GEOLOGY OF THE NORTH END OF THE RUBY RANGE, SOUTHWESTERN MONTANA

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ABSTRACT

This study consists of two parts: stratigraphy and sedimentation, and structure of rocks in the northern one-third of the Ruby Range of southwestern Montana. Detailed studies of Cambrian marine dolomite rocks in the Red Lion Formation and in the upper part of the Pilgrim Limestone resulted in their division into distinct rock units, termed lithofacies. These lithofacies contain features suggestive of subtidal, intertidal, and supratidal environments similar to those presently forming in the Persian Gulf. Stromatolitic structures occurring in the uppermost part of the Red Lion Formation are similar to those presently forming in Shark Bay, Australia.

The Ruby Range within the map area is broken into a series of northwest-plunging basement (Precambrian metamorphic rock) blocks, differentially uplifted during the Cretaceous-Tertiary orogenic period. These blocks are bordered by upthrust faults, which are nearly vertical in their lower segments and are low-angle in their uppermost parts. Asymmetrical folds in Paleozoic sedimentary rocks formed in response to the differential uplift of the blocks; thus they too plunge to the northwest. Displaced masses of rock border the range on the three sides within the map area and are interpreted as gravity-slide features resulting from uplift of the range. Normal faulting began blocking out the present range margins by Oligocene time.

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I N T R O D U C T I O N

This paper concerns the stratigraphy and structure of the northern part of the Ruby Range of southwestern Montana. The area is enclosed by 45° 15' to 45° 24' N. lat., and 112° 07' 30" to 112° 22' 30" W. long. (Fig. 1, dark stippled area). It occupies about 85 square miles and includes the mountainous region of the following quadrangles: Beaverhead Rock SE, Beaverhead Rock NE, Laurin Canyon, and Sheridan. The altitude ranges from about 5,000 feet to 9,500 feet.

Numerous workers have studied the Cambrian rocks of Montana and adjacent areas, but detailed studies are lacking. Thus, one major objective of this project was to study the Cambrian carbonate rocks of the Ruby Range, specifically the Red Lion Formation and the upper part of the Pilgrim Limestone. The second major objective was to analyze the post-Precambrian structural features in an effort to determine the structural history of the area. This phase of the project was facilitated by preparation of a detailed geologic map.

PROCEDURE

During the summers of 1967 and 1968 about 6 months were spent in the field measuring stratigraphic sections and compiling a detailed geologic map of the sedimentary strata in the northern part of the Ruby Range. Cambrian formations were sampled in detail, especially

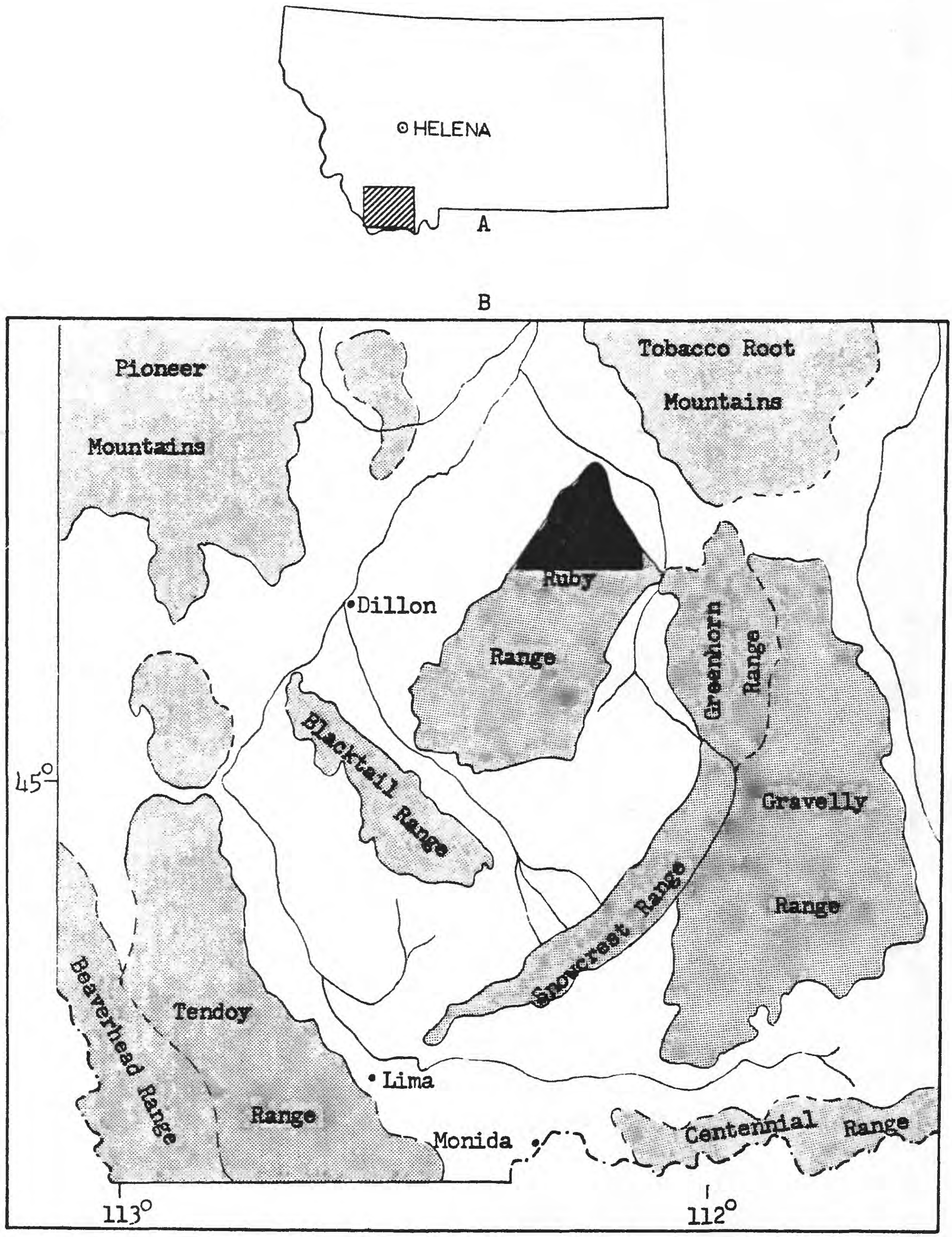

Figure 1. Index maps. A. Outline of Montana showing southwestern Montana (ruled). B. Southwestern Montana, showing ranges (light stippled), map area (dark stippled), streams, and towns. (Figure 1B modified after Ross and others, 1955.)

the upper part of the Pilgrim Formation and the Red Lion Formation which were studied closely. Other formations were sampled mainly in an effort to obtain representative samples. Thin sections, polished slabs, and hand specimens were examined to analyze the units. Fossils were collected from most of the formations to facilitate regional correlation.

Mapping was done directly on Mylar topographic maps (scale, 1:24,000) cut into quarters for field use; data were transferred to duplicate maps at the end of each day.

PREVIOUS WORK

The first geologic notation on the Ruby Range was recorded by a Hayden Survey party that briefly observed the mountains in September, 1871, calling them the Stinking Water Range (Hayden, 1872, p. 36-39, 143, 259-261). A more detailed examination was made by Earl Douglass who collected Cambrian and Mississippian fossils from the northeastern part of the range in 1902 and again in 1905 (Douglass, 1905; 1909). A Cambrian stratigraphic section was measured by Hanson (1952) in the McHessor Creek drainage area and used for regional correlation in southwestern Montana, and a small Precambrian sedimentary iron ore deposit in the northern part of the Ruby Range was mapped by James and Wier (1960).

Other studies of the Ruby Range (south of the area of this report) include those of Klepper (1950), Heinrich (1960), Becker

(1961), Dorr and Wheeler (1964), Wier (1965), and Giletti (1966). Reference to many economic geology papers pertaining to the southern two-thirds of the range are recorded in Heinrich (1960).

ACKNOWLEDGMENTS

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STRATIGRAPHY

The major emphasis in this part of the project applies to the Cambrian, especially from the standpoint of sedimentologic and environmental studies of the carbonate units. The strata were divided into "lithofacies," rock units that exhibit a unique recognizable outcrop character and have a similar genetic significance. Presentation of the data is twofold--descriptive and interpretative. Description is both megascopic and microscopic and is separate from the environmental interpretation.

Significant lateral facies changes were not observable within the relatively small area this project encompasses probably because the regional Cambrian depositional environments were widespread and uniform. However, by using Walther's Law (cf., Visher, 1965), which states that lateral positioning of sedimentary facies tends to be similar to that of their vertical superposition, an interpretation of facies positioning was possible.

Strata other than those of Cambrian age were studied in only moderate detail in the field and laboratory, but fossil collections were made where possible.

The classification of carbonate rocks used in this study is that of Dunham (1962), shown in Figure 2. Observations of polished slabs and hand specimens were commonly more useful than those of thin sections because dolomitization of much of the strata is intense.

AGE		UNIT	THICK. (feet)	LOG	DESCRIPTION
Q	Plst	Tufa	0-100		limestone, spring deposit
		unnamed cgl	50-?		pebbles and cobbles in sandy matrix
T-Q		Tertiary-Quat. undivided	varies		mainly basin deposits, but also young unstratified deposits
T	Olg	Oligocene sed.	150-?		mudstone, siltstone, cgl sandstone
CR-T		Beaverhead Fm.	?		conglomerate composed of quartzite or carbonate clasts, or both
PENN	Early-Middle	Quadrant Sandstone	1200?		interbedded fine-grained quartz sandstone and light-gray weathering limestone. thick-bedded.
MISSISSIPPIAN	L	Kibbey Fm. ?	25-100		reddish silty dolomite, thin-bedded
	Early	Mission Canyon Limestone	1370		light-gray weathering thick-bedded limestone. forms massive outcrops. solution breccia in upper part. chert nodules and stringers occur locally.
		Lodgepole Limestone	600		upper one-half is light-gray medium- and thick-bedded fossiliferous limestone. lower part is dark shaly laminae.
DEV	Late	Three Forks Fm	150		clay shale, evaporite breccia, limestone
		Jefferson Fm.	250-268		mostly brown dolomite, but also silty shaly beds and evaporite breccia.
CAMBRIAN	Late	Red Lion Fm.	0-170		clay shale of Dry Creek Member at base. Sage Member is dolomite, sandy. Algae.
		Pilgrim Limestone	295-395		lower member is massive gray dolomite. upper member is algal dolomite, sandy.
	Middle	Park Shale	175		green clay shale, with thin beds of carbonate rocks in lower and upper parts
		Meagher Limestone	550-750		pale yellowish brown dolomite in most places, but light-gray limestone locally. thin- to thick-bedded. middle part forms good outcrops.
		Wolsey Shale	50-100		clay shale. sandstone in lower part.
		Flathead SS	10-50		quartz sandstone, locally conglomeratic.
P€		Metamorphic Rocks	?		many rock types. includes metadolomite, amphibolite, quartzite, quartzo-feldspathic gneiss. granite gneiss locally.

Table I. Generalized section of stratified sedimentary rocks.

<table>
<tr><th colspan="5">DEPOSITIONAL TEXTURE RECOGNIZABLE</th><th>DEPOSITIONAL TEXTURE NOT RECOGNIZABLE</th></tr>
<tr><td colspan="4">Original Components Not Bound Together During Deposition</td><td rowspan="4">Original components were bound together during deposition... as shown by intergrown skeletal matter, lamination contrary to gravity, or sediment-floored cavities that are roofed over by organic or questionably organic matter and are too large to be interstices.</td><td rowspan="5">Crystalline Carbonate
(Subdivide according to classifications designed to bear on physical texture or diagenesis.)</td></tr>
<tr><td colspan="3">Contains mud
(particles of clay and fine silt size)</td><td rowspan="3">Lacks mud and is grain-supported</td></tr>
<tr><td colspan="2">Mud-supported</td><td rowspan="2">Grain-supported</td></tr>
<tr><td>Less than 10 percent grains</td><td>More than 10 percent grains</td></tr>
<tr><td>Mudstone</td><td>Wackestone</td><td>Packstone</td><td>Grainstone</td><td>Boundstone</td></tr>
</table>

Figure 2. Classification of carbonate rocks according to depositional textures (after Dunham, 1962).

PRECAMBRIAN

Metamorphic rocks are described only briefly because this study is primarily concerned with younger rocks. A detailed treatment of them can be found in Heinrich (1960).

Extensive areas of Precambrian metamorphic rocks are present in the south-central part of the map area and to a lesser extent in the southwestern and southeastern parts (Plate 1). Good outcrops are scattered, the rocks typically forming smooth-surfaced ridges with rounded crests. The foliation trends generally northeast, in accordance with the regional structural grain in southwestern Montana. Rocks include metadolomite, quartzite, amphibolite, many varieties of quartzo-feldspathic gneiss, and some granite gneiss in the southwestern part of the map area.

Age--Radiometric age determinations in the Ruby Range suggest the last metamorphic event occurred about 1600 million years ago and was accompanied by intrusion of a granite gneiss (Giletti, 1966; Giletti and Gast, 1961).

CAMBRIAN

FLATHEAD SANDSTONE

Nearly pure quatzitic sandstone makes up the oldest Cambrian rocks in the area and is assigned to the Flathead Sandstone. Exposures range from nearly complete in vertical outcrops, to covered slopes, although typically only a few beds of the middle part crop out. Locally the unit makes a broad outcrop, reflecting its tendency to form a dip slope. Thickness of the Flathead ranges from 10 to 50 feet.

The basal Flathead is exposed only in Taylor Canyon where it is unconformable on Precambrian metamorphic rocks. The upper contact is gradational with the Wolsey Shale and is placed at the first occurrence of a shale bed more than 5 feet thick; where the shale section is covered, the contact is arbitrarily placed where the highest sandstone ledge meets the dip slope of the Wolsey.

Quartz grains makes up more than 99% of the Flathead. Minor constituents include chert, wisps of clay, mica, hematite, limonite, heavy minerals and a few metamorphic rock fragments. Glauconite occurs locally in the upper part. Light brown and shades of orange are typical Flathead colors in the Ruby Range.

Grain size ranges from fine to coarse, but much of the Flathead is fine- and medium-grained. Most quartz grains are subrounded to rounded (3.5 to 5, classification of Powers, 1953), and are cemented by overgrowths that are optically continuous. Sutured contacts, however, are not common. At one locality (NW¼SE¼ sec. 34, T. 6 S., R. 6 W.) rounded quartz grains with double overgrowths are common, and one grain with a triple overgrowth was observed.

Sorting ranges from moderately to well-sorted (classification of Folk, 1968, p. 105), with the well-sorted sands being the fine- to medium-grained sizes. Moderately sorted sands are commonly bi-modal, consisting of coarse sand interlaminated with fine- to medium-grained sand.

Conglomerate lenses are common in the basal part, containing subangular to subrounded quartz granules and pebbles in coarse-grained sandstone. Higher in the formation occur lentils of quartz clast conglomerate. Typically the clasts are subangular, range from 1 to 15 centimeters in diameter, form lentils no thicker than the largest clast, and are assorted with coarse sand grains in a bed that is otherwise made of fine- to medium-grained sand.

Pebbles of clay shale up to 3 centimeters in length but only a few millimeters thick occur at the top of the Flathead in the SE¼NW¼ sec. 2, T. 7 S., R. 6 W. The enclosing rock is thinly laminated fine- to medium-grained sandstone, except for envelopes of coarse-grained sand around some of the pebbles.

Origin--The Flathead is a transgressive marine sandstone that must be either a first cycle deposit derived by erosion of Precambrian metamorphic rocks, a second cycle deposit derived by erosion of Belt sedimentary rocks, or a combination of both. Multiple overgrowths on some grains are indicative of a recycled sediment. The high rounding values for most of the grains is suggestive of a second cycle sediment. Conversely, much quartz must have been freed upon disaggregation of underlying metamorphic rocks; indeed, the only clasts of metamorphic rock present in the Flathead are cobbles and pebbles of quartz.

It seems improbable that the formation represents an ancient beach deposit. Very few fossil beaches are known, and those that have been described are narrow, linear features--commonly in regressive deposits. In a transgressive sea relative sea level is rising, however slowly, and the beach deposits are constantly being reworked as they migrate shoreward. Because the offshore zone must follow the same migration route, offshore processes would be expected to restructure any beach deposits encountered.

One possible depositional environment for the Flathead is the offshore area, extending seaward from the low tide line. Features present in the formation--fine lamination, bimodal sorting, stranded pebbles and cobbles--that could be formed on a beach are also typical of submerged offshore bars (Thompson, 1937). In addition, steeply-inclined cross beds like those noted at one place in the Flathead are common on the landward side of bars.

Age--No fossils were found in the Flathead in the Ruby Range. Middle Cambrian trilobites of the genus *Glossopleura* occur in the

Flathead in the Gallatin Range, about 60 miles east-northeast of the map area (Tysdal, 1966), whereas about 40 miles to the north the Glossopleura fauna occurs in the lower part of the Wolsey (Alexander, 1955). These data indicate the Flathead is older to the west and suggest that the formation in the Ruby Range is older than Glossopleura Zone time (Fig. 3). Because sedimentation was apparently continuous from the base of the Flathead to fossiliferous strata in the lower part of the Wolsey, it is not unreasonable to infer that the Flathead is also of Middle Cambrian age, but it could be older.

Chaudhuri and Brookins (1969) used radiometric techniques to date glauconite from the upper part of the formation in Montana. They obtained an age of 542 million years, considering it Middle Cambrian. Their sample localities were not published, however.

WOLSEY SHALE

The Wolsey is transitional between the Flathead and Meagher formations, forming broad benches or gentle grass-covered slopes. Natural outcrops of the unit are not present in the Ruby Range and the only exposure occurs in a mining exploration trench cut in the basal part. Because the thickness of the unit ranges from only about 50 to 100 feet, the formation is mapped with the Flathead.

Regionally the Wolsey is divisible into three parts: a basal shale unit, containing intercalated sandstone, siltstone, and shale; a middle carbonate unit; and an upper shale unit that grades into

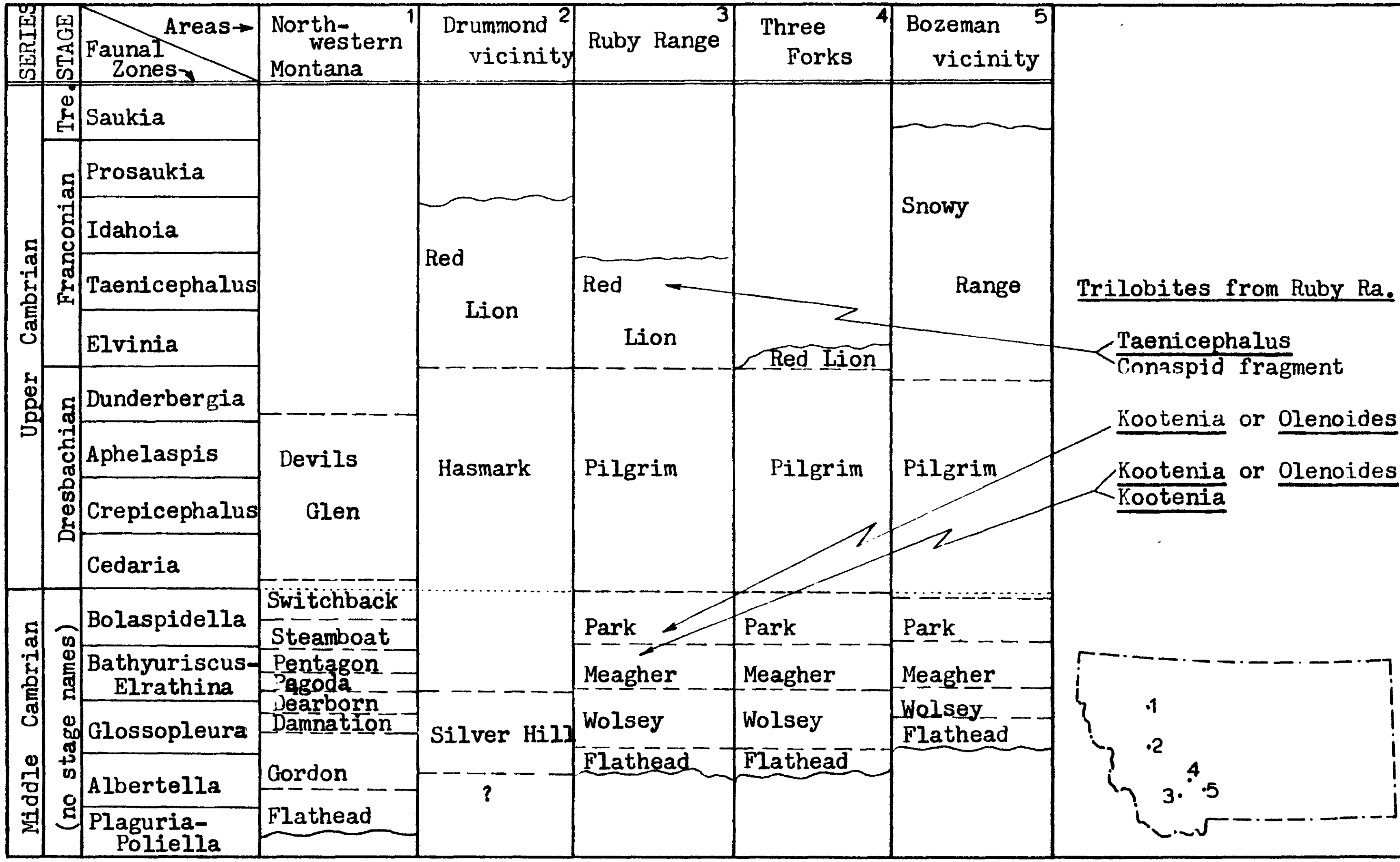


Figure 3. Correlation chart for Middle and Upper Cambrian rocks in Montana. Positioning of formation contacts is approximate because of limited data and recent revision of faunal zones. Sources of data include Howell and others (1944), Hanson (1952), McMannis (1955), Alexander (1955), McGill (1958), Kauffman (1965), Robinson (1963), Grant (1965), Tysdal (1966), and this report.

limestone of the overlying Meagher Formation (Hanson, 1952; Lebauer, 1964).

Siltstone exposed in the basal Wolsey unit in the Ruby Range is brown, thin-bedded, and is interstratified with coarsely micaceous olive green clay shale. The siltstone consists of quartz (85-90%), feldspar (5-10%), glauconite (1-10%), mica (1-2%), and hematite (<1%). Grain size is commonly in the coarse silt range, except that glauconite ranges from coarse silt to fine sand. Most grains are angular to subangular, except for the fine sand size glauconite grains which are commonly rounded. Silica cements the siltstones and sutured grain contacts are common. Sorting ranges from moderate- to well-sorted. Sorting is commonly very good except for the presence of the slightly coarser glauconite grains.

<u>Origin</u>--The basal siltstone of the Wolsey is transitional between quartz sandstone of the Flathead and clay shale of the Wolsey. This is suggested by (1) the stratigraphic position of the siltstone between the sandstone and the shale, (2) grain size in between that of sandstone and shale, (3) presence of both quartz grains and shale flakes in the siltstone, (4) presence of silt-size grains which would be sorted out of the depositional environment of the Flathead, and (5) regional paleontologic data showing that both Flathead sand and Wolsey shale were being deposited at the same time. The basal Wolsey sediments probably are offshore winnowed clastics of the Flathead and the intercalated shale and siltstone are indicative of fluctuations

in the ancient shoreline.

Glauconite denotes a low or negative sedimentation rate (Cloud, 1955). Some of the fine sand-size glauconite is angular and platy and perhaps could have formed in place by alteration of clay chips. This theory is supported by Lebauer's (1964) data showing a similarity in composition of glauconite pellets and illitic shale.

Age--No fossils were found in the Wolsey of the Ruby Range. Alexander (1955) reported Middle Cambrian *Glossopleura* and *Kootenia* from the Wolsey in the Whitehall area, about 30 miles to the north. A similar age is probable for the formation in the Ruby Range (Fig. 3).

MEAGHER LIMESTONE

Strata of the Meagher comprise the thickest Cambrian formation in the Ruby Range, ranging from 550 to 750 feet. The thicker section is present north of McHessor Creek (NE¼SE¼ sec. 19, T. 6 S., R. 5 W.), the thinner one near the head of Laurin Canyon (E½NE¼ sec. 8, T. 6 S., R. 5 W.). In the northern one-third of the map area faulting and limited depth of erosion permit exposures of only the upper 100-200 feet of the Meagher. Strata adjacent to the Wolsey-Meagher contact are unexposed in the Ruby Range, but rocks near the Meagher-Park contact are locally exposed and are transitional. Shale beds lithologically similar to the Park Shale are intercalated with carbonate beds 50 to 100 feet below the contact, and near the top of the Meagher the shale units are 4 to 9 feet thick. Thus the Meagher carbonate intertongues with the Park-like shale and the Meagher-Park contact is placed at the uppermost Meagher-like carbonate. Upper Meagher strata of the (thin) Laurin Canyon section, however, contain no shale and the change from carbonate beds to shale beds is apparently abrupt; this relationship is considered later.

The origin of the Meagher is not discussed at length because of previous study by Lebauer (1965) and because of dolomitization. A few salient lithofacies are noted and discussed, however.

Lebauer (1965) described rocks from 12 stratigraphic sections in southwestern Montana. His interpretations considered mainly the origin of mottles in the Meagher beds, although he also presented a general picture of the depositional environment of the formation and discussed dolomitization briefly. Lebauer divided the formation into three parts: a lower thin-bedded unit, a middle massive unit, and an upper thin-bedded unit.

Lower Unit

Limited exposures characterize the lower unit in the Ruby Range, with limestone rocks cropping out only locally in the Laurin Canyon stratigraphic section. Thus the rocks were not studied closely, but a brief description is summarized from Lebauer (1965). Mottled lime mudstone makes up most of the lower unit, the non-mottled rock consisting of calcite grains 5-15 microns across. The mottled areas are irregular, composed of euhedral dolomite rhombohedra and calcite crystals. Some of the rocks Lebauer studied exhibited a "microclotted" texture, rounded silt-size clots of finely crystalline calcite surrounded by lime mudstone. Fragments of trilobites locally occur in the finely crystalline calcite. Lebauer interpreted the sediments as having formed in quiet water, and he attributed the mottling to burrowing, dolomitization, and movement of solutions along stylolites and small fractures with resultant alteration of adjacent sediments.

Middle Unit

Rocks of the Middle part of the Meagher, and those of most of the younger Cambrian carbonate formations, are described and interpreted as lithofacies units. Lateral facies patterns depicted for the lithofacies units are shown in figures accompanying the text. It is important to note that the patterns were not actually observed, but are interpretations based on Walther's Law.

Rocks making up lithofacies of the middle unit of the Meagher include (1) lime mudstone, (2) oncolitic packstone, (3) pelletal, and pelletal- and intraclastic packstone, and (4) oolitic grainstone. Figures 4 and 5 illustrate a possible lateral facies pattern for these rock units.

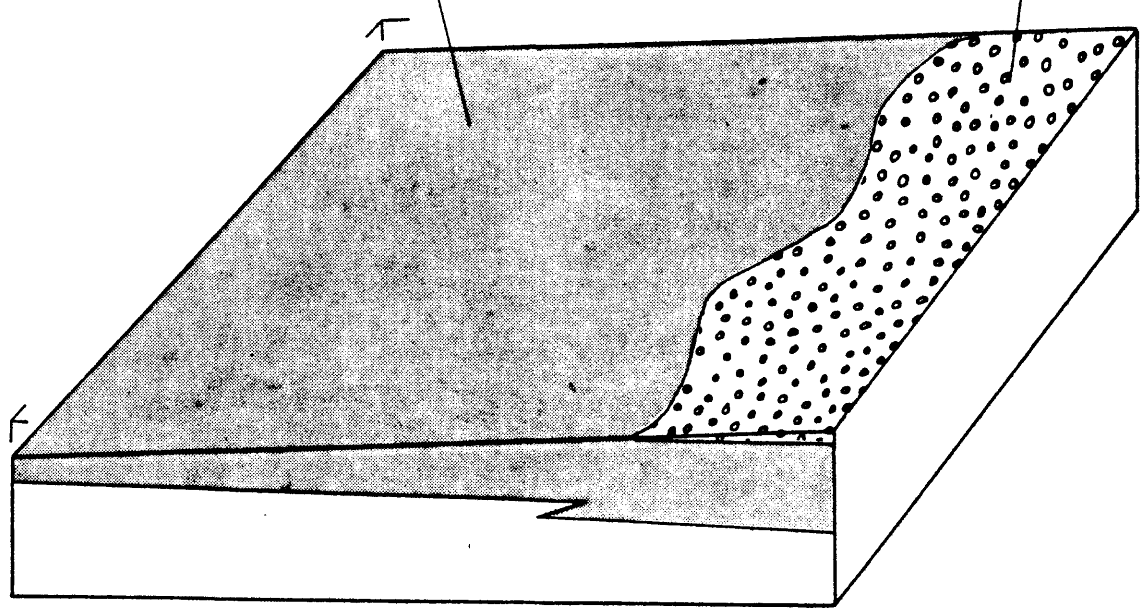
Lime Mudstone--Lime mudstone of the middle unit of the Meagher is similar to that of the lower unit, except that mottled areas are not abundant. Figure A of Plate 2 shows the main texture.

Environment--Rock of this lithofacies appears similar to that of the mud facies on the Bahamian platform west of Andros Island (cf., Purdy, 1963; Cloud, 1962). Origin of the mud is not completely resolved, but Purdy (1963) speculated that it may be formed by disintegration of fecal pellets and Cloud (1962) proposed precipitation by physicochemical processes.

Stratigraphic Position--The lime mudstone is transitional with the mottled lime mudstone of the lower unit of the Meagher and a boundary between the two is difficult ot determine, except that the middle unit tends to be cliff-forming. The lime mudstone also occurs above and below oncolitic packstone, and below pelletal packstone. The interpreted lateral facies patterns are shown in Figures 4 and 5.

Oncolitic Packstone--Oncolites (Plate 2, Fig. B) of the Meagher locally exhibit algal-like filaments which are similar to those termed *Girvanella*. Measurements of the long diameter range from 5 to 10 millimeters, that of the short diameter 1.5 to 4 millimeters. The oncolites are thus flattened, but orientation of long diameters is not typically parallel to bedding. Flattening, therefore, occurred before burial. The oncolites occur in lime mudstone matrix.

Environment--Oncolites occur in water sufficiently agitated to permit almost continual motion of the spheroid (Logan and others, 1964). In a study of modern oncolites Ginsburg (personal communication, *in* Freeman, 1964) found flattened forms more characteristic of the intertidal zone, with dome-shaped and spheroidal forms present in the subtidal zone. Although the Meagher oncolites may have thus formed in the intertidal zone, the abundance of mud matrix



NAME	ENVIRONMENT	LITHOLOGY	CHARACTERISTICS	THICK-NESS
Oncolitic Packstone	Subtidal zone, shoreward part	limestone	flattened oncolites, lime mudstone matrix	2-4 ft.
Lime Mudstone	Subtidal zone	limestone, recrystal-lized	mottling	15 ft.

Figure 4. Interpreted lateral relationships for lime mudstone and oncolitic packstone lithofacies of middle Meagher unit, using Walther's Law (see text, p. 5).

argues for a subtidal burial site. The stratigraphic position of the oncolitic packstone marginal to, and intertonguing with, (subtidal) lime mudstone suggests this rock formed in the shoreward part of the subtidal zone.

Stratigraphic Position--The oncolitic packstone is both overlain and underlain by lime mudstone. Interpreted lateral relations are shown in Figure 4.

Pelletal Packstone--The following summary is taken in part from Lebauer (1965). Pellets of the Meagher (Plate 2, Fig. C) are rounded to ellipsoidal, average ½ millimeter in diameter, and are composed of cryptocrystalline calcite. Locally aggregates of pellets occur. The matrix is medium- to coarse-grained calcite.

Commonly present in the uppermost part of the lithofacies in the Ruby Range are whitish twig-like structures (Plate 2, Fig. D), noted previously by Hanson (1952) and Robinson (1963). In the Ruby Range dolomitization has destroyed any original texture that may have been present and all that remains is dolomite of fine- and medium-crystallinity (30-90 microns in diameter). Diameter of the twig-like structures ranges from 1 to 3.5 millimeters, the length ranging to 1 centimeter. The structures may be isolated or exhibit a dendritic pattern. This unit is difficult to recognize in the field.

Environment--This lithofacies is interpreted as a subtidal deposit, formed shoreward of the lime mudstone lithofacies. A similar facies relationship is noted by Purdy (1963) for the sediments of the Great Bahama Bank. The few pelletal aggregates of the

Meagher sediment occur near the transition into oolitic rocks. This parallels a like relationship in the Bahamas noted by Purdy (1963) and by Ball (1967). The aggregates may reflect the change into an environment of greater current action and be, in effect, intraclasts of pelletal material.

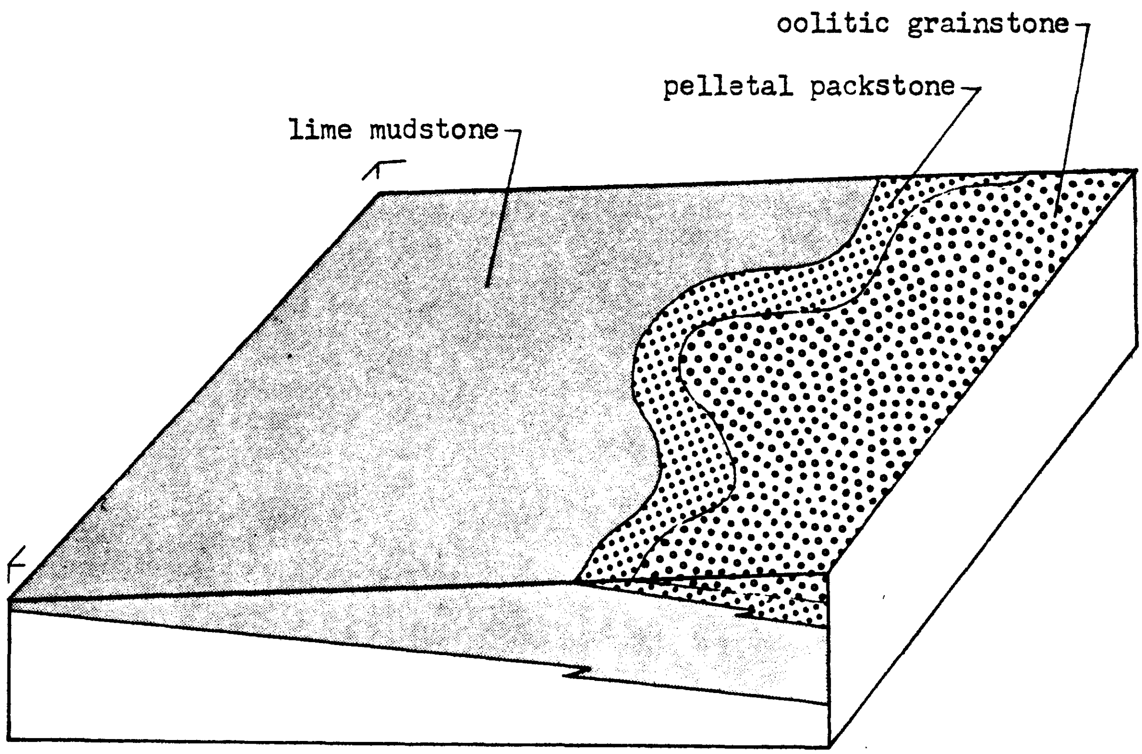
Origin of the twig-like structures is unknown, but they have been suggested as organic (cf., Robinson, 1963). Their occurrence in this facies is commonly near the transition into oolitic rocks, suggesting an environmental control.

