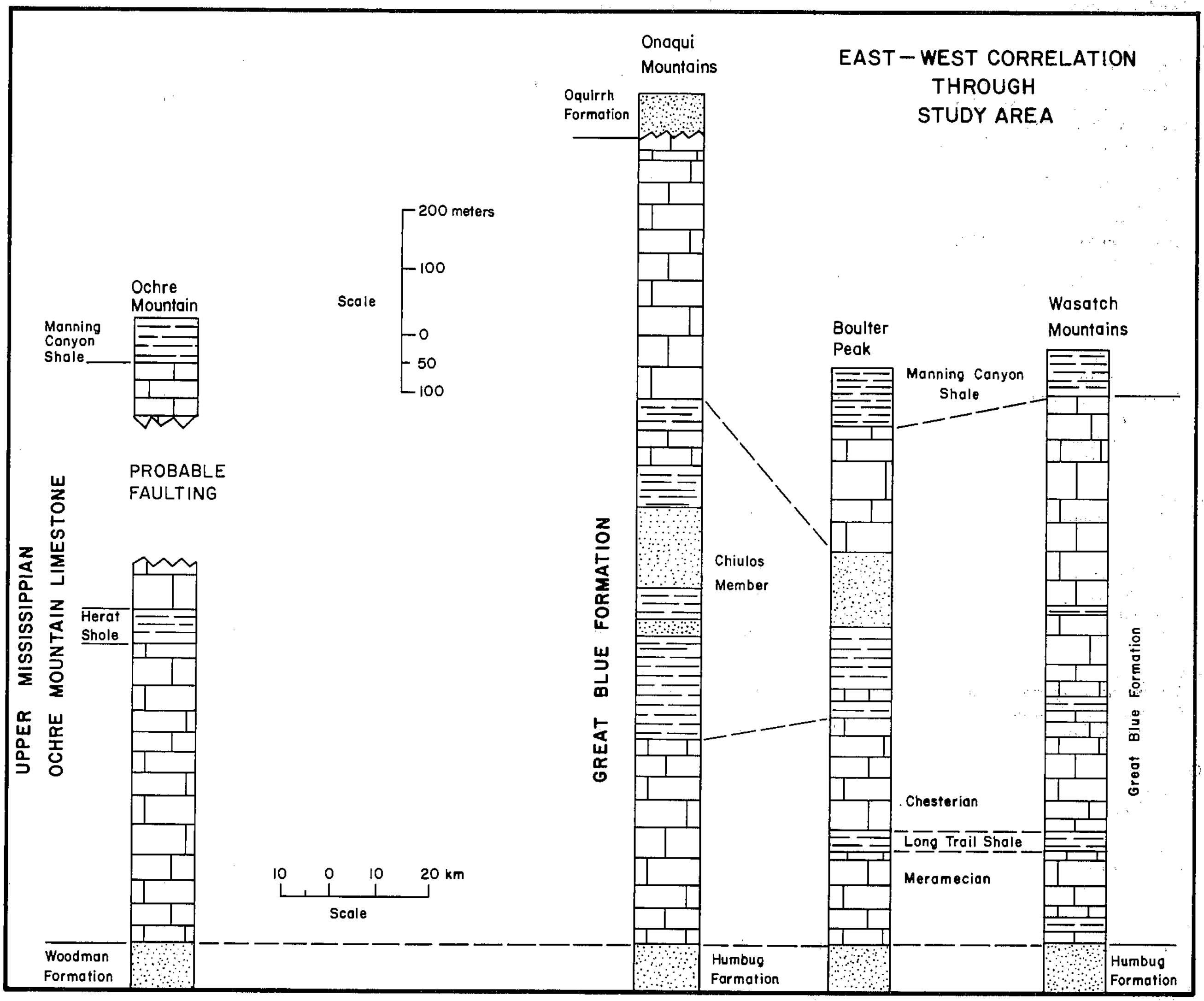

FIGURE 8.—East-west correlation.

tation of fossil occurrences within the measured sections. Terrestrial plants in place found in two shale units of the formation in its type locality suggest periods of lagoonal deposition during Great Blue time. Discovery of *Talpaspongia clavata* and *Paladin* sp. in the area may help reconstruct the phylogeny of these organisms. Except for the unreliable Ochre Mountain section, correlation of the formation from east to west shows thickening and coarsening of clastics toward the west, suggesting a western source (fig. 8). Documentation of fossil occurrences throughout the Great Blue will aid future detailed biostratigraphic studies of the formation as well as subsurface exloration in the Oquirrh Basin area.

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