Depositional environment of the Pagoda Pentagon and Steamboat formations (Middle Cambrian) northwest Montana

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DEPOSITIONAL ENVIRONMENT OF THE PAGODA, PENTAGON, AND STEAMBOAT FORMATIONS (MIDDLE CAMBRIAN), NORTHWEST MONTANA

by

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B.A., Carleton College, 1974

Presented in partial fulfillment of the requirements for the degree of

Master of Science

UNIVERSITY OF MONTANA

1978

Approved by:

Chairman, Board of Examiners

Dean, Graduate School

Date 1-27-78
Depositional environment of the Pagoda, Pentagon, and Steamboat formations (Middle Cambrian), northwest Montana (105 pp.)

Director: Don Winston

The Middle Cambrian Pagoda, Pentagon, and Steamboat formations, shallow marine carbonates with an admixture of quartz silt and shale, are well exposed in the mountainous terrain south of Glacier Park, Montana. Lithofacies within these formations indicate deposition in sub-wave-base, shallow subtidal, and intertidal to possibly lower supratidal environments.

Following the subtidal deposition of a terrigenous wedge, which marks the base of the Pagoda Formation, carbonate accumulated below wave base. Active carbonate production and build-up in the west formed a shoal complex consisting of oolitic, intraclastic, pelletal, fenestral, and cryptagal laminated limestones. To the east, carbonate shoal facies sloped down to sub-wave-base planar laminated micrite, calcareous shale, and mudstone of the Pentagon Formation. The development of the shoal complex climaxed with an eastward progradation of intrasparite and packed intramicrite sediments across the area.

Above the shoal complex, the vertical sequence of shale to carbonate repeats itself in the Steamboat Formation, passing from a lower terrigenous wedge up to sub-wave-base carbonate accumulation and build-up of carbonate sediments into wave base forming a shallow subtidal veneer throughout the area.
ACKNOWLEDGMENTS

I would like to express my indebtedness to my committee members: Dr. Don Winston, Dr. James Peterson, and Dr. Len Porter, for their valuable criticism and guidance on this project. Special thanks go to Dr. Don Winston who offered unending encouragement and who spent many hours reviewing and editing this manuscript. Conversations with Dr. Johnnie Moore were both pleasurable and enlightening. This project would not have been completed without the help of my wife, Marilyn, who provided financial support for our family. I would also like to thank John Cuplin for his valuable advice concerning the drafting of this manuscript and Katie Marron for her skillful typing.
# TABLE OF CONTENTS

<table>
<thead>
<tr>
<th>Section</th>
<th>Page</th>
</tr>
</thead>
<tbody>
<tr>
<td>ABSTRACT</td>
<td>ii</td>
</tr>
<tr>
<td>ACKNOWLEDGMENTS</td>
<td>iii</td>
</tr>
<tr>
<td>TABLE OF CONTENTS</td>
<td>iv</td>
</tr>
<tr>
<td>LIST OF FIGURES AND TABLES.</td>
<td>v</td>
</tr>
<tr>
<td>CHAPTER</td>
<td></td>
</tr>
<tr>
<td>I. INTRODUCTION</td>
<td>1</td>
</tr>
<tr>
<td>General Statement</td>
<td>1</td>
</tr>
<tr>
<td>Stratigraphic Setting</td>
<td>2</td>
</tr>
<tr>
<td>Location of Study</td>
<td>8</td>
</tr>
<tr>
<td>Question of Formational Status</td>
<td>12</td>
</tr>
<tr>
<td>General Depositional Model</td>
<td>13</td>
</tr>
<tr>
<td>II. DESCRIPTION OF LITHOFACIES</td>
<td>19</td>
</tr>
<tr>
<td>General Statement</td>
<td>19</td>
</tr>
<tr>
<td>Shale Lithofacies</td>
<td>19</td>
</tr>
<tr>
<td>Bioturbated Micrite Facies</td>
<td>23</td>
</tr>
<tr>
<td>Planar Laminated Micrite and Mudstone Facies</td>
<td>27</td>
</tr>
<tr>
<td>Intraclastic Facies</td>
<td>30</td>
</tr>
<tr>
<td>Oolite Facies</td>
<td>35</td>
</tr>
<tr>
<td>Pellet Sand Facies</td>
<td>39</td>
</tr>
<tr>
<td>Cryptalgal and Fenestral Facies</td>
<td>40</td>
</tr>
<tr>
<td>III. SHALE MINERALOGY</td>
<td>43</td>
</tr>
<tr>
<td>Relationship to the Middle Cambrian Shoreline</td>
<td>43</td>
</tr>
<tr>
<td>IV. SUMMARY AND CONCLUSIONS.</td>
<td>45</td>
</tr>
<tr>
<td>Integrated Interpretation</td>
<td>45</td>
</tr>
<tr>
<td>Speculative Tectonic Control on Sedimentation</td>
<td>52</td>
</tr>
<tr>
<td>REFERENCES CITED</td>
<td>55</td>
</tr>
<tr>
<td>APPENDIX I.</td>
<td>59</td>
</tr>
<tr>
<td>Location of Measured Sections</td>
<td>60</td>
</tr>
<tr>
<td>Measured Sections</td>
<td>62</td>
</tr>
</tbody>
</table>
LIST OF FIGURES AND TABLES

<table>
<thead>
<tr>
<th>Figure</th>
<th>Description</th>
<th>Page</th>
</tr>
</thead>
<tbody>
<tr>
<td>1.</td>
<td>Stratigraphic Section of Cambrian Formations in the Lewis and Clark and Flathead Ranges, Northwest Montana.</td>
<td>4</td>
</tr>
<tr>
<td>2.</td>
<td>Cambrian Section near Trilobite Peak</td>
<td>5</td>
</tr>
<tr>
<td>3.</td>
<td>Correlation of Cambrian Formations in Northwest Montana with Formations in Southwest Montana</td>
<td>7</td>
</tr>
<tr>
<td>4.</td>
<td>Location of Study Area</td>
<td>9</td>
</tr>
<tr>
<td>5.</td>
<td>Geologic Map of Study Area Showing Location of Measured Sections.</td>
<td>11</td>
</tr>
<tr>
<td>6.</td>
<td>Block Diagrams Depicting the Sequence of Upward Shoaling Sedimentation in the Pagoda, Pentagon, and Lower Steamboat Formations</td>
<td>15</td>
</tr>
<tr>
<td>7.</td>
<td>Fence Diagram Showing Relative Distribution of Lithofacies.</td>
<td>18</td>
</tr>
<tr>
<td>8.</td>
<td>Twin Creek Section</td>
<td>25</td>
</tr>
<tr>
<td>9.</td>
<td>Bioturbated Micrite</td>
<td>25</td>
</tr>
<tr>
<td>10.</td>
<td>Pentagon Mountain Section</td>
<td>28</td>
</tr>
<tr>
<td>11.</td>
<td>Photomicrograph of the Planar Laminated Micrite Facies</td>
<td>28</td>
</tr>
<tr>
<td>12.</td>
<td>Photomicrograph of the Intrasparite, Packed Intramicrite Facies</td>
<td>32</td>
</tr>
<tr>
<td>13.</td>
<td>Oncolite which has Grown Around a Trilobite Fragment</td>
<td>32</td>
</tr>
<tr>
<td>14.</td>
<td>Girvanella Rim of an Oncolite</td>
<td>32</td>
</tr>
<tr>
<td>15.</td>
<td>Photomicrograph of Intramicrite Subfacies</td>
<td>34</td>
</tr>
<tr>
<td>16.</td>
<td>Flathead River Section</td>
<td>34</td>
</tr>
</tbody>
</table>
LIST OF FIGURES AND TABLES (Continued)

