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PALEOECOLOGY OF THE LONG TRAIL SHALE MEMBER OF THE GREAT BLUE LIMESTONE, OQUIRRH RANGE, UTAH

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by

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ABSTRACT

The Long Trail Shale is composed of different varieties of limestone and shale rock types. Six of these limestones and five of the shale varieties predominate. Recognition of three of the predominating carbonates is facilitated by their distinctive biofacies.

The Long Trail Shale dwarfed fauna has been examined in detail and it is suggested that this assemblage consists of sorted, normally small-sized, and dwarfed fossils. It is believed that this biofacies is the result of both sorting by bottom currents and fouled bottom environment partially inaccessible to these currents.

Depositional environments of this unit apparently underwent considerable lateral variation, but certain Paleoecologic generalizations are suggested: (1) Waters were shallow in depth (600 ft. and less) and probably rather warm. (2) Turbidity during most of the Long Trail's deposition was high, but periodic cessation of turbidity is indicated by a few biofacies. Lithofacies generally indicate slight agitation.

ACKNOWLEDGMENTS

The author is indebted to Dr. J. Keith Rigby of the Brigham Young University Geology Department, whose constant encouragement and assistance proved an invaluable aid in the completion of this work. Dr. Harold Bissell of the same department also deserves the author's gratitude for assistance rendered in field work. To these two and all other persons who assisted in any one or more of the various phases of this work, the author extends his sincere thanks.

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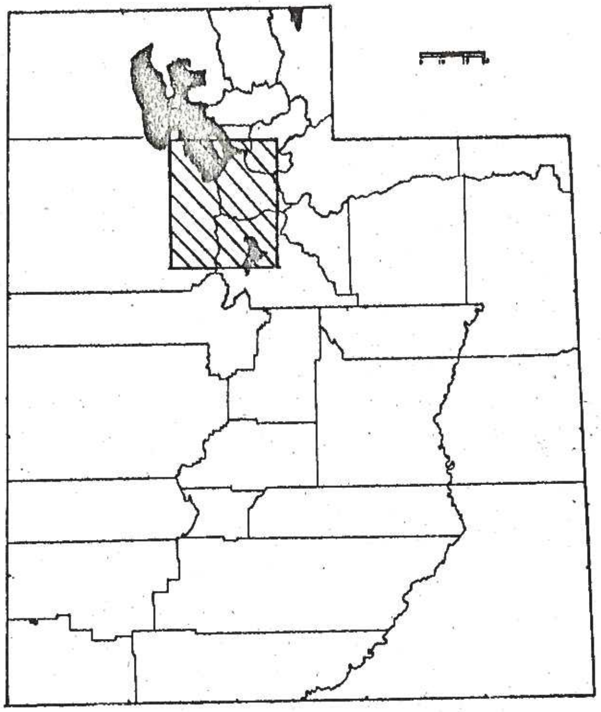

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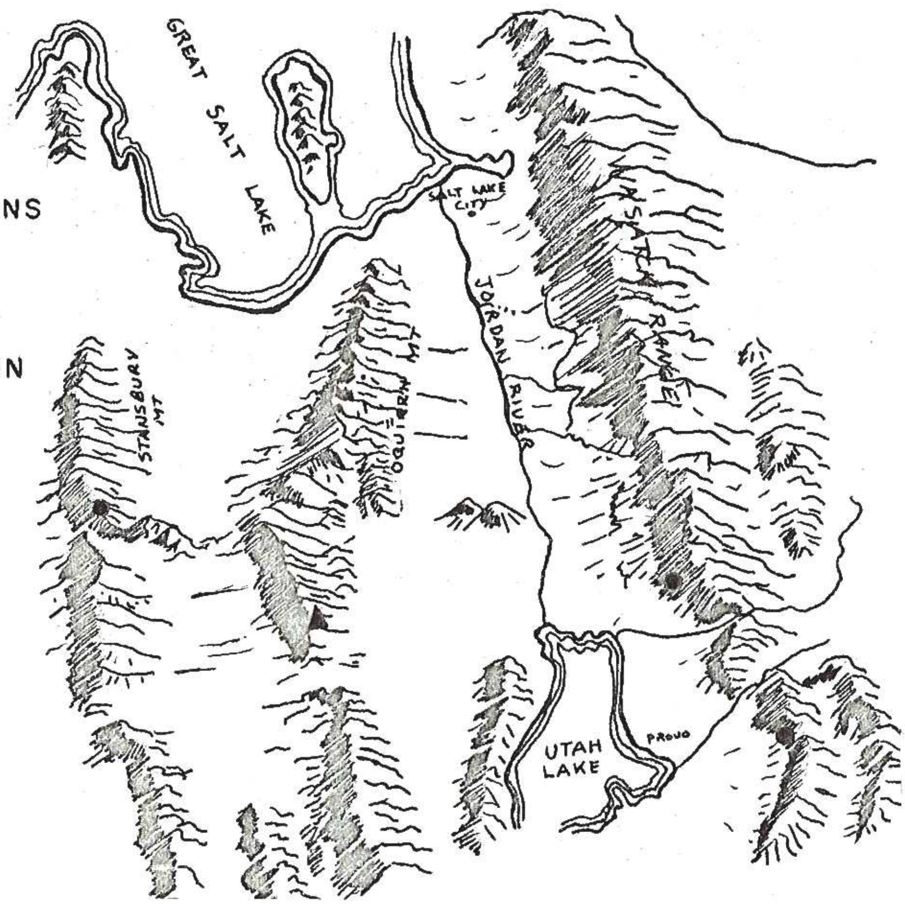


figure 1

INTRODUCTION

The Chesterian Great Blue Limestone is a uniform sequence of blue-gray limestones occurring in north-central Utah. Three members make up the Great Blue: the lower and upper limestones and a medial member known as the Long Trail Shale. The latter occurs approximately six hundred feet above the base of the Great Blue.

A fauna, probably dwarfed, of the Long Trail Shale was studied in detail to ascertain responsible factors.

Facies terminology employed is that of Moore (1949) which seems to the author to be the most concise and applicable to the present problem.

Location

The main part of this study was carried on in three separate areas in the immediate vicinity of the abandoned mining town of Mercur, Utah, which is in the southern part of the Oquirrh Range, one of the easternmost ranges in the basin-range province. The main areas of study are marked by triangles in figure 1. The three major studied sections are recorded in the appendix.

The three circles in figure 1 represent supplementary sections visited for the purpose of comparison. A section was measured and studied in the Stansbury Mountains, two miles south of the Wasatch National forest ranger station at South Willow in the pass between Martin Fork Canyon and South Willow Canyon. The sections were examined in the Wasatch Range, one in Grove Creek Canyon, near Pleasant Grove, Utah, and the other in Rock Canyon, near Provo, Utah.

Previous Work

Members of the Fortieth Parallel Survey, headed by King, attempted the first geological mapping of the area (1877). Then in 1894, a paper written by T. E. Spurr on the Mercur district mentioned the Long Trail Shale (p. 375). Spurr referred to the still unnamed unit as the lesser water-bearing zone of a black shale in the Great Blue Limestone. This designation is in reference to its relationship with another thin shale unit serving as the only aquifers in this water-scarce district. Gilluly (1932, p. 29) named the Long Trail Shale and noted its usefulness as a stratigraphic marker. He included in his paper a Long Trail Shale faunal list.