Stratigraphic Position--The pelletal packstone unit overlies lime mudstone and underlies oolite grainstone, being transitional with it. Figure 5 shows the interpreted facies pattern.

<u>Oolite Grainstone</u>--Extensive description of much oolitic rock of the Meagher was presented by Lebauer (1965) and is briefly summarized here; dolomitization of this lithofacies is extensive in the Ruby Range, obscuring most of the detail.

Oolites average ½ millimeter in diameter and exhibit both concentric and radial structure. Nuclei of the oolites are composed of cryptocrystalline calcite, pellets, and less commonly fossil fragments. Crystalline calcite (dolomite in the Ruby Range) makes up the matrix material.

Environment--Oolites form in water supersaturated with calcium carbonate and where sediment is subjected to strong current action (Eardley, 1938; Illing, 1954; many others). The water is commonly shallow, typically less than 6 feet deep in the Bahamas (Purdy, 1961)



NAME	ENVIRONMENT	LITHOLOGY	CHARACTERISTICS	THICK-NESS
Oolitic Grainstone	intertidal zone	dolomite	structures almost totally destroyed	100 ft.
Pelletal Packstone	subtidal zone	limestone, recrystal-lized	rounded to ellipsoidal pellets	30 ft.
Lime Mudstone	subtidal zone	limestone, recrystal-lized	mottling	15 ft.

Figure 5. Interpreted lateral relationships for lime mudstone, pelletal packstone, and oolitic grainstone of middle Meagher unit, using Walther's Law (see text, p. 5).

and in the Persian Gulf (Kinsman, 1964; 1969).

Oolite deposits of the Meagher are extensive, thus may have formed over extensive area or may simply have migrated as bars across shallow areas. Similar deposits in the Bahama Islands occur at the platform margins adjacent to sites of upwelling from hundreds of feet below sea level. In contrast, those of the Persian Gulf occur near lagoon entrances, the water shoaling from depths of only 125 feet below sea level. No evidence of a bank environment comparable to that of the Bahama Islands was found in the Ruby Range, nor was evidence for one reported by Lebauer (1965) in his regional study. It seems, therefore, an analogy with the Persian Gulf is the more probable comparison.

Stratigraphic Position--Oolite grainstone overlies pelletal packstone, a possible lateral relationship shown in Figure 5.

Upper Unit

Yellowish-mottled dolomitic lime mudstone similar to that of the lower unit characterizes much of the upper unit of the Meagher. Except at the thin Laurin Canyon section, the upper 100-150 feet of the Meagher contains a few oolite grainstone beds, flat pebble conglomerate, and interbedded clay shale.

Mottled Pelletal Lime Mudstone--Pelletal lime mudstone (Plate 2, Figs. E,F) makes up the gray part of the rock in this lithofacies. The pellets range from 40 to 80 microns in diameter and are made of mudstone with grains less than one micron in diameter; grains of the mudstone matrix range to 5 microns in diameter. The yellowish mottled areas are composed of calcareous dolomite grains that are dominantly euhedral and 30 to 60 microns across.

Typical of the lime mudstone is small-scale, very low angle cross-lamination. Thin-sections reveal a laminar arrangement of the larger pellets and concentration into a few laminae. A few recrystallized fossil fragments also are present. Yellowish silty calcareous dolomite makes up the mottled areas (Plate 2, Fig. F). Shapes of the mottled areas are irregular, measuring to 1 centimeter thick and 1 to 4 by 5 to 10 centimeters across. Mudstone laminae are abruptly truncated by sediment forming the mottled areas.

Environment--Rock of this lithofacies is like that of the pelletal mud facies of the Bahamas (Purdy, 1963), except for the yellowish silty mottled areas. It is also similar to part of the subtidal lagoonal complex in Khor Al Bazam, Persian Gulf, described by Kinsman (1969). Absent are typical intertidal features such as the persistent algal mats of the Persian Gulf and the intensive burrowing and resultant non-laminated sediment of the Bahamas. Desiccation features were not observed.

The small-scale low angle cross-lamination attests to some current action, and distribution of larger pellets into particular laminae argues for variability in current strength. Weak currents are probable as suggested by the mud matrix (lack of winnowing) and by preservation of the pellets themselves, structures shown to be fragile (Purdy, 1963).

PLATE 2

Figure A. x 95 plane light. Common texture of lime mudstone in middle unit of Meagher Limestone.

Figure B. x 4 plane light. Oncolitic packstone of middle unit of Meagher Limestone. Note differing orientations of flattened oncolites.

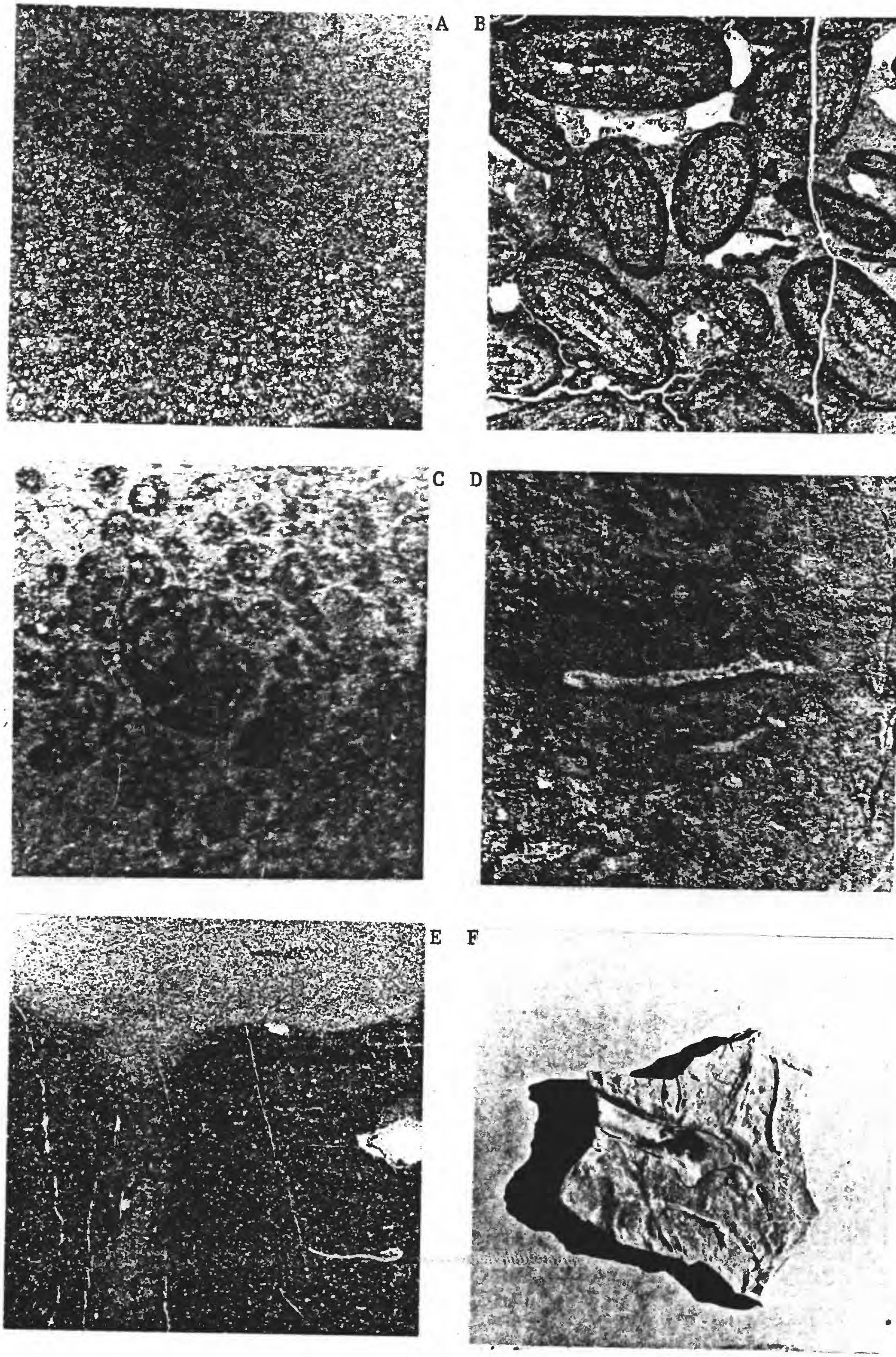
Figure C. x 30 plane light. Pellets and pelletal aggregate of middle unit of Meagher Limestone. Apparent structure of pellets is due to recrystallization of calcite.

Figure D. x 2. Twig-like structures present in middle part of Meagher Limestone.

Figure E. x 3 plane light. Mottled pelletal lime mudstone from middle unit of Meagher Limestone. Figure shows vertical burrow, yellowish mottled area at top. Section is a vertical slice across long axis of mottled area of sample in Figure F below.

Figure F. x $\frac{1}{4}$. Mottled pelletal lime mudstone from middle unit of Meagher Limestone, with yellowish mottled area outlined.

PLATE 2



Infilling of erosion-formed depressions would be a likely mode or origin for the mottled areas, although they could possibly be formed by burrowing. Clearly, abrupt termination of the mudstone laminae shows that the depressions and mottled areas formed after the mudstone. In addition, the quartz silt present only in the mottled areas suggests a new sediment type (and source?). A higher energy environment may be suggested to explain cutting of the depressions, for transporting the quartz silt, and because of the presence of vertical burrows. Compared to the environment of horizontal burrows, vertical burrows are commonly found where higher energy conditions exist at the sediment-water interface (Rhoads, 1967). Indeed, some of the depressions are elongate and appear similar to small-scale linquoid ripple marks, structures presently forming in turbulent water with sinuous flow lines (Allen, 1963).

Age--Fossils obtained from the Meagher are poorly preserved. Collections were made from the upper 100 feet of the formation in the NE¼NE¼ sec. 29, T. 5 S., R. 5 W., and identified by A. R. Palmer (written communication, 1968). The fossils include the brachiopods Micromitra and Opisthotreta, and the trilobites Kootenia?, a pygidium of either Kootenia or Olenoides, and marjumids. Palmer stated that "the total aspect...is of faunas of late Middle Cambrian age" (Fig. 3).

PARK SHALE

Rocks assigned to the Park Shale rarely crop out and a gently sloping grassy bench commonly marks the trace of the formation. A fairly well exposed outcrop of the basal part occurs in the NE¼NE¼ sec. 19, T. 6 S., R. 5 W., and an excellent outcrop of the upper 50 feet is exposed in the SW¼SW¼ sec. 33, T. 5 S., R. 5 W.

As described above, the contact of the Park with the underlying Meagher was placed at the uppermost bed of Meagher-like carbonate rock. Commonly, the upper contact is concealed by float from the Pilgrim Formation, but where exposed the contact is sharp. The significance of this contact is discussed later.

Thickness of the formation is about 175 feet, most of which is finely micaceous grayish-olive fissile clay shale. Near the base are scattered layers of thin-bedded yellow and orange nodules of limestone; these commonly contain trilobite hash, phosphatic brachiopods, oncolites, or limestone pebbles. Dolomite nodules crop out near the top of the Park.

Origin--The Park is commonly thought to represent a temporary regression in the dominantly eastward transgression of the Cambrian seas. It is thus implied that the source of the sediment was to the east, but some of the sediment may have come from central Idaho, as Robinson (1963) has pointed out.

Palmer (1960) has shown that Cambrian sediments in the Great

Basin are divisible into an inner and an outer detrital belt, with a carbonate belt in between. He stated (Palmer, 1966) that "during most periods of contraction of carbonate sedimentation, the carbonate belt was interrupted across central Idaho," and that "an important tectonic positive area west of central Idaho is indicated by...repeated interruptions of the carbonate belt across central Idaho..." Hobbs and others (1968) described quartzites in central Idaho of Early to Middle Cambrian age which are separated from early Middle Ordovician rocks by an undated quartzite unit. Perhaps some of the Park sediment was winnowed from this western facies.

The nodules of dolomite cropping out in the upper part of the Park occur in Robinson Canyon (SW¼SW¼ sec. 33, T. 5 S., R. 5 W.). The nodules are "pod" shaped (see sketch, Fig. 6) with dimensions averaging about 5 by 3 by 3/4 inches. Pods are isolated within the soft clay shale of the formation, although many occur at the same stratigraphic level. Silty dolomite mudstone forms the inner part of each pod, with micaceous dolomitic siltstone enveloping it.

A cross-section of one of the pods shows the laminae to be terminated abruptly on one end and tapered on the other as if pulled laterally; the inner part, or "core" reflects this pattern. Formation of the pods may be reconstructed in sequence as follows: (a) deposition of detrital material, coarsening from clay to silt and forming a thin layer of quartz silt; (b) deposition of a layer of carbonate mud, containing less than 20 percent quartz silt; (c) deposition of another layer of silt, grading upward to detrital

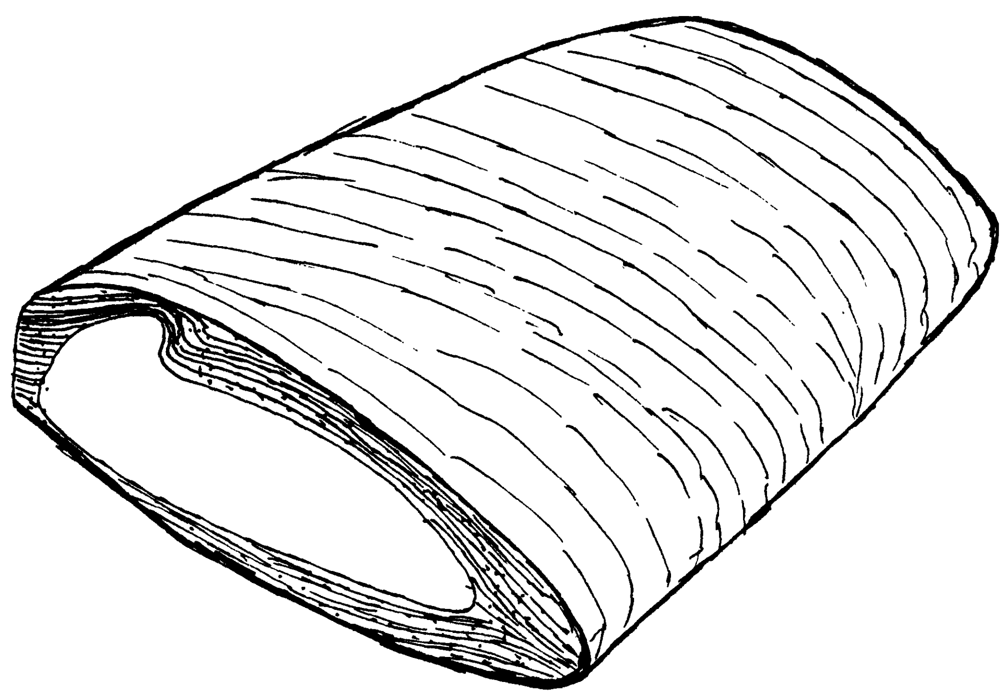


Figure 6. Sketch showing features of dolomite "pod" from the upper part of the Park Shale. Features are described in text. Sketch is about natural size of pod.

material of clay size; and (d) differential compaction and formation of the pods after burial of the layers. As the weight of the overlying sediment increased the still plastic carbonate mud flowed laterally. The thicker parts of the irregular mud layer may have served as loci for pod formation. Shearing in the silty laminae paralleled flowage of the mud, creating a tapering of the laminae (right side of Fig. 6) and abrupt truncation of laminae (at left) where the mud layer broke abruptly.

Grant (1965, p. 14-15) explained limestone pods in shale of the Sage Member of the Snowy Range Formation as concentrates of lime mud in depressions such as ripple troughs. The method is attractive, but fails to account for the structures in the pods of the Park. Another possibility is that calcareous algae could have concentrated the lime and trapped silt, but no evidence of algae was observed in the pods.

The contact of the Park with the overlying Pilgrim is sharp in the Ruby Range. Silty dolomite mudstone occurs in the upper 15 inches of the Park and is overlain by dolomite-pebble conglomerate grainstone of the basal Pilgrim. Two factors suggest that perhaps this sharp contact represents an environmental change rather than a break in the sedimentary record: (1) the occurrence of dolomite mudstone in the upper 15 inches of the Park instead of fissile clay shale, and (2) the presence of fossils in the upper part of the mudstone. In general, fossils in Cambrian rocks seem to be most common in beds transitional between those dominating the formations above and below a mutual contact.

The change from Park to Pilgrim strata in southwestern Montana is considered by most authors to be gradational, exemplified by interbedding of shale and limestone or dolomite rocks. A survey of the literature shows that in most cases the contact is concealed, however, and where exposed it is sharp (cf., Hanson, 1952, sections 3, 19, 20, and 21; Robinson, 1963; McMannis and Chadwick, 1964; Karlstrom, 1948). In south-central Montana, though, Hanson (1952) found the contact to be clearly transitional.

Age--Fossils collected from the Park are poorly preserved and were obtained from the lower part of the formation. They were identified as Kootenia or Olenoides, along with undetermined ptychoparioids, and were assigned a Middle Cambrian age (written communication, A. R. Palmer, 1970). Palmer noted that "one undetermined ptychoparioid is similar to several late Middle Cambrian forms, but without a larger sample a meaningful determination cannot be made." (See Fig. 3.)

PILGRIM LIMESTONE

Thickness of the Pilgrim ranges from 295 to 395 feet. The thickest section was measured just north of McHessor Creek in the SW¼SE¼ sec. 18, T. 6 S., R. 5 W., the thinnest near the head of Laurin Canyon (E½NE¼ sec. 8, T. 6 S., R. 5 W.). The basal beds of the unit are almost everywhere covered, with the Park-Pilgrim contact exposed only in one place, Robinson Canyon. This contact was discussed above in the description of the Park. Good exposures characterize the remainder of the formation. The upper contact is thought to be conformable with the overlying Dry Creek Member of the Red Lion Formation and is discussed with that member.

The Pilgrim in the Ruby Range is divisible into two distinct but informal members--lower and upper. The lower member is mainly dolomite, whereas the upper one is dolomite and quartz sandstone.

Lower member

The lower member ranges from 200 to 270 feet thick. The lower and upper few tens of feet of the member are characterized by thicker bedding than the main body of the unit. Thin-section study reveals few details due to dolomitization, but polished slabs of the rock show faint mottling, hints of replaced oolites, and white twig-like structures similar to those noted in the Meagher. In addition, glauconite occurs locally. Medium and thick beds are typical of these strata, which weather light gray.

A distinctive repetition of 2 to 10-inch-thick intervals of yellowish shaly dolomitic laminae characterize the main part of the lower member of the Pilgrim. Features of the dolomite between the intervals of shaly laminae are obscured by dolomitization and weathering in most outcrops. Part of the McHessor Creek section is less weathered than elsewhere, however, revealing the thinly

UNIT	LETTER FOR ROCK TYPE	DESCRIPTION OF UNITS	THICKNESS (INCHESS)	FEET ABOVE BASE
				184
30	A	Shaly laminae	6	
29	C	Laminated dolomite	18	
28	D	Pebble conglomerate, dolomite	3	
27	C	Laminated dolomite	6	
26	A	Shaly laminae	3	
25	C	Laminated dolomite	6	
24	B	Mottled dolomite	11	
23	B	Mottled dolomite?	4	
22	B	Mottled dolomite	6	
21	E	Bioclastic dolomite	3	
20	D	Pebble conglomerate, dolomite	3	
19	E	Bioclastic dolomite	3	
18	D	Pebble conglomerate, dolomite	3	
17	C	Laminated dolomite	12	
16	D	Pebble conglomerate, dolomite	3	
15	C	Laminated dolomite	5	
14	B	Mottled dolomite	3	
13	A	Shaly dolomite laminae	10	
				175

Figure 7. Abbreviated measured section showing repetition of thinly bedded strata in the middle part of the lower member of the Pilgrim Formation. Units are described in Appendix: measured section H, between 175 and 184 feet.

bedded, repeated strata of the 175 to 184-foot interval shown in Figure 7. The presence of similar rocks a few miles to the north (Robinson, 1963) suggests widespread deposition of these beds in a very broad, flat depositional environment in which relative sea level changes regularly occurred. Unfortunately, because of dolomitization, thin-sections reveal even less than the polished slabs, thus limiting the possibility of further interpretation.

Upper member

Dolomite with an abundance of quartz sand distinguishes the upper member of the Pilgrim. The outcrop expression is more like that of the overlying Red Lion than the underlying Pilgrim. Assignment of this unit to the Red Lion seems incorrect, however, because shale of the Dry Creek Member of the Red Lion is present near the middle of the combined sequence and, by definition, marks the base of the Red Lion Formation (cf., Lochman, 1950).

Figure 8 shows a generalized vertical sequence of the lithofacies units making up the upper member of the Pilgrim and the overlying Red Lion Formation in the Ruby Range. The lithofacies units of the Pilgrim are described below in ascending order.

Sandy Laminated Boundstone--Thin beds of finely laminated silty and sandy dolomite characterize this lithofacies (Plate 3, Fig. A). The silt and sand grains are quartz and are commonly concentrated along laminae which weather in relief on the outcrop face. Typically the laminae are flat, but locally they are wavy, somewhat like

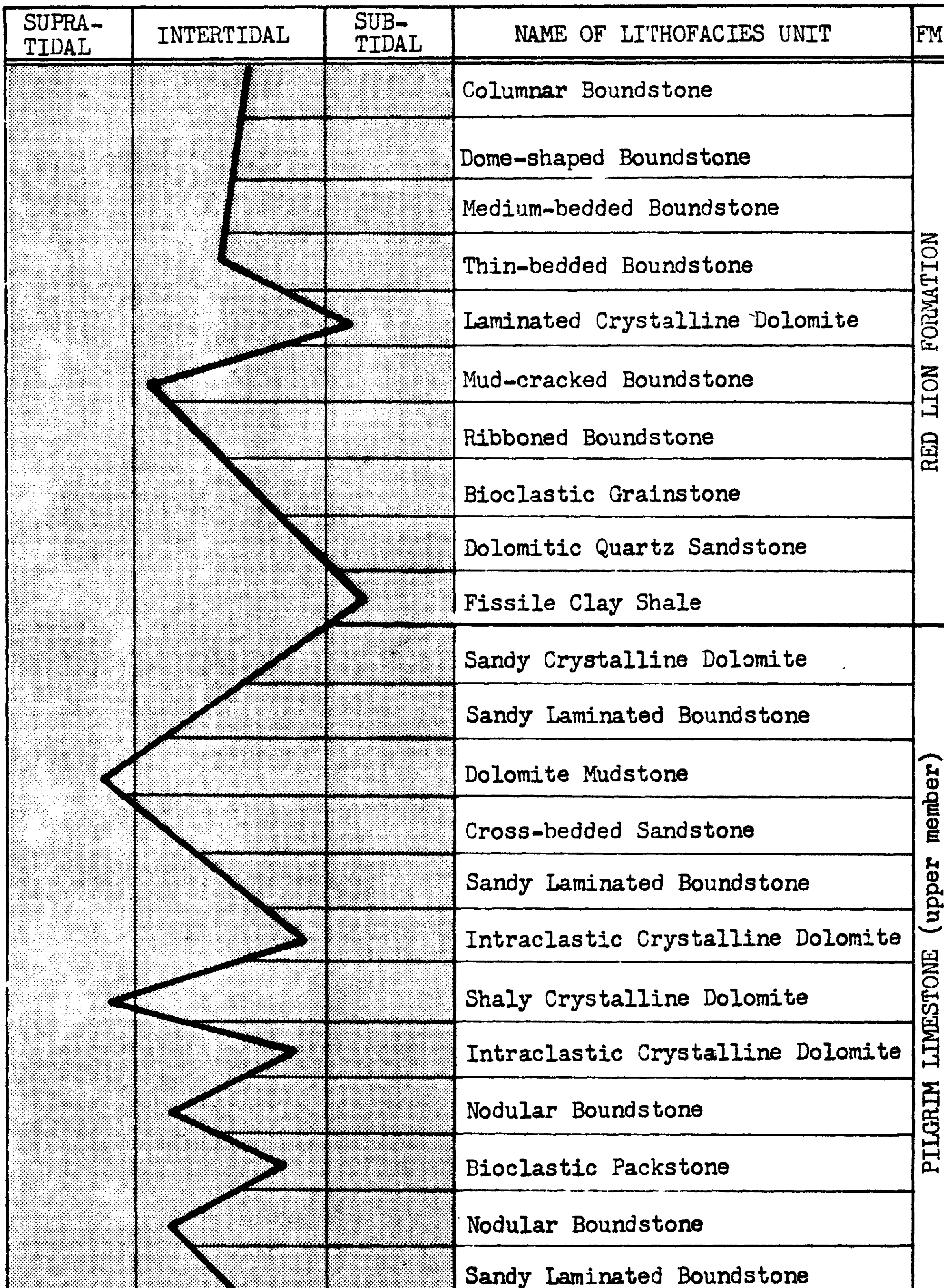


Figure 8. Vertical sequence of lithofacies units occurring in the upper member of the Pilgrim Limestone and in the overlying Red Lion Formation. Jagged line slopes to left for sediments deposited during transgression of sea, to the right for sediments deposited during regression of sea.

stromatolitic mat algal structures.

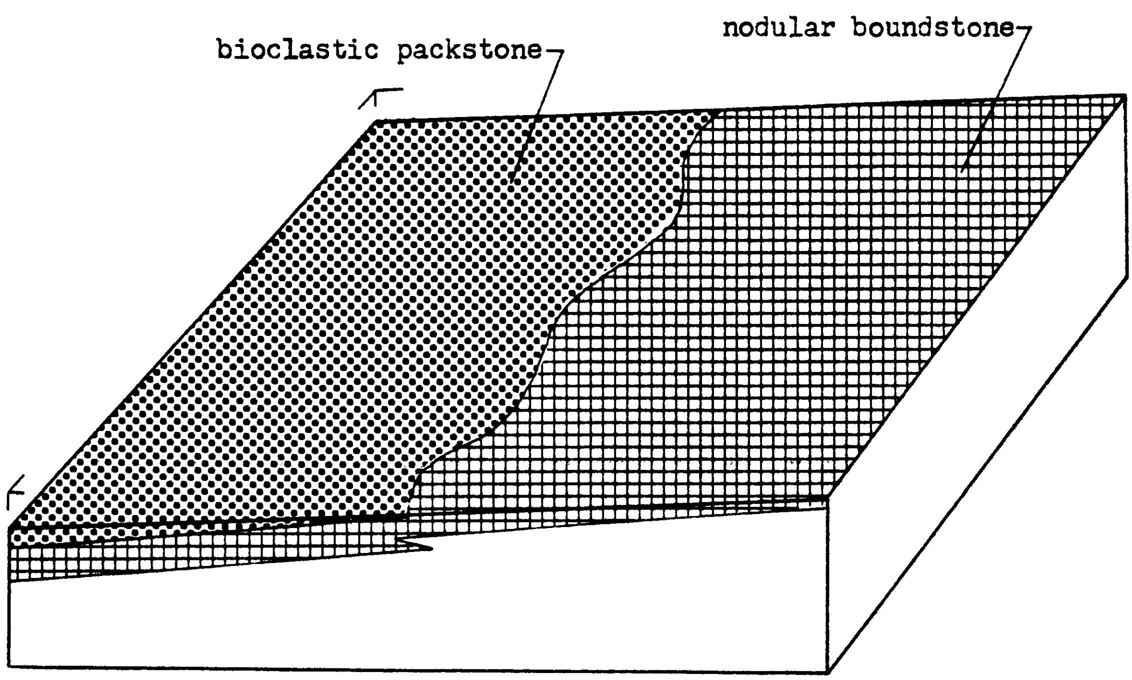
Dolomite makes up 75-80% of the rock, except near bedding surfaces where the beds are mainly composed of closely-spaced sandy laminae. Grain size of the dolomite commonly ranges from 60 to 120 microns, but near bedding surfaces grains may be no larger than 5 microns. Quartz comprises the remainder of the rock (20-25%), consisting mainly of subangular to subrounded coarse silt (30-60 microns) grains. Near bedding surfaces, however, the quartz grains are rounded and of fine sand size.

Environment--The inferred environment for this rock type is intertidal. The stromatolitic mat algae suggest binding of the grains in the intertidal zone, and where the algae are absent the sand may be considered part of a beach deposit. Kendall and Skipwith (1969) found adjacent beaches and intertidal flats composed of quartz-rich sediment in the Khor Al Bazam Lagoon, southwest Persian Gulf. In addition, the abundance and large size of the quartz grains in the sandy laminated boundstone suggest that they are not of subtidal or supratidal origin. The quartz grains in the Khor Al Bazam Lagoon show a distribution similar to that noted here, and grain transport is along the shore zone.

Frequent changes in wave energy are suggested by the observation that the laminae show changes in grain size from coarse silt adjacent to the mat algae and coarse silt to fine sand elsewhere. The algae probably persisted or grew more rapidly during times of lower energy and trapped the finer grained sediment. Under higher energy conditions they may have been killed as suggested by the association of coarser grains with fewer algal laminations or none at all. Some of the laminae present in these latter beds may be explained by the segregation of quartz grains into different size distributions. The coarser grains or mixed fine and coarse grains reflect higher energy conditions and/or rapid deposition. In either case mat algae were unlikely to be established. The suggested energy changes may reflect only a change in tidal amplitude, perhaps due to daily tidal fluctuations.

Stratigraphic Position--In the basal strata of the upper Pilgrim member this lithofacies commonly overlies oolite grainstone of the lower member and underlies nodular boundstone. Upward, the unit reappears many times and is commonly interbedded with dolomite mudstone, although it also occurs below the cross-bedded sandstone unit. The interpreted lateral facies patterns are show in Figures 11, 12 and 13.

<u>Nodular Boundstone</u>--Strata of this lithofacies (Plate 3, Fig. B) are thinly-bedded, grayish red-weathering, and consist of interlayered dolomite and mat-algal laminated dolomite. Dolomite makes up 55-70 percent of the rock and quartz 30-45 percent, the quartz grains being concentrated along algal laminae. Rounded intraclasts of dolomite are present locally, measuring ¼ to 1½ centimeters in diameter and composed of the same sediment as that of the matrix. Small-scale cross stratification is evident in the intraclastic rock and mat-algal fragments occur locally. Burrows are present but are not abundant. Dolomitic casts of worm trails to one centimeter across



NAME	ENVIRONMENT	LITHOLOGY	CHARACTERISTICS	THICK-NESS
Bioclastic Packstone	subtidal to intertidal	dolomite	ghosts of spines common	5-7 ft.
Nodular Boundstone	intertidal zone, upper part?	dolomite	interlayered dolomite and algal-laminated dolomite	3 ft.

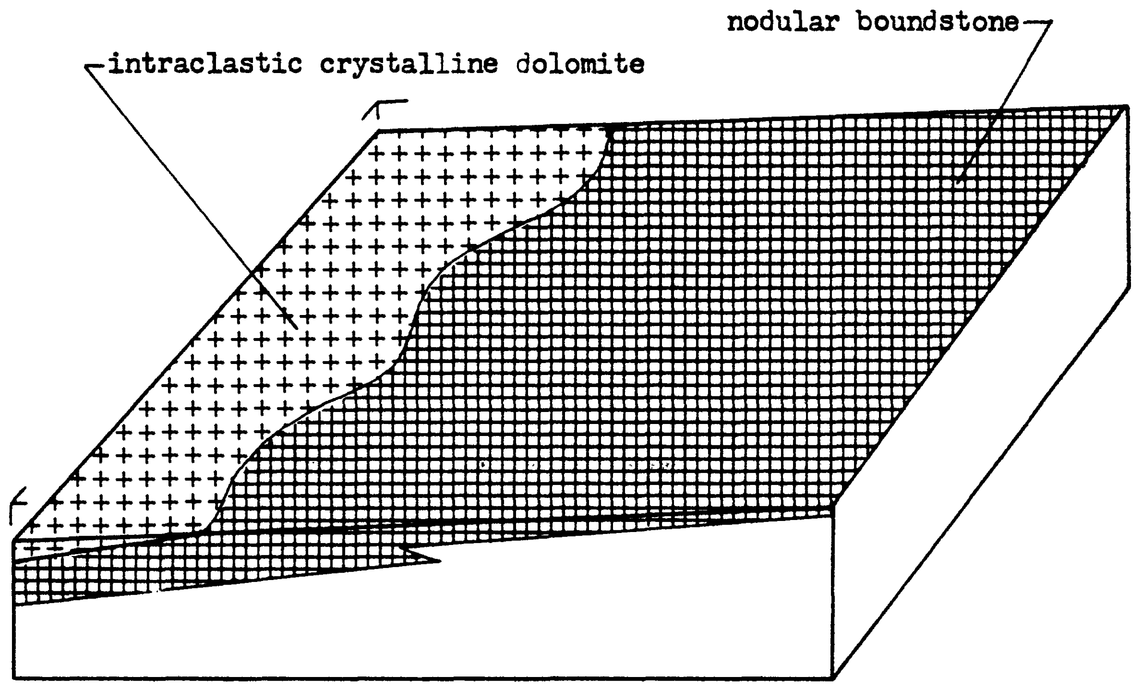
Figure 9. Interpreted lateral relationships for nodular boundstone and bioclastic packstone lithofacies, using Walther's Law (see text, p. 5).

are present at the surfaces of a few beds and disrupt the stromatolitic laminae.

Microscopic examination shows the dolomite of both the intraclasts and the matrix to be anhedral, the grains ranging between 30 and 60 microns in diameter. Quartz grains are of sand size and commonly range from 100 to 150 microns in diameter (fine sand). A few grains with 300 to 400 micron diameters are also present but they comprise less than 5% of the sand. Overgrowths are exhibited by the larger, rounded grains; the smaller grains are subangular and lack overgrowths.