**Figure** | **Page**
---|---
17. Thick Rimmed Ooids from the Oolite Facies. | 38
18. Photomicrograph of Pellet Sand Facies. | 38
19. Fenestra and Adjacent Ooids and Pellets of Fenestral Rock Type. | 38
20. Diagrammatic Cross Section of Ooid Shoal Complex. | 51

**Table**

| I. Compositional Classifications of Limestones. | 20 |
CHAPTER I

INTRODUCTION

General Statement

Recent studies in the Great Basin and Canada by many workers have contributed much to an understanding of the regional stratigraphic relationships and depositional environments of the Cambrian in western North America. Lochman-Balk and Wilson (1958) and Palmer (1971) have recognized the importance of major biofacies realms or belts. Palmer (1971), has defined these belts as follows: 1) an inner detrital belt characterized by fine clastics of the inner shelf; 2) an area dominated by shallow subtidal carbonate sedimentation, the middle carbonate belt; and 3) the outer detrital belt, marked by dark shale, siltstone, and thin bedded limestone deposited on the outer shelf. Palmer et al. (1976) have stressed the relationship of these environments to trilobite biofacies, particularly in the Great Basin. However, the Cambrian in northwest Montana remains virtually unstudied. Since Walcott and Deiss pioneered the study of Cordilleran Cambrian rocks, no detailed stratigraphic and paleoenvironmental analysis has been attempted in this area. This thesis was undertaken in an effort to help fill the gap in our understanding of the Cambrian in Montana.
Stratigraphic Setting

Middle and Upper Cambrian rocks are well exposed in the rugged mountains of the Flathead and Lewis and Clark ranges of northwest Montana. Deiss (1933, 1938, 1939) described the Paleozoic sequence in this area and divided the Cambrian into nine formations (fig. 1,2).

The Pagoda, Pentagon, and Steamboat formations range from middle Middle Cambrian to upper Middle Cambrian in age and are correlative with the Meagher and Park formations of southwest Montana (Lochman-Balk, 1956) (fig. 3). The boundary between the Upper and Middle Cambrian is placed in the overlying Switchback Formation (Lochman-Balk 1956) although its exact position is obscure because of limited paleontologic data.

A green fissile shale marks the base of the Pagoda Formation. This shale unit is overlain by a relatively thick sequence of thin bedded limestone with shale and dolomitic interlayers. The upper portion of the Pagoda Formation is composed of irregularly to massively bedded oolitic, intraclastic, and fenestral limestone. In outcrop, the limestone of the Steamboat Formation appears similar to the limestone of the upper half of the Pagoda Formation. A thin shaly unit is locally apparent near the base of the Steamboat Formation. In contrast to the dominance of relatively pure limestone in the Pagoda and Steamboat formations, the Pentagon Formation consists of shale, mudstone, and thin platy bedded argillaceous limestone with shale and mudstone interlayers.
DOMINANT LITHOLOGY

Dolomite

Limestone

Shale

Sandstone

Figure 1: Stratigraphic section of Cambrian formations in the Lewis and Clark and Flathead ranges, northwest Montana.
Figure 2. Cambrian section near Trilobite Peak: G) Gordon, D) Damnation, De) Dearborn, P) Pagoda, Pe) Pentagon, St) Steamboat, S) Switchback, DG) Devils Glen.
Figure 3. Correlation of Cambrian formations in northwest Montana with formations in southwest Montana. Correlations based on trilobite assemblages. Formations indicated as follows: DG, Devils Glen; S, Switchback; St, Steamboat; Pe, Pentagon; P, Pagoda; De, Dearborn; D, Damnation; G, Gordon; F, Flathead; RL, Red Lion; Pi, Pilgrim; Pa, Park; M, Meagher; W, Wolsey; H, Hasmark; SH, Silver Hill. From Lochman-Balk, 1956.
After Lochman-Balk, 1956
West of the Lewis Thrust (fig. 5) the limestone of the Pagoda Formation is directly overlain by limestone of the Steamboat Formation. East of the Lewis Thrust, the Pagoda and Steamboat formations are thinner, shalier, and are separated by shale, mudstone, and impure carbonate of the Pentagon Formation. I conclude that the Pentagon Formation to the east represents a shale and impure carbonate facies of the Pagoda and lower Steamboat formations of the western sections.

**Location of Study**

Six stratigraphic sections were measured, described, and sampled within and near the northern boundary of the Bob Marshall Wilderness Area (figs. 4,5). These sections are herein referred to as Beacon Mountain, Twin Creek, Flathead River, Limestone Wall, Pentagon Mountain, and Trilobite Peak. Detailed descriptions and profile sections are listed in the appendix. My measured section at Pentagon Mountain describes in more detail part of a measured section published by Deiss (1938). All other sections were previously unstudied.

In contrast to the imbricate thrusting to the east, this area is broadly folded, and is cut by several normal faults and by what is believed to be a southern extension of the Lewis Thrust (Mudge et al., 1977) which separates sections at Pentagon Mountain and Trilobite Peak from sections to the west. It is across this thrust that the facies change from the Pagoda and lower Steamboat formations to the Pentagon Formation occurs. In this study, the displacement along this thrust was not determined. However, based on a structural cross
FIGURE 4.
LOCATION OF STUDY AREA
Figure 5. Geologic map of study area showing location of measured sections. Sections identified as: 1) Beacon Mountain; 2) Twin Creek; 3) Flathead River; 4) Limestone Wall; 5) Pentagon Mountain; and 6) Trilobite Peak.
after Mudge et al., 1977
section published by Mudge et al. (1977), 16 km of displacement with no rotation was chosen for palinspastic reconstruction.

**Question of Formational Status**

The shaly lithology of the Pentagon Formation is restricted to the impressive cliffs which form the Continental Divide north of Cliff Mountain (28 km south of Kevin Mountain) and south of Gable Peak (fig. 5). To the west and south, it passes to carbonate which is included in the Pagoda and lower Steamboat formations. Lochman-Balk (1956) emphasized the limited regional extent of the Pentagon Formation and questioned its formational status. This study shows that the Pentagon Formation is a shale and impure carbonate facies of the Pagoda and lower Steamboat formations (fig. 1). The major part of the Pentagon Formation apparently intertongues with the Pagoda Formation. Perhaps it would be more accurate to consider the Pentagon Formation as a member of the Pagoda Formation.

In addition to the absence of the shaly lithology of the Pentagon Formation to the west, the stratigraphic level of the Pagoda - Steamboat boundary occurs within a continuous limestone interval and has little lithic expression west of the Lewis Thrust. At the Twin Creek and Limestone Wall sections, this level is marked by a recessive bench. However, at the Beacon Mountain section, the same level has no expression. Therefore, it appears that the Pagoda and Steamboat formations can not be recognized as separate mappable units west of
the Lewis Thrust. Deiss's formational divisions need to be examined on a regional basis and probably should be revised, particularly in the light of modern stratigraphic procedures. However, until this is done, it seems best to use Deiss's nomenclature.