In a paper on clay deposits of Utah County, Hyatt (1953) includes a discussion on clay deposits occurring in the Long Trail. These deposits in the Long Trail Shale are being worked in the Wasatch Range, northeast of Pleasant Grove, Utah, near the supplementary Grove Creek section.

McFarland (1955) recognized the Long Trail Shale in West Canyon (Oquirrh Range). He noted a quartzite sub-unit in the Long Trail, an unusual lithotype for the Long Trail of that area.

The Long Trail Shale was measured in the northern Onaqui Mountains (Tooele County, Utah) by Mack Croft (1956). He recorded fifty-five feet as its measured thickness.

Ben Olson described the geology of the west slope of Timpanogos (1955) and briefly mentioned the Long Trail Shale. He found its thickness to be about fifty feet.

The Long Trail Shale figured in the paleontologic studies of Davis (1956) and Woodland (1957). Davis, who studied Mississippian corals, obtained some of his coralline material from this member. Bert Woodland in his endothyroid studies noted the absence of endothyroids from the Long Trail Shale sections with which he worked.

The Long Trail has also been reported as outcropping in Provo Rock Canyon (Gaines, 1950), in American Fork Canyon (Perkins, 1955), and in the northern Stansbury Mountains (Rigby, 1958).

Present Work

The present work was undertaken in June of 1957. Dr. J. Keith Rigby suggested the problem which first attracted his attention because of a diminutive fauna contained in one of the Long Trail sub-units.

Purpose and Scope

The Long Trail Shale has never been described in detail. Its description and paleoecology shall be the purpose of this paper. Sediment types are described and discussed, as are associations and

distributions of the fauna. By combining lithologies with characteristic faunal assemblages, a clearer insight can be gained regarding depositional conditions of this unit and of similar small shaly units. Paleoecologic features of the Long Trail are deduced and examined.

Field Work

Field work began in August, 1957, and was pursued intermittantly until June, 1958. Three Long Trail Shale sections were suggested by Drs. Rigby and Bissell as best representing this unit in its entirety in the Oquirrhs. They were then each studied separately in the field. Fossils and lithotypes were collected for laboratory study; section units were examined and measured at each major locality. At the supplementary sections these same procedures were applied in so far as necessary to ascertain how each section compared with the major study localities.

Laboratory Work

Laboratory work included thin section preparation and study; fossils were curated, measured and identified in the laboratory.

Insoluble residues of representative Long Trail Shale rocks were studied in the laboratory. For the limestones these were obtained in the following manner: 1. Rock sample broken into pea-sized fragments, and any contained material grit-sized or less removed; 2. Samples subjected to 2 N acetic acid digestion for 96 hours; 3. Insoluble residues then filtered, washed, dried, weighed, and microscopically examined; 4. Residues treated with 1:1 hydrochloric acid to determine percentage of dolomite. The representative Long Trail shales were similarly treated except that hydrogen peroxide was substituted for the hydrochloric acid digestion. The shales were then redried and weighed. This process determined the percentage or organic material present in each of the main shale types.

LITHOTYPES

General

Gilluly (1932, p. 29) described the Long Trail Shale as a black-carbonaceous, shaly unit. The author has found that black carbonaceous shales, though predominating at the type area, are only a minor constituent of the member. Elsewhere shale type rocks such as mudstones, siltstones, and claystones are prevalent in the Long Trail along with thin interbedded carbonates. Intergradation, sediment size variation, and induration differences have resulted in a large variety of units.

Mudstones

Mudstones may be regarded as lithotypes which disintegrate upon repeated wetting and drying (Shrock, 1948), the bulk of whose detrital particles are under 1/16 mm. in diameter. All the mudstone units observed in the Long Trail Shale are calcareous and break down to muds upon a single wetting. Outcrops of mudstone appear as zones of powdery, light-colored, limey soil. The Long Trail mudstones are friable and only slightly consolidated.

Chert

In the main sections of this study, chert occurs in the form of rounded nodules 1 to 2 inches in diameter. In the section studied in the Stansbury Mountains, the limestones and siltstones contain cherty interbeds. The nodules do not reveal pronounced concentric banding or a central core. A few of the nodules contain small calcite veinlets; others, fossils. Replacement of the original sediments is indicated by the presence of nodules which contain more calcareous material than chert.

Siltstones

Many types of siltstones are found in the Long Trail Shale. Various degrees and types of color, fracture, and texture can be used

to differentiate between siltstone units. Most of these siltstones contain rounded to subrounded sediment particles. Mineral content varies from carbonaceous to quartzose. The sediments have been lithified by siliceous and carbonaceous cements. Hardness varies considerably. Three-fourths of the siltstones are only slightly or not calcareous.

Some of the siltstone units of quartz and chert particles are coarse enough to possibly warrant their classification as very fine sandstones. Sediment types of larger particles are absent.

Claystone

Claystone physiofacies are of minor extent in the Long Trail Shale. No fossils were noted in the claystone units, but in unit 11011-3 (appendix) a small pocket of clay exists which contains chonetid-type brachiopods.

Shales, General

The term shale applies to all detrital sedimentary rocks, the bulk of whose particles have a diameter under 1/16 mm. That would, of course, include the siltstones, mudstones, and claystones of this report as well as their fissile equivalents.

A study of the different shale units of the Long Trail Member results in recognition of five distinctive shale types which make up the majority of the shale units. The distinction among the five main kinds of shale is made on the basis of differing physical characteristics which in some cases reflect generic differences. Color, for instance, may indicate to the researcher whether reducing or oxidizing conditions predominated during deposition. Along with the more common shale types, are numerous intergradational units. Major shale rock types and their characteristics have been grouped together in Table 1. Descriptions are as follows:

(1) Siltstone, well indurated: usually of a light brown color with dark iron stains; contains a bryozoan biofacies; units exhibit well defined bedding; thin sectioning helpful in identifying biofacies, slightly calcareous; sediments tightly packed. Example --Unit 11013-5B (fig. 1, plate 1).

(2) Siltstone, well indurated; no biofacies; comprises 3-4 units per section; silica cement; highly stained (iron) on

weathered surface, which sometimes takes on a varnished appearance. Example--Unit 11011-11B (fig. 2, plate 1).

(3) Shale: Dark and fissile; well indurated; fine silt; siliceous; forms chippy slopes; may be interbedded with thin dirty carbonates; shale itself is non-calcareous; this lithotype is probably the dark, carbonaceous shale of the type section. Example--Unit 11012-9.

(4) Mudstone: Light in color; calcareous cement; disintegrates in water to a fine limey mud; slight fissility; loosely consolidated silt-size particles; average occurrence two units per section. Example--Unit 11012-3.

(5) Shale: Earthy; dark in color, usually olive drab; friable; slight to moderate fissility; well weathered; fossils poorly preserved; outcrops appear as soil zones in the section. Example--Unit 11013-7B.

Limestones

Various limestone physiofacies make up the non-clastic sediments in the Oquirrh sections. These occur interbedded with the detrital rocks and a small amount of gradation between the two exists. Secondary dolomite is present in small amounts in approximately three out of ten limestone units.

Limestone facies are seldom pure and seldom more than a few feet thick. Muddy and silty limestones predominate. Gradation with other lithotypes is found both vertically and laterally. Siliceous and ferruginous limestone units as well as normal marine limestone are present.