Environment--This lithofacies is interpreted as a deposit of the intertidal zone by analogy with the stomatolitic intertidal deposits of the Persian Gulf, described by Kendall and Skipwith (1968; 1969) and Kinsman (1969). Interlayering of algal and non-algal sediments may reflect a periodic shifting of the facies environment, with the non-algal sediment being deposited more rapidly. Thus algae would not have had sufficient time to become established. The nodular tendency probably reflects differential compaction.

The rounded intraclasts may be indicative of the upper part of the intertidal zone, rather than the supratidal zone, as no desiccation features as associated with the strata. However, the clasts may be of supratidal origin, with deposition occurring in the intertidal zone perhaps during storm action. Cross-bedding suggests rapid deposition, as shown by the range in clast size (½ to 1½ centimeters). The presence of rippled-up mat algal sediment in the clastic rock and



NAME	ENVIRONMENT	LITHOLOGY	CHARACTERISTICS	THICK-NESS
Intraclastic Crystalline Dolomite	intertidal	dolomite	thick-bedded, nearly featureless dolomite	5-7 ft.
Nodular Boundstone	intertidal, upper part?	dolomite	interlayered dolomite and algal-laminated dolomite	3 ft.

Figure 10. Interpreted lateral relationships for nodular boundstone and intraclastic crystalline dolomite lithofacies, using Walther's Law (see text, p. 5).

capping of the beds with continuous algal laminae are characteristic of an intertidal sediment.

Stratigraphic Position--The nodular boundstone lithofacies occurs between sandy laminated boundstone (below) and bioclastic packstone (above), and also sandwiched between units of intraclastic crystalline dolomite. Interpreted lateral facies relationships are illustrated in Figures 9 and 10.

Bioclastic Packstone--This lithofacies is mainly composed of fossil hash (50-70%) in a matrix of fine-grained dolomite (30-50%). Spicule ghosts (Plate 3, Fig. C) commonly make up the only identifiable fragments, with minor intraclasts and oolites. Spicules are oriented about parallel to bedding, measure to 10 millimeters in length, and range from 150 to 300 microns in diameter. They are largely supported by a fine-grained dolomite matrix with grain size ranging from 10 to 50 microns. Local patches of 300-microns grain-size dolomite occur at random, and some of the patches are probably burrows.

Intraclasts range from 2 to 12 millimeters long and are mainly composed of dolomite grains 10-25 microns in diameter. Other components include angular quartz grains of coarse silt (60 microns across) and oolites that show concentric structure. The latter are made of dolomite grains 10-15 microns in diameter and are themselves 300-400 microns in diameter.

Environment--Deposition of this lithofacies probably took place in the subtidal zone as the sediment is similar to that described by

Kendall and Skipwith (1968; 1969; 1969a) and Kinsman (1969) in the subtidal zone of the Khor Al Bazam Lagoon, southwest Persian Gulf. A lack of sorting is shown by the types of components present and by the contrast in size of the components. The abundance of fine-grained dolomite suggests a lack of currents for winnowing; the oolites and intraclasts are thus interpreted as admixed constituents, perhaps deposited during storms.

Stratigraphic Position--Bioclastic packstone occurs at only one position in the upper member of the Pilgrim--above and below nodular boundstone. Interpreted facies relations are shown in Figure 9.

<u>Intraclastic Crystalline Dolomite</u>--Crystalline dolomite (75-90%) is the main component in this lithofacies (Plate 3, Fig. D) with quartz (12-25%) and feldspar (1-3%) grains also present. The rocks are thick-bedded and weather dark yellowish brown. Grain size is typically medium-crystalline, ranging between 100 and 250 microns. Quartz grains are very fine sand size, 60 to 125 microns. Most of them are subangular, the larger ones rounded. Feldspar grains are angular. No preferred orientation of grains are noted.

Intraclasts make up 10 to 25 percent of the rock and, except in the upper few feet of the lithofacies, are of subrounded dolomite grains 1 to 2 centimeters in diameter. Intraclasts in the upper part of the lithofacies range from 2 to 6 centimeters in diameter and are composed of mat algal dolomite.

Environment--An intertidal position is suggested by its stratigraphic position immediately above and below a rock (shaly crystalline

PLATE 3

Figure A. Sandy laminated boundstone from upper member Pilgrim Limestone. Note wavy laminae in NE¼ of picture.

Figure B. Nodular boundstone (thin beds above hammer) from upper member of Pilgrim Limestone.

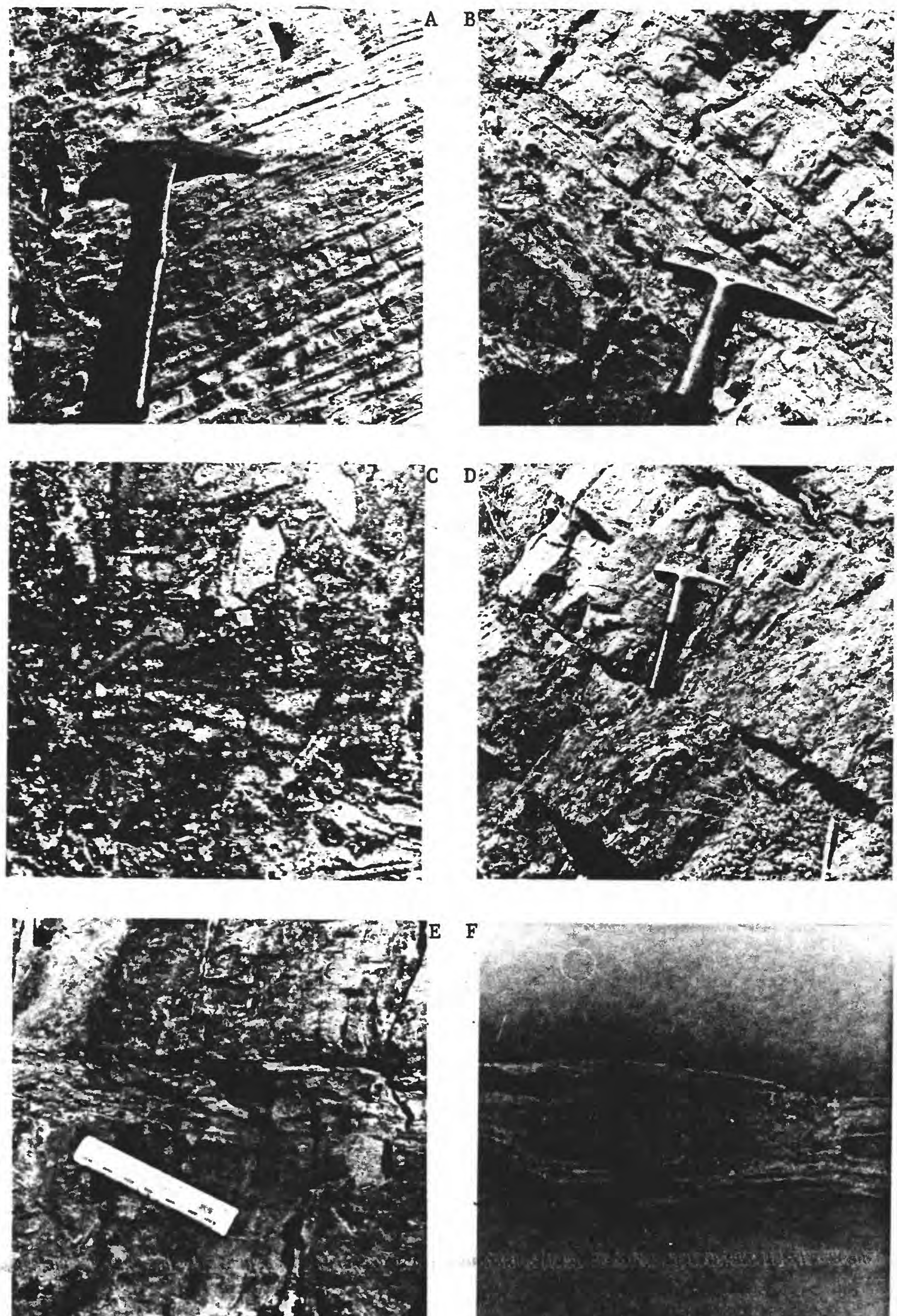
Figure C. x 6 plane light. Ghosts of spicules in bioclastic grainstone of upper member of Pilgrim Limestone.

Figure D. Thick beds of intraclastic crystalline dolomite, upper member of Pilgrim Limestone.

Figure E. Zone near center of picture is shaly crystalline dolomite in upper member of Pilgrim Limestone. Scale is about 6 inches long. See Figure F, below.

Figure F. x 3. Boudins in shaly crystalline dolomite. Picture shows one large boudin enveloped by numerous smaller ones.

PLATE 3



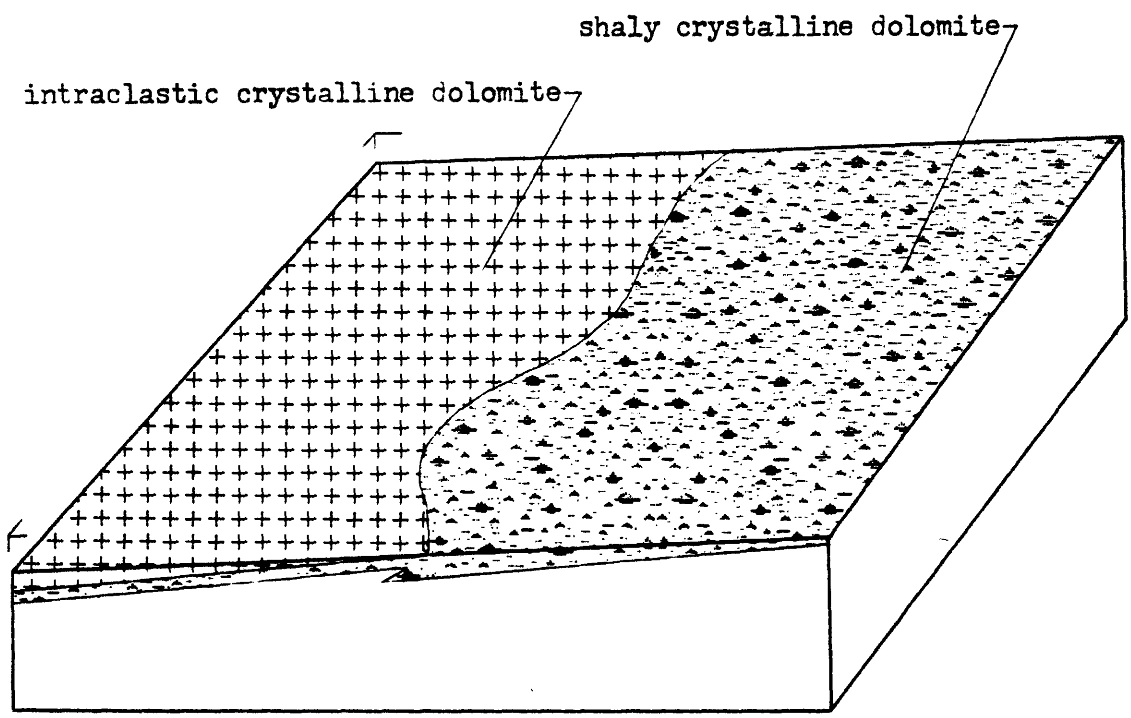
dolomite) of probable supratidal origin. The lack of detail and distinctive features limits further interpretation.

Stratigraphic Position--Intraclastic crystalline dolomite is present only in the lower part of the member. It commonly occurs between nodular boundstone (below) and shaly crystalline dolomite (above), or locally overlies the latter and underlies sandy laminated boundstone. Interpreted stratigraphic relations are show in Figures 10, 11 and 12.

Shaly Crystalline Dolomite--This rock (Plate 3, Fig. E) consists of thinly bedded finely laminated silty dolomite that is locally stromatolitic. The silt fraction is composed of feldspar grains that range from 60 to 100 microns in diameter and diagenetically replace dolomite rhombohedra, making up 20 to 40 percent of the rock locally. The dolomite is medium crystalline, ranging from 60 to 100 microns across. The lithofacies occurs in sequences to 10 centimeters thick.

Grayish mud chips bordered above and below by mat algae occur locally on the facies. The chips are angular and to 5 millimeters across. Boudinage-like structures are also present, shown in Plate 3, Figure F.

Environment--This lithofacies is interpreted as representative of the supratidal zone. Shinn (1968), Shinn and others (1969), and van Stratten (1954, cited in Matter, 1967) have described and illustrated modern marsh sediments containing mud chip structures similar to those described for the Pilgrim. Braun and Friedman (1969)



NAME	ENVIRONMENT	LITHOLOGY	CHARACTERISTICS	THICK-NESS
Intraclastic Crystalline Dolomite	intertidal	dolomite	thick-bedded, non-descriptive	4-8 ft.
Shaly Crystalline Dolomite	supratidal	dolomite	yellowish shaly chips locally has small boudins	0-6 inches

Figure 11. Interpreted lateral relationships for shaly crystalline dolomite and intraclastic crystalline dolomite lithofacies, using Walther's Law (see text, p. 5).

have described boudinage structures in Ordovician strata similar to that of the Pilgrim, and interpreted it as a marsh deposit.

Origin of the mud chip structures (called "lumpy structure" by Matter, 1967) is attributed to deposition during storms, followed by desiccation and mud-cracking (Shinn and others, 1969). Some chips may have originated in part from burrowing, as described both by Shinn (1968) and Matter (1967). Boudinage structures probably owe their origin at least in part to differential compaction.

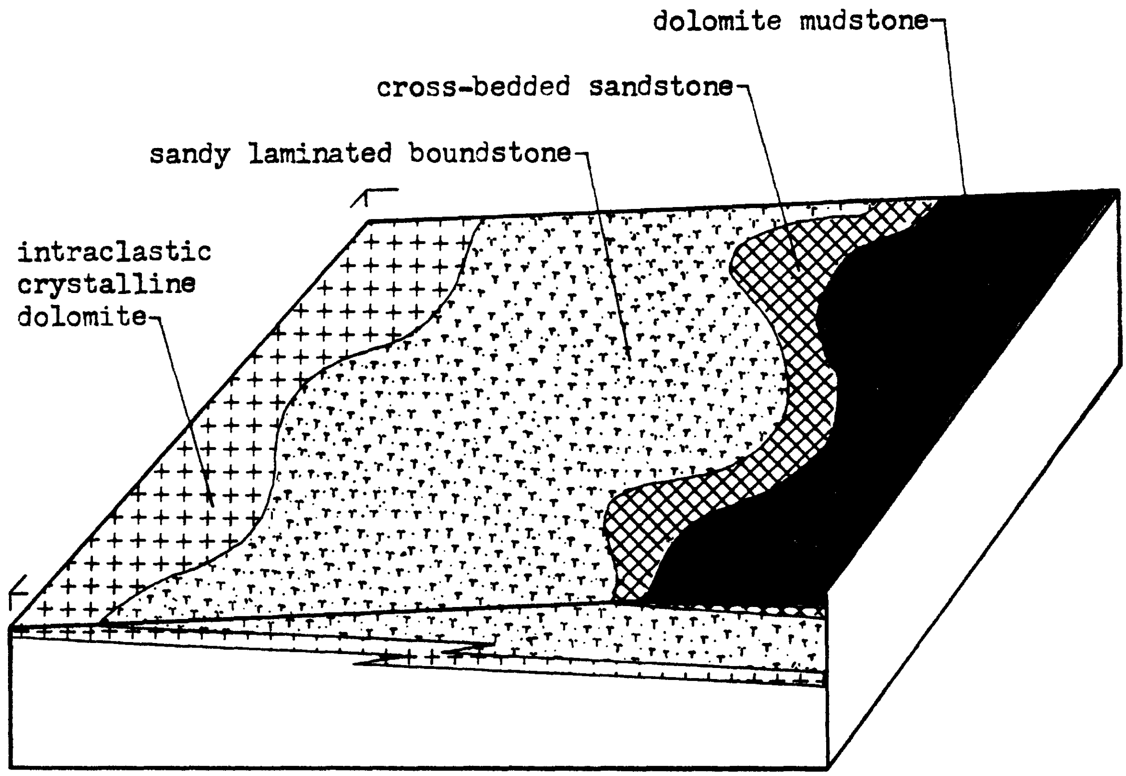
Stratigraphic Position--Rock of this lithofacies is present at only one interval in the upper member, and is bounded above and below by intraclastic crystalline dolomite (the clasts being made of algal boundstone). The interpreted lateral facies relationships are illustrated in Figure 11.

<u>Cross-bedded Sandstone</u>--Rock of this lithofacies (Plate 4, Fig. A) is composed of quartz (40-100%) and dolomite (0-60%). The quartz grains are of fine to medium sand size, range from 90 to 300 microns in diameter, are mostly rounded, and are moderately to well-sorted. Overgrowths are common, even where grains appear isolated in dolomite. The dolomite is finely crystalline, with grain diameters of 15 to 35 microns.

Thickness of the unit is not consistent; it ranges from about 4 feet to as much as 7 feet, although the latter thickness is unusual. Where thick, the sandstone unit commonly does not crop out, but instead weathers into blocks which form talus piles.

Tabular and locally trough cross-beds are distinctive features of this lithofacies, the forms corresponding to the avalanche and accretion deposits of Imbrie and Buchanan (1965). Avalanche deposits are composed of steeply inclined (about 30°), tabular cross strata that terminate abruptly at the lower boundary surface of the set. Thickness of sets commonly ranges from 15 to 30 centimeters. The accretion deposits are gently inclined, curved, tapering cross strata, with the maximum angle of dip less than 30°. The cross strata meet the lower boundary surface at a low angle or are tangential. Thickness of the sets is typically about 15 centimeters. Accretion deposits are not common in the Pilgrim but they do occur locally.

Environment--A clue to the origin of the cross stratified unit is its stratigraphic position above strata of probable intertidal origin and beneath strata of probable supratidal origin. Deposits with similar characteristics extend along the seaward margin of the supratidal zone west of Andros Island, Bahamas (Shinn and others, 1969), where they make up beach ridges, measuring 1 to 5 feet high and hundreds of feet across. Ridges less than 2 feet high are laminated, whereas those 3 to 5 feet high show trough and tabular cross-bedding (Shinn and others, 1969, p. 1212). The cross-bedded sandstone of the Pilgrim displays similar trough and tabular cross beds, although the Pilgrim ridges are made of quartz grains, whereas those of the Bahamas, in the absence of quartz, are made of carbonate shell debris. In both cases, however, the grains are of sand size, important when considering dimensions of the deposits, as pointed



NAME	ENVIRONMENT	LITHOLOGY	CHARACTERISTICS	THICK-NESS
Dolomite Mudstone	supratidal	dolomite	medium gray, thinly bedded locally laminated	3-9 ft.
Cross-bedded Sandstone	intertidal zone, upper part	quartz sand, dolomite	cross-bedding very distinctive	4-7 ft.
Sandy Laminated Boundstone	intertidal zone	dolomite and quartz sand	wavy laminae weather in relief	25-35 ft.
Intraclastic Crystalline Dolomite	intertidal	dolomite	thick-bedded, non-descriptive	4-8 ft.

Figure 12. Interpreted lateral relationships for intraclastic crystalline dolomite, sandy laminated boundstone, cross-bedded sandstone, and dolomite mudstone lithofacies, using Walther's Law (see text, p. 5).

out by Shepard (1960, p. 191). He showed that sand beaches are of limited height above a plain because waves can easily move the sand inland across the plain. Accordingly, sandy beach ridges of storm origin are raised only a few feet above the tide level which produced them. Shepard also noted that these ridges are very broad, quite in contrast to the steep-sided ridges composed of gravel and shell material. Thus the beach ridges of the Pilgrim (and the Bahamas) are only a few feet high, but hundreds of feet in width.

The beach ridges of the Pilgrim are thought to be part of a regressive sequence. If so, the zone of broad, low deposits might be expected to have migrated laterally, with later deposition of additional ridges. The small vertical dimension makes it very difficult to distinguish individual ridges in a lateral sequence of like deposits such as in the Pilgrim. Furthermore, at least the upper strate of the deposits have been reworked.

A range of thicknesses have been noted for the ridges in the Pilgrim Formation. Shinn and others (1969) found a similar characteristic in the Bahamas, noting that the higher ridges occur in embayed areas of the shore whereas the lower ridges are present on headlands.

Sand in the cross stratified unit and in the upper member of the Pilgrim has apparently been recycled. This is shown by quartz grains with overgrowths "floating" in dolomite.

A general source for the sand grains must have been west or southwest of the Ruby Range inasmuch as the sandy strata thin and pinch out in all other directions (cf., Hanson, 1952). Possible source beds include the Cambrian Flathead Sandstone and Precambrian Belt and Belt-like rocks. In addition, Hobbs and others (1968) have described quartzite formations in central Idaho of Early to Middle Cambrian age (and possibly of younger Cambrian age) that could have supplied quartz grains.

Stratigraphic Position--This lithofacies occurs near the middle of the upper member, bounded below by sandy laminated boundstone and above by dolomite mudstone. Figure 12 shows the interpreted facies pattern.

Dolomite Mudstone--This lithofacies (Plate 4, Fig. B) is dominantly of dolomite (90-98%), quartz (1-5%), and feldspar (0-5%). The strata are thinly bedded (3-5 centimeters thick), weather medium gray, and form well exposed outcrops. Some of the rocks are laminated, containing dark brown mat algal sediment interlaminated with light gray-brown dolomite. Algal sediment forms laminar beds in sequences to 1 centimeter thick, and they are discontinuous. Locally the laminae form minute algal heads, their height measured in millimeters. Angular dolomite fragments are present in places, ranging up to 1.5 millimeters across.

Petrographically, dolomite crystals range from very fine (5-20 microns) to fine (40-60 microns). Quartz grains are of very fine and fine sand size, ranging from 100 to 150 microns in diameter. They are commonly subrounded to rounded and are typically concentrated along stromatolitic laminae. The feldspar is dominantly silt-sized and is angular.

Environment--This lithofacies is interpreted as supratidal, having many similarities with the marsh environment as described by Shinn and others (1969) in the Bahama Islands. Similarities include the following: (1) locally, dark sediment occurring in distinct laminae; (2) laminated non-algal sediment; (3) discontinuous laminations, typical of the dark sediment in the Pilgrim; (4) presence of minute algal heads; and (5) the fragmented dolomite appears texturally similar to that pictured by Shinn and others (1969, Fig. 22-B), showing alternating layers of dolomitic crusts.

Stratigraphic Position--Dolomite mudstone is present only in the upper part of the member. It commonly occurs between units of sandy laminated boundstone, but it does overlie the cross-bedded sandstone unit and underlie the sandy crystalline dolomite unit. Interpreted lateral facies are shown in Figure 12.

Sandy Crystalline Dolomite--Rocks of this lithofacies are medium-bedded and typically weather pale reddish brown. Components of the rock include dolomite (40-60%), quartz (40-50%), feldspar (1-5%), hematite (2%), glauconite (trace), and locally fossil fragments.

Laminae to ½ millimeter thick dominate this facies, reflecting a variation in grain size and content of the quartz sand. Subrounded dolomite intraclasts are common (as much as 5%), ranging from less than 1 millimeter to more than 1½ centimeters in diameter. Stromatolitic laminae are common in the lower and upper few millimeters of a few beds. Burrowing occurs locally.

Dolomite crystals range from 100 to 125 microns (medium crystalline), and quartz and feldspar grains are of sand size. The quartz sand is subrounded to rounded and exhibits overgrowths.

Environment--The environment inferred for this lithofacies is subtidal to intertidal. The sediment is dominantly poorly sorted, contains quartz sand, with intraclasts ranging from silt to granule size, in a matrix of medium-crystalline dolomite. If one assumes that the dolomite is a replacement of calcite and that recrystallization results in an increased grain size (Folk, 1965), then the original matrix can be considered a fine-grained carbonate mud. This suggests deposition in a low energy environment even though the intraclasts may have formed under high energy conditions.

The stromatolitic algae occurring in the upper and lower parts of some beds suggests that at least some of the sediment is intertidal. Concentration of spines along these laminae perhaps indicates deposition from receding waves in the intertidal environment.

Stratigraphic Position--This unit forms the uppermost beds of the Pilgrim, occurring above a sandy laminated boundstone unit and beneath the reddish clay shale of the Red Lion Formation. Interpreted facies relations are shown in Figure 13.

Age--No identifiable fossils were found in the Pilgrim, presumably due to dolomitization. Fossil debris, consisting mainly of fragmented spines, is present in the bioclastic rocks. The Pilgrim is considered Late Cambrian in age because of its position below Red

PLATE 4

Figure A. Cross-bedded sandstone of upper member of Pilgrim Limestone.

Figure B. Dolomite mudstone of upper member of Pilgrim Limestone. Rock is actually thinly bedded but weathers to form massive outcrops.

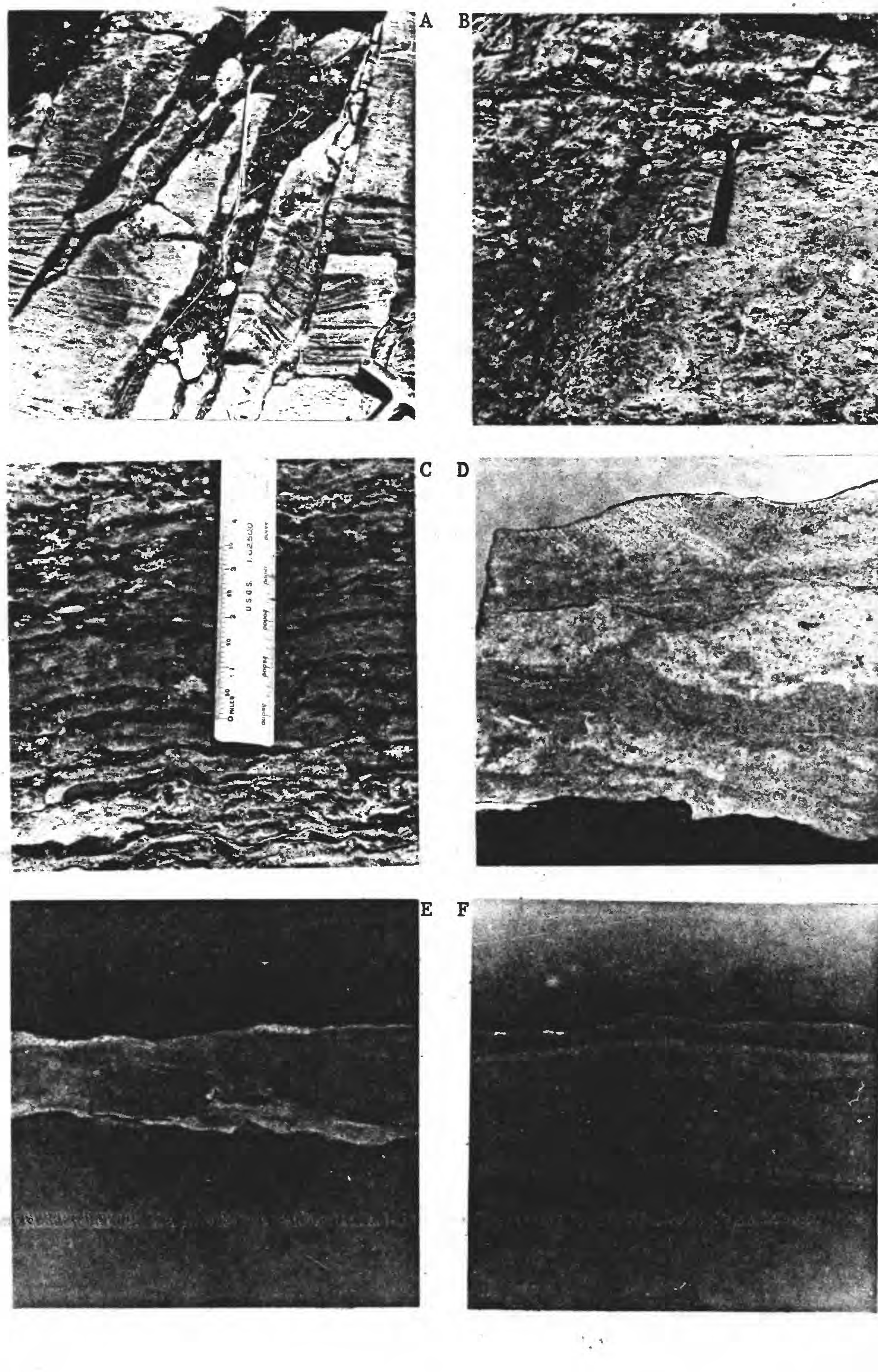
Figure C. Ribboned boundstone of upper member of Pilgrim Limestone. Thin dark wavy layers are interpreted as mat algae, outlining boudins.

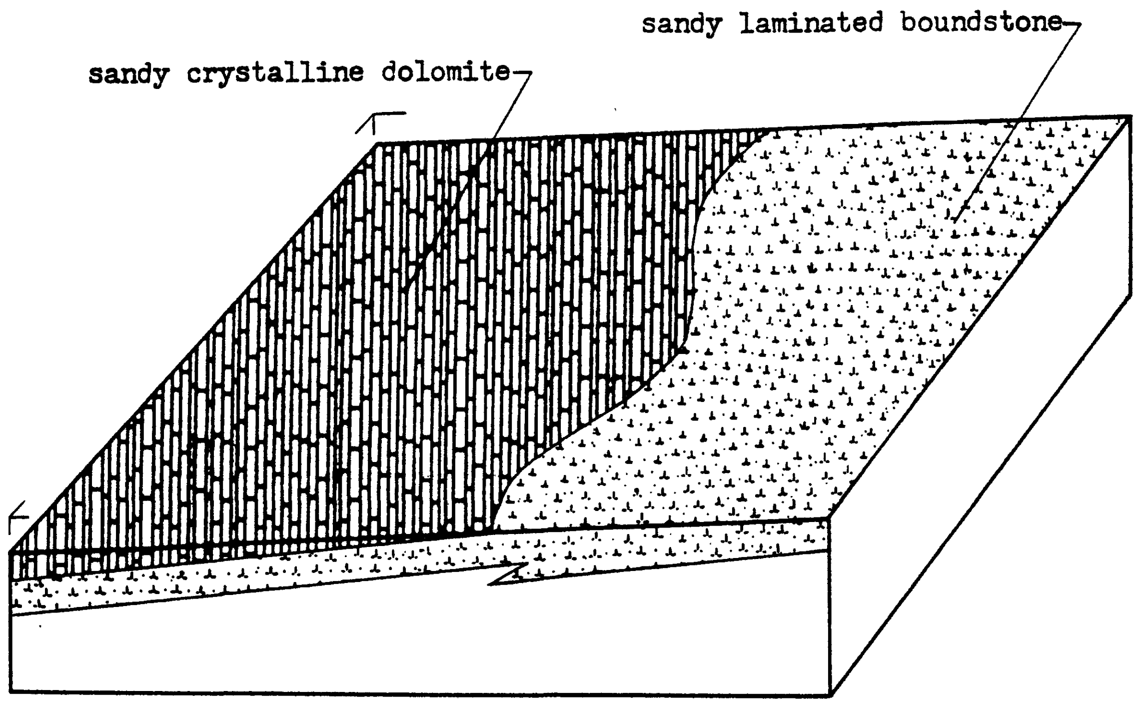
Figure D. x 3½. Ribboned boundstone. Dark layers are interpreted as mat algae, light areas are probably bioclastic grainstone.

Figure E. x 4. Mud chips (outlined) enveloped by mat algal sediment in mud-cracked boundstone lithofacies of upper member of Pilgrim Limestone.

Figure F. x 2. Laminated crystalline dolomite lithofacies of upper member of Pilgrim Limestone. Note occurrence of dark gray laminae at top and bottom of rock, medium gray rock in between.

PLATE 4





NAME	ENVIRONMENT	LITHOLOGY	CHARACTERISTICS	THICK-NESS
Sandy Crystalline Dolomite	subtidal to intertidal	dolomite & quartz sand	reddish, mottled, sandy with local laminae and intra-clasts	6-8 ft.
Sandy Laminated Boundstone	intertidal	dolomite & quartz sand	wavy laminae weather in relief	3-5 ft.

Figure 13. Interpreted lateral facies relationships for sandy laminated boundstone and sandy crystalline dolomite lithofacies, using Walther's Law (see text, p. 5).

Lion beds of Late Cambrian age and above Park strata of probable late Middle Cambrian age, shown in Figure 3.

RED LION FORMATION

Cambrian beds above the Pilgrim in southwestern Montana are referable to either the Red Lion or Snowy Range formations. In some cases the same sequence of strata has received both names. Because this is the case in the nearby Gravelly Range (cf., Hanson, 1952; 1960; Hadley, 1960) it seems best to state my reasons for assigning the sequence ot the Red Lion Formation in the Ruby Range.

Features in common with the Red Lion of the type section (Emmons and Calkins, 1913) include the presence of (1) siliceous laminae, and (2) quartz silt, with the propostion of siliceous material to carbonate being greater in the lower part. Features *not* present in the Ruby Range, but which are typical of the Sage Member of the Snowy Range include (1) the so-called *Collenia magna* stromatolites at the base, and (2) clay shale intercalated with the carbonate rock. In addition intraformational conglomerate, characteristic of the Snowy Range Formation, is present only locally in the Ruby Range, occurring only at the base and has a maximum thickness of 2 feet.

Dry Creek Member

Exposures of the Dry Creek Member are commonly poor. Thickness of the unit ranges from about 10 to 15 feet north of McHessor Creek and from 0 to 5 feet at the south, where it is mapped with the Pilgrim

Formation because it is so thin and younger Cambrian rocks are absent.

The Dry Creek is in sharp contact with the underlying Pilgrim, but the upper contact is gradational with the Sage Member. The top of the Dry Creek was placed at the top of the uppermost sandstone beds or at the base of the lowest dolomitic beds.

Fissile Clay Shale--Shale of the Dry Creek is mostly grayish olive, soft, fissile, and finely micaceous. However, grayish red or blackish red shale is typical of the basal 6 to 12 inches.

Environment--Shale of the Dry Creek probably formed as an offshore subtidal deposit. Reddish coloration of the shale at the base of the Red Lion is universal throughout the Ruby Range and is commonly noted elsewhere in southwestern Montana where the Dry Creek is exposed. Its thinness--but wide distribution--and its occurrence above different rock types--but typically beneath green shale--suggests that its color may reflect conditions that existed early in its history as opposed to recent alteration.

Walker (1967) has shown that young intertidal flat deposits in the Gulf of California are slowly altered to a reddish color, after prolonged exposure when isolated from the intertidal zone. He suggests a process of intrastratal alteration of iron silicates to provide iron oxide pigment and authigenic clay matrix. The stratigraphic position of the reddish shale in the Dry Creek above reddish mottled upper intertidal to supratidal sediments of the Pilgrim is a clue that the red shale may also reflect this environment. Prolonged exposure seemingly requires the sediment to have existed in the supratidal zone, even though it may originally have been deposited in the intertidal or subtidal zone.