**General Depositional Model**

The Pagoda, Pentagon, and Steamboat formations represent shallow water marine carbonate, shales, and silts deposited in the middle carbonate belt of Palmer (1971).

The base of the Pagoda Formation is marked by a green fissile shale representing a thin terrigenous wedge deposited over the previously drowned carbonate platform of the Dearborn Formation. With a reduced influx of terrigenous sediment from the east, carbonate sedimentation was initiated below wave base (fig. 6a). Active carbonate production and build-up in the west led to the development of an ooid shoal with flanking shallow subtidal, intertidal, and possibly lower supratidal sedimentation on its shoreward or eastern margin. To the east, the shoal facies of the upper Pagoda and lower Steamboat formations sloped down to sub-wave-base micrite, calcareous shale, and mudstone of the Pentagon Formation (fig. 6b). An abundance of planar laminated micrite and the absence of bioturbation suggest that this area was often inhospitable to burrowing organisms. During the final development of the shoal complex, very shallow subtidal sediments prograded eastward at least as far as Pentagon Mountain and Trilobite Peak (fig. 6c).
Figure 6. Block diagrams depicting the sequence of upward shoaling sedimentation in the Pagoda, Pentagon, and lower Steamboat formations.
Figure 6a. Deposition of a thin terrigenous wedge followed by sub-wave-base carbonate sedimentation.

Figure 6b. Formation of shoal complex

Figure 6c. Eastward progradation of very shallow subtidal sediments marks the final development of the shoal complex.
The shale unit near the base of the Steamboat Formation at Pentagon Mountain and a correlative shale unit at Beacon Mountain represent a second terrigenous wedge. This period, initiated by suspended silt and clay deposition, culminated in the accumulation of intraclastic carbonates in a broad, very shallow, subtidal environment that extended across the entire area.
Figure 7. Fence diagram showing relative distribution of lithofacies. Constructed on a palinspastic base assuming 16 km of displacement on the Lewis Thrust: 1) Beacon Mt., 2) Twin Creek, 3) Flathead River, 4) Limestone Wall, 5) Pentagon Mt.
CHAPTER II

DESCRIPTION OF LITHOFACIES

General Statement

The preceding depositional model is based on an interpretation of a three-dimensional framework of the seven lithofacies within the six measured sections. The relative relationships of lithofacies is presented graphically in Figure 7.

Below, lithofacies are described from a megascopic and microscopic standpoint and are discussed in sequence from the bottom up. The interpretation of depositional environments of the lithofacies is largely based on analogy to modern carbonate environments, analogies which are only possible due to tremendous advances made within the last two decades in an understanding of carbonate sedimentation.

In the following descriptions, Folk's (1974) classification system for carbonate rocks is used. Table I illustrates this classification system.

Shale Lithofacies

Description. The base of the Pagoda Formation is characterized by a distinctive, recessive weathering, olive to dark green, fissile, calcareous shale which gradationally overlies flaggy oomicrite beds of the uppermost part of the Dearborn Formation. This basal shale
Table 1. Compositional Classification of Limestones (from Folk, 1974, p. 64).
unit ranges in thickness from slightly less than 1.5 m at Flathead River, 12.2 m at Twin Creek, to 27.4 m at Pentagon Mountain. Discrete micrite nodules (4 cm by 2 cm) are common in the shale and become more abundant upsection, and appear to grade into the overlying wavy beds of the bioturbated micrite facies. Both disarticulated and small articulated trilobites (Glyphaspis, Bolapsis) are locally present.

At Pentagon Mountain and Trilobite Peak the basal green fissile shale of the Pagoda Formation grades upward into a brown fissile shale and contains more coarse detrital mica on bedding surfaces than in sections to the west. In addition to discrete micrite nodules, the basal 15 m of the shale facies at Pentagon Mountain contains widely spaced 5 - 8 cm thick horizontally laminated calcareous siltstone beds and abundant 5 - 15 cm thick beds of flat-pebble conglomerate. The flat-pebble beds consist of crudely imbricated clasts up to 4 cm in length. The larger clasts are calcareous siltstone with very angular quartz grains and are mostly horizontally laminated. Rarely, bioturbated and pelloidal calcareous siltstone clasts are observed. The smaller clasts are less platy, contain no quartz, and are petrographically similar to the bioturbated micrite facies. The matrix of the flat-pebble beds includes silt sized angular quartz grains, argillaceous biomicrite, minor glauconite, and local concentrations of coarse biosparite composed of pelmatazoan and trilobite fragments.

In the upper 12 m of the basal shaly unit at Pentagon Mountain, siltstone beds and siltstone clasts are absent, and quartz is limited
to the matrix of flat-pebble beds and to rare grains in laminated micrite. The intercalated limestone beds are argillaceous and locally pelloidal micrites, and flat-pebble conglomerates. Two 10 cm fossil hash beds occur near the 24 m level. Some micrite clasts and shale beds are red. However, color contacts are not sharp and coloration is probably due to later diagenetic or weathering environments rather than to syndepositional oxidation.

The shale lithofacies is everywhere present at the base of the Pagoda Formation and recurs in the upper Pentagon and lower Steamboat formations at Pentagon Mountain and in the middle of the Steamboat Formation at Beacon Mountain.

Depositional Environment. Many shales in the Cambrian sequence of the Great Basin have been interpreted as mudflat sediments. However, the shaly unit at the base of the Pagoda Formation and recurrent shaly units in the Pentagon and Steamboat formations lack sedimentary structures indicative of tidal flats (see Reineck, 1967). Ripple cross beds and channels are absent. The presence of horizontally laminated silts, clays, and micrites, and stratigraphic position beneath a sub-wave-base micrite indicate that these shaly units were deposited in a subtidal environment, probably below day-to-day wave base.

Abundant flat-pebble conglomerate beds and local trilobite coquinas in the shaly units at Pentagon Mountain represent storm lag deposits. Storm-generated currents probably periodically swept across this otherwise quiet area ripping up partially lithified
bottom sediments (see Shinn et al., 1969) and concentrating fossil fragments.

The absence of quartz to the west, paucity of coarse detrital mica, distribution of clay mineralogy (discussed below) and the lack of high energy deposits suggests that the shales in sections west of the Lewis Thrust were deposited farther from the shore below storm wave base.

The origin of the discrete micrite nodules, which are abundant in the shales, is unclear. Fossil fragments are not common in the nodules and the nodules lack concentric banding characteristic of concretions (Henningsmoen, 1974). Nodules increase in number and are more closely spaced where the shale grades into the overlying wavy beds of the bioturbated micrite facies. Perhaps these nodules are remnants of continuous or lenticular micrite beds that were partially dissolved during diagenesis. A similar origin has been proposed for limestone nodules in the lower Paleozoic of the Oslo region by Bjorlykke (1973).