One or two of the Long Trail clastic limestones contain only indefinite characteristics and consequently in these biofacies evaluation must be relied solely upon to furnish data for interpretation.

Six limestone lithofacies stand out as recurring and predominating in the Long Trail Shale. Many other seldom occurring varieties make up the remaining carbonates. Insoluble residue results and a biofacies summary have been grouped in Table 2. The six major carbonate lithofacies follow:

(1) Clean Encrinitic Carbonates: consist almost entirely of crystalline calcite; crinoidal columnals; one to two units of

Table 1. Predominating carbonate lithofacies found in the Long Trail shale (Oquirrh Range)

No.	% Calcite	% Dolomite	% insoluble residue	Biofacies
1	69.3	13.8	16.9	Crinoidal with a few Bryozoans
2	63.8	14.2	22.0	Crinoidal small amounts of fossil hash
3	47.0	5.8	47.2	Crinoidal Bryozoan
4	67.5	13.6	18.9	Fossil hash
5	65.6	19.4	15.0	Bryozoans Brachiopods Crinoids Corals Fossil hash
6	48.8	4.8	46.8	Brachiopods Bryozoans Fossil hash

Table 2. Predominating shaly lithofacies found in Long Trail shale (Oquirrh Range)

No.	% Calcite	% Organic Matter	% Insoluble	Biofacies
1	18.8	5.8	75.4	Bryozoan, few misc. fossil fragments
2	3.5	1.2	95.3	None
3	.0	35.7	64.3	None
4	39.8	2.5	42.3	None
5	5.6	9.8	84.6	Poorly preserved fossils or unfossiliferous.

this type per section; thin sectioning helpful to distinguish from dirty encrinite. Example--Unit 11013-5E (fig. 3, plate 1).

(2) Dirty Encrinitic Carbonates: contain silt of complex composition; coarse silt present in matrix; as in type 1, slightly dolomitized (14.2%); weathered surface iron stained; calcified fauna; crinoidal material very prominant. Example--Unit 11011-10C (fig. 4, plate 1).

(3) Encrinitic-Bryozoan Carbonates: 47% insolubles of coarse silts of complex composition; similar to type 2 except for the greater amount of silty matrix and the different biofacies; thin section or insoluble residue study necessary to identify. Example--Unit 11013-5A (fig. 5, plate 1).

(4) Bioclastic Carbonates: carbonate matrix; considerable fossil hash; carbonate matrix; dark iron stains on weathered surface; crystalline; chlorite and gypsum in the insoluble residue; coarse texture; thin sectioning aids in determining distinctive fossil hash biofacies. Example--Unit 11011-2 (fig. 6, plate 1).

(5) Normal Marine Carbonates: commonly contains distinct fauna zones of a single phyla; medium crystallinity; bedding well defined; well preserved fossils; shale partings often present in this type unit; probably represent greatest environmental depth of Long Trail Shale sections. Occur near middle of section; one to two units per section. Example--Unit 11011-8.

(6) Silty Marine Carbonates: weather brown, gray brown on fresh surface; streamers of calcite present; carbonate type cement; well defined thin bedding; fossils often weather out; large amount of silt present. Example--Unit 11012-12.

Lithotype Summary

The Long Trail Shale is not only a black, carbonaceous shale unit, but also consists of many different kinds of carbonates and shales. Some of these sediment types exhibit easily recognizable singular physiofacies while others show physiofacies intergradation and are of infrequent occurrence.

PALEONTOLOGY

The fossils collected from the Oquirrh sections are only fairly well preserved. At 11013-8, the fossils were silicified. All other collecting areas contained fossil casts of calcite.

The Long Trail Shale fauna is primarily composed of recognized Chester forms. Many different phyla of organisms are present though some are represented by a single species or genus.

Brachiopods appear to dominate the Long Trail fauna both in numbers and species. In a few biofacies however, the brachiopods are inconspicuous. Well preserved brachiopods are usually found in brachiopod assemblages (Table 3) along with corals, crinoids, and bryozoans. Fossil fragments occur in most of the limestones.

Brachiopoda
- Orthotetes aff. O. kaskaskiensis
- Brachythyris sp.
- Composita subtilita
- Composita subquadrata
- Composita wasatchensis
- Composita trinuclea
- Eumetria vera
- Eumetria deltoides
- Dictyoclostus mesialis
- Dictyoclostus americanus
- Dictyoclostus inflatus
- Chonetes chestereinsis
- Chonetes shumardianus
- Avonia aff. A. pustulifera
- Marginicinctus aff. M. maginicinctus
- Spirifer rockymontanus
- Spirifer opimus
- Rhipidomella sp.
- Echinoconchus sp.
- Girtyella aff. G. indianensis
- Leptaena sp.
- Cleiothyridina aff. C. sublamellosa

Hydrozoa
- Nigriporella sp.

Pelecypoda
- _Nuculana_ sp.
- _Acanthopecten_ sp.
- _Phestia_ aff. _P. inflata_
- _Nucula_ sp.

Cephalopoda
- nautaloid cephalopod
- _Bactrites_ aff. _B. nevadense_

Gastropoda
- _Bucanella_ sp.
- _Straparolus_ sp.

Ostracoda
- _Bythocypris_ sp.

Bryozoa
- _Stenopora_ sp.
- _Polypora Chestriensis_
- _Fenestella_ sp.
- _Rhombopora_ sp.

Coelenterata
- _Triplophyllites_ sp.
- _Ekvasophyllum turbinium_
- _Neozaphrentis fenella_

Crinoid columnals
Echinoid plates

Plates 1 and 2 illustrate a part of the Long Trail Shale fauna.

Biofacies

Units containing and composed of crinoid columnal fragments occur throughout each of the major sections. These units contain both large, well preserved crinoidal stems and calcareous silts of crinoid fragments.

To avoid repetition other biofacies are treated under the lithofacies section of this paper.

SOURCE AREAS AND SEDIMENTARY ENVIRONMENTS

During late Mississippian time, clastics from several areas were shed into the Cordilleran miogeosyncline. The site of the present Oquirrh Range was in one of the more negative parts of this geosyncline. The incoming sediments were being supplied from three newly positive areas nearby. Different elements of the ancestral Rockies had begun to rise and experience mild erosion. The area now known as the Paradox Basin had been epierogenically elevated and was experiencing chemical weathering of earlier Mississippian carbonates (Herman, 1957). The Antler Peak Orogeny had begun to affect central and eastern Nevada, and possibly western Utah. This created a source of sediments for the westerly Long Trail and its equivalents. Clastics comprising the Long Trail Shale in the Oquirrh Range probably were derived from the rising ancestral Rockies because of their proximity to the area of deposition, although a high area or bank existed in west-central and northwestern Utah (Bissell, 1958).

The Great Blue Limestone appears to represent a facies resulting from conditions in which deposition matched miogeosynclinal sinking rates. The Long Trail Shale was deposited when this sinking exceeded the building up of the bottom by deposition. Upper Great Blue Limestones began to be deposited when rate of sinking again balanced deposition.

PALEOECOLOGY

The different Long Trail biofacies when combined with their containing lithotypes indicate a varying marine environment. A lithofacies is the sedimentary record of a particular environment. In the Long Trail Shale, lithofacies variation is apparent both laterally and vertically. The following is a discussion of the more distinctive lithofacies.