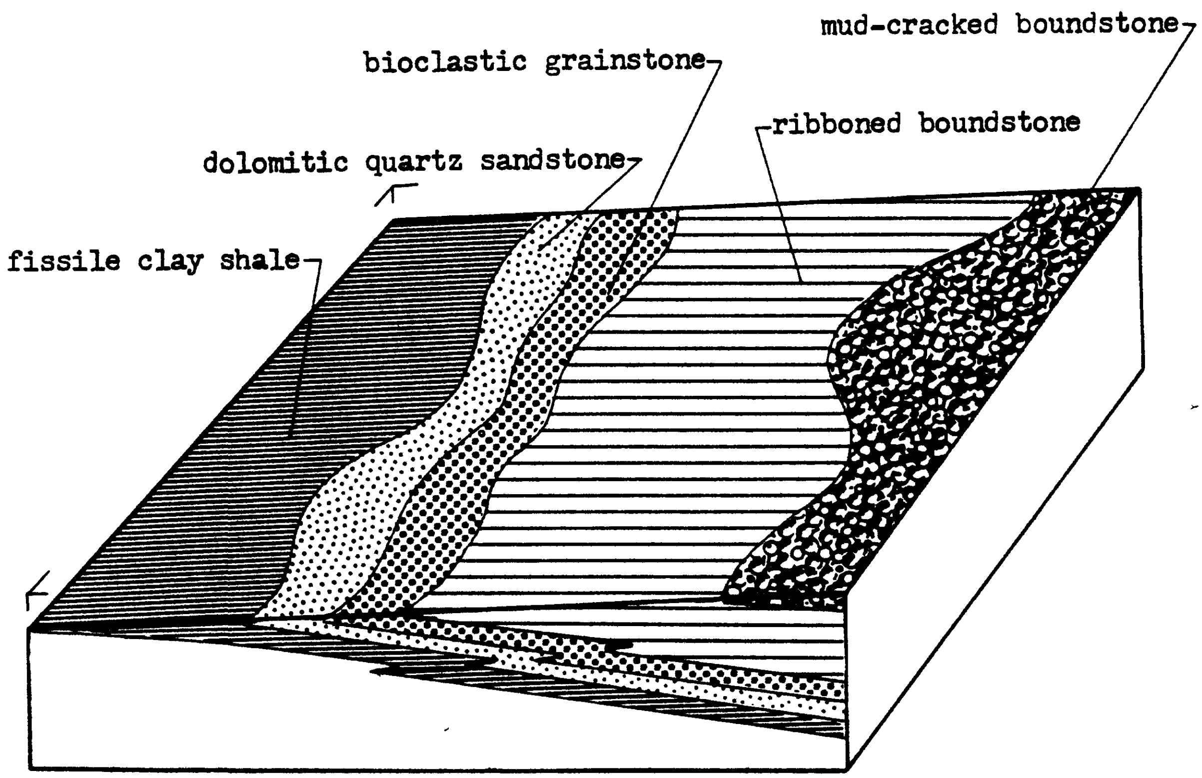
Stratigraphic Position--Throughout the Ruby Range this unit overlies sandy crystalline dolomite of the Pilgrim and underlies dolomitic quartz sandstone. An interpretation of lateral relationships is shown in Figure 14.

Dolomitic Quartz Sandstone--Dolomitic sandstone containing grains of glauconite and quartz of fine- to medium-sand size commonly occurs at the top of the Dry Creek Member. The grains are rounded and moderately to well-sorted. Many dolomite "chips" to 2 centimeters long are present locally.

Environment--This lithofacies is interpreted as subtidal to intertidal occurring in the shoreward part of the zone near the beach. Sorting by wave action is indicated by grain size, sorting, and composition. Absence of quartz from the underlying rocks and its fine grain-size in the overlying beds suggests transport of the grains along the beach and adjacent near shore area.

The few dolomite clasts present cannot have come from the underlying shale, indicating a lateral source, perhaps in the intertidal to supratidal area. This interpretation is supported by fine-grain size and algal laminations. Matrix dolomite of the sandstone is medium crystalline and may be recrystallized fossil fragments.

Stratigraphic Position--The dolomitic quartz sandstone unit occurs above fissile clay shale and beneath bioclastic grainstone. Suspected lateral facies patterns are shown in Figure 14.



NAME	ENVIRONMENT	LITHOLOGY	CHARACTERISTICS	THICK-NESS
Mud-cracked Boundstone	intertidal zone, upper part	dolomite	mud-chips overlapped by mat algae, reddish.	6 inches
Ribboned Boundstone	intertidal zone	dolomite, quartz sand	mat algae enveloping bioclastic grainstone, boudins common.	10-20 ft.
Bioclastic Grainstone	subtidal to intertidal zone	dolomite	ghosts of spines	2-4 ft.
Dolomitic Quartz Sandstone	subtidal to intertidal zone	dolomite, quartz sand	sandstone, commonly with mud chips	to 4 ft.
Fissile Clay Shale	subtidal zone	shale	green and red shale chips	5-8 ft.

Figure 14. Interpreted lateral relationships for fissile clay shale, dolomitic quartz sandstone, bioclastic grainstone, ribboned boundstone, and mud-cracked boundstone lithofacies, using Walther's Law (see text, p. 5).

Sage Member

Exposures of the Sage Member are commonly good, with the thickness ranging from about 110 to 150 feet north of McHessor Creek, being absent southward near Trout Creek. The lower contact is conformable, as previously noted, and the upper contact is unconformable below the Devonian Jefferson Formation. The Sage in the Ruby Range is easily divisible into distinct lower and upper parts, which are described separately below.

Sage Member, lower part

Bioclastic Grainstone--Composition of this lithofacies is dolomite (90-95%), quartz (5-10%), and glauconite (1-5%). Bedding ranges from thin to thick. Most of the dolomite occurs as a replacement of fragmented fossil material of which the only identifiable fragments are from trilobites. The dolomite is medium- to coarsely crystalline, the grain size ranging from 180 to 240 microns. Dolomite of this type also forms subrounded intraclasts, commonly of about one centimeter diameter, and making up 10 to 15 percent of the dolomite components.

The quartz and glauconite grains occur together in small disturbed areas that are probably burrows. Grain size of the two constituents ranges from 30 to 60 microns (coarse silt) for the quartz grains, 60 to 100 microns (very finely crystalline) for the dolomite fraction. The quartz is angular.

Environment--Sediments with characteristics similar to those described above are forming at present in Khor Al Bazam Lagoon of the Persian Gulf (Kendall and Skipwith, 1969, 1969a; Kinsman, 1969). The depositional environment is interpreted as the shoreward part of the subtidal zone, perhaps extending into the lower intertidal zone. The absence of finely crystalline dolomite and the presence of medium and coarsely crystalline dolomite may indicate this facies formed in a higher energy environment. The dominant uniformity of grain size may connote a uniform and continual sorting process. Another mechanism for breakdown of skeletal material is that of burrowing animals. However, recognizable burrows occur within the uniformly grained dolomite and are identified by the smaller size of dolomite crystals and by the introduction of quartz silt and glauconite. This suggests that the abundant larger grains are a product of physical parameters.

Stratigraphic Position--The unit overlies dolomitic quartz sandstone and underlies ribboned boundstone. Locally it occurs between units of ribboned boundstone. Figures 14 and 15 show the interpreted facies pattern.

<u>Ribboned Boundstone</u>--Dolomite (85-90%), quartz (10-15%), and glauconite (1-5%) make up the rock in this lithofacies (Plate 4, Fig. C), which is similar to that termed "ribboned" by Matter (1967). Most of the beds are made up of three parts: the upper and lower thirds of each bed consist of laminated stromatolitic dolomite,

with the middle third composed of crystalline dolomite or rarely dolomitic bioclastic grainstone. Medium crystallinity is characteristic of the dolomite, with the only identifiable fossil fragments being recrystallized spines. Commonly, small pieces of laminated sediment are contained within the crystalline dolomite.

Polished slabs of ribboned rock show that the bioclastic grainstone tends to become pinched off and form boudins between the laminated mat sediment. Conversely, the laminated sediment between the boudins may be "streaked off," forming wisps of laminated sediment (see Plate 4, Fig. D).

Quartz grains are concentrated along the stromatolitic laminae, although some grains (10-15%) are isolated in the coarser grained dolomite. The quartz weathers in relief on the outcrop face, thus making the laminae very prominent. Glauconite grains are also concentrated along the laminae. Both the quartz and glauconite grains are of silt size (30-60 microns), but the quarts is angular whereas the glauconite is rounded.

Environment--The bioclastic dolomite is interpreted as a deposit of the shoreward subtidal to lower intertidal environment (see section entitled Bioclastic Grainstone, p. 55). The algal laminated sediment is thought to represent the intertidal zone, as described for the Persian Gulf by Kendall and Skipwith (1968) and Kinsman (1969).

Alternating stromatolitic and fragmental layers characteristic of the ribboned rocks suggests that this facies represents an intertonguing of intertidal and intertidal to subtidal strata. The dominance of stomatolitic layers, however, indicates that the fragmental debris may have been derived from the subtidal zone and deposited in the intertidal zone. In either case, sedimentation was rhythmic.

The laminated part of the ribboned beds contain small angular pieces of laminated sediment within the bioclastic fragmental rock of the ribboned beds. The contact between sedimentation units of a bed thus reflects scour and reworking, with intraclasts of underlying material incorporated in the fragmental sediment. These data, therefore aid the interpretation of an intertidal origin for the ribboned beds, with derivation of fragmental material from the subtidal zone.

Burial must have occurred before either sediment type became lithified--at least both were still plastic. Boudins formed, probably due to differential compaction. "Streaking" of the stromatolitic sediment suggests it was less viscous than the fragmental sediment.

Stratigraphic Position--Ribboned boundstone is a common lithofacies unit in the Sage Member, typically overlying bioclastic grainstone and underlying mud-cracked boundstone. The interpreted facies pattern is shown in Figures 14 and 15.

Mud-Cracked Boundstone--Rock components in this lithofacies (Plate 4, Fig. E) are dolomite (90-95%) and quartz (5-10%). The dolomite is of medium crystallinity with grains ranging from 60 to 100 microns, except in burrows where it ranges from 100 to 240 microns. Quartz grains are of coarse silt size, range from 30 to

60 microns, are angular, and tend to form laminae.

Beds are commonly one-half to one centimeter thick and are composed of mat algae in the upper and lower parts, with chips of mud sandwiched in between. The chips are flat, strung out in discrete but discontinuous layers, and are parallel to continuous laminated mat algal layers. They are like the mud-cracked sediment in the laminated and ribboned strata pictured by Matter (1967, p. 604). In cross-section the cracks show nearly vertical walls, but seldom can the cracks be traced to the surface. This is due to overlap of the mud chips, and infilling of the cracks by mat algal sediment. The algal laminated sediment is thicker in the cracks than above the chips. This observation corresponds with that of Shinn (1968) who found modern examples of algal mats growing preferentially in, and accentuating, the mudcracks.

Environment--Many workers have described mud-cracked sediments from modern intertidal and supratidal flats. In the Red Lion of the Ruby Range this rock type occurs interbedded with non-mud-cracked ribbon strata thought to be of intertidal origin. Factors suggestive of a position transitional between the intratidal and supertidal zones are thinness and only local presence of the rock type.

Thinness is prominent in two ways: (1) The beds themselves are thin relative to those of the ribbony strata. This probably represents a lack of sediment, as the quantity of sediment would have been low during subaerial exposure. (2) The mat algae and chips which make up the thin beds show an intertonguing of intertidal sediment (mat algae) and desiccated sediment more typical of a supratidal environment (mud chips and cracks).

Stratigraphic Position—Mud-cracked boundstone occurs interbedded between units of ribboned boundstone. Figure 14 shows the interpreted lateral facies pattern.

Laminated Crystalline Dolomite--Composition of the rock (Plate 4, Fig. F) in this lithofacies is finely-crystalline dolomite (30-60 microns). Finely laminated pale yellowish brown beds 1 to 4 centimeters thick make up most of the rock, but medium gray and dark gray interlaminated layers occur locally in the lower part of the lithofacies. The unit intertongues with (intertidal) stromatolitic sediment in the uppermost part of the lithofacies. Burrows occur in the pale yellowish brown dolomite and uncommonly in the medium gray laminae; none were observed in the dark gray laminae.

Occurring locally in the upper part of this lithofacies unit are thin beds of bioclastic grainstone, separated by shaly laminae. These laminar zones are less than one-half centimeter thick and contain all of the well preserved brachiopods found in the Red Lion of the Ruby Range.

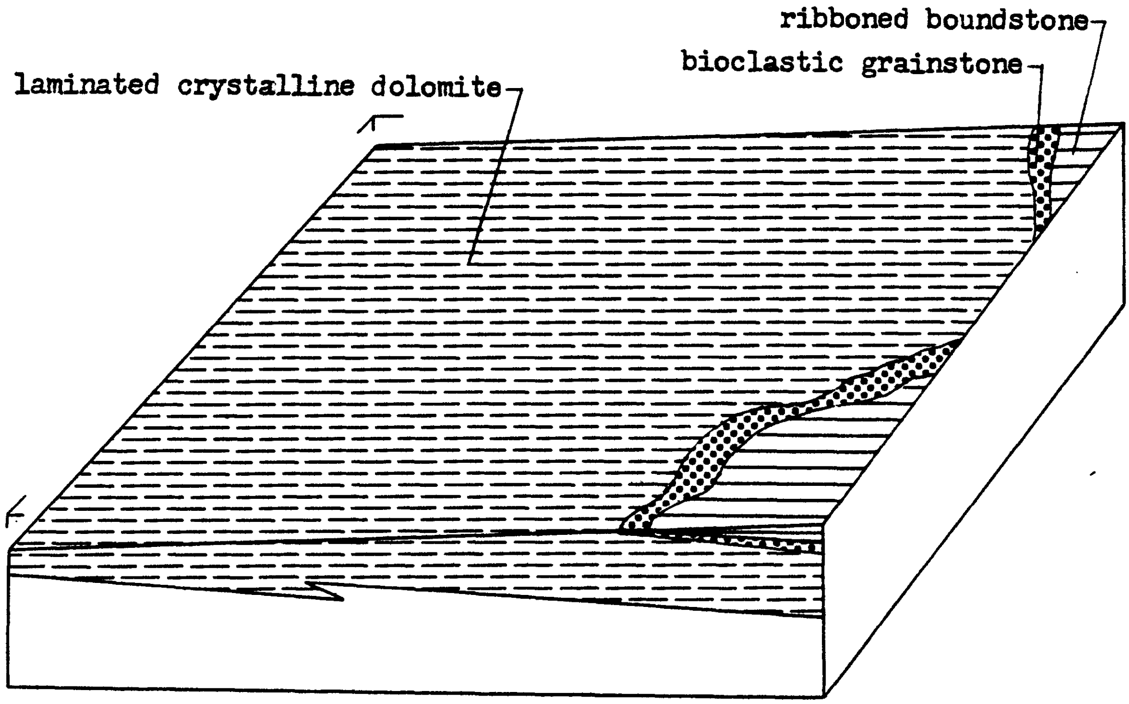
Environment--A subtidal origin is postulated for most of the rock in the unit. Conditions transitional from slightly oxidizing to slightly reducing are suggested for the interlaminated medium gray sparsely burrowed sediment and the dark gray undistubed layers in the lower part of the lithofacies. Characteristics suggesting deeper and/or quiet water deposition for the pale yellowish brown sediments include: (1) small grain size, which must have been even smaller before recrystallization to dolomite; (2) uniform grain size; (3) homogenerous composition; (4) thin and consistent laminae; and (5) similarity of the brown sediment and the gray sediment, except the former lacks the dark laminae.

The pale yellowish brown sediment probably formed shoreward of the gray sediment, or at least in a less restricted environment. Evidence for this is (a) a lack of dark laminae, (b) a slight thickening of individual laminae, and (c) intertonguing of the sediment with intertidal mat algal rocks. The bioclastic rocks are probably of the upper subtidal to intertidal zone.

Stratigraphic Position--The lower contact of this unit is commonly concealed, the covered interval occurring above ribboned boundstone. The unit underlies thin-bedded boundstone of the upper part of the Sage Member of the Red Lion. Figure 15 shows the interpreted facies pattern.

Sage Member, upper part

The upper part of the Sage Member is easily distinguished from the underlying part by its light gray color and more intense dolomitization. The unit is composed of a variety of stromatolite forms in an area north of McHessor Creek (secs. 13 and 18, T. 6 S., R. 5 W.). The algal structures form thin laminated beds (termed thin-bedded boundstone), small columns in broad, low 6 to 18 inch thick beds (termed dome-shaped boundstone), and columnar stromatolites (termed



NAME	ENVIRONMENT	LITHOLOGY	CHARACTERISTICS	THICK-NESS
Ribboned Boundstone	intertidal	dolomite and quartz sand	mat algae enveloping bioclastic grainstone, boudins common	1-3 ft.
Bioclastic Grainstone	intertidal	dolomite	ghosts of spines	½-1 ft.
Laminated Crystalline Dolomite	subtidal	dolomite	commonly finely laminated	12-15 ft.

Figure 15. Interpreted lateral relationships for laminated crystalline dolomite, bioclastic grainstone, and ribboned boundstone lithofacies, using Walther's Law (see text, p. 5).

columnar boundstone). Elsewhere the unit is thin- to thick-bedded, dense featureless dolomite. Interpreted lateral facies relations for the upper part of the Sage Member are shown in Figure 16.

Thin-bedded Boundstone--Thin beds of laminated dolomite make up most of the upper part of the Sage. Adjacent to the dome-shaped mounds the beds dip beneath them, are draped over them, or sharply abut the structures (Plate 5, Fig. A). Thickness of these beds ranges from 1 to 4 centimeters, with most beds showing very faint lamination. The upper one-third of some otherwise evenly laminated beds show wavy laminae that are flexed over pellets or small intraclasts. These same laminae are locally distubed by small dolomite-filled burrows that are reflected by casts of worm-like trails on the bedding surface (Plate 5, Fig. B).

Environment--Sediment with the characteristics of this lithofacies is forming today in the upper part of the intertidal zone in the Bahamas west of Andros Island (Black, 1933; many subsequent authors), in Shark Bay, Australia (Logan, 1961), and in the Persian Gulf (Kendall and Skipwith, 1968, 1969, 1969a). All of these existing depositional sites have in common a protected lagoonal or bay environment where the upper intertidal flats are characterized by a firm, smooth or slightly undulatory algal mat surface. In some places desiccation polygons are present in the zone but not everywhere; none were found in the upper part of the Sage. Perhaps the mats of the Sage remained moist.

Draping of the thin-bedded strata over algal mounds is suggestive of differential compaction. Draping can only partly be explained by compaction, however, because individual beds are not much thinner above a stromatolite mound than lateral to it. More probable, the dips displayed by the beds are largely initial, resulting from sediment-binding mat algae overlapping the stromatolitic domes.

Kendall and Skipwith (1968) found this form of mat established in intertidal areas where moderately high energy conditions prevail. This observation is significant to the present interpretation because the thin-bedded boundstone is the initial deposit in the stromatolitic sequence of the upper part of the Sage Member.

<u>Medium-bedded Boundstone</u>--These beds (Plate 5, Fig. C) range from 6 to 18 inches thick, commonly extend laterally more than 100 feet, and may have a thin unit of pebble conglomerate grainstone at the base. The few stromatolites preserved in the beds are small columnar-shaped structures that range from 2 to 4 inches wide at the base to 4 to 8 inches high. The columns are separate and contain dolomite grains of 30 to 60 microns diameter; intercolumn dolomite is commonly of 30 to 60 micron size, but is locally 100 to 200 microns. Columns may become laterally linked at some level, with subsequent development of a second layer of stacked hemispheroids.

Environment--This type of stromatolite is similar to that described by Kendall and Skipwith (1968) as occurring in the inner part of their Cinder Zone, the most seaward zone of stromatolites in

PLATE 5

Figure A. Thin-bedded boundstone, overlapping dome-shaped boundstone (upper part of Sage Member of Red Lion Formation).

Figure B. Worm-like casts on bottom of bed of thin-bedded boundstone, upper part of Sage Member of Red Lion Formation. Pen is 5½ inches long.

Figure C. Medium-bedded boundstone, overlain by thin-bedded boundstone (upper part of Sage Member of Red Lion Formation).

Figure D. x 3½. "Spongy" fabric (Aitken, 1967) in stromatolite (dark areas).

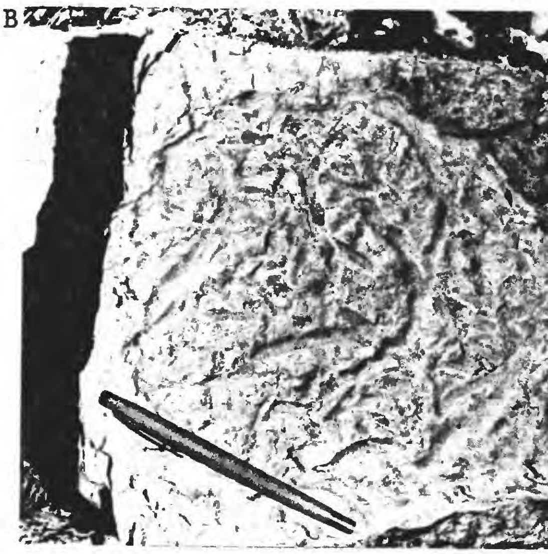
Figure E. Columnar stromatolite (outlined) in columnar boundstone of upper part of Sage Member of Red Lion Formation. Stromatolite is about 5 feet high.

Figure F. Columnar stromatolites (outlined) "stacked" atop one another, in columnar boundstone lithofacies of upper part of Sage Member of Red Lion Formation.

PLATE 5

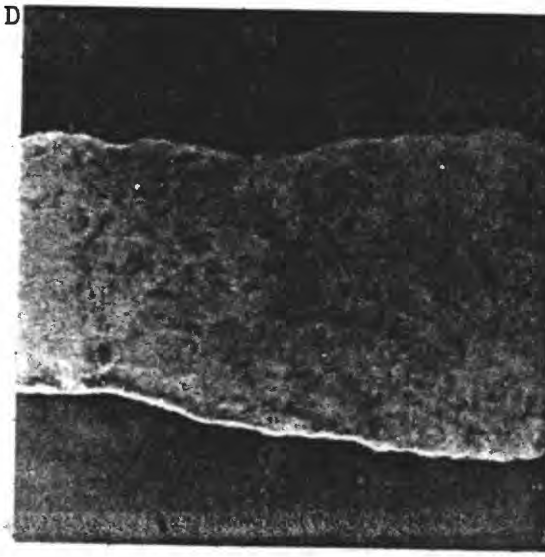
A

B



C

D



E

F

the intertidal flat of the Khor Al Bazam, Persian Gulf. They described algal colonies 20 to 50 centimeters high which coalesce to form wave resistant structures. No replicas of this type were described by Logan (1961) for Shark Bay, although it would seem to fit between his zones of algal flat and low, domed stromatolites.

The stromatolites of this facies are apparently a modification of the flat algal laminated sediment, formed by successive layers deposited on a single raised hemispheroid that persisted with deposition. The height of individual stromatolites would seemingly require support while forming. Subaerial exposure would greatly aid lithification and thus increase strength, but deposition of intercolumn sediment concurrent with upward growth of the structures may also have taken place and given support.

<u>Dome-shaped Boundstone</u>--Dome-shaped mounds of boundstone (Plate 5, Fig. A) of the Sage Member measure 1 to 2 feet high and 2 to 4 feet wide, with dolomite pebble conglomerate grainstone at the base. The mounds are mainly composed of stromatolites make of concentrically stacked hemispheroids, although other types of stacking may be present and obscured by dolomitization. Stromatolitic columns contain dolomite of 30 to 60 micron grain size, with a few intraclasts to 4 millimeters in diameter trapped between laminae.

Some of the intercolumnar rock has a "spongy" fabric (Plate 5, Fig. D) composed of non-laminated oval-shaped structures. The structures are 1 to 3 millimeters long and are composed of 30 to 60 micron grains of dolomite, in a dolomite matrix of grains 100 to 120 microns in diameter. A few rounded intraclasts of 30 to 60 micron size dolomite and up to 5 millimeters across are also part of the spongy fabric.

Environment--The dome-shaped mounds may be similar to the low-domed stromatolites of Logan (1961). He found them in the landward part of the intertidal zone and interspersed with broad flats of algal laminated sediments. However, the Sage mounds are not sinuous like those in Shark Bay. Gebelein (1969) has shown that the more cylindrical or uniform stromatolites are indicative of greater water velocities than are irregular shaped ones. Thus the stromatolites of the Sage Member are thought to have formed in the seaward part of the intertidal zone.

The domal stromatolites appear to be modifications of the small columnar stromatolites previously described. Stromatolite type is the same or similar, but occurrence in mounds again suggests modification of the physical environment. As interpreted by Logan (1961), the domes were formed by differentation of an originally continuous mat into domes and depressions. As relief increased the environment became unstable for the mat--possibly due to increased current velocity--resulting in mat only on the highs.

Spongy fabric (Aitken, 1967) in the mounds occurs adjacent to individual stromatolites or between closely spaced ones. It appears to be formed of a few intraclasts and pieces of algal mat that are attached to the stromatolite but have one end free; these constituents became embedded in the intercolumn sediment. Kendall and Skipwith (1968) attributed spongy fabric to forcing of trapped air through algal mats by rising tides. Subsequently, sediment filled the air pockets.

Columnar Boundstone--Columnar boundstone stromatolites are 4 to 5 feet high, 1 to 2 feet across, and are of smaller diameter at the base than upward. The form is discrete, composed of vertically stacked hemispheroids in which the upper laminae do not reach the base of the preceeding ones, shown in the photograph of Plate 5, Figure E. At one place columnar stromatolites are stacked one atop another (Plate 5, Fig. F).

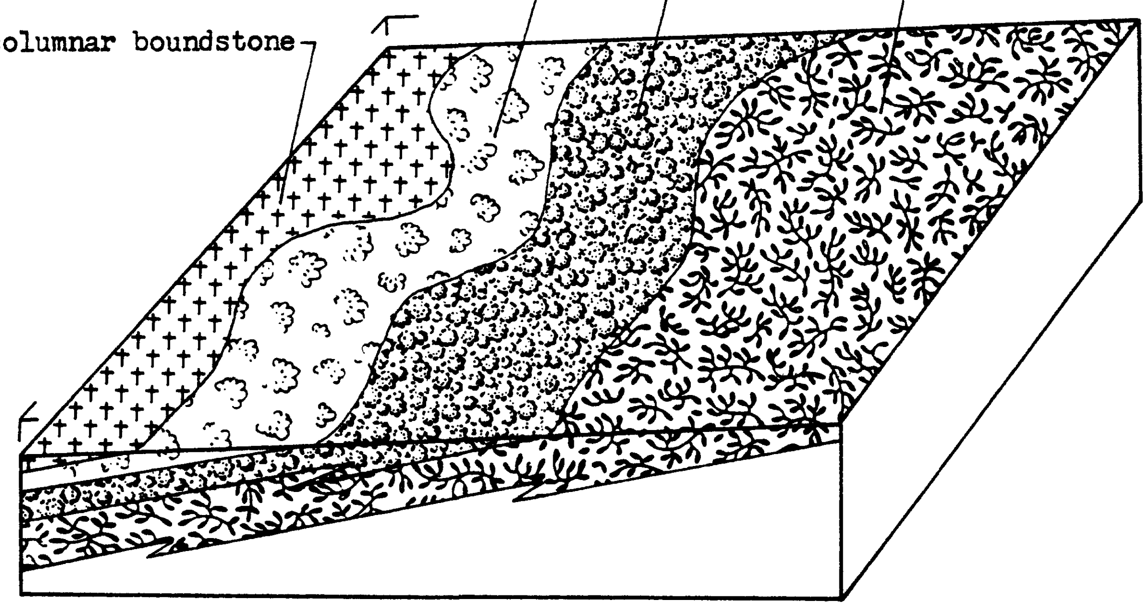
The stromatolites are severely dolomitized and the preserved features are only faintly evident. However, thin sections show a clotted fabric composed of rounded intraclasts to 1.5 millimeters in diameter and angular clots to 4 millimeters across. Grain size of the clasts averages about 40 microns, whereas the matrix grain size is commonly about 60 microns. Differential weathering and a mottled pattern represent the surface expression of the clotted fabric.

A pebble conglomerate grainstone typically occurs at the base of columnar stromatolites (Logan, 1961; Aitken, 1967), but none was observed in the Ruby Range. Dolomitization and weathering could easily have obscured this feature if originally present, however.

Environment--The stromatolitic structures of this facies are analogous to those called <u>Cryptzoon</u> by Logan (1961), and found in the seawardmost part of the intertidal zone off headlands in Shark Bay. Kendall and Skipwith (1968) similarily located this type in the southwest Persian Gulf, and they cite Monty (1965) as noting them to a depth of 2 meters in the subtidal environment east of Andros Island, Bahamas.

The cylindrical shape (plan view) of the columns, the greater amount and larger size of clastic debris as compared to that in other stromatolites of the Sage Member, and their spatial position relative to other stromatolites are all in accord with formation of the columnar stromatolites in a more turbulent environment than other types. The enveloping and intercolumn thin beds, however, are like those described earlier and must have been deposited after formation of the columns. Stacking of columnar stromatolites requires lithification before superposition of subsequent layers of stromatolites. Thus lithification could easily have preceeded formation of intercolumn and enveloping strata.

Dolomitization has made structures vague and this necessarily limits interpretation. However, a clotted fabric similar to that described by Aitken (1967) for thrombolitic structures was observed in thin-section in part of the columnar stromatolites. The clots must reflect a pre-dolomite grain size different from that of the more coarsely grained and intraclastic "matrix." But it could not be determined if the clot-forming bodies are intraclasts or localized algal growths. No laminae were observed within or around the clots,



NAME	ENVIRONMENT	LITHOLOGY	CHARACTERISTICS	THICK-NESS
Columnar Boundstone	intertidal zone	dolomite	columns of stromatolites to 5 feet high, 1 to 2 feet across	4-5 ft.
Dome--shaped Boundstone	intertidal zone	dolomite	mounds to 2 feet high and 4 feet wide. Contain stromatolites	2 ft.
Medium-bedded Boundstone	intertidal zone	dolomite	6 to 18 inch-thick beds to 100 feet long, contain stromatolites	½-1½ ft.
Thin-bedded Boundstone	intertidal zone	dolomite	thinly bedded, laminated	to 20 ft.

Figure 16. Interpreted lateral relationships for thin-bedded boundstone, medium-bedded boundstone, mound-shaped boundstone, and columnar boundstone lithofacies, using Walther's Law (see text, p. 5).

but it seems some binding agent was necessary to retain the structures in the stromatolite; if the agent was not mucilaginous algae, then perhaps it was subaerial exposure and cementation by calcium carbonate.

Pebble Conglomerate Grainstone--Dolomite conglomerate grainstone occurs beneath stromatolitic structures. Pebbles range to 40 millimeters across, are rounded, and are typically disc- or oval-shaped. Orientation of most clasts is at a small angle to bedding, but some exhibit a high angle. Fine lamination is characteristic of the pebbles and grain size is in the 30 to 60 micron range.

A few of the pebbles (less than 2%) have a pin-size hole through them surrounded by a mottle of about 2 millimeters diameter. Others may have similar mottle but lack the hole. Grant (1965) and Dorf and Lochman (1940) noted the association of this "peculiar" type of pebble with a matrix containing pelmatozoans, but I did not find any pelmatozoans.

Rock in between the pebbles consists of coarse sand size and granule size subangular to subrounded dolomite intraclasts in a matrix of dolomite. Grain size in the clasts ranges from 30 to 60 microns, whereas that of the matrix ranges from 10 to 200 microns.

Environment--The dolomite pebble conglomerate grainstone was probably derived from ripped-up mat algal sediments. The clasts are lithologically like the thin-bedded boundstone and their sorting is poor, suggesting local derivation. In addition, the clasts must have been somewhat plastic when deposited as some pebbles are embayed along their contacts with other pebbles. Commonly, pebble conglomerates were observed in the upper part of the Sage.

Pebbles cannot be considered abundant in the upper part of the Sage but they are very important as they seem to be a prerequisite for growth of vertical stromatolites. That the pebbles are more common beneath medium-bedded boundstone suggests that the pebbles there were closer to their source. Pebbles in the domal and columnar boundstone are fewer but better sorted; this may suggest a greater distance from the source and some sorting. Perhaps the pebbles were formed during higher than normal tides or during storms.

Age--Fossils from the Red Lion obtained from the SW¼SE¼ sec. 18, T. 6 S., R. 5 W., were identified by A. R. Palmer (written communications, 1968; 1970). Fossils collected about 75 feet above the base of the Red Lion include the brachiopod *Billingsella* and the trilobite *Taenicephalus*. An indeterminate conaspid trilobite was collected from near the top of the formation. The fossils are of Late Cambrian (Franconian) age (see Fig. 3).

Regional Correlation--The *Billingsella* and *Taenicephalus* fossils are common in the Sage Member throughout western and southern Montana. Few conaspid trilobites have been reported in Montana but those reported must correlate with the *Taenicephalus* Zone of Grant (1965), which in southern Montana is equivalent to part of the *Conaspis* Zone of the Cambrian Correlation Chart (see Howell and others, 1942). The *Taenicephalus* Zone is the most populous zone of the Sage Member in southwestern Montana and in northwestern Wyoming (Grant, 1965). In addition, the overlying Idahoia Zone of the Franconian Stage is also confined to the Sage Member (Grant, 1965). The above data are emphasized because the unit in the upper part of the Sage Member in the Ruby Range that contains the conaspid trilobite has similarities with the Grove Creek as described by Dorf and Lochman (1940) and Grant (1965). The unit is assigned to the Sage Member, however, because of the very widespread and near uniform thickness of Upper Cambrian rock units in Montana and adjacent areas and their common parallelism to fossil zones.

DISCUSSION

Thickness--Thicknesses of the Cambrian formations at different places in the Ruby Range are shown in the cross-section of Figure 17. The total thickness of Cambrian strata in the McHessor Creek section is about 1650 feet, in contrast with about 1250 feet in the Laurin Canyon section. The difference is apparently not related to post-Cambrian removal of sediments from the area of the Laurin Canyon section because individual formations and members are present but thinner there.