Bioturbated Micrite Facies

Description. The bioturbated micrite facies gradationally overlies the shale facies. Nearly 61 m thick at Twin Creek and Flathead River, this facies intertongues with planar laminated micrite, mudstone, and shale at Pentagon Mountain and Trilobite Peak.
The lowermost 9 to 15 m of the bioturbated micrite facies consists of thin bedded limestone, averaging 1 cm to 5 cm thick, intercalated with green fissile shale 1 cm thick or less. Bedding surfaces of the limestone are very irregular and in cross section are wavy and somewhat nodular. Shale interbeds are replaced upsection by granular, recessive weathering, buff to yellow orange, dolomitic interlayers averaging 1 cm thick. The shale and dolomitic interlayers in the lower half of this facies impart a distinctive ribbed and undulatory appearance to the outcrop (Fig. 8). The dolomitic interlayers thin upward to paper thin, continuous and discontinuous partings. Concurrent with the thinning of the dolomitic interlayers, the outcrop loses its ribbed appearance and the limestone beds become more massive, locally as thick as 0.9 to 1.5 m.

The blue gray, argillaceous micrite of the lowermost 3 m of the bioturbated micrite facies is replaced upsection by dark gray, gray, or dark chocolate micrite. Clear spar patches, which are mostly rimmed or filled by pyrite or marcasite, reflect ancient, open burrows. More common are randomly oriented sediment infilled burrows up to 5 mm in diameter which are marked by yellow orange to buff dolomitic pods or by a concentration of microspar which produces a distinctive light and dark mottled pattern to slab surfaces. In thin section compaction rings (Bathurst, 1975) encircle the burrows (Fig. 9).

Pellets up to 0.08 mm in diameter are common in the micrite and equal-sized spheres of clear spar are locally abundant. These spheres
Figure 8. Twin Creek section. Typical outcrop of the lower half of the bioturbated micrite facies. Note ribbed and undulatory character of the outcrop.

Figure 9. Bioturbated micrite (FR 40 m). Mag. X 10

1 mm
have a thin micrite or microspar rim and are probably recrystal-
lized pellets or pellets which have been dissolved and replaced by
void filling spar. Small filaments of the alga *Girvanella* are
locally present in the eastern sections and spicular micrite is
characteristic of all sections west of the Lewis Thrust, except
Flathead River. Although sparse and commonly absent, trilobite
fragments outnumber pelmatozoan fragments.

The bioturbated micrite facies recurs in the upper half of the
Steamboat Formation throughout the study area. In the Steamboat
Formation, this facies is represented by relatively massive lime-
stone with paper thin dolomitic wisps characteristic of the upper
half of the bioturbated micrite facies in the Pagoda Formation.

**Depositional Environment.** The bioturbated facies was deposited
below wave base, probably on an extensive, shallow shelf similar to
that described by Brady *et al.* (1976) and Halley (1975) in the Great
Basin. This environment was hospitable for soft-bodied, burrowing
organisms. The lenticular intraclastic beds at the Twin Creek section
are interpreted as lag deposits from large storms.

I believe that the dolomitic interlayers in the bioturbated
micrite facies were produced by solution and dolomitization of once
relatively pure micrite. Solution is suggested by the very irregular
bedding surfaces of the micrite. Dolomitization may have been con-
trolled by permeability differences within the micrite as suggested
by the concentration of dolomite in burrows. However, this may or may not apply to the dolomitic interlayers. The questions remains as to whether the solution and dolomitization occurred relatively syndepositionally or at a much later date. Perhaps, the consistent spacing and thickness of dolomitic interlayers indicate dolomitization near the sediment water interface rather than after burial, compaction, and loss of permeability in a micrite sediment.

**Planar Laminated Micrite and Mudstone Facies**

**Description.** The "Pentagon fauna" of Deiss (1938) was collected from a light gray brown, limy mudstone unit 13.5 m thick which marks the base of the Pentagon Formation. Bedding is massive and irregular and the mudstone commonly breaks concoidally. Limestone stringers a few mm thick increase in number and thickness up section. Agnostids and Bathyuriscus are common trilobites in this rock type.

Gradationally overlying the limy mudstone is thin platy bedded limestone with shale and mudstone interbeds characteristic of the planar laminated micrite rock type (Fig. 10). Limestone beds range in thickness from 0.3 cm to 7.6 cm, averaging 1.2 cm to 2.5 cm. Shale and mudstone interbeds are of approximately equal thickness to the limestone, are brown to light gray brown in color, and are calcareous. The limestone is generally gray to chocolate, argillaceous micrite with smooth bedding surfaces. Well preserved articulate trilobites, including agnostids and Bathyuriscus, are common on
Figure 10. Pentagon Mountain section. Thin platy beds of the planar laminated micrite facies. Hammer is 29 cm long.

Figure 11. Photomicrograph of the planar laminated micrite facies (PM 62.5 m). Mag. X 10
bedding planes in the lower five m of this rock type. However, fossil fragments are rare within the micrites. In thin section, the micrite of this facies completely lacks sedimentary structures and is largely recrystallized to homogeneous microspar (Fig. 11). The sub parallel orientation of the rare trilobite fragments suggests that the micrite was once horizontally laminated. The planar laminated micrite and mudstone facies is only recognized in the Pentagon Formation at Pentagon Mountain and Trilobite Peak.

**Depositional Environment.** Similar to the deposition of the bioturbated micrite facies, the planar laminated micrite and mudstone facies was deposited below wave base. This environment was not conducive to habitation by burrowing organisms, perhaps due to elevated or depressed salinities and/or temperatures. The high mud content of this facies suggests that waters were turbid, which may have been a factor restricting burrowers. The sporadic appearance of bioturbated micrite at Pentagon Mountain and Trilobite Peak reflect restrictive conditions that were occasionally eliminated permitting burrowing organisms to inhabit the region.

The abundance of agnostids, *Bathyuriscus* and other articulated trilobites on the bedding surface of the micrite and mudstone is somewhat of an enigma. With the exception of agnostids, which were apparently pelagic forms (Robison, 1972) trilobites are thought to have been detritus feeders and undoubtedly stirred up sediment as they scurried along the bottom (Robison, 1972). Thus, if trilobites
were living in this area one would expect to see bioturbation or 
trails of which there is none. In addition, agnostids and Bathyur-
iscus were presumably inhabitants of open shelf environments (Palmer 
et al., 1976; Robison, 1976). Yet, the planar laminated micrite 
and limy mudstone at Pentagon Mountain and Trilobite Peak definitely 
do not represent open shelf sediments. More likely, they reflect a 
local basin or an inner, somewhat restricted part of the shelf.

Intraclastic Facies

Description. The intraclastic facies is the most variable of 
all facies and is recognized in the Pagoda, Pentagon, and Steamboat 
formations. Bedding varies from thin platy to massive irregularly 
bedded limestone. Yellow orange to buff dolomitic pods and both thick 
and continuous and paper thin, discontinuous dolomitic partings are 
common. On a fresh surface the intraclastic limestones are dark 
chocolate to chocolate in color and locally have a bituminous odor, 
particularly in oncolitic beds. A thin zone of light cream colored 
limestone is developed in this facies directly below sediments inter-
preted to be deposited in an intertidal to lower supratidal environ-
ment. Allochems include micrite clasts with one or more of the follow-
ing: pellets; pelmicrite; pisolites; oncolites; ooids; fossil frag-
ments. The intraclastic facies includes subordinate micrite and flat-
pebble conglomerate interbeds.
The intraclastic facies is divisible into two, intergradational subfacies. These are: 1) intrasparite, packed intramicrite subfacies (which is most abundant); and 2) intramicrite subfacies.