Carbonates

A few normal marine limestones occur in the Long Trail Shale containing well preserved biofacies. One of these units (11011-10, appendix) has pronounced bryozoan, coral, and brachiopod fauna zones. These zones grade vertically into one another. Table 4 shows the per cent (by volume) of the lithofacies constituents of a gradational zone.

Encrinitic carbonates occur having both silty-muddy matrix or having a comparatively clean matrix of simple chemical composition.

Spirifer-dominated biofacies occur in muddy carbonate rocks. These same muddy lithotypes often contain bryozoans and corals. Biofacies largely composed of bryozoans and corals are found in finely crystalline encrinitic carbonates.

Clastics

Limey siltstones contain hashy fossil material. The limey mudstones are unfossiliferous. Non-calcareous, dirty siltstones contain poorly preserved fossils. The dwarfed fauna is found in an olive drab silty shale. Most of the fissile shales are unfossiliferous, but unit 11011-3 contained a crushed pelecypod zone and elsewhere in the same unit Acanthopecten occurs.

Faunal assemblages of the Long Trail Shale appear to be almost entirely biocoenosic. The lithofacies observed in general reflect lithotopes consistant with sedimentary evidence.

Table 3. Distribution of brachiopoda at major collecting localities by units

Genera	11011	11012	11013
Orthotetes	10 (unit)		
Chonetes	10		2
Brachythyris	10		
Avonia	8		
Diaphragmus			2
Marginicinctus	8		
Composita	12; 8		7 c
Spirifer	4	15; 2; 4	7 c
Dictyoclostus	8	4	2
Eumetria			8
Rhipidomella			
Echinoconchus	10		5
Girtyella	8		
Leptaena	10		
Cleidthyridina			2 7 c

Table 4. Percentage by volume in gradational biofacies of normal marine limestone, computed by traverse methods, of organic and inorganic components

Brachiopoda	39.35%
Gastropoda	0.90%
Bryozoa	3.1 %
Misc. & Unidentified	4.1 %
Matrix	52.65%
TOTAL	100.00%

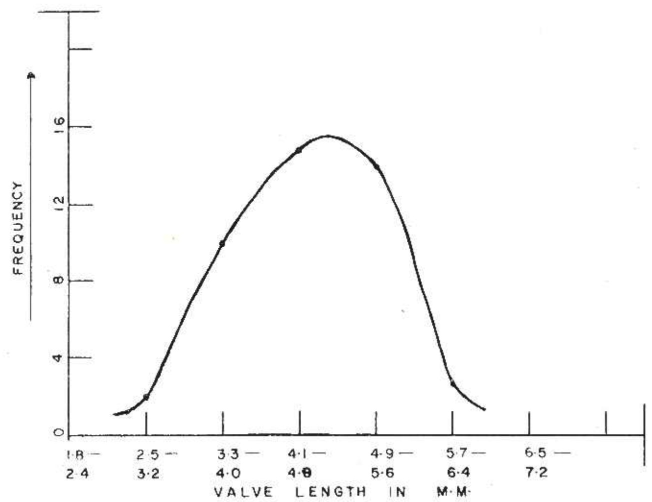


figure 2· LENGTH VS FREQUENCY IN *PHESTIA*

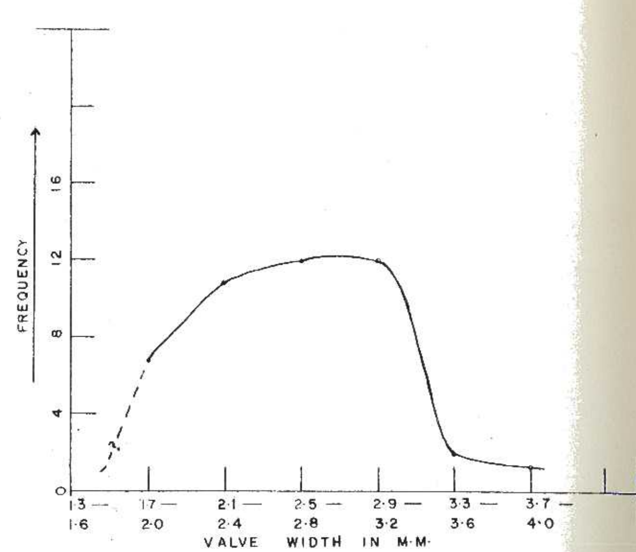


figure 3· WIDTH VS FREQUENCY IN *PHESTIA*

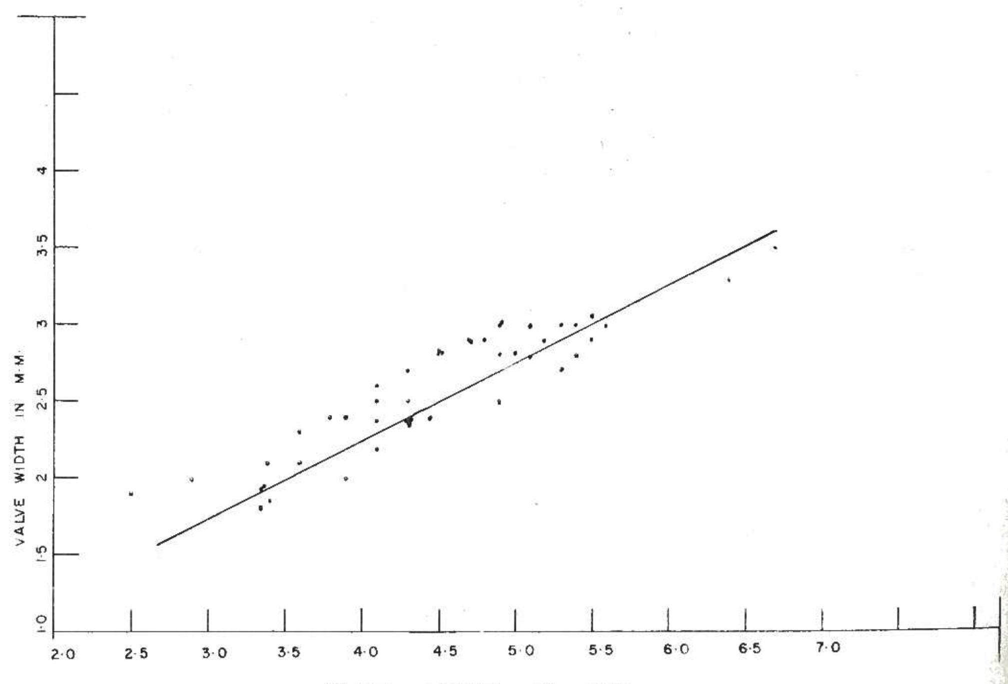


figure 4· LENGTH VS WIDTH IN *PHESTIA*

Table 5. Raw data for figures 2, 3 and 4

No.	Length mm.	Width mm.	No.	Length mm.	Width mm.
1	5.4	2.7	23*	4.7	2.9
2	5.5	2.8	24	3.3	2.1
3	4.3	2.4	25	4.1	2.2
4	4.9	2.8	26	4.3	2.5
5	6.4	3.3	27	4.1	2.6
6	4.1	2.5	28	4.4	2.4
7*	6.7	3.5	29	4.9	3.0
8	5.1	2.8	30	5.1	3.0
9	2.9	2.0	31	4.8	2.9
10	2.5	1.9	32	3.9	2.0
11	3.3	1.9	33*	4.3	2.4
12	5.1	2.9	34	3.6	2.1
13	4.3	2.7	35	4.3	2.2
14*	5.4	3.0	36	3.3	1.9
15*	5.8	2.4	37	3.8	2.4
16	4.5	2.8	38	5.2	2.9
17	4.9	2.5	39	3.9	2.4
18	4.5	2.8	40	5.6	3.1
19	3.6	2.3	41*	5.3	3.0
20	4.1	2.4	42	3.4	1.8
21	4.9	3.0	43	5.7	3.0
22	4.7	2.9	44	3.3	1.7
			45	5.0	2.8

* Specimen incomplete - length estimated

The Dwarfed Fauna

During the summer of 1955, the Brigham Young University Geology Department held a field camp class in the Oquirrh Range under the supervision of Professors Rigby and Bissell. Several students noted the occurrence of a fauna composed of small brachiopods, pelecypods, and other diminutive fossils in the Long Trail Shale. This assemblage of small forms became known informally as the Long Trail Shale "dwarfed fauna." To determine the paleoecologic significance of the unit (which is very restricted in areal extent), each element of the fauna has been separately treated. Some of the dwarfed fauna species are illustrated in Plate 2.