The Meagher is about 750 feet thick in the McHessor Creek section and about 550 feet in the Laurin Canyon section. The thicker section includes in its uppermost part a lithofacies not otherwise present at either locality. Strata below the upper Pilgrim unit and above the Park Shale are about 300 feet thick at Laurin Canyon, but poor exposures preclude determination of the stratigraphic level of thinned or "missing" rocks. The Sage Member of the Red Lion is about 150 feet thick at McHessor Creek and about 100 feet thick at Laurin Canyon. The lithofacies units in the Laurin Canyon section are commonly thinner than the correlatable ones in the Red Lion at McHessor Creek and a similar relationship was noted for the lithofacies units of the upper part of the Pilgrim. The data seem to indicate continued slow uplift for the area of the Laurin Canyon section.

A major fault now exists between the Laurin Canyon and McHessor Creek sections and possibly was active during Cambrian deposition. If so, it would be a growth fault--a fault across which correlative strata show a thickening on the downthrown side (Dennis, 1967). All of the Cambrian formations attain their greatest thicknesses in the McHessor Creek section near this fault. Conversely, their average thicknesses are between the two extremes, but are closer to the maximum. Thus the reatest thickness contrast occurs across the fault in sections only 2 miles distant; hence the supposition that the fault may have been active during Cambrian time.

A growth fault could not, however, account for all of the thickness change, the general tendency of all Cambrian formations toward the maximum thickness arguing against it. The growth fault concept may account for the stromatolite buildup being located in the McHessor Creek section of the Red Lion Formation, as organic buildups

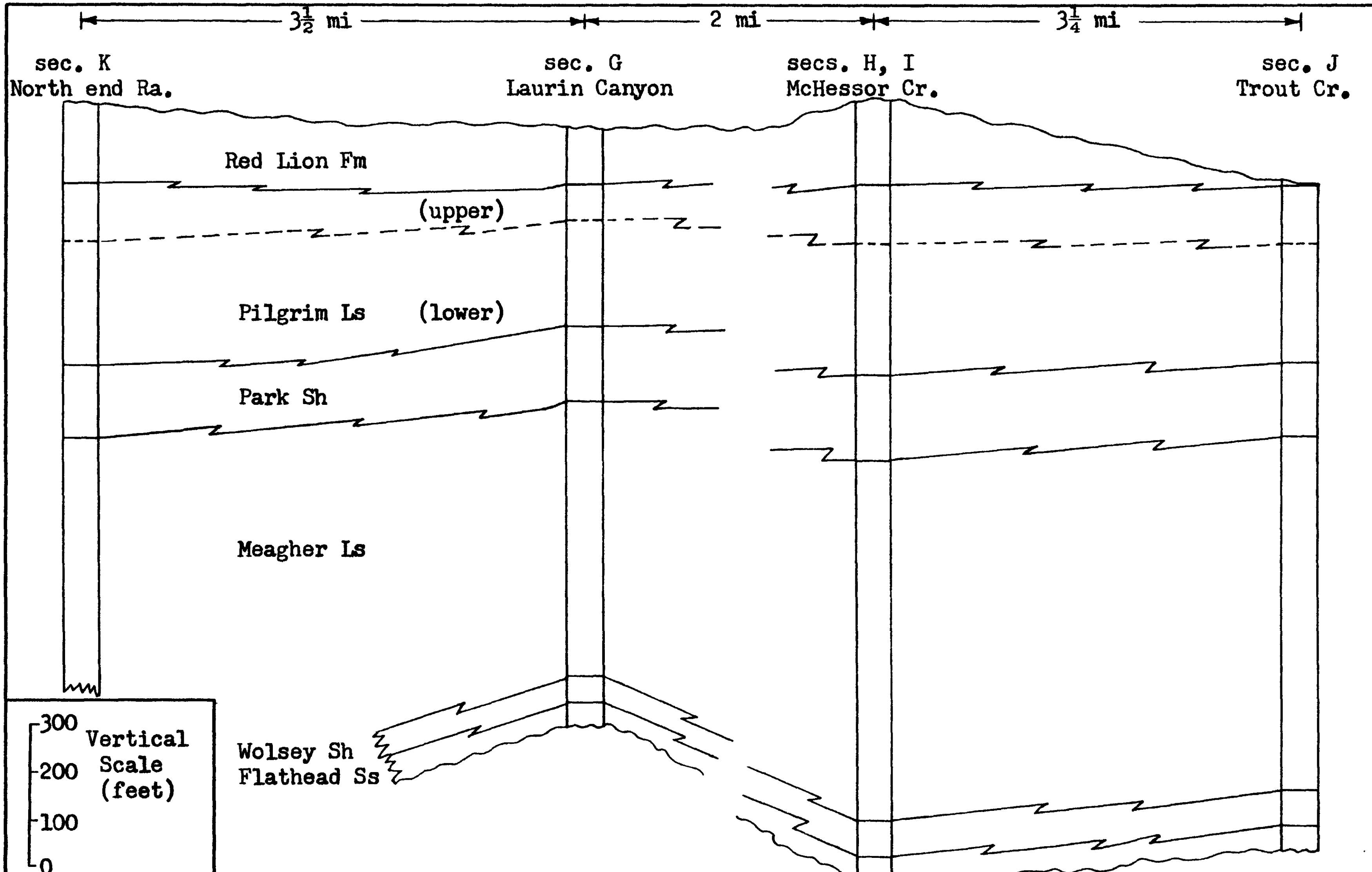


Figure 17. Northerly trending cross-section of Cambrian formations. Dashed contact divides Pilgrim Limestone into members. Broken contact between secs. G and H, I, indicate possible presence of Cambrian growth fault (see text, p. 73). Location of sections are shown in Appendix.

in the geologic record are locally found along active faults.

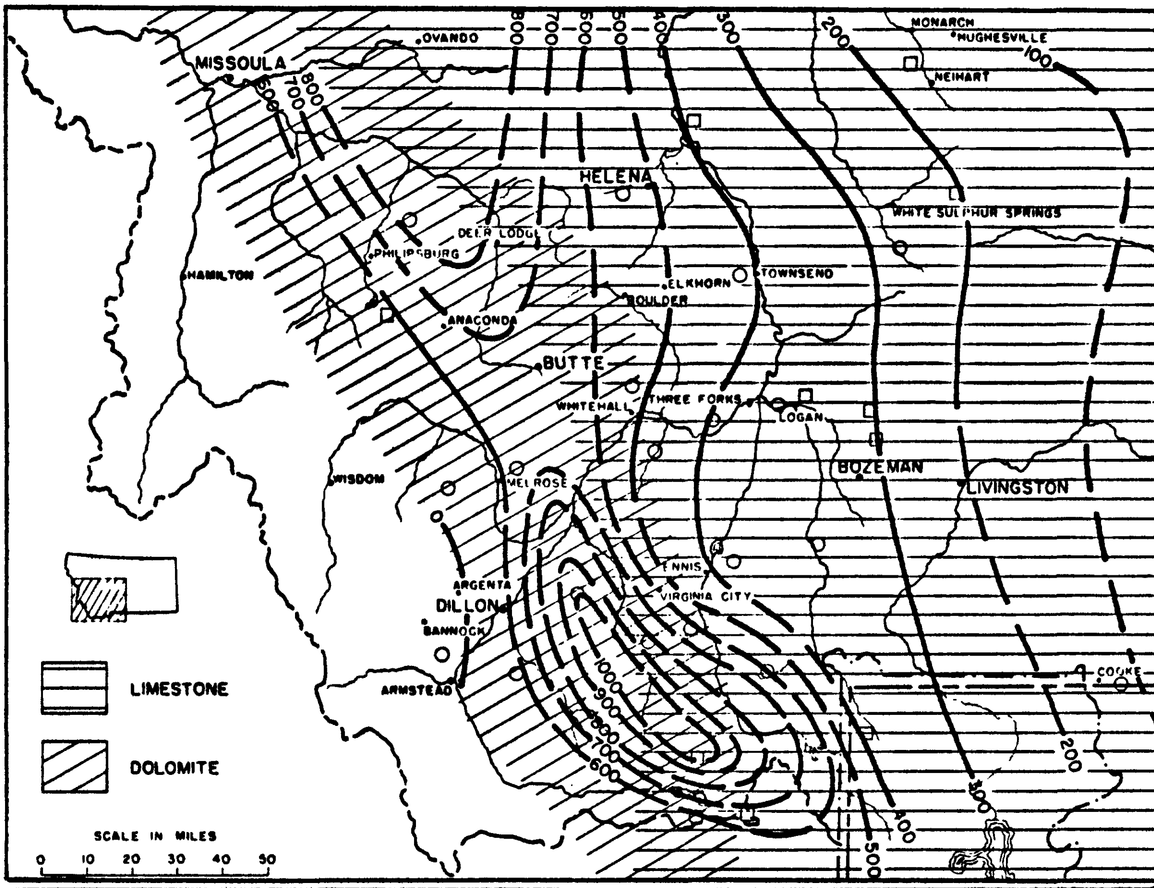
An isopach map of the Cambrian system constructed by Hanson (1952) and shown here in Figure 18, delineates an isopach thick in southwestern Montana, its center near the Ruby Range. Part of this isopach basin results from the 1000 feet of Meagher measured by Hanson at McHessor Creek, as illustrated in Hanson's Meagher isopach map shown here in Figure 19. Structural complications invalidate his measurement--750 feet is the maximum Meagher present, with an average range of 675 to 700 feet being more common. Thus a downward revision in thickness largely eliminates the basin shown for the Meagher and reduces that shown for the total Cambrian isopach map to 1500 feet. Thus a slight thickening is still evident for the Ruby Range area but an unpublished isopach map of Christina L. Balk suggests that it may be only the northern marginal part of a slight thickening which extends southeastward.

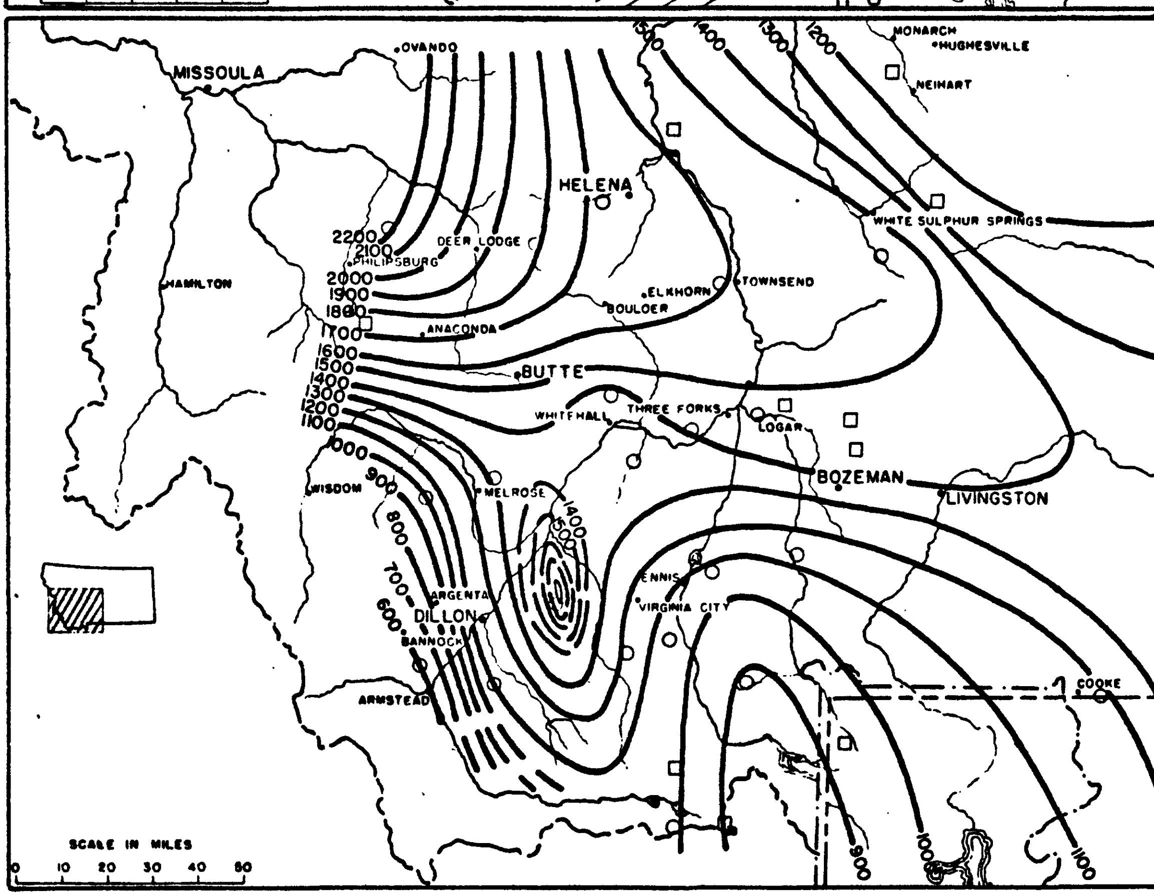
Dolomitization--Dolomitization of the Cambrian rocks is part of a regional problem in that Cambrian dolomite is common in offshelf (miogeosynclinal) areas of southwestern Montana and central Idaho, whereas limestone characteristizes the shelf strata. Although the Ruby Range is in the shelf province, it is near the miogeosyncline and contains both limestone and dolomite.

The entire Cambrian carbonate sequence in the Ruby Range has been dolomitized except for part of the Meagher. In the McHessor Creek drainage and southwestward the Meagher is all dolomite, but northeastward it contains limestone and dolomite. Thin-section

Figure 18. Isopach map of the Meagher Limestone in southwestern Montana (after Hanson, 1952).

Figure 19. Isopach map of the Cambrian system in southwestern Montana (after Hanson, 1952).


MISSOULA
OVANDO
MONARCH
HUGHESVILLE
NEIHART
HELENA
DEER LODGE
PHILIPSBURG
HAMILTON
ELKHORN
TOWNSEND
BOULDER
ANACONDA
BUTTE
WHITE SULPHUR SPRINGS
WHITEHALL
THREE FORKS
LOGAN
BOZEMAN
LIVINGSTON
WISDOM
MELROSE
ENNIS
VIRGINIA CITY
ARGENTA
DILLON
BANNOCK
ARMSTEAD
COOKE
LIMESTONE
DOLOMITE
SCALE IN MILES
0 10 20 30 40 50


MISSOULA
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BOULDER
ANACONDA
BUTTE
WHITE SULPHUR SPRINGS
WHITEHALL
THREE FORKS
LOGAN
BOZEMAN
LIVINGSTON
WISDOM
MELROSE
ENNIS
VIRGINIA CITY
ARGENTA
DILLON
BANNOCK
ARMSTEAD
COOKE
SCALE IN MILES
0 10 20 30 40 50

studies show dolomitized rock in areas dominantly of limestone are (1) oolitic, (2) intraclastic, or (3) mottles in yellowish mottled lime mudstone. Thus original porosity appears to have been a control in transitional areas of dolomite into limestone. But where the Meagher is completely dolomitized porosity cannot have been the control as the dolomitized sequences of rock contain lithofacies units that are equivalent to those of wholly limestone sequences and the latter include lime mudstones that probably had little original porosity. Also, structural weaknesses are not followed, thus are not controls.

Lebauer (1965) on the other hand, stated that dolomite in transitional areas is "...restricted to the lower and upper thin-bedded, fine-grained units." Furthermore, Hanson (1951) described interbedded limestone and dolomite, both of which contain oolites and mottled strata with "...the dolomite apparently not showing any preference to layers of a particular textural type." The foregoing observations on dolomite distribution in transitional areas are all different, but they may all be valid. A regional study of the dolomite is pertinent, as the local distribution must be related to the regional pattern.

DEVONIAN

JEFFERSON FORMATION

The Jefferson Formation is a distinctive, cyclically bedded unit commonly occurring in good exposures. Its thickness ranges between 250 and 268 feet, being thinnest in the southern part of the map area. The contact with the underlying Cambrian strata is disconformable, whereas the upper contact is apparently conformable. Two members are present--a lower unnamed one and the overlying Birdbear Member.

Lower member

Rocks of the lower member are mostly pale yellowish brown dolomite with a very few beds being slightly calcareous. Outcrops are marked by repetition of three main rock types: (1) silty and sandy (quartz) shaly dolomitic beds, termed detrital units by Benson (1966); (2) rubbly weathering dolomite breccia beds, probably evaportie solution breccias; and (3) medium- and thick-bedded dense or sucrosic dolomite beds.

Discussion--Wilson (1955) described cycles of the Jefferson in northwestern Montana and noted a sequence in which ideally unit 1 (above) occurred at the top and units 2 and 3 successively below, except that unit 3 consisted of massive sucrosic dolomite in the upper part and dense limestone in the lower part. With later detailed study of equivalent rocks in eastern Montana, Wilson (1967) noted that the clastic content increased near the Jefferson (Duperow) depositional margin in southeastern Montana and adjacent Wyoming. In addition, the limestone beds, which he interpreted as open marine deposits, were not common; but the sucrosic dolomite and evaporite units, interpreted as restricted marine deposits, intertongued with clastics. The ideal cycle is uncommon in southeastern Montana and adjacent Wyoming.

Wilson's ideal cycle was not recognized in the Ruby Range and limited thin-section studies failed to establish if the strata are correlatable with Wilson's (1967) "restricted marine carbonates." Much of the uncertainity is due to intense dolomitization of the rocks and the absence of equivalent limestone strata for comparison, but also because there are no data on the Jefferson between the two areas to facilitate reliable correlation. Furthermore, the Ruby Range is 50 miles north of the Tendoy Dome (Scholten, 1957; Lemhi Arch of Sloss, 1954) and the effect of this feature on carbonate sedimentation patterns is unknown, other than on the thicknesses.

Birdbear Member

The Birdbear Member overlies the uppermost detrital unit of the lower member and ranges from about 55 to 65 feet thick. The basal 9 to 12 feet of the unit is thin-bedded dolomite, whereas the remainder is a massive ledge-forming dolomite breccia--a probable evaporite solution breccia.

Age--Except for Amphipora, fossils were not found in the Jefferson. The age of the formation is considered Late Devonian on the basis of correlation with the Jefferson of the Three Forks area (Robinson, 1963).

THREE FORKS FORMATION

Poor exposures characterize the Three Forks Formation, except for a middle limestone unit that serves as a stratigraphic marker. In the one good exposure in the range (SW¼NW¼ sec. 28, T. 5 S., R. 5 W.), the formation is about 150 feet thick. The lower contact is apparently conformable with the Jefferson and the upper contact is everywhere concealed.

Sandberg (1965) divided the type section of the Three Forks Formation (near Logan, Montana) into three members, which in ascending order are: (1) Logan Gulch Member, 111 feet thick and dominantly composed of evaporite solution breccia; (2) Trident Member, 73 feet thick and composed of clay shale with a 9 foot-thick limestone unit at the top; and (3) Sappington Member, 57 feet thick and dominantly siltstone. In the Ruby Range the Logan Gulch Member is about 110 feet thick. The lower part consists mainly of dolomite (evaporite) breccia that is locally interbedded with green clay shale; the upper part is about 50 feet thick, consisting of ledge-forming thin-bedded limestone. The Trident Member is largely olive green clay shale and is about 25 feet thick. The Sappington Member is about 15 feet thick. It is commonly covered but the lower few feet are composed of thin-bedded siltstone where the section was measured.

The above correlations need further investigation because, although the rocks physically correlate with the type section as measured by Sandberg (1965), the fossils collected from the ledge-forming limestone of the Logan Gulch Member (listed below) were thought by J. T. Dutro, Jr., to be from the Trident Member (see below).

Age--The faunal elements listed below are from the Logan Gulch Member in SE¼SW¼NW¼ sec. 28, T. 5 S., R. 5 W., and are of Late Devonian age, probable middle Famennian (J. T. Dutro, Jr., written communication, 1968). The fossils are:

Schuchertella sp.

"*Camarotochia*" sp.

Crytospirifer monticola (Haynes)

Crytospirifer sp.

Cyrtiopsis? sp.

Cleiothyridina devonica Raymond

MISSISSIPPIAN

LODGEPOLE LIMESTONE

Good exposures of the Lodgepole are displayed on ridge crests near the northeast flank of the range, the formation measuring 600 feet in thickness. The basal contact is everywhere concealed but the upper contact is conformable with the Mission Canyon and was placed at the base of the first ledge-forming outcrop. This also marks a change from medium and thick, distinct beds to thicker (greater than 2 feet) but less distinct beds.

Much of the lower 300 feet is made up of 6 to 12 centimeter beds of laminated limestone, the laminae weathering into "books" of one millimeter thick "pages." The rock weathers pale to dark yellowish brown, but appears dark gray on fresh exposures.

Silty, pelletal packstone is the main rock type, with limited studies showing the pellets making up 40 to 70 percent of a sample. Pelletal diameters range between at least 15 and 60 microns, with the range for any particular sample commonly less. Medium-and coarse-grain size (20-50 microns) characterize the silt fraction, which is mainly quartz. Its percentage range is typically 1 to 10, but may be more. The matrix is largely lime mudstone but it also contains a few percent recrystallized comminuted fossil debris, some of which is siliceous (spines?).

The upper strata were not observed in thin-section, but field sampling shows they are partly clastic limestones with a few chert nodules and stringers present. The beds are medium and thick and are separated by thin silty, shaly laminae. Contact with the underlying is transitional, thus arbitrary.

Age--The faunas listed below are of Early Mississippian age, and were identified by J. T. Dutro, Jr. (written communication, 1968). They are from a measured section (see Appendix) on the ridge crest north of Robinson Canyon.

1. From about 120 feet above the base:

   Retichonetes cf. *R. logani* (Norwood and Pratten)

   Rugosochonetes cf. *R. loganesis* (Hall and Whitfield)

   Unispirifer sp. (small)

   Eumetria? sp.

   productid brachiopod, indet.

2. From about 215 feet above the base:

   echinoderm debris, indet.

   Sulcoretopora sp.

   Ptilopora sp.

   bryozoans, indet.

   Rugosochonetes cf. *R. loganesis* (Hall and Whitfield)

   productid, undet. (large)

   Spirifer cf. *S. gregeri* Weller

   Cleiothyridina cf. *C. tenuilineata* (Rowley)

   Punctospirifer cf. *P. solidirostris* (White)

3. From about 275 feet above the base:

    Spirifer cf. _S_. _gregeri_ Weller

    syringothyroid, indet.

4. From about 320 feet above the base:

    Sulcoretopora sp.

    fenestrate and ramose bryozoans, indet.

    productoid, indet.

    Unispirifer? sp.

    Actinochonchus sp.

5. From about 350 feet above the base:

    echinoderm debris, indet.

    Rhipidomella sp.

    Axiodeania? sp.

    Unispirifer sp.

    Composita sp.

    Cleiothyridina cf. _C_. _obmaxima_ (McChesney)

6. From about 370 feet above the base:

    echinoderm debris, indet.

    horn coral, indet.

    worm tubes and burrows, indet.

    productoid, undet.

    Unispirifer sp..

    Composita sp.

7. From about 480 feet above the base:

    echinoderm debris, indet.

    Platycrinites sp. (columnals)

    Schuchertella? sp.

    Retichonetes cf. *R. loganensis* (Hall and Whitfield)

    Unispirifer sp.

    Composita sp.

    Cleiothyridina cf. *C. tenuileneata* (Rowley)

    Punctospirifer cf. *P. solidirostris* (White)

8. From about 490 feet above the base:

    echinoderm debris, indet.

    Platycrinites sp. (columnals)

    horn coral, indet.

    Schuchertella? sp.

    Straparollid gastropod, indet.

9. From about 500 feet above the base:

    fenestrate bryozoans, indet.

    rhynchonellid brachiopods, indet.

    productoid brachiopod, undet.

    Conularia? sp.

10. From about 510 feet above the base:

    echinoderm debris, indet.

    Leptagonia cf. *L. analoga*

    Schuchertella sp. (small)

Composita sp.

Ambocoelia? sp.

11. From about 530 feet above the base:

echinoderm debris, indet.

Schuchertella? sp.

Retichonetes cf. *R. logani* (Norwood and Pratten)

Unispirifer sp. (small)

Straparollid gastropod, indet.

12. From about 550 feet above the base:

echinoderm debris, indet.

Platycrinites sp. (columnals)

fenestrate bryozoans, indet.

Schuchertella? sp.

Retichonetes cf. *R. logani* (Norwood and Pratten)

Rugosochonetes cf. *R. loganesis* (Hall and Whitfield)

Unispirifer sp. (small)

13. From about 600 feet above the base:

echinoderm debris, indet.

Schuchertella sp.

Unispirifer sp. (large)

Punctospirifer cf. *P. solidirostris* (White)

MISSION CANYON LIMESTONE

The Mission Canyon Limestone forms much of the eastern flank of the Ruby Range within the map area. Prominent ledges typify this unit adjacent to recent stream incisions, but exposures are poor elsewhere. Bedding is typically thick and indistinct, resulting in massive outcrops. A thickness of 1370 feet was measured for the Mission Canyon, considered a maximum figure because the measurement was necessarily made on a dip slope.

With the exception of a 30-foot interval of dolomite 240 to 270 feet above the base, the entire formation is limestone. The carbonate beds weather light gray, but fresh exposures are pale to dark yellowish brown. Recrystallization is evident in much of the rock, obscuring features in hand specimens; no petrographic studies were made. Chert forms stringers locally but is not common. Solution breccias occur in the upper strata, exhibit a silty, grayish orange limestone matrix, and may be silicified. Angular limestone blocks to three feet across were observed in some of the breccias.

Age--No fossil collections were made from the Mission Canyon. Its age is considered Mississippian on the basis of its conformable occurrence above the Lodgepole, its presence below (Mississippian) Kibbey? strata and its likeness to dated Mission Canyon strata in nearby areas. The formation could contain rocks as young as Chester, if the unit correlates with Mission Canyon rocks to the south in the Blacktail Range (Huh, 1967).

KIBBEY? FORMATION

Upper Paleozoic red beds in the Ruby Range are like those of the Kibbey and unlike those of the Amsden Formation, according to William L. Harris.* He has traced the Kibbey and Amsden (Mississippian-Pennsylvanian) formations into southwestern Montana form the central Montana area and was able to distinguish between the formations by (1) the intense redness of the Kibbey, (2) presence of pinkish chert in the Kibbey, and (3) absence of quartz sand from the Amsden. It is not a purpose of this project ot undertake a study of this problem, but it should be noted that (a) the Amsden of southwestern Montana is at least locally an intense red, but conversely (b) to the east in the Gravelly and Greenhorn ranges measured sections (furnished by J. B. Hadley, U. S. Geol. Survey) reveal little sand in the Amsden, thus supporting Mr. Harris' interpretation. In addition, Harris noted that much more work needs to be done on the two formations in the area south of the latitude of Jefferson Canyon (45° 45' N. lat.), the southern margin of his project area.

Kibbey? rocks are present only along the margins of the Ruby

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*A Ph.D. candidate at the University of Montana, studying the Big Snowy Group for his dissertation.

Range, except at the north end, and are truncated by faults. The only exposed section crops out along the western side of the range adjacent to Big Dry Creek (NE¼NW¼ sec. 7, T. 6 S., R. 5 W.), a reddish soil-covered zone marking the trace of the formation elsewhere. Thickness of the Kibbey? ranges from about 20 to 130 feet, the range probably due both to an uneven surface on top of the Mission Canyon Limestone and to later removal of Kibbey? sediments by erosion. Both the lower and upper contacts are concealed.

Exposures of the Kibbey? are thin- to medium-bedded and weather pale reddish brown due to the presence of hematite. Most of the rocks are silty lime or dolomite mudstones, with a few beds of algal laminated boundstone. The silt is mostly quartz, of medium- to coarse-grain size (20-60 microns), and commonly making up 10 to 20 percent of the rock.

A few thin beds of fine- to medium-grained calcareous sandstone are also present. The sand grains are mostly rounded quartz, but chert commonly comprises 10 to 15 percent of the grains and makes the rock distinctive in hand specimen. Another rock type distinctive in the field is an intraclastic grainstone, composed of subrounded dolomite clasts to 8 millimeters across and interstitial dolomite mudstone between. Mottling characterizes the hand specimens.

PENNSYLVANIAN

QUADRANT SANDSTONE

As interpreted here the Quadrant Formation includes as its basal bed the first sandstone unit above the Kibbey? red beds. There are no Amsden red beds in the Ruby Range and the entire section above the Kibbey? is considered to be Quadrant.

Quadrant rocks are present only at the north end of the range (NW¼ sec. 21, T. 5 S., R. 5 W.) in an outcrop terminated by faults on three sides and cut by at least one and probably two more. About 1200 feet of Quadrant strata were measured in the section, but the minimum unfaulted thickness is only about 300 feet. The basal contact of the formation is concealed but the reddish beds beneath are considered part of the Kibbey? and thus the contact is presumed unconformable. A fault terminates the uppermost Quadrant strata.

Interbedded limestone and quartz sandstone in about equal amounts make up the formation, with good exposures characterizing the limestone beds and covered intervals marking the location of sandstong strata. Bedding of the limestone is medium to thick, that of the sandstone thin to medium.

Quartz grains 60 to 150 microns in diameter make up the very well sorted and rounded fine-grained sandstone. The cement is largely silica occurring as grain overgrowths, although calcite comprises a small amount of it.

The limestone beds include much lime mudstone and wackestone, with some packstone and algal laminated boundstone. Pellets seem to be abundant as are fossils and fossil debris, although recrystallization has obscured much of the fauna.

Age--Fossils identified from the Quadrant of the Ruby Range are *Anthracospirifer*, aff. *A. occidus* (Sadlick), and *Composita*, aff. *C. subtilita* Hall. They are probably Early or Middle Pennsylvanian in age (written communication, J. T. Dutro, Jr., 1968).

CRETACEOUS--TERTIARY

BEAVERHEAD FORMATION

Historical Review--Two detailed studies (Wilson, 1967; Ryder, 1968) of the Beaverhead Formation have recently been completed. Ryder's work was partially published in 1967, whereas that of Wilson is published only in abstract (Wilson, 1967). These studies are briefly reviewed here because they are germane to the structural interpretation of the Ruby Range.

From the distribution of the Beaverhead Conglomerate in extreme southwestern Montana, Scholten and others (1955) concluded that it was derived from uplift of the Blacktail and Snowcrest ranges, mountains which they believed formed opposite flanks of a single arch, the Blacktail-Snowcrest uplift (Fig. 20). Later Scholten (1967) postulated that the arch was one anticline of several major folds

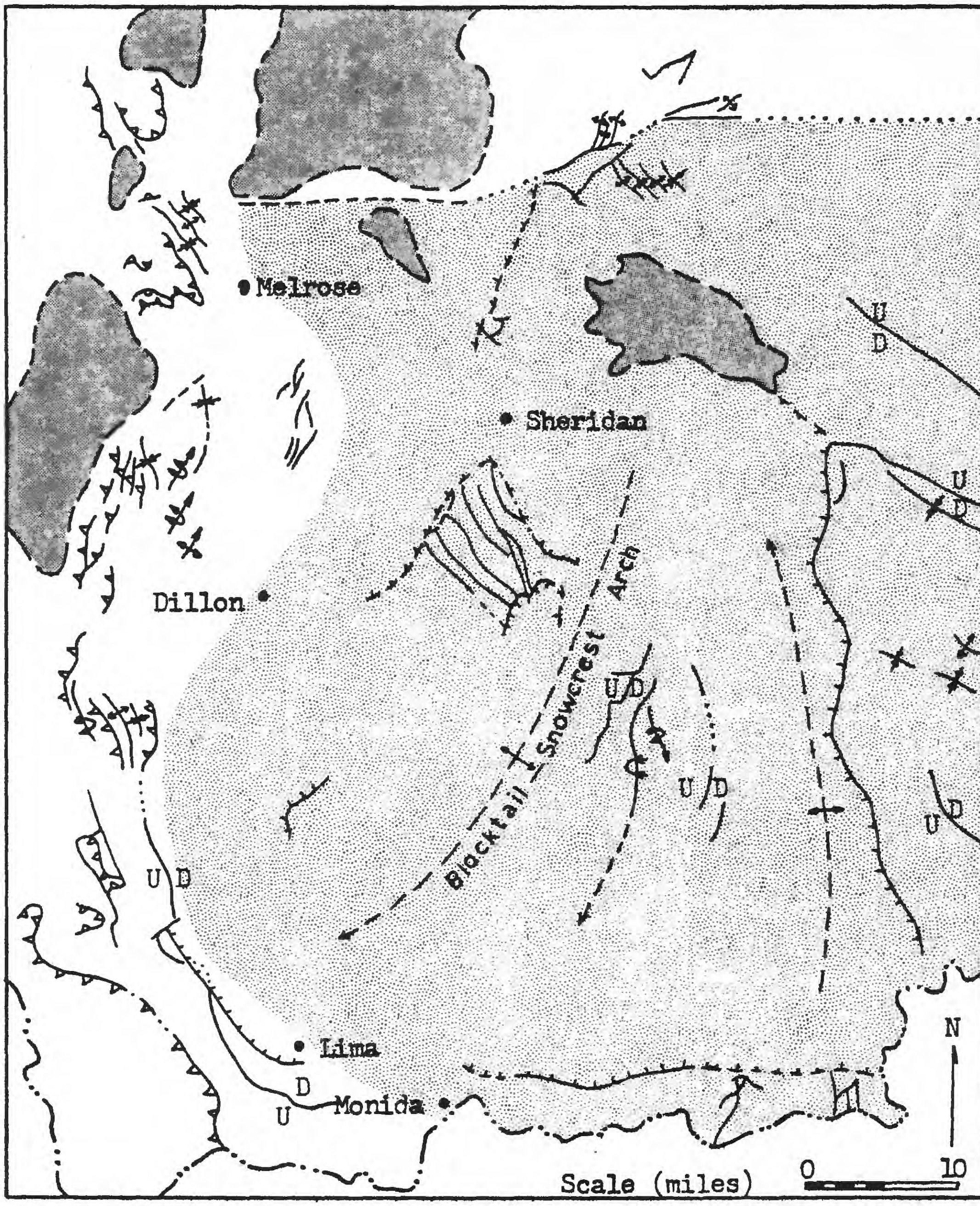

Figure 20. Regional tectonic map, showing major regional structures, area of basement rock (light stippled), and major intrusives (dark stippled).

radiating from a domal uplift centered in the Tobacco Root Mountains. Basin and range faulting later segmented the anticline into distinct intermontane basins and intervening ranges, one of which is the Ruby Range.

Ryder (1968) described several units in the Beaverhead Formation of the Monida area, and he and Wilson (1967) noted that one of these--the Lima Member--occurs adjacent to the southeast and south margins of the Blacktail-Snowcrest uplife. Wilson indicated the Lima Member to be made of clasts derived from strata of the uplife and deposited in an order inverted from the original depositional sequence of the eroded formations represented. Clasts derived from the Madison Group are by far the most dominant type present; clasts and sediment from Precambrian metamorphic rocks occur at the top of the member. Along the southwestern margin of the uplift the Lima member intertongues with and is overlapped by conglomerate containing clasts derived largely from Belt strata, which are exposed in areas to the west by uplift concurrent with that of the Blacktail-Snowcrest arch.