Allochems in the intrasparite, packed intramicrite subfacies are rounded to subangular, poorly to moderately well sorted (Fig. 12). Rarely, well washed intrasparite beds occur as interruptions in high energy deposits such as oosparite. Allochems are often composite, consisting of pelmicrite, biomicrite, and oomicrite. Symmetrical and assymetrical oncolites up to 2 cm in diameter occur in both subfacies (Fig. 13). The alga *Girvanella* is the primary constituent of the oncolites and also occurs as thin rims around some intraclasts (Fig. 14). Apparently, many of the micrite clasts were dissolved after cementation of the sediment. These are now partially replaced by monocrystalline spar. A hardground (Shinn, 1969; Bathurst, 1975) was observed at the Beacon Mountain Section (107.6 m interval).

The intramicrite subfacies is distinguished from the intrasparite, packed intramicrite subfacies by poorer sorting, greater percentage of micrite matrix, and greater angularity of the clasts. Allochems are angular, subangular, and rarely subrounded, spicular micrite, pelmicrite, and micrite (Fig. 15). *Girvanella* may occur as discrete lumps or fragments and oncolites, ooids, and fossil fragments are local constituents.
Figure 12. Photomicrograph of the intrasparite, packed intramicrite subfacies (FM 125 m). Mag. X 10

Figure 13. Oncolite which has grown around a trilobite fragment (TC 100 m). Mag. X 10

Figure 14. *Girvanella* rim of an oncolite (TC 100 m). Mag. X 40
Depositional Environment. The intraclastic limestone was deposited in a shallow subtidal environment within storm-wave-base. Variations within this facies were produced by differences in current activity, agitation frequency of the allochems, and position of the depositional environment relative to contemporaneous facies.

Relatively open areas with moderate exposure to wind and waves may have characterized the depositional environment of the subrounded, moderately well sorted, poorly washed intrasparite and packed intramicrite typical of the bulk of the intraclastic beds at Pentagon Mountain, Trilobite Peak, and correlative facies at Beacon Mountain and Twin Creek (see Fig. 7). Thin oolitic coats developed on some grains in this subfacies, and the presence of concentrically laminated oncolites indicate that current activity was great enough to keep bottom sediments in relatively constant motion, at least for short periods (Bathurst, 1975; Logan et al., 1964). The local presence of hardgrounds in the more micritic, less rounded intraclastic beds indicate early submarine cementation and are suggestive of a slow rate of deposition (Shinn, 1969). Grapestone lumps (Illing, 1954), common allochems in some intraclastic horizons, reflect an environment characterized by long periods of bottom stability interrupted by short periods of bottom agitation, presumably during storms (Purdy, 1963; Windland et al., 1974). Such environments could occur in shallow lagoons or protected areas behind or flanking ooid shoals as exemplified by the modern Bahama Bank (Purdy, 1963).
Figure 15. Photomicrograph of intramicrite subfacies (FR 97.5 m). Compare with fig. 12. Mag. X 10

Figure 16. Flathead River section. Note distinctive cliff-forming oolitic horizon (o).
The proximity of contemporaneous facies, in a large part, controlled the composition of the allochems in the intraclastic beds. Thus, allochems in intraclastic horizons found stratigraphically above the bioturbated micrite facies are pelmicrite, spicular micrite, and micrite derived from that facies. Similarly, intraclastic beds stratigraphically above the oolite facies have a high percentage of ooids as allochems and probably were deposited shoreward or flanking the ooid shoal.

Oolite Facies

Description. The oolite facies is best developed in the Pagoda Formation at the Flathead River and Limestone Wall sections. At the Twin Creek and Beacon Mountain sections, this facies is interrupted by packed pelmicrite and intraclastic limestone. The oolite facies is not recognized east of the Lewis Thrust.

Generally cliff forming, the oolitic beds of the Pagoda Formation form a distinctive unit marked by massive, irregularly bedded, somewhat blocky limestone 15 cm - 91 cm thick with locally developed paper thin discontinuous, dolomitic partings (Fig. 16). At Limestone Wall, however, only the lowermost 6 m of this facies is massive limestone. These beds grade upward into thin platy limestone .6 - 1.3 cm thick which may reflect original bedding of the ooid sands.

Sedimentary structures in the oolitic facies are difficult to discern; however, high angle, planar cross bed sets 3 to 4 cm thick
are locally apparent. The best developed cross beds in the oolite facies are found in an outcrop 1.6 km south of the Flathead River section along U.S.F.S. South Fork Flathead River Trail. Here, low angle, trough set cross beds 0.3 to 1 m high and several m in length are developed. Superposed on the trough cross beds are high angle planar cross beds 4 to 6 cm thick and small current ripple cross beds averaging 1 cm high.

On a fresh surface the color of the oolite facies varies from dark chocolate to buff. Locally, particularly at the Flathead River section, a distinctive light and dark banding is developed. The dark bands are areas of well formed, robust ooids, while the buff zones represent ooids which have been partially dissolved, compacted, and dolomitized. These diagenetic processes have resulted in distorted ooids which are often connected by narrow apophyses. Similar distorted ooids have been described from the Plattsburg Limestone by Conley (1977) and by Carozzi (1961).

Individual ooids of the oolite facies have both thick and thin rims. The thick rimmed ooids may occur with pellets or as relatively pure oosparite beds with minor, rounded and rimmed intraclasts and fossil fragments (Fig. 17). Where pellets are present, they occur interstitially or concentrated in thin beds. Angular to subrounded intraclasts of micrite, pelmicrite, or pelloomicrite are common.

Thin rimmed ooid beds always have a high pellet content. In addition, grapestone lumps and asymmetric ooids similar to Freeman's
quiet water ooids are common. Rounded to subangular micrite clasts are always present in these beds and occasionally irregular patches of micrite, largely recrystallized to microspar or replaced by dolomite, occur as matrix.  

**Depositional Environment.** The physiochemical factors controlling ooid formation are not fully understood (Bathurst, 1975). Holocene oolite sand bodies are developed on bank margins, such as on the Bahama Bank (Newell et al., 1960) or at the mouth of tidal channels as exemplified in the Persian Gulf (Loreau et al., 1963). Apparently, ooid growth is most active in and just below the intertidal zone (Newell et al., 1960) in an environment characterized by day-to-day bottom agitation. Thus, the ooids in the Pagoda and lower Steamboat formations are interpreted to have formed in shoal waters. Lack of recognizable tidal channels, associated channel lag deposits, and the wide areal distribution of the oolite facies suggest that the oolitic sediments developed as a bank complex rather than as small bodies concentrated at the mouth of tidal channels.

The thick rimmed nature of the ooids at Flathead River and Limestone Wall reflect optimum conditions for ooid growth, while the preponderance of thin rimmed ooids, grapestone lumps, asymmetric ooids, and minor micrite matrix at Twin Creek and Beacon Mountain implies that this area was a marginal ooid producing environment. Conceivably, the Beacon Mountain, Twin Creek area represents a relatively immobile ooid sand belt (Bathurst, 1975) in which grains moved only during storms.
Figure 17. Thick rimmed ooids from the oolite facies (LW 67.5 m). Note radial cement fabric. Mag. X 10

Figure 18. Photomicrograph of pellet sand facies (TC 170 m). Mag. X 10

Figure 19. Fenestra and adjacent ooids and pellets of Fenestral rock type (LW 130 m).
The local development of trough cross bed sets with superposed megaripples and current ripples indicate that the ooid sands accumulated in a current, rather than a wave dominated regime (Ball, 1967). Zones of distorted ooids probably are the result of early diagenetic processes (Conley, 1977) and do not directly relate to the depositional environment.