Pelecypods.--Three pelecypod genera were collected from the dwarfed fauna unit. They are Nuculana, Phestia, and Nucula. The pelecypod aspect is composed of both juvenile and mature forms, the juveniles predominating. This fact was established by morphological comparison with adult forms. These pelecypod genera consist normally of small forms, and adults found in the dwarfed fauna assemblage appear to be of normal size.

Elias (1957) recognized the valve of Phestia inflata as having a length of 6 mm. Phestia pelecypods of the dwarfed fauna unit strongly resemble this species.

Statistical analysis of Phestia shows normal distribution, as well as sorting, in frequency versus length and in frequency versus width graphs (figs. 2 and 3). The author believes all the pelecypod genera are indigenous to the locality of their burial. This interpretation seems to be borne out by the absence of any disarticulated valves. It is suggested that slight biological sorting may have affected the pelecypods. Figure 4 indicates that length and width characteristics are a function of growth and maintain a constant ratio to one another making them valid characters to study statistically. Statistical raw data utilized has been assembled into table form (Table 5).

Gastropods. Bucanella and Straparolus constitute the gastropod aspect of the dwarfed assemblage.

Tasch (1953) mentions number of whorls as a criteria for determining growth state of a Straparolus specimen. Four to six whorls indicate a mature form. Sixty per cent of the Straparolus

specimens studied (total specimens examined--145) had three whorls or less. These are regarded as juveniles. The specimens with four or more whorls are regarded as adult forms. Adult forms range in diameter from 2 to 5 mm. This is a smaller size than is generally attributed to mature Straparolus. Several species appear to be present in the specimens collected but lack of growth lines prevented positive identification.

The gastropod Bucanella is smaller than normal; however, the scarcity of specimens along with their poor preservation makes the determination of growth stages indefinite. Evidence for dwarfing in this genus is inconclusive.

Crinoids. Crinoidal material found in the dwarfed fauna assemblage is composed of broken columnals. These fossils are of relatively small size when compared with crinoid columnals observed elsewhere in the Long Trail Shale. This small size appears to be the result of sorting action. The disarticulated nature of the columnals substantiates this conclusions. Because of a lack of identifiable crinoidal matter, little could be done with them.

Bryozoans. Stenopora and Fenestella were the only bryozoan genera found in the dwarfed assemblage. They are of normal size but have been broken into small chips along with their encasing sediments. Here again sorting is postulated. The very muddy shales of the dwarfed fauna unit appear to be incompatible with envisioned bryozoan environment.

Brachiopods. Brachiopods are prevalent throughout the diminutive assemblage. Most of the brachiopods appear to be juvenile forms. The brachiopods that were identifiable are forms that are normally small. The two species Eumetria vera and Eumetria deltoides occur in this biofacies. The Long Trail specimens appear to be mature when examined by morphologic comparison with the holotypes, but they are of a smaller than normal size and seem to have experienced growth retardation.

Along with these small brachiopods occur normal-sized Composita and Rhipidomella. The scarcity of these two genera, as well as their highly abraded condition suggests transportation after death to this biotope.

Cephalopods. A single well weathered specimen of Bactrites was noted in the dwarfed assemblage. This cephalopod is of normal size, but it is probably foreign to the normal benthos of this unit.

Ostracoda. The ostracods collected, though small (1.9 mm. average), are of normal or slightly larger than normal size. One genera of ostracoda was collected (Bythocypris) and is assumed to be alien to the benthonic element of the dwarfed assemblage.

Summary. What appears to be a dwarfed faunal assemblage at locality 11013-8 is an assemblage of normally small indigenous genera and sorted fossil material from other areas. Many juveniles are present in this assemblage of small forms. Dwarfism may have been present in the gastropods, but evidence is inconclusive. Eumetria vera and Eumetria deltoides appear to have been dwarfed.

The Long Trail Shale dwarfed fauna was recognized at only one locality. None of the small brachiopod or gastropod genera were noted elsewhere, but similar crinoidal material was observed at several other localities. The author believes the indicated biotope was of a specialized nature. Ecological conditions apparently existed which enabled these smaller forms to avoid competition with the more numerous larger benthonic constituents of marine environments. Fossil remains of these larger forms are so few as to indicate their avoidance of this physiotope.

Aggregations of dwarfed, juvenile, and small faunal forms are not unique. Such assemblages have often been reported throughout geologic literature. Numerous explanations have been advanced to account for this type of assemblage. The reader is referred to Tasch (1953) for a useful bibliography on dwarfism and diminutive faunas. Abnormal salinity, high ionic iron content, fouled bottom conditions, and algae forests are a few of the explanations advanced to explain similar faunas. It is suggested that the Long Trail Shale dwarfed fauna is the result of these factors: (1) sorting by bottom currents (crinoids and bryozoans), which is substantiated by ripple marks and fossil disarticulation; (2) a localized fouled bottom environment having a high concentration of one or more growth retarding agents. This environment was partially inaccessable to the sorting bottom currents. This idea appears to be substantiated by the presence of retarded forms.

Paleoecological Conclusions

By comparing the faunal associations and sediment types of the Long Trail with modern marine counterparts, paleoecological conditions may be deduced. Thanatocoenosic elements and the time separating the inferred environments from present day ecologies are the limiting factors to the accuracy of our interpretation.

Depth. A shallow water depositional environment is postulated for the Long Trail Shale in the Oquirrh and Wasatch areas. Toward the west somewhat greater depth is envisioned. The depositional depths, though of similar magnitude, varied slightly in the different lithotopes mainly because of the lateral variation in the difference between sinking sediment rates and deposition rates on the miogeosyncline bottom. Long Trail sections reflect a depth increase from basal units to about their middle units, then a general decrease in depth successively upwards is indicated by the lithofacies. Silty non-dolomitic limestones are regarded as forming at greater depth than the limey muds or fossil hash carbonates, and they are usually medial in section position. Fossil hash carbonates, and limey muds or gradations of these types are section end members. Unstable shelf conditions prevailed during most of the Long Trail deposition. Depth probably never exceeded 200 meters.