Age of the formation is partly in dispute, Ryder (1968) believing the basal strata are of latest Albian age and Wilson (1967) believing early to middle Campanian age. The dispute is two-part: Wilson's (1967) palynological material is thought by Ryder to indicate middle Turonian to Coniacian ages, instead of Campanian; and Wilson (1967) considers Ryder's latest Albian strata to be older than that of the Beaverhead Formation. Wilson (1967) dated the uppermost part of the Lima Member (that part containing sediment from a metamorphic rock source) as latest Cretaceous or earliest Paleocene and Ryder (1968) apparently concurs. In the earliest Paleocene the quartzite conglomerate started to cover the southwestern margin of the Blacktail-Snowcrest uplife and by mid-Paleocene time as more extensive. Beaverhead sedimentation continued until the late Paleocene, when regional northwest trending thrust faults advanced from the west and the wouthwest (Ryder, 1968).

Description--Conglomerate of the Beaverhead Formation in the Ruby Range forms two main rock groupings, one composed of carbonate clasts derived largely from the Madison Group and the other composed of quartzite clasts eroded from Precambrian Belt rocks. Both groupings are largely restricted to the western margin of the range, with exposures ranging from good for the carbonate conglomerate to poor for the quartzite conglomerate. Thickness of the formation is unknown, but the maximum thickness of that exposed is approximately 150 feet.

The carbonate conglomerate occurs on the downthrown sides of cross-range faults and cemented on carbonate formations at the outer margin of that part of the range deformed before initiation of normal faulting. Poor sorting characterizes the conglomerate with clast size ranging from that of cobbles to boulders 2 to 3 feet across. Most of the clasts are subrounded and those that are disc-shaped locally reveal a crude imbrication.

Making up the matrix is fine- to coarse-grained sandstone, the grains comprised of limestone, quartz, and chert. Quartz grains are of medium-and fine-sand size and most are angular, but a few are euhedral; granule size material is made of carbonate and chert grains. Calcite cements the rock and iron oxide has stained the matrix, giving the formation its characteristic reddish color.

Conglomerate made of quartzite clasts occurs basinward from the limestone-cobble conglomerate (see map, Plate 1). Good sorting is typical of this unit, most clasts being of cobble size. The cobbles are rounded to well-rounded, commonly exhibit a high polish, may contain crescent-shaped percussion marks, and are highly fractured where adjacent to faults.

Within the map perimeter only one outcrop of the Beaverhead occurs high in the range (Plate 1, SE¼ sec. 35, T. 6 S., R. 6 W., SE¼ sec. 2, T. 7 S., R. 6 W.). It differs from the foramtion elsewhere in that it contains clasts derived from Belt, Meagher, Flathead, and Precambrian metamorphic rocks older than the Belt, and it overlies the Cambrian Meagher Limestone. Only one isolated outcrop was observed on the eastern flank of the range, 3 miles south of the map area (Metzel Ranch quadrangle, sec. 4, T. 7 S., R. 5 W.). There the Beaverhead overlies Precambrian metamorphic rocks and contains Belt cobbles in the lower few feet but upward rapidly grades into rock containing Madison limestone clasts. A maximum thickness of about 100 feet is present.

To summarize, Belt quartzite clasts at the eastern margin of the range overlie Precambrian metamorphic rock; and at the western margin

Belt quartzite clasts are down-faulted, commonly adjacent to Beaverhead clasts derived from Paleozoic carbonate rocks. Paleozoic clasts show a similar distribution in that younger Paleozoic formations are represented in the more westward exposures of the carbonate conglomerate. An exception occurs at the Metzel Ranch quadrangle locality where Madison clasts are present; there is a nearby source area for these, however.

Source--The source of the Belt cobbles in the Beaverhead Formation was probably to the west, suggested by the following factors. (1) No Belt strata are known east of the Ruby Range. (2) Belt strata to the north make up the LaHood Formation, a unit that differs lithologically from clasts in the conglomerate. No Beaverhead-type conglomerate has been reported from the Tobacco Root Range. Pediments adjacent to the west side of the Ruby Range contain Belt clasts apparently reworked from the Beaverhead, whereas pediments adjacent to the west side of the Tobacco Root Range do not. (3) Studies of Wilson (1967) and Ryder (1968) indicate the Blacktail and Snowcrest ranges to the wouth were source areas for clasts exclusive of Belt in the Beaverhead, thus a southern source for the Belt clasts is unlikely. To the west Belt strata are present in the overthrust plates of the Pioneer Mountains (Myers, 1952).

Age and Discussion--No fossils were obtained form the Beaverhead Formation in the Ruby Range, thus its age cannot be directly determined. A minimum age is Eocene, however, as Dorr and Wheeler (1964) and Becker (1960) postulated a late Eocene age for basinal deposits at the eastern side of the range, 3 miles south of the map area. These deposits are of strikingly different aspect from the Beaverhead. Early and middle Oligocene sediments adjacent to the western and northern margins of the Ruby Range also differ from the Beaverhead, although they are locally conglomeratic.

Regionally, it seems the Beaverhead of the Ruby Range should be about time correlative with the formation southward, especially if the Ruby Range is actually part of the Blacktail-Snowcrest uplift as postulated by Scholten (1967). The northeast corner of the Ruby Range (outside of the map area) is structurally continuous with the Greenhorn Range (northern extension of the Snowcrest Range; see Fig. 1), the northern margin of the connecting rocks being overlain by Flathead and Wolsey formations which dip steeply to the north. This plus the outcrop pattern of rocks in the Snowcrest-Greenhorn, Blacktail, and Ruby ranges, suggests the combined area may have comprised one arch. Additionally, the proposed arch is about the same size as those to the east which are more easily demonstrated (see map, Fig. 20). If the present ranges were not originally part of the proposed but were separate from the time of their inception, then the basin between the Ruby and Snowcrest-Greenhorn ranges should contain conglomerate of the Beaverhead Formation. No Beaverhead has been reported (cf., Klepper, 1950; Lowell and Klepper, 1953; Dorr and Wheeler, 1964) except for the one outcrop noted 3 miles south of the map area and it is near the northern margin of the proposed arch. Thus Scholten's (1967) postulate seems to be valid.

The distribution of the non-Belt clasts within the range suggests the lower Paleozoic and Precambrian metamorphic clasts are a younger part of the Beaverhead than the upper Paleozoic ones. The Belt clast-conglomerate overlies only Precambrian metamorphic rocks and locally the Meagher Limestone, and it occurs downdropped adjacent to carbonate-clast conglomerate at the western margin of the range and thus must have originally been stratigraphically higher than the latter. An inverted sequence for the represented formations is thus indicated, a feature noted by Wilson (1967) for the Lima Member of the Beaverhead. This interpretation agrees with that of Ryder (1968) who found conglomerate made of Belt clasts overlapping the carbonate-clast conglomerate as the Belt clasts began to spread across the southwestern margin of the Blacktail-Snowcrest uplife. Seemingly, the influx into the two areas should be roughly synchronous as the material is thought to have come from the same general area.

TERTIARY, OLIGOCENE

Sediments of Oligocene age crop out locally at the north end of the range and along the western flank. Making up the strata at the north end of the range is gray and green mudstone interspersed with pebbles, cobbles, and boulders (to 7 feet in diameter) of basaltic and andesitic volcanic rock (Fields and Petkewich, 1967). Tertiary sediments cropping out near McHessor Creek along the western flank of the range were assigned to the Oligocene by R. M. Petkewich (personal communication, 1969). They consist of mudstone interstratified with poorly sorted locally conglomeratic siltstone and sandstone. The sand and silt grains are quartz, feldspar, biotite, and rock fragments, and the conglomerate clasts are largely of metamorphic rock.

TERTIARY--QUATERNARY

Strata in the basins beyond the margins of the Ruby Range were not mapped in detail; hence, they are grouped under one heating, Tertiary-Quaternary undivided (TQu). These strata include Oligocene and Miocene--Pliocene deposits, minor volcanic rocks, loess deposits, gravel deposits, alluvium, and colluvium.

QUATERNARY

Quaternary deposits were studied only superficially and mapped for completeness or to aid interpretation of structures. These map units include tufa, an unnamed conglomerate, alluvium, colluvium, mass movement deposits, and glacial deposits.

TUFA

Spring deposits made of tufa crop out at two locations in the map area, both along the western flank of the range. Springs are no longer active at the deposit near Trout Creek but near the McHessor Creek deposit warm water still issues from the spring, although deposition of calcium carbonate is very minor.

These deposits are probably very young, suggested by the still active spring water at McHessor Creek. In addition, the deposit near McHessor Creek is planed off by a pediment, the latter feature considered to be of Pleistocene age. The Trout Creek deposit is not truncated by this pediment so it must be young, too.

UNNAMED CONGLOMERATE

An unnamed conglomerate crops out locally along the flanks of the range and is assigned to the Quaternary because it intertongues with the tufa deposits near McHessor Creek. Making up the conglomerate are angular to subangular pebbles, cobbles, and locally boulders in a coarse sand matrix, the clasts reflecting the lithologies of nearby formations. The deposits are believed to be fanglomerate.

ALLUVIUM

Unconsolidated material deposited along streams was mapped as alluvium. Most of this sediment is probably of Recent Age. Alluvium also occurs as a veneer atop the pediments marginal to the range on the west and is mapped with the undivided Tertiary-Quaternary deposits.

COLLUVIUM

Deposits mapped as colluvium include unconsolidated angular rock fragments, hillwash, and talus. These deposits are most abundant along the western flank of the range where they overlap pediments, are adjacent to stream deposits, and mask bedrock. Locally the colluvium is mixed with old stream deposits. Thickness of the colluvium ranges up to as much as 50 feet and locally may exceed that. Colluvial deposits were not mapped where they constitute only a thin cover.

MASS MOVEMENT DEPOSITS

Deposits formed by mass movements include landslides, earthflows, and slump deposits. Landslide deposits are caused by removal of support from beneath cliffs, most commonly due to erosion of shale beneath carbonate formations. Earthflows occur in hydrated shale units, the toes of which are undergoing erosion by streams. Slump deposits occur in unconsolidate deposits that may be hydrated; the toes of these deposits are typically undergoing stream erosion, too.

GLACIAL DEPOSITS

Glacial deposits are not common in the Ruby Range, only two being noted. One is a small terminal moraine occurring high in Laurin Canyon (SW¼ sec. 9, T. 6 S., R. 5 W.), the other a protalus rampart present near the head of Trout Creek (NW 1/16 sec. 6, T. 7 S., R. 5 W.).

I G N E O U S   R O C K S

INTRUSIVE ROCKS

Igneous rocks intrude formations ranging in age from Precambrian to Oligocene, with most intrusions present along fault zones or in clay shales of the Cambrian strata. Most of the intrusives are basaltic, but andesite and rhyolite are present near McHessor Creek on the western flank of the range.

EXTRUSIVE ROCKS

Andesitic breccia occurs in the W½ sec. 6, T. 6 S., R. 5 W. These rocks are in fault contact with the neighboring strata, except they grade upward into volcanic ash containing rounded clasts from the andesite unit below and quartzite clasts from the Beaverhead Formation. The age of this breccia is unknown.

STRUCTURE

REGIONAL SETTING

The Ruby Range is elongate north-south, measuring about 30 miles in length and 10 to 15 miles across (Figure 1). It occurs at the western edge of the foreland of the Rocky Mountains in a structural setting characterized by (1) high-angle faults that cut basement rocks, (2) extensive exposures of Precambrian metamorphic rocks in the cores of mountain uplifts, and (3) a thin cover of Paleozoic and Mesozoic sedimentary rocks. In the Ruby Range these sedimentary strata had an aggregate thickness of about 10,000 feet or less during deformation in the Late Cretaceous-early Tertiary, whereas correlative strata plus Late Precambrian Belt sediments to the west in the miogeosyncline may have totaled as much as 35,000 to 50,000 feet or more. (See Figure 20 for regional tectonic map.)

The range is flanked on all sides by intermontane basins containing Tertiary sedimentary rocks. Major normal faults border the range on the west, north, and much of the eastern side. Outcrop patterns, field observation, and Bouger gravity anomaly data (Burfeind, 1967) suggest the remainder of the range is delimited by faults, too, except for the northeastern corner which is structurally continuous with the Greenhorn Range to the east.

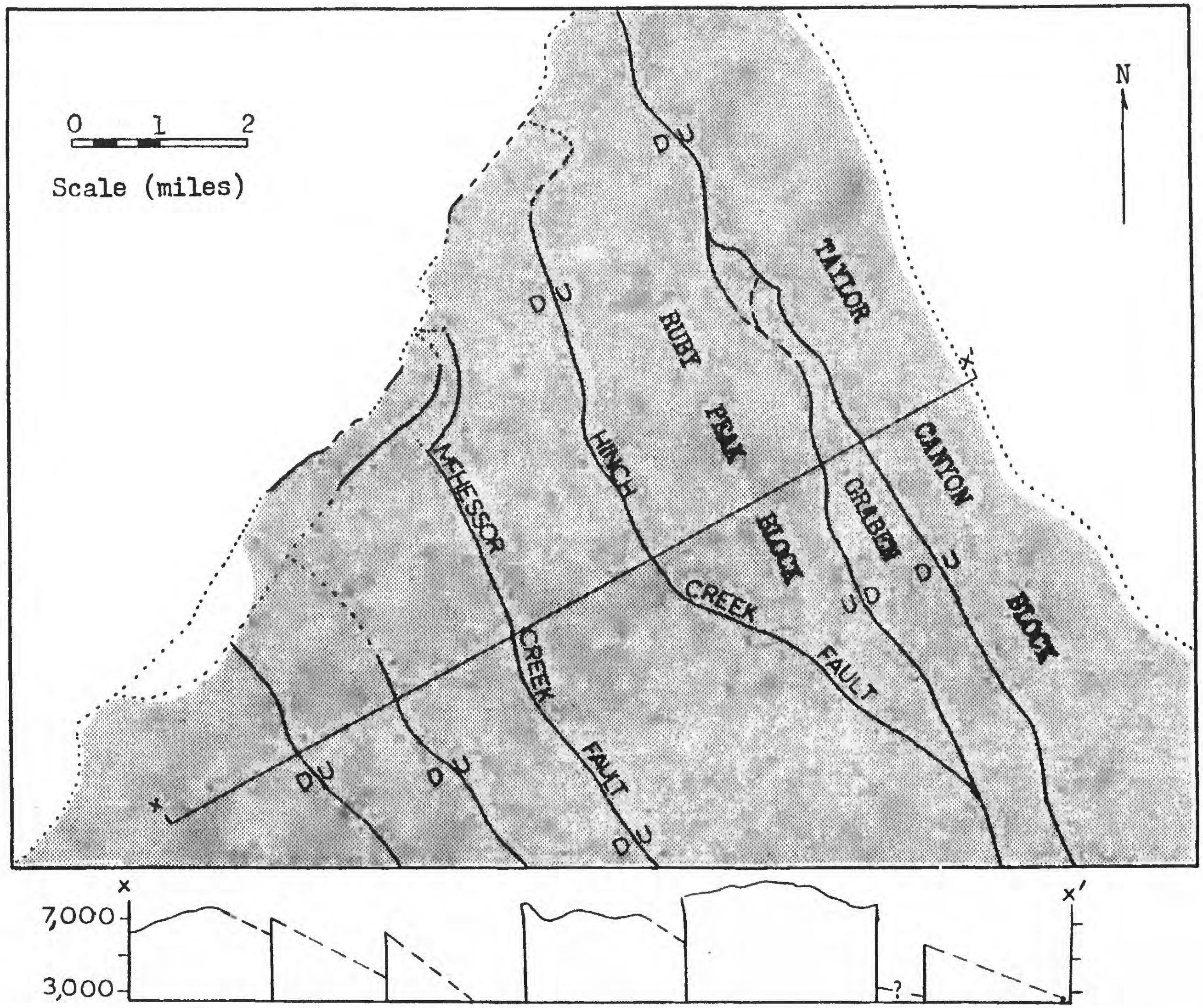

Figure 21. Reproduction of major part of map area, showing (metamorphic) basement blocks and master faults. Cross-section shows surface of metamorphic rock.

BASEMENT BLOCKS

Basement rocks, as used here, are the metamorphic rocks which unconformably underlie the unmetamorphosed, dominantly sedimentary rocks of the Ruby Range. In the northern part of the range (the map area) the basement is segmented into discrete blocks by a relatively few major high-angle faults. The faults are termed master faults and are shown in Figure 21, reproduced from the geologic map (Plate 1) to illustrate the relationships among the blocks. Relative positioning of the basement blocks is shown in the cross-section of Figure 21. The blocks make a pattern of stair-steps, ascending to the Ruby Peak block from both the northeast and southwest. The northeastern stair-steps are irregular because of a graben formed in between the Ruby Peak and Taylor Canyon basement blocks (see Fig. 21).

Basement rock exposed in the blocks shows a nearly planar contact with the overlying Cambrian strata and permits a determination of the dip of the blocks. The direction of dip ranges from about N 18 E to N 36 E and the dip itself is commonly 30 to 40 degrees, although one block is inclined almost 60 degrees. The dips are a result of the blocks plunging to the northwest and tilting to the northeast. Resulting is a series of en echelon faults, folds, blocks and outcrop patterns. The nearly planar basement-sedimentary rock contact suggests rupture, plunge, and tilt of the blocks was accomplished with only minor internal flexing.

FAULTS

Two main directions of faulting are readily apparent within the map area, namely northwest to north-northwest and northeast. Trending northwest to north-northwest are the master faults, which exhibit greatest throw and, except rarely, truncate those faults trending northeast. The McHessor and Hinch creek faults (see Fig. 21 and Plate 1) exhibit maximum throw for faults within the map area. They show about 6,000 and 7,000 feet of throw. Throw on a fault is commonly difficult to measure because (1) sedimentary rocks overlying the immediately adjacent parts of two basement blocks are typically folded, and/or (2) key Paleozoic sedimentary rocks may be absent near a fault on one or both of the blocks, and the contacts have to be projected from as far away as 2 miles.

Faults trending northeast are high-angle and exhibit displacements less than those of the master faults. They are truncated by the master faults (cf., sec. 31, T. 6 S., R. 5 W.).

Upthrust Faults--The basement blocks are bordered by major faults which extend upward from the basement into the overlying sedimentary rocks. The structural style of the map area is thus one of block faulting, with the basement being closely involved in the deformation of the overlying sedimentary rocks.

The theoretical stress field for block uplift was developed by Hafner (1951) and experimental model studies were made by Sanford (1959). The geometry of the theoretical structure associated with a block uplift affecting deep-seated crystalline rocks is shown in Figure 22 (after Crosby, manuscript), and in three dimensions in Figure 23 (after Prucha and others, 1965, p. 971).

The principal stress trajectories at the surface are parallel and perpendicular to the surface of the earth because no shear stress can exist on a free surface. Further, the subvertical fault in the crystalline basement block is a shear while one block is uplifted relative to the other; therefore, maximum principal stress is oriented about 30° to the fault at the level of the top of the basement (Hubbert, 1951, p. 361). Its orientation in space is indicated by the sense of displacement on the fault. The three principal stresses, mutually perpendicular, must curve continuously (exceptionally, intermediate principal stress does not curve in 2-dimensional deformation, but lies in the fault surface) between the top of the basement and the air-earth interface where maximum stress is horizontal in the vicinity of the fault. Inasmuch as the fracture that results from the differential stress forms at about 30° to the maximum principal stress, th fault surface will be curved, and thus reflect the curvature of the stress trajectories. Accordingly, the fault which is steep at depth flattens progressively toward the surface. Faults with these characteristics are termed upthrusts and have been treated theoretically and produced in model experiments by Sanford (1959). Field examples have been described by numerous authors (e.g., Berg, 1962).

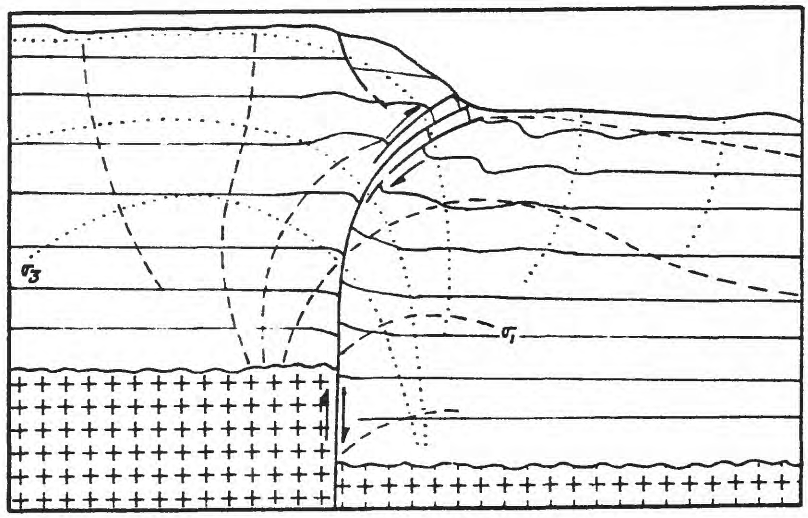

Figure 22. Block uplift model. Stress system does not take into account the modifying effects of the topography produced by faulting. (Diagram after Crosby, manuscript.)

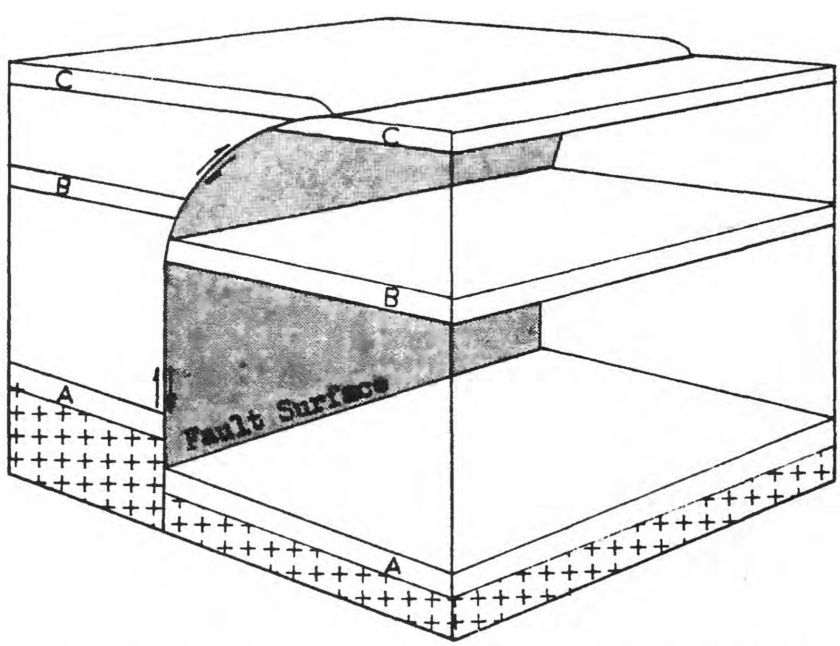

Figure 23. Diagram showing dip of upthrust fault as a function of level of observation relative to corresponding structural segment of fault. Fault is vertical in segment of bed A, high-angle reverse in segment of bed B, and low-angle reverse in segment of bed C (after Prucha and others, 1965).

Cross-section B-B' (Plate 1) and a telescoped reproduction of the fold in the E2/3 sec. 6 and E½ sec. 7, T. 6 S., R. 5 W., (Fig. 24e) clearly show a series of related upthrust faults which are nearly vertical in their lower segments and curve progressively in their upper parts. As predicted by theory they curve upward and away from the uplifted block. In this example and in all others within the map area, the axis of curvature of the upthrust plunges to the northwest in accordance with the northwestward plunging of the basement blocks.

Prucha and others (1965) noted that the attitude of an upthrust depends on the thickness of the sedimentary section above the basement, the type of rocks involved, the attitude and magnitude of the discontinuity in the basement, topographic effects produced by faulting, and other factors. Thus the structurally lower, near vertical parts of the upthrusts shown in Figure 24 involve crystalline basement rocks on one or both sides, whereas the curved segments typically involve sedimentary rocks on one or both sides.

The lower parts of upthrusts within the map area are topographically higher than the upper segments because the basement blocks and overlying sedimentary rocks plunge to the north. In addition, erosion has cut deeper into the section at higher elevations than at lower elevations. Thus because the orientation of the surface trace of an upthrust is dependent upon the depth of erosion, fault traces commonly change trends toward the margins of the range. Indeed, some are sinuous whereas the basement fractures may be linear (cf., northern central part of map).

Imbricate upthrust slices occur in the W½ sec. 23, T. 6 S., R. 5 W., of the Laurin Canyon quadrangle, the formations making up the three slices stacked in a sequence inverted from their depositional order (the strata are not overturned). As each slice was emplaced uplift must have continued, severed each slice from its "roots," and permitted emplacement of the succeeding slice from older strata.

A scissors relationship exists between the Ruby Peak and Taylor Canyon basement blocks (ignoring the graben in between) because northwestward plunge of the two blocks is different. The axial area for the scissors must occur about in the S½ sec. 9, T. 6 S., R. 5 W. South of the axial area the Ruby Peak basement block is up relative to the Taylor Canyon basement block and the graben. Thus in theory (Sanford, 1959) the upthrust should flatten eastward at the highest structural level and that it does is suggested by overturned strata in the graben adjacent to the fault. North of the axial area the relationship is reversed, strata overlying the Taylor Canyon basement block being upthrust over that of the Ruby Peak basement block.

Origin of the Fault Pattern--The master faults display a pattern that may be of Precambrian origin, reactivated during the Cretaceous-Tertiary orogenic period. Jack Garihan (Penn. State Univ., written communication, 1970) described the fault system in the Ruby Range south of the map area as very pervasive, exhibiting a series of northwest-trending strike-slip faults with left-lateral offsets of at least 2 to 3 miles. The movement is considered to be Precambrian in age because later movement on the northwest-trending faults throughout the range is dominantly dip-slip, and because diabase dikes of probable Precambrian age are locally intruded along the faults in the middle and southern parts of the range. Intense shearing is associated with the strike-slip movement but not with post-Precambrian dip-slip movement.

Foliation trends within the Ruby Peak block (see map, Plate 1) curve progressively from an easterly trend to a southeasterly trend adjacent to the fault bordering the western side of the graben (Fig. 21, and Plate 1). This may be due to strike-slip movement, but no investigation was made to prove it. Thus, although there is no reason to expect the pervasive strike-slip deformation pattern to cease its existence abruptly at the southern margin of the map area, its existence has not been proven and thus must remain as a possibility.

FOLDS

Folds in the sedimentary strata have formed in response to differential uplift of basement blocks. Strata adjacent to a master fault and on the downthrown side are commonly upturned sharply, whereas correlative strata on the upthrown side are commonly downturned sharply. If a fault between differentially uplifted basement blocks fails to penetrate the sedimentary section a monocline may exist, as shown in Figure 24e. The fold axis parallels the contour of the basement surface and the fault plane. Failure of the sedimentary rocks to adjust by folding results in faulting, and continued uplift will permit formation of a syncline on the downthrown side of the fault and an anticline on the upthrown side.

Northward plunge is characteristic of all folds within the map area, whether anticline or syncline, and results from the northward plunge of basement blocks. Because the basment blocks all dip to the northeast and exhibit an asymmetric surface profile due to uplift along their western margins (except for one), the steepest limb of each syncline is always along the eastern margin of a block and the steepest limb of each anticline is always along the west. The largest folds are adjacent to faults exhibiting the greatest throw.

Anticlines--All anticlines in the map area show similar characteristics, thus only one needs detailed explanation. The Spring Creek anticline is the example used because it is the most complete and best exposed.

The series of diagrams in Figure 24 shows diagrammatically a possible sequence of events resulting in formation of the Spring Creek anticline. Interpretation of the sequence is as follows. (a) Differential uplife of basement blocks occurred with the sedimentary strata adjusting to the fracture by folding. (b) With continued differential uplift the sedimentary strata

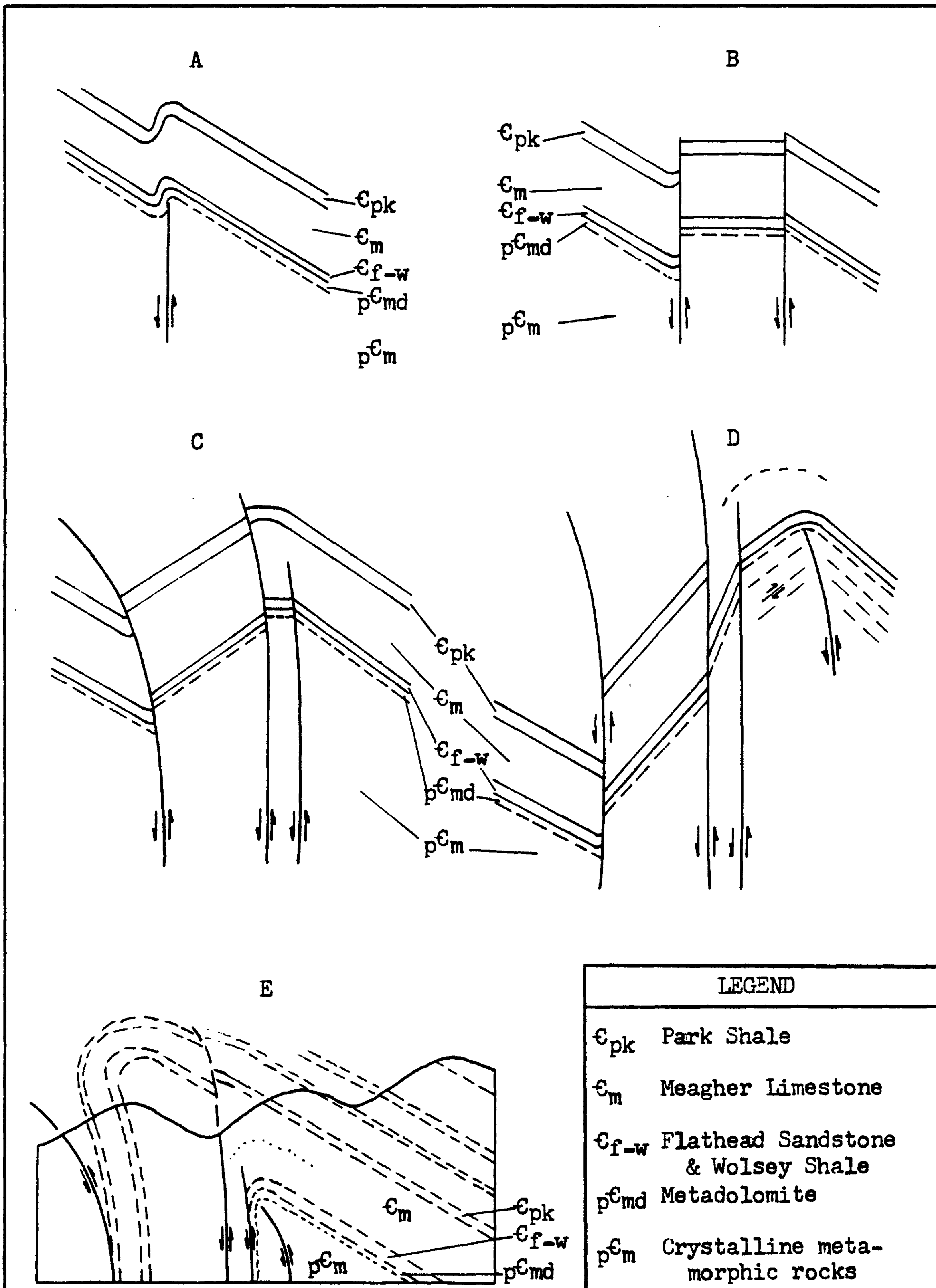

Figure 24. A series of diagrams illustrating a possible sequence of events in formation of the Spring Creek anticline.

adjusted by fracturing. (c) Another fracture then formed with more uplift. The easternmost block of the three rose farther than either of the other two and the intermediate block was rotated mainly because of differential movement between the neighboring blocks. (d) More differential uplift occurred and another fracture formed but it did not penetrate the sedimentary strata or metadolomite that occurs in the uppermost part of the basement block; rather, the sedimentary rocks adjusted by folding. (e) Differential uplift continued and the fold continued to develop.

Mechanics of Folding--Structural features in the Paleozoic carbonate strata of the Spring Creek anticline suggest the fold is of the flexural slip type. Folding of the carbonate beds was apparently accomplished mainly by slip between layers. The shale units (Wolsey and Park), however, do not obey the rules of flexural slip folding, but rather display characteristics of flexural flowage folding (Donath and Parker, 1964). The shales show nearly constant thicknesses in the eastern limb and thin drastically in the western limb. Both types of folding can occur in the same fold because the two rock types exhibit a ductility contrast. The fold as a unit, however is best termed a flexural flow fold.

Folds associated with upthrusting ideally are expected to display geometric characteristics compatible with the stress field of upthrusting. Thus the axial plane of the Spring Creek anticline curves and flattens to the west and, in its upper part, is slightly overturned to the west. In addition, cross section B-B' and the sketch in Figure 24 show the anticline is slightly asymmetrical and that the asymmetry is greater in the upper part of the fold. Some of the asymmetry can be attributed to thinning of the shales in the western limb. But perhaps part can also be attributed to horizontal compression because the low angle or flattened part of the upthrusts and the fold are in a zone of horizontal compression, as shown by the stress trajectories in Figure 22.

The Precambrian metamorphic rocks of the exposed basement block adjusted to the folding in two ways. (1) Metadolomite in the upper part of the block seems to have folded passively and is continuous from one limb of the fold to the other. It does not show appreciable thickening or thinning in the axial area as expected for a passive fold, but instead maintains a near constant thickness from one limb to the other. In part this is because the unit is only a few feet thick and is bounded above and below by rocks of less ductility. (The Flathead Formation, a quartz sandstone, overlies the dolomite.) A more improtant reason is found in a mechanical analogy with a slab of material that is bent into a fold (Fig. 25). Upon bending the convex side is under tensional or extensional stress, the concave side is under compressional stress, and separating thse zones is a neutral surface. In the Spring Creek anticline the zone of extension is exemplified by the flexurally folded sedimentary rocks and the zone of compression by the gneiss and amphibolite. Thus the metadolomite probably contains the surface of neutral stress, and presumably it occurs in the center of the unit

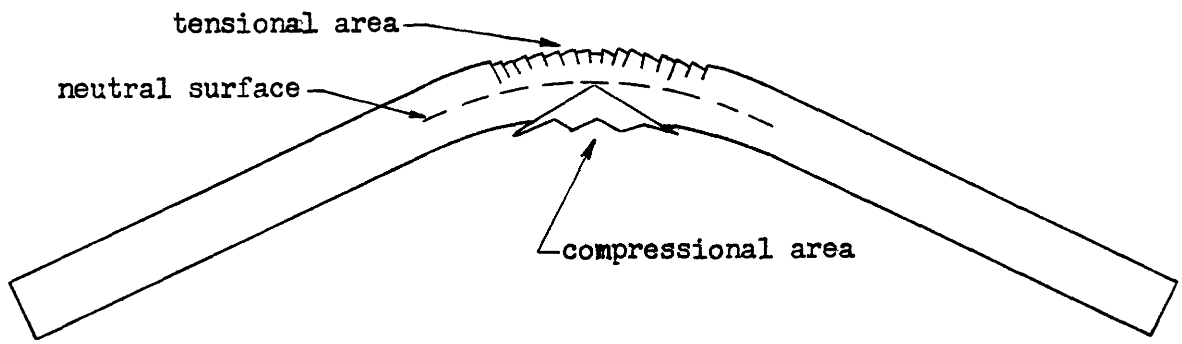

Figure 25. Cross-section of slab, showing stress zones. Figure is used as a model for interpretation of folded metadolomite in core of Spring Creek anticline.

midway between the zones of extension and compression. Therefore, even though the metadolomite deformed passively, there need be no thickness change in the hinge area because the two different stress fields should affect equal but opposite areas and a change necessitated by stresses in one area should be compensated in the other.