**Pellet Sand Facies**

**Description.** In outcrop, the pellet sand facies is distinguished from the irregularly bedded portion of the bioturbated micrite facies by the local presence of horizontal laminations and high angle planar cross bed sets 3 - 5 cm thick. In addition, the pellet sand facies is often characterized by thin, somewhat platy beds averaging 4 cm thick, a general lack of dolomitic pods, and broad, diffuse dolomitic bands which parallel bedding. On a fresh surface, color varies from light gray to dark chocolate.

With the exception of sparse trilobite fragments, the pellet sand facies consists of very well sorted, rounded micrite pellets approximately 0.08 mm in diameter (Fig. 18). In thin section, pellets often appear to be in grain to grain contact and differentiating pelsparite from packed pelmicrite is difficult. Other pellet beds contain slightly more micrite matrix and are easily classified as packed pelmicrite. Often the micrite matrix is recrystallized to microspar or replaced by fine grained dolomite. Bioturbation structures are rare in this facies.
Depositional Environment. Horizontal laminations, cross beds, and the stratigraphic association of the pellet sand facies with oolitic and intraclastic carbonates suggest that this facies accumulated in a shallow subtidal environment. Pellets probably accumulated as local sand bodies behind the ooid shoal or on the shallow subtidal platform. The local abundance of high angle, planar cross beds may reflect the migration of pellet sand bars across the subtidal shelf.

Cryptalgal and Fenestral Facies

Description. Limestone with fenestral or birdseye fabric (Shinn, 1968) is present at the Flathead River and Limestone Wall sections while cryptalgal laminated limestone crops out at the Beacon Mountain section. Both rock types are light cream colored.

The fenestral limestone is extremely massively bedded and often displays a well developed carenfelder weathering surface. Irregular pods of partially silicified, resistantly weathering, void filling spar several millimeters long and a few millimeters wide are diagnostic of this rock type. In thin section, allochems rimming the spar filled voids show no sign of solution except where silica has replaced the carbonate (Fig. 19). The infilling spar has a radial fabric (Bathurst, 1975) and geopetal micrite underlies the spar in some fenestrae. Dolomite is a minor constituent of this rock type. Fenestral fabric is developed in a pelmicrite at Flathead River and an oolitic and intraclastic pelmicrite at Limestone Wall.
In contrast to the massive beds of the fenestral limestone, the cryptalgal limestone at Beacon Mountain is thin, platy bedded. Laminations are defined by thin dolomitic wisps and concentrations of small, rounded, bound intraclasts. Laminations are both wavy and crenulated imparting a fabric to the rock much like the scalloped fabric described by Logan et al. (1974).

**Depositional Environment.** The cryptalgal and fenestral facies reflects deposition in an intertidal to possibly lower supratidal environment. Shinn (1968) and Logan et al. (1974) have observed fenestral fabric in carbonates of the intertidal and supratidal zone. This fabric is produced by internal shrinking and swelling of the sediment during periods of exposure, and is preserved by early lithification (Shinn, 1968). Further evidence for an intertidal to lower supratidal origin of this rock type is the light cream color, a color characteristic of sediments deposited above the low tide level (Shinn et al., 1969).

The fabric of the cryptalgal laminated rock type is similar to that developed under tufted algal mats in Shark Bay, Western Australia (Logan et al., 1974). Logan et al. observed that tufted mats were restricted to relatively moist areas of the middle and upper intertidal zone.

Lack of algal mat fabrics characteristic of the supratidal zone (Logan et al., 1974), and of other supratidal indicators such as mud-cracks, and early dolomite suggests that the deposition of the cryptal-
gal and fenestral facies was predominantly restricted to the inter-tidal zone.
CHAPTER III

SHALE MINERALOGY

Relationship to the Middle Cambrian Shoreline

Laboratory experiments and studies of recent muds have demonstrated that mixtures of clay minerals carried in suspension are mineralogically segregated upon entering the marine environment (Whitehouse et al., 1958; Porrenga, 1966; Gibbs, 1977; and others). Recent work by Gibbs (1977) suggests that particle size controls which clay minerals settle out more rapidly than others. Although the relative distribution of some clay minerals varies, kaolinite consistently accumulates in nearshore environments while smectite concentrates in offshore areas. Work by Lee et al. (1976) indicates that similar distributions can be recognized in ancient rocks.

I was able to recognize a clay mineral segregation in the shale of the Pagoda and Steamboat formations. All samples contained kaolinite and illite, but kaolinite is two to three times more abundant at Pentagon Mountain and Trilobite Peak than at sections to the west. The illite was characterized as the 1Md polytype (see Yoder et al., 1955) with Kalkberg type ordering and 5 - 10% expandable layers (see Reynolds et al., 1970).

The work of Burst (1969), Frey (1970), Perry et al. (1970), and Hower et al. (1976) strongly suggests that 1Md illite is formed by
the burial metamorphism of smectite. Therefore, it appears that
the concentrations of kaolinite in the shale of the Pagoda and Steam-
boat formations at Trilobite Peak and Pentagon Mountain can be
related to the proximity of the Middle Cambrian shoreline to the
east. Similarly, the concentration of 1Md illite at Flathead River
and Twin Creek reflects a distal part of the shelf. This conclusion
is confirmed by the presence of quartz silt only at Pentagon Mount-
tain and Trilobite Peak and indicates that the source of terrigenous
material lay to the east or northeast.
CHAPTER IV

SUMMARY AND CONCLUSIONS

Integrated Interpretation

The Middle Cambrian Pagoda, Pentagon, and Steamboat formations consist of shallow marine carbonate and minor quartz silt and shale deposited on a vast shelf of a stable continental margin. The dominance of shallow water carbonates characterizes the study area as part of the middle carbonate belt (Palmer, 1971). The Trilobite Peak and Pentagon Mountain area probably marks the eastern extent of the middle carbonate belt which presumably passed shoreward into shallow, clastic dominated sediments. Completion of ongoing studies by Aadland (1977) and by Bush (1977) may define the westward limit of active carbonate production. Perhaps the transition to deep water limestone and shale occurred somewhere near Lakeview, Idaho (Bush, 1977, personal communication).

A shale at the base of the Pagoda Formation represents a thin terrigenous wedge deposited over the previously drowned carbonate paltform of the Dearborn Formation. During the deposition of the shale, carbonate sedimentation was limited to thin micrite beds at Twin Creek, Flathead River, and probably Limestone Wall, and to flat-pebble conglomerate beds and calcareous siltstone at Pentagon Mountain and Trilobite Peak. Waves probably broke east of Pentagon
Mountain and Trilobite Peak and bottom sediments in this area were only disturbed during storms. Absence of high energy deposits west of the Lewis Thrust suggest that the carbonate shelf deepened westward and this area was below storm-wave-base.