Bottom Conditions. Obviously if depth fluctuated, bottom conditions must have behaved likewise. This supposition is further attested by the numerous lithotype varieties found throughout the Long Trail Shale. Sometimes bottoms consisted of well packed sediments with clear water and little agitation. Bryozoans in particular favored this type of bottom. Most of the time and in most of the areas the bottom was of a soft, muddy or silty character, loosely packed and often agitated. Bottom conditions were varied at any given time. Lateral variation expresses the gradational character of the bottom. Bottom environments probably were also related to distances from the depositional sites to the various source areas.

Agitation and turbidity. The silty character of most of the lithotypes suggests turbid conditions. This turbidity often abated sufficiently to enable bryozoans, corals, and crinoids to experience favorable environment.

Disarticulared crinoid material, ripple marks and fossil hash units indicate times of agitation. Productid brachiopods, possessing delicate spines, and attached pelecypod valves suggest period of quiescence.

Salinity. The large number of fauna forms in the Long Trail strongly argues for a normal marine salinity. No indications are noted to the contrary.

Temperature. Shallow, well lighted waters and varied fauna forms generally regarded as favoring warm seas suggest that the waters of the Long Trail Shale deposition were warm and probably semitropical.

EXPLANATION OF PLATE 1

Figure 1. Thin section - fossil hash biofacies.

Figure 2. Thin section - dirty encrinite.

Figure 3. Thin section - encrinitic-bryozoan biofacies.

Figure 4. Thin section - clean encrinite

Figure 5. Thin section - silty lithofacies.

Figure 6. Thin section - bryozoan silty lithofacies.

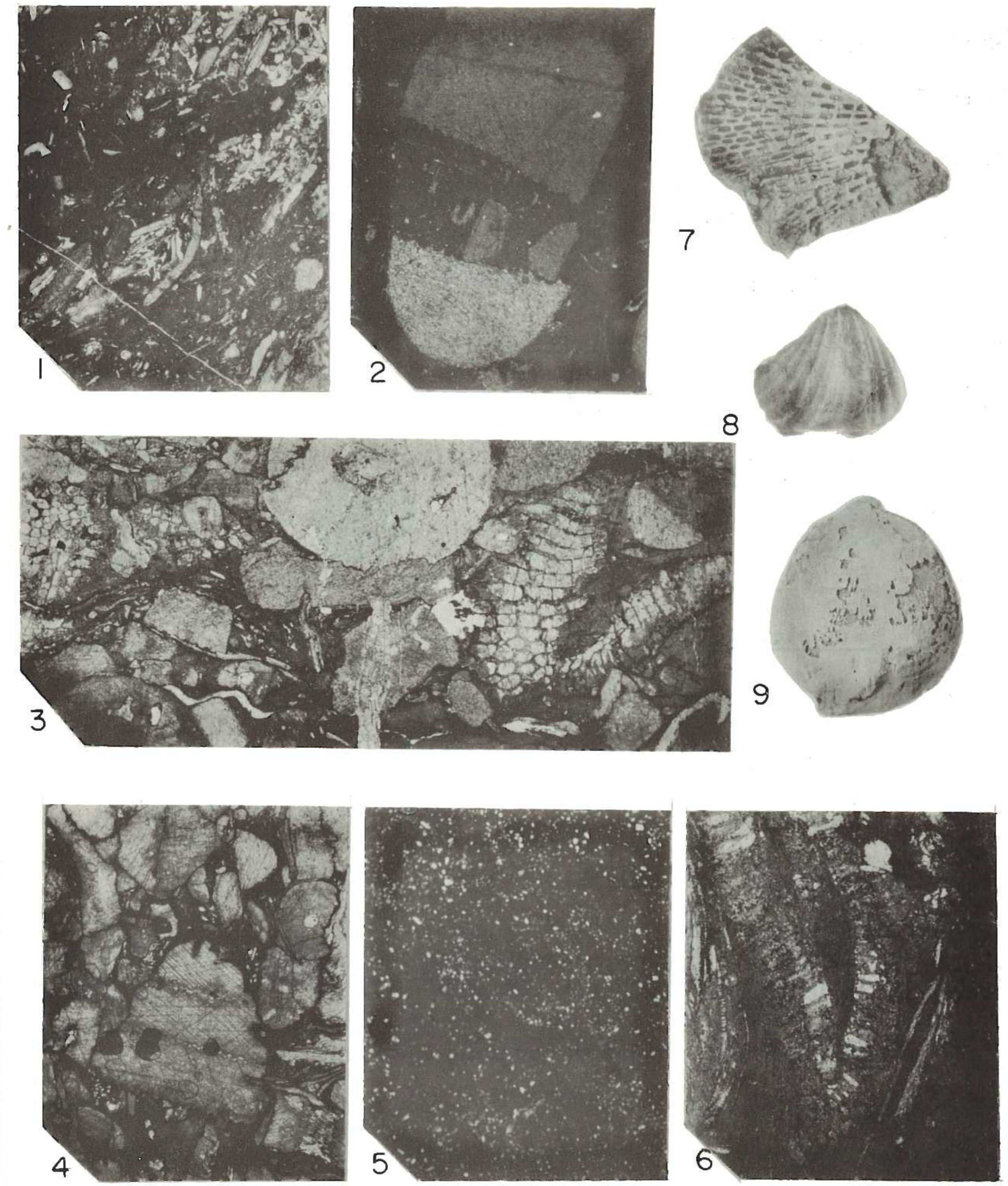
All thin sections X 10

Figure 7. Polypora cestriensis X 1½

Figure 8. Spirifer opimus X 1½

Figure 9. Abraded Rhipidomella X 1½

PLATE I



EXPLANATION OF PLATE II

Figure 1. Dictyclostus mesialis - interior brachial valve

Figure 2. Dictyclostus mesialis - exterior view

Figure 3. Echinoconchus alternatus

Figure 4. Bactritis sp.

Figure 5. Composita sp.

Figure 6. Girtyella aff. G. indianensis

Figure 7. Spirifer rockymontanus

Figures 1 through 7 X 1½

Figures 8 through 16 X 5

Figure 8. Straparolus sp.

Figure 9. Eumetria vera

Figure 10. Bucanella sp.

Figure 11. Bythocypris sp.

Figure 12. Nucula sp.