(2) The second way in which the metamorphic rocks adjusted to the folding was by faulting of the gneiss and amphibolite units; west of the fault these rocks rotated in sympathy with the folded metadolomite and sedimentary strata (Fig. 24c,d,e). The folded slab in Figure 25 shows that a wedge of material in the zone of compression must be compensated if the fold is to exist. Compensation for a wedge, made of amphibolite and gneiss in the Spring Creek anticline, was accomplished by slippage and granulation along folia in the crystalline rock west of the fault.

The fault within the crystalline rocks is also the axial plane for the compressional part of the Spring Creek anticline, and projected upward it coincides with the axial plane of the folded sedimentary rocks. Coupled with the other data cited for the anticline, this is strong evidence that the geometry of the internally deformed basement block is very closely related to that of the folded sedimentary strata. Studies made by some other workers have also shown internal deformation of basement blocks to be related to that of the overlying sedimentary strata (cf., Hudson, 1955; Berg, 1962; LeMasurier, 1970). Conversely, other studies of uplifted basement blocks have revealed no evidence for deformation related to that of the overlying folded sedimentary strata; and the sedimentary strata folded simply by draping over the surface of the uplifted block (cf., Wise, 1962; Prucha and others, 1965; Hodgson, 1965; Palmquist, 1967).

A controversy has developed over which of the above viewpoints is correct (LeMasurier, 1970). According to the theoretical geometry associated with foreland-type uplifts (see Fig. 22) stresses exist within the uplifted basement block, as they do in the associated sedimentary rock. Whether the block reacts to the stresses by folding, fracturing, or resists deformation depends on the properties of the rock. Thus, if the uplifted block resists the applied stresses, the sedimentary strata may simply drape over the faulted flank of te block. If the block does not resist the stresses, then its internal geometry will show deformation which should be correlatable with that of the overlying folded sedimentary strata, deformed within the same stress system.

<u>Synclines</u>--The McHessor Creek syncline occurs adjacent to the McHessor Creek master fault (Plate 1, secs. 24, 25, 26, T. 6 S., R. 6 W., secs. 30, 31, T. 6 S., R. 5 W.), and is used as the synclinal model because of its good exposure. Except near its northwestern terminus, the syncline is progressively more deformed toward the southeast. This is shown by increasing tightness of the fold, steepening of the eastern limb (which becomes vertical and then overturned), intense shearing and fracturing about the nose, and (farther to the southeast) by faulting which terminates the fold.

A roughly north-south trend is exhibited by the major faults southeast of the synclinal nose. The western two of these faults are demonstrably of the upthrust type, the fault planes flattening upward to the west. The overturned axial plane of the syncline also becomes flatter to the west and curves from a southeasterly trend to a southerly trend about parallel to that of the faults. These data indicate the fold and faults are closely related.

The block containing the syncline narrows toward the nose of the fold and the basment block to the east has a corresponding bulge (SW¼ sec. 30, T. 6 S., R. 5 W.). Visualizing northwestward plunging, northeastward tilting, and formation of the syncline all occurring together, the bulge of the upthrown eastern block must impinge upon rock of the downthrown block. (This argument assumes the faults along which the blocks adjust are not defined by unique properties wherein one block can move completely independent of another.) It is difficult to determine if the impinging bulge is an inherent feature of the uplifted block and is thus complimented by a re-enrant in the basement part of the downthrown block, or if the bulge formed by outward movement in accordance with the horizontal component of stress in the upper part of the upthrust model (see Fig. 22). In either case part of the stress must be directed horizontally.

Assuming the north trending faults near the synclinal nose formed in response to a compressive stress directed about 30° to teh faults, one possible stress direction is oriented about N 25 E to N 30 E. This direction agrees closely with the dip direction of the basement blocks, measured as ranging from N 18 E to N 36 E, and a result of the northeastward tilting of the basement blocks. The above data do not prove that the fold formed due to compression related to block upthrust, more data being needed, but they are suggestive of it.

In the constricted area the easiest movement direction for relief of stress was probably upward. Thus most of the small fault slivers bordered by the north-trending faults are uplifted, relative to rocks northwestward.

NORMAL FAULTS

Blocking out of the present range took place by normal faulting. Steeply dipping northeast trending normal faults along the western margin of the range clearly truncate the older northwest trending structural features within the range. Normal faults along the northeastern margin are not as evident, but must trend northwest and be about parallel to structural features within the range. Normal faults delimit most of the range margin south of the map area (cf., Burfeind, 1967; Dorr and Wheeler, 1964; Pardee, 1950; and Klepper, 1950), an exception occurring along the eastern margin where the Ruby Range is structurally continuous with the Greenhorn Range.

Using gravity data, Burfeind (1967) calculated basin fill along the western margin of the range to be about 6,000 feet, that along the northeastern margin to be about 4,000 feet, and that south of the map area along the eastern margin of the range to be as great as 7,000 feet. Throw on the faults bordering the range is not directly determinable, but assuming a nearly complete stratigraphic section on the downthrown basin blocks, individual throws could easily exceed 12-14,000 feet. The structural relief from the range crest (within the map area) to the basin bottom is a minimum of about 10,000 feet and could exceed 20,000 feet, using the above assumption.

Western Margin--The marginal normal fault bordering the Ruby Range on the west is not one continuous feature, but is locally segmented where it intersects older cross-range faults. It is expressed by a fault-line scarp along much of its lenth, but southwestward from Trout Creek no scarp is present and there is no surface expression of the fault. Locally in gullies, however, the fault has been exposed by erosion.

Inward from the marginal normal fault occur normal and high angle faults that are clearly of the same vintage as the marginal fault. These faults commonly outline small grabens, the infaulted strata being Oligocene sediments and Belt-cobble-bearing conglomerate of the Beaverhead Formation. The grabens are not everywhere simple; indeed, the superposition of a new fault system upon a pervasive older one might be expected to result in a complex intersection.

Three important differences exist between the sediments basinward from the marginal normal fault and the Tertiary sediments contained within the system of normal faults at the range flank. (1) No strata younger than Oligocene are present within the range but those in the basin include distinctive Miocene-Pliocene strata. (2) The Beaverhead and Oligocene strata, displaying a great variety of strikes and dips, are intricately faulted. In fact the strata are believed to contain more faults than shown on the map, but poor exposures preclude definite proof of their existence. Conversely, the exposed strata within the basin are not greatly diversified in orientation, all strata dipping gently. (3) Quartzite cobbles of the Beaverhead make up quartzite conglomerate, whereas quartzite clasts of the same rock types occur as pebbles and small cobbles interspersed with other clast types within Miocene-Pliocene conglomerate of the basin.

The above data may be indicative of at least two stages of normal faulting: One before deposition of strata younger than Oligocene and another later. Belt quartzite clasts occur in the Miocene-Pliocene rocks and are nearly absent from Oligocene sediments. Because the Beaverhead Formation must be the source of the Belt clasts, it must not have been exposed to erosion until Miocene-Pliocene deposition. This indicates concealment of Beaverhead and Oligocene rocks in post-Oligocene time and exposure of the same strata during deposition of Miocene-Pliocene sediments. This may indicate a step-fault relationship exists for the basin-and-range structure, the normal-faulted rocks at the range margin forming one step and the other formed by the basin floor. Conversely, the rocks may simply have been covered by younger sediments and exposed to erosion during Miocene-Pliocene deposition.

Eastern Margin--The fault bordering the northeastern side of the range is not as easily demonstrated as that along the western side. East of the map area Cambrian Flathead and Wolsey formations of the range front are clearly upfaulted relative to Oligocene strata (R. M. Petkewich, personal communication, 1969). Immediately adjacent to the eastern margin of the map area the Wolsey is highly contorted along the same fault-line scarp, the scarp being easily traced along the northeast margin of the Ruby Range. The actual fault is concealed by fan deposits within the map area, but its presence is indicated by: (1) the scarp, (2) the faulted margins of the unnamed conglomerate (Qcgl) of probable Quaternary age, (3) occurrence of springs along the scarp, (4) steep dips (to 80°) of Paleozoic rocks, and (5) faceted spurs of Paleozoic rock.

Between Porter and Robinson canyons the above criteria do not apply and the fault is believed to pass beneath the alluvial fan.

Obvious steepening of the fan is evident along the projected fault trace, probably caused by the presence of Mission Canyon strata beneath the fan head. Northwestward beyond Bouge Canyon aerial photographs reveal a slight topographic break in the alluvial fan deposits, but it is difficult to discern on the ground.

Northern Margin--The rock units present at the northern margin of the range and their outcrop relationships are like those along the western margin. Known faults fit this pattern, but some faults are not readily demonstrated; hence, they were mapped as "probable faults."

Pebbles, cobbles, and boulders of volcanic rocks occur in the early Oligocene sediments at the northern margin of the Ruby Range (Fields and Petkewich, 1967), whereas the Oligocene sediments at the western flank of the range contain cobbles mainly of metamorphic rocks. Because such coarse material is uncommon in the Oligocene sediments of southwestern Montana, even adjacent to the basin margins (Fields and Petkewich, 1967); and because the sediments are suggestive of a more humid climate than presently exists or existed in the Miocene-Pliocene (R. M. Petkewich, personal communication, 1969) and thus formed in an environment not typically disposed to production of coarse sediments; the conglomerate near the flanks of the Ruby Range is probably due to uplift of the range. This suggests outlining of the northern margin of the range may have begun in the early Oligocene. Conversely, the conglomerate at the north end of the range may not be of tectonic origin; then, regional data suggest normal faulting began in perhaps middle Oligocene time (R. W. Fields, personal communication, 1970).

GRAVITY SLIDE MASSES

A series of rock masses are common along the margins of the range within the map area. They are commonly observed to be in fault contact with underlying rock units, but where not observed to be overlying a rock unit, they are separated from adjacent units by high-angle faults. Along the southeastern margin of the range front (N½ sec. 24 and S¼ sec. 13, T. 6 S., R. 5 W.) thin interfaulted masses or slices of rock occur, the fault planes dipping less than 30° basinward, and at the northern margin of the range a 15° inclination was determined for the fault separating the Mission Canyon Formation form the overlying metamorphic rock unit. Those masses along the western margin of the range are truncated by near vertical faults or normal faults (secs. 14, 15, 21, 22, and 28, T. 6 S., R. 6 W.).

Brecciation characterizes the basal strata of all the masses, whereas the rocks immediately beneath are fractured but are not commonly brecciated. For example, strata exposed beneath the rock mass at the north end of the range show deformation consisting mainly of small fractures, now filled with calcite.

Three possible methods for emplacement of the rock masses include reverse faulting due to regional horizontal compression, upthrust faulting, and gravity sliding. Where not truncated by high angle faults, the masses can be viewed as separated from underlying rock by reverse faults. It is difficult to attribute such reverse relationships to regional horizontal compression because (1) the range seems to have been formed by vertical uplift; (2) it is unreasonable to find evidence of such compression only at the range margins; and (3) distribution of the blocks on three sides of the range would have required regional compression directed east-west and north-south, presumably concurrently, but perhaps alternately.

Emplacement of the masses along upthrust faults would require the present basin areas to have been upthrust relative to the mountain block and subsequently downdropped to form the present basins. The rock masses would represent remnants of the upthrust rock, later severed by normal faults which delimit the basins and ranges. Stated another way, the range was uplifted as part of the Blacktail-Snowcrest arch, was later downdropped relative to the basin areas, and was rising again by Oligocene time.

Emplacement of the masses by gravity sliding is the third possible method, requiring only that the masses slid off the flanks of the range as the range was uparched. Contrasting upthrusts within the range with the range-marginal masses, the following arguments are all cited as favorable to emplacement of the masses by gravity sliding and unfavorable to the upthrusting hypothesis. (1) Within the range, metamorphic rock is not present above the upper flattened part of any upthrust, that part to which the range marginal metamorphic rock masses would have had to belong. (2) The Mission Canyon Formation is not displaced adjacent to the low angle part of any upthrust fault within the range, but in the SE¼ sec. 20, T. 5 S., R. 5 W., both it and Precambrian metadolomite are intricately interfaulted. (3) Imbricate upthrust slices within the range show an orderly emplacement in that they are stacked inversely to their normal stratigraphic sequence. No preferred order is shown for the fault slices at the range margin (cf., N½ sec. 24 and S½ sec. 13, T. 6 S., R. 5 W.). (4) The metamorphic rock within the displaced masses at the range margin in all cases is metadolomite adjacent to the fault surface, although other rock types are present away from the fault surface. Within the range no preference is shown for any particular metamorphic rock severed by an upthrust fault. (5) Folding characterizes the metadolomite adjacent to upthrust faults within the range, illustrated in the core of teh Spring Creek anticline. Metadolomite adjacent to the faults of the displaced masses at the range margins has deformed cataclastically and is thoroughly brecciated. (6) Where data are abundant, foliation trends in uplifted basement blocks adjacent to upthrust faults within the range show a regular pattern, even where deformed. At the range margins the foliation trends of the rock masses show no general orientation, and at the north end of the range they appear chaotic.

The data presented above certainly seem to rule out emplacement of the rock masses at the range margin by regional compression, neither do they favor an upthrust origin. A gravity mechanism is most easily reconciled with observed relations.

The crestal region of the Ruby Range is thought to be the source area of the rock masses. A source in the Tobacco Root Range to the north is unrealistic because the displaced masses occur at the western flank of the Ruby Range as well as the north and northeast flanks. A western source in addition to a northern one is not probable because the slide masses would have had to slide more than 15 miles. The distance is not prohibitive, but a ready source is nearby within the Ruby Range.

The Ruby Peak basement block (Fig. 21) is the highest uplifted basement block within the map area. Thus it is a probable source area for gravity slide masses, having provided the greatest potential for sliding. This block contains the greatest volume of metadolomite of any of the basement blocks and is therefore the most logical source.

Individual basement blocks within the Ruby Range are tilted to the northeast, and the axis of the range itself is apparently inclined northward because Paleozoic rocks occur only at the north end of the range. These inclinations may have provided slopes down which at least some of the blocks could have moved. Similar down-slope movement of rock masses has been suggested by numerous workers (cf., Longwell, 1951; Pierce, 1957; Jones, 1963; Wise, 1963; Palmquist, 1967).

Inclination of the fault between the Mission Canyon Formation and the overlying metamorphic rock at the north end of the range may be about the same as when sliding took place. The profile of section A-A' is shown in Plate 1 and the dashed line above it represents the southward projection of the fault plane. The Flathead-metamorphic rock contact in the NW¼ sec. 9, T. 6 S., R. 5 W., dips about 35° northward; a line representing the projection of this contact intersects the projected fault plane above the Ruby Peak basement block, suggesting the block is a possible source area for the metamorphic rock at the north end of the range.

The mechanism of detachment of the masses is unknown. Oversteepening of slopes in conjunction with hydration of shale units and upthrusts faulting may have permitted movement of the Paleozoic rock masses. Shale is common along the fault planes of most of the displaced masses of rock. Severing of the metadolomite and overlying metamorphic rocks which make up some of the displaced masses is more problematical. Perhaps a basement block was thrust upward such that its upper part was not confined by a neighboring block. Then gravity, acting on the metadolomite and overlying strata, may have had a great enough effect to cause the metadolomite to deform cataclastically and move downslope. The metadolomite presumably has a low ultimate strength.

Displaced rock masses at the north end of the range are overlain by early Oligocene sediments, thus emplacement must have occurred earlier. How much earlier is uncertain as contact of the masses with the Beaverhead Formation is everywhere along high angle faults.

The displaced masses overlie the Pennsylvanian Quadrant Formation at the north end of the range and the Cambrian Flathead and Wolsey formations southeastward along the range front (immediately east of the map area). Stripping of the sedimentary rock cover to these formations thus had to occur prior to emplacement of the rock masses, suggesting final movement took place after stripping was well under way.

CRETACEOUS-TERTIARY STRUCTURAL HISTORY

The structural histroy summarized here was mostly gleaned from within the map area. (1) The Ruby Range began to rise in the Late Cretaceous, forming a part of the Blacktail-Snowcrest arch. (2) Concurrent stripping of sedimentary strata took place, with deposition of the eroded strata making up much of the Beaverhead Formation which occurs at the range flanks and locally along the downthrown sides of cross-range faults. (3) Uplift of the range was accompanied by differential movement of discrete basement blocks within the range, with resultant formation of upthrust-type faults marginal to the blocks. (4) During the latest Cretaceous or Paleocene, quartzite clasts derived from Belt strata west of the Ruby Range lapped upon at least the western margin of the range. (5) Gravity slide masses derived from the range crest were emplaced marginal to the range, probably during the latter part of sedimentation which formed the Beaverhead Formation, or immediately afterward. (6) Normal faulting began to outline the present margins of the Ruby Range at least by early or middle Oligocene time, with normal faulting continuing into the Quaternary.

CONCLUSIONS

(1) The upper part of the Pilgrim Formation and the overlying Red Lion Formation are divisible into distinct lithofacies units.

(2) The lithofacies units of the two formations are similar in that they consist of sediments deposited mainly in shallow subtidal, intertidal, and locally supratidal environments.

(3) The depositional environments were extensive, the lithofacies units extending throughout the map area.

(4) The depositional environments for most of these units are much like those existing presently in the Persian Gulf, although features similar to those in the Bahama Islands are present, too. Lithofacies units in the upper part of the Red Lion, however, contain algal strutures like those found in Shark Bay, Australia.

(5) A series of discrete basement blocks dipping to the north-northeast make up the northern part of the Ruby Range.

(6) These basement blocks are bordered by upthrust faults, which typically flatten in their uppermost segments.

(7) Folds developed adjacent to the upthrusted basement blocks in response to differential vertical uplift.

(8) All folds plunge northwestward and are asymmetrical due to tilting of individual basement blocks.

(9) Displaced masses of rock present at the range margins were probably emplaced by gravity sliding.

(10) The present margins of the range were delimited by normal faulting, initiated by early or middle Oligocene time.

SECTION A

Section A occurs at the north end of the Ruby Range, NW¼NW¼ sec. 21, T. 6 S., R. 5 W. The section is sheared, brecciated, contorted and faulted, but represents the only Quadrant strata present in the range. The thickness can only be approximate.

Fault.

		Unit Thick. (feet)	Cumul. Thick. (feet)
QUADRANT FORMATION:			
50.	Dolomite--highly brecciated and contorted---	75±	1204±
49.	Limestone--same as unit 46-----------------	150	1129
48.	Quartzite--medium bedded-------------------	4	979
47.	Limestone--same as unit 46, but thick bedded	40	975
46.	Limestone--pale yellowish brown (10 YR 6/2), weathers med. lt. gray (N 6), thin and med. bedded, cherty----------------------------	5	935
45.	Covered------------------------------------	9	930
44.	Limestone--same as unit 43, but with cherty zones--------------------------------------	2	921
43.	Limestone--pale yellowish brown (10 YR 6/2), weathers lt. gray (N 7), medium and thick bedded, fossil hash------------------------	22	919
	(Moved eastward about 300 feet and continued to measure section. Probably crossed a fault in gully, thought to have minor throw.)		
42.	Covered------------------------------------	57	897
41.	Limestone-Quartzite breccia----------------	10	840
40.	Covered------------------------------------	10	830
39.	Quartzite breccia--grayish orange (10 YR 7/4, weathers lt. brown (5 YR 5/6), very fine grained------------------------------	30	820
38.	Limestone--same as unit 26-----------------	40	790
37.	Covered--quartzite float common------------	45	750

A P P E N D I X

MEASURED SECTIONS

Measured sections and their locations are described in this section, the locations plotted in the figure below.

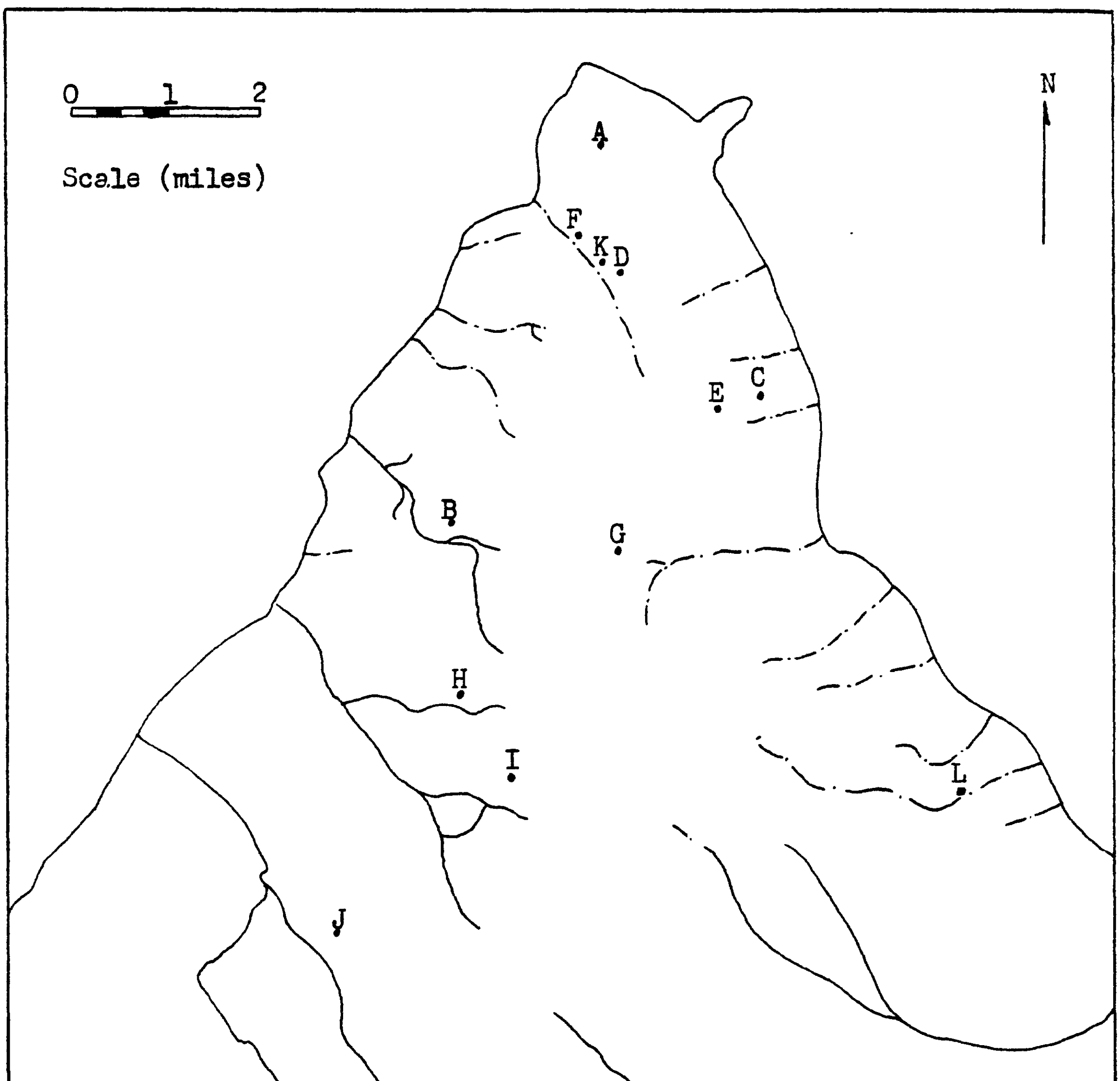

Figure 26. Map outlining major part of area studied, showing prominent streams and location of measured sections. Exact locations of sections are given in text of Appendix.

Quadrant Formation, continued.		Unit Thick. (feet)	Cumul. Thick. (feet)
36.	Limestone--same as unit 26----------------	15	705
35.	Covered--quartzite float------------------	38	690
34.	Limestone--same as unit 26----------------	2	652
33.	Covered--much quartzite float-------------	25	650
32.	Limestone--same as unit 26----------------	5	625
31.	Covered-----------------------------------	30	620
30.	Limestone--same as unit 26----------------	87	590
29.	Covered-----------------------------------	27	503
28.	Limestone--same as unit 26----------------	4	476
27.	Covered-----------------------------------	9	472
26.	Limestone--pale yellowish brown (10 YR 6/2), weathers grayish orange, medium and thick bedded. Some chert nodules and stringers---	6	463
25.	Limestone-Quartzite breccia---------------	8	457
24.	Limestone--same as unit 22, but no fossil hash--------------------------------------	23	449
23.	Limestone-Quartzite breccia---------------	4	426
22.	Limestone--pale yellowish brown (10 YR 6/2), thin to thick bedded. Massive outcrops. Fossil hash common. Chert nodules and stringers common-------------------------	62	422
21.	Covered--fault?---------------------------	20	360
20.	Sandstone, quartz--very pale orange (10 YR 8/2), massive, very fine grained, well cemented, calcareous---------------------	12	340
19.	Limestone--pale yellowish brown (10 YR 6/2), weathers medium lt. gray (N 6), thick bedded. Cherty stringers-------------------------	23	328
18.	Covered-----------------------------------	10	305

Quadrant Formation, continued.		Unit Thick. (feet)	Cumul. Thick. (feet)
17.	Limestone--pale yellowish brown (10 YR 6/2), weathers grayish orange (10 YR 7/4), medium and thick bedded. Chert stringers locally--	4	295
16.	Covered--------------------------------------	19	291
15.	Sandstone, quartz, calcareous--moderate orange pink (5 YR 8/4), fine grained. Breccia of tectonic origin-----------------	5	272
14.	Limestone--same as unit 11, with chert present locally-----------------------------	3	267
13.	Covered--quartzite float--------------------	4	264
12.	Limestone--dark yellowish brown (10 YR 4/2), weathers lt. gray (N 7), thick bedded, finely crystalline---------------------------	32	259
11.	Quartzite and quartzitic limestone--limestone is like that of unit 8. Quartzite--moderate orange pink (5 YR 8/4), thin bedded, very fine grained. Brecciated. Quartzite stands in relief in quartzitic limestone-----------	32	259
10.	Limestone--same as unit 8, lithilogically---	12	227
9.	Covered--------------------------------------	10	215
8.	Limestone--very pale orange (10 YR 8/2), massive. Brecciated. Vuggy----------------	15	205
7.	Covered--------------------------------------	28	190
6.	Limestone--dark yellowish brown (10 YR 4/2), weathers lt. gray (N 7), medium and thick bedded. Locally contains chert, most prominent on bedding surfaces, is grayish brown (5 YR 3/2)----------------------------	7	162
5.	Covered--float much like that of unit 2-----	60	155
4.	Limestone--same as unit 2------------------	20	95
3.	Covered--------------------------------------	30	75
2.	Limestone--dark yellowish brown (10 YR 4/2), weathers lt. gray (N 7), thin and medium bedded, finely crystalline. Poor exposure--	39	45

Quadrant Formation, continued.	Unit Thick. (feet)	Cumul. Thick. (feet)
1. Covered------------------------------------	6	6

Kibbey Fm--not measured.

SECTION B

Section B occurs on the west side of the Ruby Range, S½NE¼NW¼ sec. 7, T. 6 S., R. 5 W. In this 1/16 part of sec. 7 the measured section is north of the northernmost fork of Big Dry Creek and immediately above (west of) the Mission Canyon Formation. It is nearly vertical and was measured at an altitude of about 6700 feet.

Fault.

KIBBEY FORMATION:	Unit Thick. (feet)	Cumul. Thick. (feet)
24. Sandstone, Mudstone, and Dolomite -- as below. Unit is in fault contact with Lodgepole Fm.------------------------------	39	138.5
23. Sandstone, quartz--same as unit 12----------	2.5	99.5
22. Mudstone, dolomitic--same as unit 10--------	4.5	97
21. Sandstone, quartz--same as unit 12----------	.5	92.5
20. Sandstone, quartz--same as unit 17----------	3	92
19. Dolomite, silty--mottled. Like unit 7------	.5	89
18. Limestone, dolomitic, sandy--same as unit 9-	5	88.5
17. Sandstone, quartz--pale reddish brown (10 R 5/4), medium bedded. Fine to medium grained	2	83.5
16. Limestone, dolomitic sandy--same as unit 9--	2.5	81.5
15. Sandstone, quartz--same as unit 12----------	1	79
14. Covered-------------------------------------	7	78
13. Sandstone, quartz--pale reddish brown (10 R 5/4), thin bedded, fine to medium grained---	2.5	71
12. Sandstone, quartz--moderate orange pink (10 R 5/4), medium bedded, medium grained. Contains pink chert grains--------------------	2	68.5

Kibbey Formation, continued.		Unit Thick. (feet)	Cumul. Thick. (feet)
11.	Limestone, dolomitic, sandy----------------	10.5	66.5
10.	Mudstone, dolomitic--pale reddish brown (10 R 5/4), medium bedded----------------------	10	56
9.	Limestone, dolomitic--pale reddish brown (10 R 5/4), thick bedded, finely crystalline, sandy---------------------------------------	3	46
8.	Dolomite--silty. Same as unit 5-----------	5	43
7.	Dolomite, silty, mottled--pale reddish brown (10 R 5/4), medium bedded------------------	4.5	38
6.	Limestone, dolomitic--pale reddish brown (10 R 5/4), thin bedded, finely crystalline-----	.5	33.5
5.	Dolomite, silty--pale reddish brown (10 R 5/4), medium and thick bedded, laminated----	2.5	33
4.	Siltstone--pale reddish brown (10 R 5/4), thin bedded---------------------------------	6.5	30.5
3.	Sandstone, quartz--pale reddish brown (10 R 5/4), thick bedded but finely laminated. Fine- to medium-grained-------------------	.5	24
2.	Covered--reddish float--------------------	13	23.5
1.	Covered--questionably assigned to Kibbey. Unit overlies thick-bedded limestone of Mission Canyon----------------------------	10.5	10.5

Mission Canyon Fm.--not measured.

SECTION C

Section C crops out on the northeast flank of the Ruby Range, S½SE¼ sec. 34, and SW¼SW¼SW¼ sec. 35, T. 5 S., R. 5 W. The section was measured from west to east along the ridge crest divide (between Robinson Canyon and the next canyon to the north) to the 7302-foot-peak; then ESE down the ridge crest into the southwesternmost corner of section 35.

Kibbey Fm.--not measured.