With a decreased influx of terrigenous material from the east, major carbonate sedimentation was initiated below wave base. This sedimentation is represented by the relatively thick section of bioturbated micrite in the Pagoda Formation at Limestone Wall, Flathead River, and Twin Creek and by the planar laminated micrite, bioturbated micrite, and calcareous mudstone of the Pagoda Formation and lower Pentagon Formation at Pentagon Mountain and Trilobite Peak. The interfingering of the planar laminated micrite and bioturbated micrite in the east reflects conditions which periodically restricted benthonic organisms. Several factors could explain this restriction. Some suggestions are: 1) abnormally high or low salinities; 2) elevated or depressed temperature; or possibly, 3) turbid waters that lowered photosynthesis and oxygen production.

Intraclastic beds overlying the bioturbated micrite facies at Limestone Wall, Flathead River, and Twin Creek reflect build-up of the shelf into storm-wave-base. At Limestone Wall and Flathead River the intraclastic beds quickly give way upward to very shallow subtidal to lower intertidal oolitic sediments.

Whether or not the oolitic limestone at Limestone Wall, Flathead River, Twin Creek, and Beacon Mountain represent one large shoal or several discrete shoals is unknown. However, the ooid shoals
probably did not develop at the mouth of tidal channels; more likely, they developed on the shelf due to widespread turbulent conditions (text page 37). The dimensions of the modern Bahama Bank ooid shoal developed on the bank margin indicate that one large oolitic sand body could have extended over an area as large as that defined by these four sections. For simplicity, in the following discussion the oolitic horizons at the aforementioned sections will be treated as representing part of the same ooid shoal.

The oolitic sand developed probably in response to turbulence from waves and currents generated on the open shelf to the west. This conclusion is supported by the dominance of eastward transported allochems as reflected in the intraclastic limestones. For example, flat-pebble conglomerate beds in the Pagoda Formation at Pentagon Mountain commonly contain rounded clasts of bioturbated micrite, primarily a western facies, while flat-pebble conglomerate beds at Beacon Mountain and Twin Creek do not contain clasts of planar laminated micrite. Similarly, the discrete fragments of clumps of *Girvanella* locally found at Pentagon Mountain may represent eastward transport from Twin Creek and Beacon Mountain where *Girvanella* is commonly associated with oncolites.

The thinned rimmed nature of the ooids at Twin Creek and Beacon Mountain indicate that this was a marginal environment for ooid production (Newell et al. 1960). Perhaps the water was too deep for good ooid production as suggested by the common interbeds of onco-
lite-rich intramicrites. This area is interpreted as the northern boundary of a large ooid shoal which extended southward, possibly as far as Flathead River.

Intraclastic and packed pelletal limestone of the upper Pagoda and lower Steamboat formations accumulated in the protected waters adjacent to the ooid shoal. In the Twin Creek and Limestone Wall sections, the packed pelmicrites probably represent local bodies of pellet sand which accumulated in areas swept by relatively constant, mild currents. Millimeter size laminations of ooids in the lower 2 m of the pellet facies at Limestone Wall indicate that this body accumulated just east of the ooid shoal. Common high angle planar cross beds suggest that pellet sands migrated across a relatively flat, shallow subtidal surface in the form of bars or sand waves (Ball, 1967).

Because the previously described intraclastic and pelletal beds are restricted to areas west of the Lewis Thrust, they are interpreted to be part of an offshore shoal complex. To the east of the shoal complex was a broad, shallow basin which was filled with the planar laminated micrite, bioturbated micrite, and shale of the upper half of the Pentagon Formation. During the final development of the shoal complex, intrasparite, packed intramicrite prograded eastward across the infilled basin forming the tongue of intraclastic limestone at Pentagon Mountain and Trilobite Peak. The shallowest sediments associated with the shoal complex were deposited in inter-
tidal to possibly lower supratidal environments in the western part of the area as represented by the fenestral rock type at Limestone Wall and Flathead River and by the cryptalgal laminated limestone at Beacon Mountain. A diagrammatic cross section of the ooid shoal complex is presented in Figure 20. Similar offshore peritidal shoals which prograded eastward during final stages of development have been proposed for Cambrian sequences in the Great Basin by Palmer et al., (1974), by Halley (1975), and by Palmer and Halley (in press).

Preceding the deposition of the upper shale at Pentagon Mountain and Beacon Mountain the carbonate shelf was deepened. This deepening is reflected by the gradation of intrasparite, packed intramicrite to intramicrite at Pentagon Mountain and by the transition of cryptalgal laminated limestone to intramicrite at Beacon Mountain. The deepened shelf permitted higher energy conditions to reach farther shoreward and caused suspended sediment to be carried across the shelf at least as far as Beacon Mountain. Relative subsidence of the shelf continued throughout the deposition of the shale. With reduced influx of terrigenous sediments, carbonate deposition was once again initiated below wave base. The intrasparite, packed intramicrite comprising the uppermost portion of the Steamboat Formation at Pentagon Mountain, Trilobite Peak, Beacon Mountain, and Twin Creek probably reflect the formation of a subtidal veneer similar to that developed on the embayment plains in Shark Bay, Western Australia (Reed, 1974; Logan, 1974). This environment
Figure 20. Diagrammatic cross section of ooid shoal complex.
was moderately affected by waves and currents and included at least one body of pellet sand.

The distribution of lithofacies in the Pagoda, Pentagon, and Steamboat formations reflects one complete and one nearly complete cycle of upward shoaling sedimentation, starting with a basal terrigenous wedge, passing upward to sub-wave-base carbonate sedimentation and build-up into peritidal lithologies.

Speculative Tectonic Control on Sedimentation

The pattern of lithofacies development in the Pagoda, Pentagon, and Steamboat formations (Fig. 7) is similar to what has been described as Grand Cycles in the Cambro-Ordovician sequence of the southern Canadian Rocky Mountains (Aitken, 1966). Each Grand Cycle consists of a basal terrigenous unit overlain by a relatively thick sequence of subtidal carbonates and is capped by peritidal lithologies. Significant is the rather abrupt appearance of clastics marking the next Grand Cycle. Palmer et al. (in press) have attributed the development of Grand Cycles to relative rates of subsidence of the continental shelf (in relationship to sea level). However, they do not state what causes the shelf to subside at different rates. Aitken (1966) proposed a tilting craton model to explain the Grand Cycles. This model requires pulsatory tilting of the continental shelf about a horizontal axis parallel to the general trend of the shoreline in conjunction with continuous, slow subsidence of the axis. What Aitken found attractive in this model was the coupling
of movement in both the source area and area of deposition. He felt that this mechanism most effectively explained the contemporaneous deepening of the shelf and increased influx of terrigenous sediments as manifested by the shales at the base of each Grand Cycle.

Neither Palmer et al. nor Aitken examined the shale mineralogy of the terrigenous units at the base of the Grand Cycles. The observed mineralogic facies in the shale at the base of the Pagoda Formation and in the Pentagon Formation, perhaps, sheds some light on the genesis of Grand Cycles.