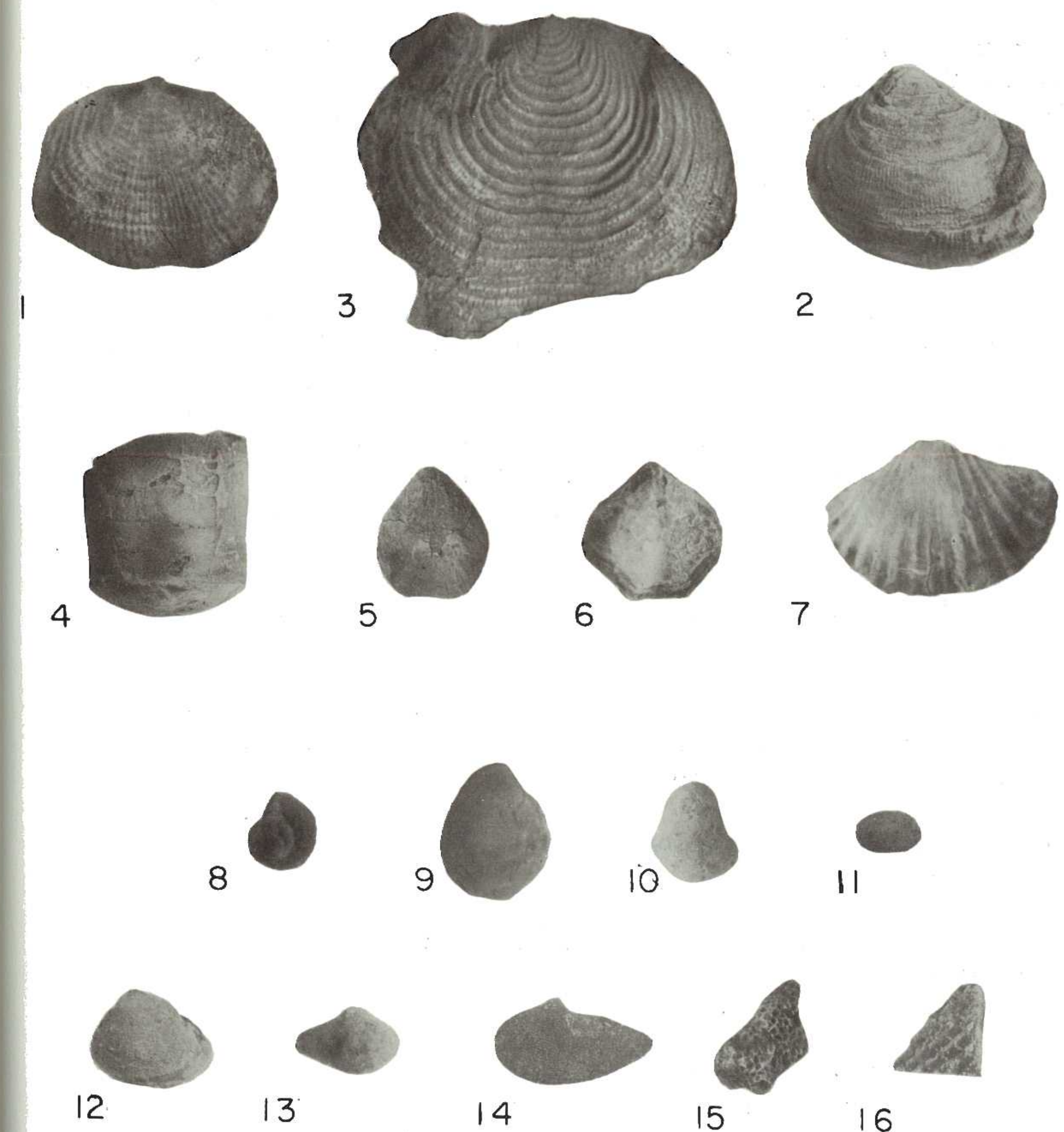
Figure 13. Phestia aff. P. inflata

Figure 14. Nuculana sp.

Figure 15. Stenopora sp.

Figure 16. Fenestellid bryozoan in encasing sediment chip

PLATE II



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APPENDIX

Long Trail Shale, Section # 11011

A. Measured section location.--S. E. ¼, Sec. 13, R. 4 W., T. 6 S. To reach this collecting locality, first travel to dirt road entering Mercur Canyon on the western side of the Oquirrh Range. Drive up this canyon road to a point about a hundred yards from a light-colored igneous dike which is just to the right of the road. From here walk about one-half mile south (or four spurs south) of the road. The Long Trail, which consists of interbedded limestone and shales, contrasts notably with the monotonous thick sections of grayish-blue limestones which make up the Lower and Upper Great Blue. The contacts are somewhat gradational and this particular unit is highly fossiliferous.

B. Description of measured section, Great Blue Limestone (Chester), Long Trail Shale Member: Section # 11011

Unit	Description	Thickness (in feet)
15	Concealed slope: contains shales; weathers to a light buff color; some parts of unit olive drab; finely fractured; some fissility present; a few very thin limestone beds present containing calcite streamers .	8
14	Siltstone: tightly cemented; fine texture; partly fossiliferous, containing squashed brachiopods; varnished appearance on weathered surface; dark gray on fresh surface; forms resistant ridge; some parts highly iron stained; these parts are unfossiliferous	6
13	Shales: slightly calcareous; variegated; weathers brown to gray-black; some parts of unit are silty; finely laminated; fossiliferous (crinoid fragments and poorly preserved brachiopod fragments); chert nodules on surface; six feet	

Unit	Description	Thickness (in feet)
	from base is a 3 to 4 inch, coarsely crystalline limestone containing brachiopod fragments and spines, bryozoans, and crinoid fragments all poorly preserved; rock highly iron-stained; a muddy-hashy limestone .	9
12	Limestone: slightly silty; medium dark brown on fresh surface; weathers dull brown; coarsely crystalline; fossiliferous (crinoid plates, corals, and other fossil fragments); fairly clean encrinitic rock type; thin calcite stringers	2
11	Shales and Siltsone: Three sub-units; distinction is made on basis of fractures and color; sub-units a and c are rather similar and are divided by b which is different in color as well as fracture; sub-units a and c weather a dull gray; b is a dark brown in color, and highly stained on weathered surface; all three sub-units are fossiliferous and contain fine silica silts cemented by a siliceous cement. The fracture of sub-units a and c is regular; that of sub-unit b is irregular; b is a ridge-former and probably best classified as a silica siltite; sub-units a and c are unfissile shale type rock units	10
10	Limestones: several zones or sub-units are recognizable:	
	a. Limestone: fossiliferous (zaphrenthid type spirifers, crinoid columnals); lithotype that of a shaly limestone; fine laminae noticed in thin section; dark gray to black on fresh surface	
	b. Limestone: similar lithology to sub-unit a, but has mainly fenestelled type bryozoans and brachiopods (chonetes and Echinoconchus) as contained fauna.	
	c. Limestone: contains much red silt (30%) and is 20% crinoid stems and fragments; very calcareous; a dirty encrinite.	
	Unit total	9

9 Shale: slightly calcareous, containing a few poorly preserved small fossils; variegated; red localized small stains throughout; fresh surface is of a blue-gray color; paper thin and clayey; two thin earthy limestones interbedded 10

8 Limestone: weathers to a dull gray; thin-medium bedded; some very fossiliferous zones (corals, productid type brachiopods that shell out, and other fossils); some shale partings; dark gray on fresh surface; regular fracture; tightly indurated by calcareous cement; a normal marine limestone 7

7 Shales: weathers blue-gray with red and orange staining; fresh surface is gray-green in color; thin-bedded shales; iron staining; a few poorly preserved fossils; non-calcareous. An uncommon lithotype 6

6 Limestone: weathers a rust color; gray on fresh surface; thin calcite streamers numerous; slightly silicious; very fossiliferous (spirifer type brachiopods); some shaly partings 2

5 Shale: light brown and gray well-weathered shales; has one-half foot thick limestone in the center containing authigenic pyrite; with a lithology similar to unit 4; forms a slope of fine dirt 4

4 Limestone: dark gray on fresh surface; light gray on weathered surface; coarsely crystalline; clean encrinitic type limestone; authigenic pyrite present; contains some silica; fossiliferous (mostly fragmental material) 1

3 Shales: black siliceous shales; fossiliferous (poorly preserved fragments); slightly fissile; forms chippy weathered slope; contains large pockets of slightly calcareous red clay which are localized and contain small poorly preserved brachiopods 4

2 Limestone: weathers gray with some orange coloration; weathered surface smooth with some

localized iron stains; crystalline; fine matrix; fossiliferous (hashy fossil remains); thin-medium bedded; some interbedded shales; ledge former; shales weather to a fine dirt 15

1 Mudstone: white to buff gray in color; fine texture; slakes in water; calcareous; dry powdery white soil formed upon weathering; this is base of Long Trail Shale 5

Total thickness 98

Section 11012

A. Location: N.E. 1/4, S.E. 1/4, Sec. 29, T.6 S., R. 3 W., one spur to the south of the old Sunshine Canyon smelter which can still be recognized though equipment is now scattered. Roads to the smelter are of pickup-truck quality.

B. Detailed Section

Unit	Description	Thickness (in feet)
15	Shale: unit grades from chippy, limey shales to paper thin, slightly calcareous shales; the limey shales are a brownish cream color, and the calcareous shales a dark gray color; both types form a slope of fine dirt. These shales are moderately fissile; no fossils noted	13
14	Limestone and shale: three sub-units:	
	c. Limestones: light lavender in color on weathered surfaces; fossiliferous (poorly preserved gastropods and brachiopods); slightly crystalline; rock well indurated; contains calcite stringers; irregular fracture.	
	b. Shale: light gray very calcareous shales; weathers to a fine dirt; no fossils noted; slight fissility.	

a. Limestone: weathers light brown; dark gray on fresh surface; contains localized iron stains; contains calcite stringers; fossil material hashy; fracture regular.

Unit total 5

13 Shale: variegated shales; slightly calcareous; dark gray on fresh surface; somewhat fissile; fossil remains poorly preserved; contains a 2 inch siltstone bed which is very porous and crumbly (fossiliferous and exhibits a heavy concentration of iron, contains pyrite crystals); this unit is a rust-brown color when weathered 2

12 Limestone: weathers dark brown in color, fresh surface is a gray-brown color; very silty; very fossiliferous (fossils fairly well preserved); some thin well weathered shales interbedded with the limestones; chert nodules present 20

11 Shales: blue-gray in color; very fissile; weathers into chips; slightly siliceous, non-calcareous 2

10 Limestone: weathered surface and fresh surface blue-gray in color; some localized iron staining; an encrinitic limestone with some poorly preserved fossils; coarsely crystalline; crumbly; regular fracture . . . 4

9 Shale: dark gray, non-calcareous, fissile shales; weathers to form a slope with paper thin fragments; contains a 4 inch limestone bed; 5½ feet from the base which is fossiliferous (crinoid fragments) and light gray in color; the thin limestone is crystalline and encrinitic 10

8 Limestone: weathers to a gray brown and is of a medium crystallinity; an encrinitic limestone with very little silt; dark gray on fresh surfaces; contains small calcite veinlets; fossiliferous (corals, crinoids, and brachiopods); contains several thin beds of well weathered shale 2

7 Mudstone: buff colored, highly calcareous, weathers to a very fine soil; slight regular fracture; no fossils noted 15

6 Siltstone: weathers light brown, fresh surface dark brown; rock porous with somewhat regular fracture; calcite encrustations present; unit contains a calcareous light gray shale (very thin zone) 2

5 Shale: fresh surface olive drab, weathered surface variegated; fossiliferous (badly preserved crinoids and brachiopod fragments); non-calcareous, clayey shales; moderately fissile 12

4 Limestone: weathers dark brown, fresh surface, dark gray; contains orange calcite stringers; crystalline; fossiliferous (brachiopods) 1

3 Mudstone: buff color with a lavender tint; slakes readily; somewhat calcareous (cement mainly); forms well weathered slope 4

2 Limestone and siltstone: interbedded limestone and siltstones; limestones gray in color and encrinitic; siltstone a light gray on weathered surface with some iron staining; fossil hash noted in the limestone; this unit is highly fractured into 2 inch blocks 2

1 Various rock types; unit consists of 4 thin limestones beds, 4 thin shale sub-units and a limey mudstone sub-unit; the limestones weather brown and are encrinitic, the shales are calcareous; the mudstone exhibits fissility and weathers to paper thin fragments; the shales form well weathered and chippy slopes; the limestones are fossiliferous . . 17

Total thickness 111

Section 11013

A. Location: This section was measured near Porphyry Hill, a weathered igneous intrusion which occurs to the north of the town of Mercur, Utah. The location is in the N. E. ¼ of the N. W. ¼ of Section 31, T. 5 S., R. 3 W. An old jeep trail runs right up to the collecting locality from Mercur. The section was measured in the saddle immediately to the west of Porphyry Hill.

B. Detailed Section # 11013.

Unit	Description	Thickness (in feet)
9	Limestone and Shale: six sub-units:	
	f. Limestone: weathers brown; thin bedded; well brecciated; crystalline; lots of iron staining; fossilization poor.	
	e. Limestone and shale: thin and interbedded; platey limestones; chippy shales; large amount of chert present; highly fractured; shales slightly fissile; non-calcareous silt rock.	
	d. Limestones and shales: dark gray; thin interbeds.	
	c. Limestone: a brown, hard, fossiliferous sub-unit with regular fracture.	
	b. Shales: form well-weathered dirt slope; dark brown; somewhat muddy.	
	a. Limestone: weathers light brown; dark gray on fresh surface, localized iron stains; coarsely crystalline, large calcite veins throughout sub-unit; chert nodules abundant; fossiliferous (fossils poorly preserved, mainly encrinitic material); thin bedded and platey.	
	Total thickness of unit	36

8	Shale: dark olive drab; non-calcareous; forms chippy dip slope; shales fissile; fossiliferous (mainly small pelecypods and brachiopods); contains a large amount of chert nodules; contains also a thin muddy limestone bed of very crumbly poorly indurated limestone; large amount of iron staining present . . .	11
7	Limestone and shale: interbedded limestone and shales:	
	c. Limestone: weathers brown in color; dark brown-gray on fresh surface; crystalline; very fossiliferous; slightly silty; some staining noted; contains an abundance of calcite streamers that run for long distances; forms dip slope of irregularly fractured rock.	
	b. Shale: light brown; well weathered; muddy shale zone rather thin; no fossils noted.	
	a. Limestone: similar to sub-unit 7 c, with crinoidal material more pronounced in the rock; crystalline; fossils mostly hashy; authigenic pyrite noted; fracture slightly regular.	
	Total thickness of unit	17
6	Siltstone: weathers very light brown, is light gray on fresh surface; iron staining present, unfossiliferous; well indurated, mottled appearance; thin-medium bedding; regular fracture	3
5	Limestone and siltstone and shale: an interbedded unit exhibiting sub-units of about equal thickness; most sub-units are siltstones with regular fracture; two limestone composed of crinoid stems and plates; most sub-units are fossiliferous	12

4 Siltstone: gray on fresh surface, weathers to light brown; regular fracture; resembles the siltstone of unit 5; iron staining; ridge former; forms little blocks of rock when weathered; has three distinctly different zones of fracture; few poorly preserved fossils present 11

3 Shales: colored blue-gray and tan; shales very fissile; forms slope of paper-thin pieces; unfossiliferous; non-calcareous; irregular bedding 2

2 Limestone: fresh and weathered surfaces gray; some iron staining; fossil hash type of limestone; thin bedding and highly fractured; a few very thin shales interbedded 2

1 Shale and siltstone: dark tan to yellowish-brown; grades from shale into claystone; fossiliferous (fossils few and poorly preserved); claystone exhibits regular fracture; unit is non-calcareous 7

Total thickness 101