Kaolinite is two to three times more abundant in the shale at the Pentagon Mountain and Trilobite Peak sections than at sections to the west, reflecting the proximity of these sections to the Middle Cambrian shoreline (text page 44). It is interesting to note that the shale mineralogy at these sections is consistent in a vertical sense. This fact suggests that the shales do not represent major transgressions or regressions of the Middle Cambrian shoreline for a progradation or regression of mineralogic facies is not evident. Rather, the shales probably represent short intervals of terrigenous influx that spread far seaward. Relative synchronism of deposition is further supported by the occurrence of Glyphaspis and Bolapsis in the shale of the Pagoda Formation at all sections. In addition, the deposition of the shales is preceded by a deepening of the shelf (text page 49). Aitken's tilting craton model could explain the
relative synchronous deposition of the shale, deepening of the shelf, and apparent stillstand of the shoreline.
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56


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APPENDIX I
LOCATION OF MEASURED SECTIONS

Beacon Mountain Section

The Beacon Mountain section was measured starting at a point 1.8 km S. and 2.5 km W. of the N.E. corner of U.S.G.S. Tin Creek Quadrangle topographic map (7.5 minute series). The section is accessible from the Upper Twin Creek Trail (U.S.F.S. Trail 237). Just west of North Creek, this trail bends north around a north-south ridge. The Beacon Mountain section starts on the west side of the ridge, 1.5 km N. of U.S.F.S. Trail 237, continues north over the ridge, and ends at a knoll south of Beacon Mountain.

Twin Creek Section

The Twin Creek section was measured starting at a point 2.9 km S. and 2 km W. of the N.E. corner of U.S.G.S. Tin Creek quadrangle topographic map. This section starts in the Dearborn Formation at the junction of North Creek and Upper Twin Creek. The section follows Upper Twin Creek for approximately 100 m to where the basal shale of the Pagoda outcrops, and continues up the hill on the north side of Upper Twin Creek to the top of the hill (125 m level). From the top of the hill, strata were followed along strike to North Creek and the section was continued up North Creek.

Flathead River Section

The Flathead River section was measured 0.5 km S. of Meadow Creek Gorge on the South Fork Flathead River. The section starts at a point 2.6 km N. and 1.7 km W. of the S.E. corner of the U.S.G.S. Meadow Creek Quadrangle topographic map (7.5 minute series). The section starts at the cliff adjacent to a pool at the base of a small falls just south of Bunker Creek. The section was measured up the cliff on the north side of the South Fork Flathead River and ends at the top of the hill.

Limestone Wall Section

The Limestone Wall section was measured along the impressive cliffs which form the south valley wall of the Spotted Bear River south of Dean Creek. This section is accessible from the Limestone Peak Trail which follows the east side of Silvertip Creek and then veers southeast to the top of the Limestone Wall. The section was started at the base of an east-west cliff approximately 1.7 km W.
and 2.6 km N. of the S.E. corner of U.S.G.S. Whitcomb Peak Quadrangle topographic map (7.5 minute series).

Pentagon Mountain Section

The 0 to 154 m interval of the Pentagon Mountain section was measured on the spur of Kevin Mountain approximately 3 km S. of Pentagon Mountain. This spur is 4 km N. and 3.1 km E. from the S.W. corner of U.S.G.S. Pentagon Mountain Quadrangle topographic map (7.5 minute series). The remaining portion of the section was measured 1.5 km to the north starting on the trail to Dean Lake just south of a small falls formed by an eastward flowing creek. This point is 4.9 km N. and 2.7 km E. from the S.E. corner of the Pentagon Mountain Quadrangle map. From this point, the section continues up the cliff of the southern spur of Pentagon Mountain and ends at the recessive bench formed by the Switchback Formation.

Trilobite Peak Section

The Trilobite Peak section is accessible from Chair Mountain Trail. Just north of Trilobite Lakes is a small eastward flowing creek. The section was measured north of this creek on a spur approximately 2 km Northeast of Trilobite Peak, starting at a point 0.3 km S. and 0.4 km W. of the N.E. corner of U.S.G.S. Trilobite Peak Quadrangle topographic map (7.5 minute series).
MEASURED SECTIONS

The measured sections are presented as stratigraphic columns with outcrop profiles. From left to right the columns indicate:

1) grain size of the rock: ─ fine grain, ■ medium grain, ☐ coarse grain; 2) major constituents of the rock: ○ ooids, ⊙ intraclasts, ⬝ oncolites, ⬞ pellets, ☯ Girvanella, ⬖ algal bound intraclasts, ☯ bioturbated, ■ planar laminated; 3) whether the rock is a micrite or a sparite: ☐ micrite, ■ sparite.
FEET

BEACON MOUNTAIN (BM)

Irregularly bedded

Sheared zone

METERS

- 20

STEAMBOAT

PAGODA

Thin dolomitic partings

Irregularly bedded

Section starts in Pagoda

- 0
Float green fissile shale

Packed intramicrite

Cryptalgal laminated

Cream colored

Covered
Introsporite bed

Thin dolomitic partings

Covered

90

80
Packed intramicrite micrite interbeds

Intrasparite packed intramicrite

Horizontally laminated

Flat pebble bed

Horizontally laminated
Dolomitic interlayers
Covered

Intramicrite

Oncolite beds

High angle planar cross beds

Packed pelmicrite
Beds 2.5 - 7.5 cm

Irregularly bedded

Covered
Intrasporite & intramicrite interbeds
Dolomitic pods and interlayers
Dark and light bonding

Intraclasts

Irregularly bedded
Irregularly bedded

Intrsparite bed

Dark & light banding

- 90

- 80
LIMESTONE WALL (LW)

FEET
80-
60-
40-
20-
0-

COVERED

METERS

— 20

— 10

Base of Pagoda — 0
Dolomitic interlayers
Irregularly bedded

1 cm shale bed
High angle planar cross beds

Thin platy beds

1 - 6 cm
PENTAGON MOUNTAIN (PM)

- Fossil hash beds 10 cm thick
- Reddish
- Flat pebble beds
- Brown fissile shale
- 5 cm fossil hash bed
- Green fissile shale
- Flat pebble beds with quartz silt matrix and minor glauconite
- Base of Pagoda
Brown limey mudstone
with mm. size limestone stringers

Brown shale

Black paper limestone
Trilobite biosparite
Black paper limestone
Brown shale

Reddish
Thin platy bedded muddy limestone with shale interlayers

Dolomitic interlayers

Thin platy bedded muddy limestone with shale interlayers
Dolomitic interlayers

Beds average

0.6 - 15 cm
Thin platy bedded limestone with shale interlayers

Green fissile shale
Green fissile shale

Flat pebble bed

Intramicrite
Dolomitic partings

STEAMBOAT

PENTAGON

Intrasparite
packed intramicrite
interbeds

Massive, one bed
Irregularly bedded with discontinuous dolomitic partings

Thin platy bedded limestone with shale interlayers
10 cm flat pebble bed
Packed intramicrite

Micrite, flat pebble, intrasparite interbeds

Covered

Flat pebble bed
Packed intramicrite
97

TRILOBITE PEAK (TP)

METERS

Tan calcareous mudstone

Poorly exposed float indicates limestone & shale

Flat pebble bed with quartz silt matrix

10 cm flat pebble bed

Brown fissile shale

Green fissile shale

Base of Pagoda intrasparite
Beds 0.6 - 1.5 cm

Platy bedded limestone with mudstone interlayers

Mudstone with limestone stringers

Limestone with shale interlayers
Flat pebble bed

Dolomitic interlayers
Dolomitic interlayers

Beds average 1 cm

Limestone with shale interlayers
Irregularly bedded with discontinuous dolomitic partings

Dolomitic interlayers
Poorly exposed float indicates platy limestone & shale

Green fissile shale

Mudstone

Limestone with shale interbeds