MISSION CANYON FORMATION:	Unit Thick. (feet)	Cumul. Thick. (feet)
51. Limestone--same as unit 43. Contact with Kibbey Formation-------------------------	30	1370
50. Covered------------------------------------	30	1340
49. Limestone--same as unit 43------------------	40	1310
48. Covered------------------------------------	120	1270
47. Limestone--same as unit 43------------------	130	1150
46. Covered------------------------------------	50	1020
45. Limestone--same as unit 43------------------	30	970
44. Covered------------------------------------	50	940
43. Limestone--dark yellowish brown (10 YR 4/2), thick bedded (massive), fine grained. Chert uncommon-----------------------------------	45	890
42. Solution breccia, evaporitic--matrix is grayish orange (10 YR 7/4). Limestone blocks to 3 ft. diameter, all angular. Matrix is silty and calcareous-----------------------	15	845
41. Covered------------------------------------	50	830
40. Limestone--dark yellowish brown (10 YR 4/2), thick bedded (massive), fine grained. Some chert present-------------------------------	80	780
39. Covered------------------------------------	10	700
38. Limestone, slightly dolomitic--dark yellowish brown (10 YR 4/2), thick bedded, fine grained. Chert stringers present--------------------	5	680
37. Limestone, dolomitic--pale yellowish brown (10 YR 6/2), thin and medium bedded, fine grained-------------------------------------	30	675
36. Covered------------------------------------	95	497
35. Limestone--same as unit 33------------------	58	555
34. Limestone--same as unit 32------------------	8	497

Mission Canyon Formation, continued.	Unit Thick. (feet)	Cumul. Thick. (feet)
33. Limestone--dark yellowish brown (10 YR 4/2), weathers lt. gray (N 7), thick bedded, fine grained. Chert stringers common----------	24	489
32. Limestone--pale yellowish brown (10 YR 6/2), medium bedded, medium to coarsely crystalline. Fossil hash----------------------	28	465
31. Limestone--pale yellowish brown (10 YR 6/2), weathers lt. gray (N 7), thick bedded, medium crystalline----------------------	53	437
30. Covered--------------------------------	4	384
29. Limestone--same as unit 27---------------	10	380
28. Covered--------------------------------	5	370
27. Limestone--dark yellowish brown (10 YR 4/2), weathers lt. gray (N 7), thick bedded (massive), medium crystalline. Fossil hash-----	23	365
26. Covered--------------------------------	7	342
25. Limestone--dark yellowish brown (10 YR 5/2), medium and thick bedded, v. fine grained---	30	335
24. Covered--------------------------------	13	305
23. Limestone--pale yellowish brown (10 YR 6/2), weathers lt. gray (N 7), thick bedded, medium grained. Chert stringers----------------	13	292
22. Limestone--pale yellowish brown (10 YR 6/2), thin and medium bedded, fine grained. Chert stringers------------------------------	9	279
21. Dolomite--pale yellowish brown (10 YR 6/2), medium bedded, finely crystalline----------	30	270
20. Limestone--pale yellowish brown (10 YR 6/2), thick bedded, medium to coarsely crystalline	22	240
19. Covered--------------------------------	8	218
18. Limestone breccia--same as unit 17, but medium bedded----------------------------	6	210

Mission Canyon Formation, continued.	Unit Thick. (feet)	Cumul. Thick. (feet)
17. Limestone breccia--pale yellowish brown (10 YR 6/2), thick bedded. Evaporite solution breccia?--	14	204
16. Limestone--dark yellowish brown (10 YR 4/2), thick bedded, sparite, fossil hash----------	12	190
15. Limestone--dark yellowish brown (10 YR 4/2), medium bedded, fossil hash in sparite. Interbedded with thin bedded, pale yellowish brown (10 YR 6/2), sparite hash------------------	9	178
14. Limestone--dark yellowish brown (10 YR 4/2), thick bedded, v. fine grained---------------	26	169
13. Limestone--same as unit 10-----------------	7	143
12. Limestone, silty--yellowish gray (5 Y 7/2), thin bedded----------------------------------	4	136
11. Limestone--dark yellowish brown (10 YR 4/2), medium and thick bedded, sparite, fossil hash. Yellowish gray silty shaly partings----------	6	134
10. Limestone--dark yellowish brown (10 YR 4/2), thin and medium bedded, v. fine grained. Interbedded with limestone, shaly, silty--yellowish gray (5 Y 7/2), thin bedded to shaly--	21	128
9. Limestone--dark yellowish brown (10 YR 4/2), medium bedded, v. fine grained---------------	13	107
8. Limestone--yellowish gray (5 Y 7/2), thin bedded to platy, silty-----------------------	5	94
7. Limestone--dark yellowish brown (10 YR 4/2), medium bedded, v. fine grained---------------	2	89
6. Limestone--same as unit 2------------------	1	87
5. Limestone--like unit 4, but thin bedded. Beds separated by silty laminae--yellowish gray (5 Y 7/2)-------------------------------	5	86
4. Limestone--dark yellowish brown (10 YR 4/2), weathers lt. gray (N 7), medium bedded, fine grained--------------------------------------	12	81

Mission Canyon Formation, continued.	Unit Thick. (feet)	Cumul. Thick. (feet)
3. Limestone--yellowish gray (5 Y 7/2), thin bedded, platy, fine grained, silty----------	4	69
2. Limestone--dark yellowish brown (10 YR 4/2), thick bedded, crinoidal debris, weathers lt. gray (N 7)----------------------------------	56	65
1. Limestone--dark yellowish brown (10 YR 4/2), weathers lt. gray (N 7), medium and thick bedded. Fossil hash--mainly crinoid debris. Parting laminae, silty, shaly, yellowish gray (5 Y 7/2). Contact with Lodgepole is conformable-------------------------------------	9	9
LODGEPOLE FORMATION:		
23. Limestone--dark yellowish brown (10 YR 4/2), thick bedded, fine grained, dense. Forms steep slope. Contact with cliff-forming Mission Canyon Fm. is conformable-----------	34	594
22. Limestone--same as unit 21, interbedded with limestone, shaly--grayish orange (10 YR 7/4). Slope-forming unit-------------------------	25	560
21. Limestone--dark yellowish brown (10 YR 4/2), thin bedded, fine grained. Top of prominent ledge-------------------------------------	37	535
20. Limestone--dark yellowish brown (10 YR 4/2), weathers lt. gray (N 7), medium bedded, v. fine grained, dense. Interbedded with zones to 3 inches thick of laminae, silty--grayish orange (10 YR 7/4)------------------------	33	498
19. Limestone--dark yellowish brown (10 YR 4/2), weathers dark yellowish orange (10 YR 6/6) due to silty calcareous laminae. Thin bedded to rubbly----------------------------------	3	465
18. Limestone--dark yellowish brown (10 YR 4/2), weathers lt. gray (N 7), thick bedded, v. fine grained. Interbedded with zones to 3 inches thick of laminae, silty, calcareous--pale red (5 R 6/2) to very pale orange (10 YR 8/2), containing much fossil debris-------	61	462

Lodgepole Formation, continued.	Unit Thick. (feet)	Cumul. Thick. (feet)
17. Limestone--dark yellowish brown (10 YR 4/2), medium bedded, v. fine grained. Interbedded with zones to 3 inches thick of limestone, argillaceous, silty, shaly--pale yellowish brown (10 YR 6/2) to grayish orange (10 YR 7/4)------------------------------------	47	401
16. Limestone--dark yellowish brown (10 YR 4/2), weathers lt. gray (N 7), thick bedded, v. fine grained. Contains chert lenses and nodules. Between beds are laminae, silty, calcareous, form zones to 3 inches thick--grayish orange (10 YR 7/4)----------------	14	354
15. Limestone--pale yellowish brown (10 YR 6/2), weathers grayish orange (10 YR 7/4), thin bedded to shaly. Locally argillaceous------	6	340
14. Limestone--pale yellowish brown (10 YR 6/2), medium and thick bedded, v. fine grained, dense. Forms base of prominent ledge. Marks abrupt appearance of abundantly fossiliferous strata-------------------------------------	11	334
13. Covered------------------------------------	52	323
12. Limestone--pale yellowish brown (10 YR 6/2), weathers lt. bluish gray (5 B 7/1), medium bedded, v. fine grained, dense-------------	2	271
11. Covered------------------------------------	16	269
10. Limestone--dark yellowish brown (10 YR 4/2), medium bedded, v. fine grained-------------	8	253
9. Limestone--dark yellowish brown (10 YR 4/2), weathers pale yellowish brown (10 YR 6/2) to grayish orange (10 YR 7/4), thin bedded to shaly. Forms book-like beds------------	100	245
8. Limestone--dark yellowish brown (10 YR 4/2), medium bedded, interbedded with limestone, argillaceous, shaly--pale yellowish brown (10 YR 6/2), thin bedded------------------	12	145
7. Limestone, argillaceous, shaly--dark yellowish brown (10 YR 4/2), weathers pale yellowish brown (10 YR 6/2), to grayish orange (10 YR 7/4), fine grained---------------------	13	133

Lodgepole Formation, continued.	Unit Thick. (feet)	Cumul. Thick. (feet)
6. Limestone--dark yellowish brown (10 YR 4/2), thin bedded, fine grained, interlaminated with limestone, argillaceous, shaly--yellowish gray (5 Y 7/2). Worm-like trails locally present on bedding surfaces-------------	17	120
5. Limestone--dark yellowish brown (10 YR 4/2), thin bedded, v. fine grained---------------	8	103
4. Limestone, argillaceous--dark yellowish brown (10 YR 4/2), thin bedded to paper-thin. Beds parted by limestone, argillaceous, shaly--yellowish gray (5 Y 7/2)------	14	95
3. Limestone, argillaceous, shaly--dark yellowish brown (10 YR 4/2), paper-thin, finely laminated. "Wavy" beds--------------------	4	81
2. Limestone, argillaceous, shaly--dark yellowish brown (10 YR 4/2), thin bedded to paper-thin-------------------------------------	17	77
1. Covered-------------------------------------	60	60

Three Forks Fm.--covered.

SECTION D

Section D occurs in the SE¼SW¼NW¼ sec. 28, T. 5 S., R. 5 W. It is exposed on a slight ridge between two draws, all trending NE-SW, between 7000 and 7200 feet in altitude.

Lodgepole Fm.--not measured.

THREE FORKS FORMATION, Sappington Member:	Unit Thick. (feet)	Cumul. Thick. (feet)
20. Covered--contact with Lodgepole concealed Lodgepole exposed at 150 foot level---------	9	150
19. Siltstone--same as unit 18, but medium bedded---------------------------------------	4	141
18. Siltstone, calcareous--grayish orange (10 YR 7/4), thin bedded-------------------------	3	137
Trident Member:		
17. Covered-------------------------------------	9	134

Three Forks Fm., Sappington Member, Continued.	Unit Thick. (feet)	Cumul. Thick. (feet)
16. Covered--float is clay shale chips, pale olive (10 Y 6/2), v. finely micaceous. "Iron nodules" to ¼" dia. also present------	14.5	125
Logan Gulch Member:		
15. Limestone--moderate yellowish brown (10 YR 5/4), thin bedded, v. fine grained, dense---	.5	110.5
14. Limestone--pale yellowish brown (10 YR 6/2), weathers lt. brownish gray (5 YR 6/1), thin and medium bedded. Beds separated by silty laminae, yellowish gray (5 Y 7/2)-----------	29	110
13. Limestone--dark yellowish brown (10 YR 4/2), thick bedded, fine grained, weathers lt. gray (N 7)---------------------------------	7.5	81
12. Limestone--dark yellowish brown (10 YR 4/2), thin bedded, fine grained------------------	1.5	73.5
11. Limestone, dolomitic--pale yellowish brown (10 YR 6/2), weathers lt. gray (N 7), thick bedded--------------------------------------	9	72
10. Dolomite--pale yellowish brown (10 YR 6/2), medium bedded, faintly laminated, contains chert nodules (max. is 1.5 inch long)-------	1.5	63
9. Dolomite--same as unit 8, but top and bottom of bed are scour surfaces. Upper one inch of bed is porous, vuggy and limonite stained (weathered glauconite?)--------------------	.5	61.5
8. Dolomite--pale yellowish brown (10 YR 6/2), thick bedded, fine grained. Base of ledge--	6	61
7. Dolomite--pale yellowish brown (10 YR 6/2), thin, medium and thick bedded, vuggy (evaporite solution)----------------------	9	55
6. Covered--float is shaly limestone and shale, pale greenish yellow (10 Y 8/2)------------	10	46
5. Limestone--pale yellowish brown (10 YR 6/2), medium bedded, brecciated------------------	1	36
4. Covered--float same as unit 2--------------	6	35

Three Forks Formation, Lower Part, continued.	Unit Thick. (feet)	Cumul. Thick. (feet)
3. Limestone--yellowish gray (5 Y 7/2), thick bedded, finely brecciated-------------------	4	29
2. Covered--float is clay shale chips, grayish yellow green (5 GY 7/2)--------------------	21	25
1. Dolomite--pale yellowish orange (10 YR 8/6), thin and medium bedded, brecciated. Contact with Jefferson apparently conformable-------	4	4

Jefferson Fm.--not measured.

SECTION E

Section E is on the east side of the Ruby Range, SW¼SW¼ sec. 34, T. 5 S., R. 5 W. It occurs north of the northernmost fork of the creek in Robinson Canyon, and at the base of the cliff in the western 1/3 of the above noted 1/16 part of sec. 34. The altitude is about 7650 feet.

Pilgrim Fm.--not measured.

PARK SHALE:	Unit Thick. (feet)	Cumul. Thick. (feet)
7. Mudstone--grayish orange (10 YR 7/4), thin bedded, silty. Contact with Pilgrim is sharp--no shale in dolomite of Pilgrim------	.5	196.5
6. Shale--grayish olive (10 Y 4/2), finely micaceous, fissile chips-------------------	28.5	196
5. Dolomite--grayish green (5 GY 5/2), weathers lt. brown (5 YR 6/4), thin bedded-----------	.5	167.5
4. Shale and Dolomite--as in unit 1, but dolomite is nodular----------------------------	6.5	167
3. Dolomite--same as in unit 1, but medium bedded---------------------------------------	.5	160.5
2. Shale--grayish olive (10 Y 4/2), finely micaceous, fissile chips. Interbedded with dolomite--grayish green (10 GY 5/2), weathers lt. brown (5 YR 6/4), thin bedded-----------	10	160

Park Shale, continued.	Unit Thick. (feet)	Cumul. Thick. (feet)
1. Covered--landslide. Thickness of this unit is estimated-------------------------------	150	150

Covered interval.

SECTION F

Section F is located in the northern part of the Ruby Range, NW¼NE¼ sec. 29, T. 5 S., R. 5 W. It is north of the northernmost creek in sec. 29, with its base at about 6300 feet in altitude and about 40 feet above the creek bottom. This is a partial section of the upper part of the Meagher, and is the most Meagher exposed in the northern part of the range.

Park Fm.--not measured. MEAGHER FORMATION:	Unit Thick. (feet)	Cumul. Thick. (feet)
21. Limestone--same as unit 19 only shale occurs above this unit--------------------	6	100
20. Shale--grayish olive (10 Y 7/4)------------	5	94
19. Limestone--dark yellowish brown (10 YR 4/2), locally mottled dark yellowish brown (5 YR 5/6), medium bedded. Upper 1 ft. contains limestone pebble conglomerate--------------	4	89
18. Shale--gray olive (10 Y 7/4), with a few thin interbeds of limestone--dark yellowish brown (10 YR 4/2). Mottled light brown (5 YR 5/6)	7	85
17. Limestone--dark yellowish brown (10 YR 4/2), mottled lt. brown (5 YR 5/6) to yellowish gray (5 Y 7/2), thin and thick bedded-------	4	78
16. Shale--grayish olive (10 Y 7/4), with a few interbeds of limestone, pebble conglomerate--dark yellowish gray (10 YR 4/2)-------------	9	74
15. Limestone--dark yellowish gray (10 YR 4/2), thin bedded, sparite. Flat pebble conglomerate is common. Intercalated shale--grayish olive (10 Y 7/4)-----------------------	5	65

Meagher Formation, continued.	Unit Thick. (feet)	Cumul. Thick. (feet)
14. Limestone--dark yellowish brown (10 YR 4/2), weathers pale yellowish brown (10 YR 6/2), locally mottled grayish orange (10 YR 7/4), thin bedded. Locally nodular. Parting laminae shaly, dolomitic, or silty--grayish olive (10 Y 4/2)-------------------------	6	60
13. Limestone--pale yellowish brown (10 YR 6/2), locally mottled yellowish gray (5 Y 7/2), medium and thick bedded. Finely crystalline	19	54
12. Shale--grayish olive (10 Y 4/2), finely micaceous-----------------------------------	3	35
11. Limestone pebble conglomerate--dark yellowish brown (10 YR 4/2), thick bedded---------	3	32
10. Limestone--pale yellowish brown (10 YR 6/2), mottled grayish orange (10 YR 7/4), thin bedded--------------------------------------	2	29
9. Shale--grayish olive (10 Y 4/2), finely micaceous-----------------------------------	1	27
8. Limestone--dark yellowish brown (10 YR 4/2), weathers pale yellowish brown (10 YR 6/2) to lt. brown (5 YR 5/6). Thick bedded. Sparite	4	26
7. Shale--grayish olive (10 Y 4/2), finely micaceous. Interbedded sparingly is limestone--dark yellowish brown (10 YR 4/2), mottled grayish orange (10 YR 7/4), thin bedded. Locally silty and glauconitic. Sparite and micrite-----------------------	4	22
6. Limestone--same as unit 5, but no pebbles or glauconite----------------------------------	6	18
5. Limestone--dark yellowish brown (10 YR 4/2), weathers pale yellowish brown (10 YR 6/2), mottled grayish orange (10 YR 7/4), medium bedded. Contains glauconite and limestone pebble conglomerate. Mottles are slightly dolomitic and seem to parallel bedding. Parting laminae--greenish gray (5 GY 6/1), finely micaceous--------------------------	2	12

Meagher Formation, continued.	Unit Thick. (feet)	Cumul. Thick. (feet)
4. Sill--light brown (5 YR 6/4)----------------	5	10
3. Limestone--dark yellowish brown (10 YR 4/2), weathers pale yellowish brown (10 YR 6/2), medium bedded, fine grained----------------	1.5	5
2. Limestone--dark yellowish brown (10 YR 4/2), thin bedded, laminated. Contains brachiopods. Very fine grained------------------	.5	3.5
1. Shale--dark greenish gray (5 GY 4/1), finely micaceous. Lower contact is conformable----	3	3

Remainder of Meagher Fm. is concealed.

SECTION G

Section G is located along the backbone of the Ruby Range, E¼NE¼ sec. 8, T. 6 S., R. 5 W. Its base is in the lowest saddle of the N-S oriented ridge crest at about 8450 feet altitude. The measured section trends north along the crest for about 1/3 mile, terminating near the peak with an altitude of 8885 feet.

Jefferson Fm.--not measured.

RED LION FORMATION, Sage Member, upper part:	Unit Thick. (feet)	Cumul. Thick. (feet)
19. Dolomite--pale yellowish brown (10 YR 6/2), weathers lt. gray (N 7), medium and thick bedded. Occurs on dip slope; thickness approximate--------------------------------	40	115
Sage Member, lower part:		
18. Dolomite--pale yellowish brown (10 YR 6/2), locally mottled pale yellowish orange (10 YR 8/6), thin and medium bedded. Thin laminae between beds----------------------	10	75
17. Covered--float is pencil-shaped pieces of pale yellowish brown (10 YR 6/2) dolomite, thinly bedded. Bedding surfaces are silty, weather yellowish gray (5 Y 7/2)------------	15	65

Red Lion Fm., Sage Member, lower part, continued.	Unit Thick. (feet)	Cumul. Thick. (feet)
16. Dolomite--pale yellowish brown (10 YR 6/2), weathers pale green (5 G 7/2) on bedding surfaces. A mud-chip occurs in the bottom 3 inches. Thin bedded-------------------	2	50
15. Covered------------------------------------	1.5	48
14. Dolomite--pale yellowish brown (10 YR 6/2), thinly bedded, locally glauconitic, separated by silt------------------------------	1.5	46.5
13. Covered------------------------------------	2	45
12. Dolomite--same as unit 5------------------	4	43
11. Dolomite, silty--same as unit 9------------	1.5	39
10. Dolomite--much like unit 4----------------	7.5	37.5
9. Dolomite, silty--pale yellowish brown (10 YR 6/2), thin bedded. Pale brown (5 YR 5/2), silty laminae in relief on weathered face---	2	30
8. Dolomite--same as unit 4------------------	3	28
7. Covered------------------------------------	2	25
6. Dolomite--same as unit 4------------------	5	23
5. Covered------------------------------------	4	18
4. Dolomite--pale yellowish brown (10 YR 6/2), thinly bedded to nodular and rubbly. Beds separated by silty laminae. Locally glauconitic--------------------------------	2.5	14
Dry Creek Member:		
3. Dolomite--pale yellowish brown (10 YR 6/2), thinly bedded, glauconitic. Upper part is dolomite pebble conglomerate---------------	1.5	11.5
2. Covered------------------------------------	5	10
1. Shale--grayish olive (10 Y 4/2), clay shale chips. Poorly exposed---------------------	5	5

PILGRIM FORMATION:	Unit Thick. (feet)	Cumul. Thick. (feet)
17. Dolomite, sandy, mottled--pale reddish brown (10 R 5/4), medium bedded. Sand is quartz--	1	295
16. Dolomite--same as unit 12-------------------	2	294
15. Dolomite--same as unit 10-------------------	2	292
14. Dolomite--same as unit 12-------------------	2	290
13. Dolomite--same as unit 10-------------------	4	288
12. Dolomite, sandy (quartz)--pale yellowish brown (10 YR 6/2), thin and medium bedded. Mat algae?----------------------------------	2	284
11. Covered-------------------------------------	5	282
10. Dolomite--pale yellowish brown (10 YR 6/2), thick bedded, fine grained, dense-----------	3	277
9. Sandstone, quartz, dolomitic--pale yellowish brown (10 YR 6/2), thick bedded, cross-bedded------------------------------------	5	274
8. Dolomite, sandy--pale yellowish brown (10 YR 6/2), thin bedded. Weathered face is wavy in relief. Mat Algae?---------------------	39	269
7. Dolomite--dark yellowish brown (10 YR 4/2), medium bedded, finely crystalline, dense----	9	230
6. Covered--contact of lower and upper members concealed in this unit---------------------	3	221
5. Dolomite--dark yellowish brown (10 YR 4/2), weathers pale yellowish brown (10 YR 6/2), medium and thick bedded, fine grained, dense, mottled----------------------------	4.5	218
4. Dolomite, shaly--dusky yellow (5 Y 6/4)-----	1.5	213.5

	Unit Thick. (feet)	Cumul. Thick. (feet)
Lower part of Formation:		
3. Dolomite--pale red (5 R 6/2), weathers pale yellowish brown (10 YR (6/2), thin bedded, weathered faces are silty to feel----------	2	212
2. Dolomite--pale yellowish brown (10 YR 6/2), thick bedded, mottled---------------------	5	210
1. Covered--talus slope--contact with Park is concealed-----------------------------------	205	205
PARK FORMATION:		
1. Covered--float is mostly shale--pale olive (10 Y 6/2), finely micaceous, fissile. Other float includes fossil fragmental limestone--pale yellowish brown (10 YR 6/2), thin bedded. Also dolomite with oncolites to 1 cm. diameter-------------------------	150	150
MEAGHER FORMATION:		
35. Limestone--dark yellowish brown (10 YR 4/2), mottled grayish orange (10 YR 7/4), weathers lt. gray (N 7), thin bedded. Contact with Park at 565--------------------------------	34	565
34. Limestone--dark yellowish brown (10 YR 4/2), weathers pale yellowish brown (10 YR 6/2), mottled yellowish gray (5 Y 7/2) to pale red (5 R 6/2), medium bedded------------------	20	531
33. Limestone--same as unit 32, but thin bedded-	6	511
32. Limestone--dark yellowish brown (10 YR 4/2), weathers medium gray (N 7), mottled yellowish gray (5 Y 7/2), medium and thick bedded-----	35	505
31. Limestone, dolomitic--dark yellowish brown (10 YR 4/2), medium bedded, fine grained, suggary, locally mottled, oolitic-----------	98	470
30. Limestone--dark yellowish brown (10 YR 4/2), weathers medium gray (N 7), thick bedded. Mottles not common. White twig-like bodies present. Top of unit is top of cliff-------	31	372

Meagher Formation, continued.	Unit Thick. (feet)	Cumul. Thick. (feet)
29. Limestone--same as unit 27, but weathering color depends on exposure: tends toward gray where protected------------------------	11	341
28. Limestone--same as unit 27, but contains pisolites and is fetid---------------------	2	330
27. Limestone--dark yellowish brown (10 YR 4/2), weathers medium gray (N 7), medium and thick bedded. Forms cliff base------------------	12	328
26. Limestone--dark yellowish brown (10 YR 4/2), weathers medium gray (N 7), mottled yellowish gray (5 Y 7/2), thin and medium bedded--	10	316
25. Limestone--dark yellowish brown (10 YR 4/2), mottled pale yellowish brown (10 YR 6/2), weathers same colors, medium bedded---------	6	306
24. Limestone--same as unit 23, except medium and thick bedded, mottling less common----------	22	300
23. Limestone--dark yellowish brown (10 YR 4/2), mottled pale yellowish brown (10 YR 6/2) to grayish orange (10 YR 7/4), weathers medium gray (N 7), thin bedded. Unit is at top of lower ledge and base of slope-forming strata	29	278
22. Limestone--dark yellowish brown (10 YR 4/2), mottled pale yellowish brown (10 YR 6/2), weathers same colors, thick bedded----------	19.5	249
21. Limestone--pale yellowish brown (10 YR 6/2), thin bedded, rubbly------------------------	.5	229.5
20. Limestone--dark yellowish brown (10 YR 4/2), medium to thick bedded, mottled pale yellowish brown (10 YR 6/2)----------------------	21	229
19. Limestone--pale yellowish brown (10 YR 6/2), weathers medium gray (N 7), thin bedded, mottled yellowish gray (5 Y 7/2)------------	7.5	208

Meagher Formation, continued.	Unit Thick. (feet)	Cumul. Thick. (feet)
18. Laminae zone--greenish yellow (10 Y 8/2), with some shaly limestone "lenses" ¼ inch x 1½ inch, medium gray (N 7)----------------	.5	200.5
17. Limestone--same as unit 14------------------	7	200
16. Limestone--medium gray (N 7), medium bedded, mottling less common (i.e., not continuous)-	4	193
15. Limestone--like unit 14, but subordinate to the mottles, which are really laminate with limestone contained in between: thus limestone tends to be nodular------------------	3	189
14. Limestone--medium gray (N 7), thin bedded, fine grained, mottled yellowish gray (5 Y 7/2). Mottles are parallel to bedding------	11	186
13. Limestone--medium gray (N 7), thin bedded, mottled pale red (5 R 6/2). Mottles are silty and calcareous-----------------------	1	175
12. Limestone--same as unit 10------------------	19	174
11. Covered-------------------------------------	4	155
10. Limestone--medium gray (N 7), mottled yellowish gray (5 Y 7/2), thin bedded. Mottles are silty, calcareous; most are along irregular bedding surface-------------	3	151
9. Covered--------------------------------------	25	148
8. Dolomite--same as unit 3, except it is suggary-------------------------------------	1	123
7. Covered--------------------------------------	2	122
6. Dolomite--same as unit 3--------------------	4	120
5. Covered--------------------------------------	4	116
4. Dolomite--dark yellowish brown (10 YR 4/2), medium and thick bedded, fine grained, dense-	2	112
3. Covered--------------------------------------	5	110

Meagher Formation, continued	Unit Thick. (feet)	Cumul. Thick. (feet)
2. Dolomite, calcareous--pale yellowish brown (10 YR 6/2), medium to thick bedded, fine grained, dense, mottled-------------------	20	105
1. Covered--contact with Wolsey concealed------	85	85
WOLSEY FORMATION:		
1. Covered--float is shale, grayish olive (10 Y 4/2)------------------------------------	58	58
FLATHEAD FORMATION:		
5. Sandstone, quartz--grayish red (5 YR 4/2), thin bedded, fine grained to v. fine grained. Grains are round, small limonite spots. Some intercalated shale--grayish olive (10 Y 4/2), micaceous-------------------------	6	47
4. Sandstone, quartz--lt. brown (5 YR 6/4), thin and medium bedded, medium grained. Grains round. Limonite and hematite spots to ½ inch diameter--burrowing?-------------	4	41
3. Covered-------------------------------------	7	37
2. Sandstone, quartz--lt. brown (5 YR 6/4), medium bedded, fine to coarse grained. Grains are round, well cemented-------------	5	30
1. Covered--contact concealed-----------------	25	25

Precambrian Metamorphic Rock

SECTION H

Section H occurs in the McHessor Creek drainage, W½SW¼SE¼ sec. 18, T. 6 S., R. 5 W. The measured section is north of the McHessor Creek tributary in this ¼ sec., its base being about 50 feet up the hill (directly north) from where the 6880-foot contour intersects the tributary stream.

Lodgepole Fm.--not measured.

JEFFERSON FORMATION, Birdbear Member:	Unit Thick (feet)	Cumul. Thick (feet)
56. Dolomite--pale yellowish brown (10 YR 6/2), thick bedded (massive), fine grained, dense. Brecciated and rubbly. Faintly fetid locally. Forms prominent ledge. Beds in upper 10 ft. are mottled grayish orange (10 YR 7/4)--coloring occurs between clasts--------	51	268
55. Dolomite--pale yellowish brown (10 YR 6/2), thin bedded, v. fine grained, dense---------	4	217
54. Dolomite--same as unit 50------------------	1	213
53. Covered--contact of lower and Birdbear members concealed in this unit-------------	12	212
Lower Member:		
52. Dolomite--same as unit 50------------------	2.5	200
51. Dolomite, silty?--yellowish gray (5 Y 7/2), thin bedded, rubbly------------------------	.5	197.5
50. Dolomite, sl. calcareous--pale yellowish brown (10 YR 6/2), medium and thick bedded, fine grained, evaporite breccia------------	4	197
49. Dolomite--pale yellowish brown (10 YR 6/2), medium bedded, v. fine grained, dense-------	1	193
48. Shale, silty--yellowish gray (5 Y 7/2), thin bedded to paper-thin (book-like)------------	5	192
47. Dolomite--dark yellowish brown (10 YR 4/2), thick bedded, suggary, fetid----------------	6	187
46. Dolomite--pale yellowish brown (10 YR 6/2), rubbly-------------------------------------	1	181
45. Dolomite--pale yellowish brown (10 YR 6/2), thick bedded, fine graineed, not dense------	16.5	180
44. Dolomite--same as unit 42------------------	.5	163.5
43. Shale, silty--yellowish gray (5 Y 7/2)------	.5	163
42. Dolomite--pale yellowish brown (10 YR 6/2), medium bedded, fine grained, dense----------	.5	162.5

Jefferson Formation, Lower Member, continued.	Unit Thick. (feet)	Cumul. Thick. (feet)
41. Dolomite--dark yellowish brown (10 YR 4/2), thick bedded, suggary, fetid----------------	8	162
40. Shale, silty--yellowish gray (5 Y 7/2)------	1	154
39. Dolomite--pale yellowish brown (10 YR 6/2), thin bedded, fine grained, dense------------	.5	153
38. Dolomite--dark yellowish brown (10 YR 4/2), medium bedded------------------------------	2.5	152.5
37. Dolomite--same as unit 36, but yellowish gray (5 Y 7/2)-----------------------------	1	150
36. Dolomite--pale yellowish brown (10 YR 6/2), thick bedded, rubbly. Evaporite solution breccia------------------------------------	4	149
35. Dolomite--dark yellowish brown (10 YR 4/2), thick bedded, fine and medium grained, suggary, fetid------------------------------	7	145
34. Dolomite--same as unit 34, but rubbly-------	2	138
33. Dolomite--dark yellowish brown (10 YR 4/2), thick bedded, fine and medium grained, suggary, fetid------------------------------	4.5	136
32. Dolomite--pale yellowish brown (10 YR 6/2), medium bedded, fine grained, dense----------	3.5	131.5
31. Shale, silty--yellowish gray (5 Y 7/2)------	1	128
30. Covered-------------------------------------	27	127
29. Shale, silty--yellowish gray (5 Y 7/2)------	2.5	100
28. Dolomite--pale yellowish brown (10 YR 6/2), thin bedded, fine grained, dense------------	.5	97.5
27. Dolomite--same as unit 25------------------	2	97
26. Covered-------------------------------------	2	95
25. Dolomite--pale yellowish brown (10 YR 6/2), thick bedded, fine grained, not dense. Suggary. Intricately dissected weathered surface-------------------------------------	11	93

Jefferson Formation, Lower Member, continued.	Unit Thick. (feet)	Cumul. Thick. (feet)
24. Dolomite--yellowish gray (5 Y 7/2), rubbly, silty?----------	.5	82
23. Covered--float is dolomite, yellowish gray (5 Y 7/2), rubbly----------	1.5	81.5
22. Dolomite--pale yellowish brown (10 YR 6/2) to dark yellowish brown (10 YR 4/2), medium and thick bedded, fine grained but not dense. Suggary, fetid----------	5	80
21. Covered----------	4.5	75
20. Dolomite--same as unit 16----------	.5	70.5
19. Dolomite--dark yellowish brown (10 YR 4/2), thick bedded, suggary, fetid----------	.5	70
18. Dolomite--same as unit 16----------	.5	69.5
17. Shale, dolomitic, silty--yellowish gray (5 Y 7/2)----------	1	69
16. Dolomite--pale yellowish brown (10 YR 6/2), medium bedded, finely laminated, fine grained, dense----------	.5	68
15. Dolomite--dark yellowish brown (10 YR 6/2), thick bedded, suggary, fetid----------	2.5	67.5
14. Dolomite--same as unit 13, but fractured----	.5	65
13. Dolomite--pale yellowish brown (10 YR 6/2), thick bedded, fine grained, dense----------	2	64.5
12. Dolomite--dark yellowish brown (10 YR 4/2), thick bedded, suggary, fetid. Scour surface at top----------	1.5	62.5
11. Shale, dolomitic, silty--yellowish gray (5 Y 7/2), finely laminated to thin bedded------	1	61
10. Dolomite--pale yellowish brown (10 YR 6/2), medium bedded, fine grained, dense, slightly fetid----------	1.5	60
9. Dolomite--grayish orange (10 YR 7/4), thin bedded, rubbly, silty----------	1	58.5

Jefferson Formation, Lower Member, continued.	Unit Thick. (feet)	Cumul. Thick. (feet)
8. Dolomite--pale yellowish brown (10 YR 6/2), thick bedded, fine grained, slightly fetid. Rubbly weathering. Solution breccia?-------	3	57.5
7. Dolomite--dark yellowish brown (10 YR 4/2), thick bedded, fetid, suggary. Forms ledge--	13.5	54.5
6. Covered--	13	41
5. Dolomite--same as unit 3------------------	4	28
4. Covered--	15.5	24
3. Dolomite--dark yellowish brown (10 YR 4/2), thick bedded, fetid, suggary----------------	4	8.5
2. Dolomite--pale yellowish brown (10 YR 6/2), thick bedded, hint of lamination. Dense, fine grained--------------------------------	1	4.5
1. Dolomite--dark yellowish brown (10 YR 4/2), medium and thick bedded, fine grained, fetid. Lower contact is irregular, unconformable---	3.5	3.5
RED LION FORMATION, Sage Member, upper part:		
54. Dolomite--pale yellowish brown (10 YR 6/2), weathers lt. gray (N 7), thin and medium bedded, dense, fine grained. Contact with Jefferson Formation irregular---------------	15.5	170
53. Dolomite--same as unit 44------------------	.5	154.5
52. Dolomite--same as unit 36------------------	1	154
51. Covered--	3	153
50. Dolomite--same as unit 36------------------	3	150
49. Mound--4 ft. high, 4 ft. wide--Dolomite--pale yellowish brown (10 YR 6/2), weathers lt. gray (N 7), finely crystalline, dense---	4	147
48. Dolomite--same as unit 44------------------	1.5	143
47. Mound--Dolomite--pale yellowish brown (10 YR 6/2), weathers lt. gray (N 7), fine grained, dense--	.5	141.5

Red Lion Fm., Sage Member, upper part, continued.	Unit Thick. (feet)	Cumul. Thick. (feet)
46. Dolomite--same as unit 36------------------	1	141
45. Dolomite--same as unit 36, but thin bedded--	.5	140
44. Dolomite--pale yellowish brown (10 YR 6/2), weathers lt. gray (N 7), thin bedded, rubbly	.5	139.5
43. Dolomite--same as unit 36------------------	6	139
42. Mound--5 ft. high, 4 ft. wide--Dolomite--pale yellowish brown (10 YR 6/2), weathers lt. gray (N 7), finely crystalline, dense---	5	133
41. Dolomite--same as unit 36, but thin bedded--	1	128
40. Dolomite--same as unit 36------------------	.5	127
39. Dolomite--same as unit 36, but thin bedded--	.5	126.5
38. Dolomite--same as unit 36------------------	2	126
37. Dolomite--same as unit 36, but thin bedded--	.5	124
36. Dolomite--pale yellowish brown (10 YR 6/2), weathers lt. gray (N 7), medium bedded, fine and medium crystalline---------------------	3.5	123.5
35. Dolomite pebble conglomerate--flat pebbles--	.5	120
34. Dolomite--same as unit 32------------------	2	119.5
33. Mound--greater than 30 ft. long--Dolomite--pale yellowish brown (10 YR 6/2), weathers grayish orange (10 YR 7/4). Has pseudo-brecciated appearance---------------------	1.5	117.5
32. Dolomite--pale yellowish brown (10 YR 6/2), weathers lt. gray (N 7), thin and medium bedded, suggary, fetid--------------------	1	116
31. Mound--Dolomite--pale yellowish brown (10 YR 6/2), weathers lt. gray (N 7), dense, fine grained------------------------------------	.5	115
30. Dolomite--pale yellowish brown (10 YR 6/2), weathers lt. gray (N 7), thin bedded, fine grained------------------------------------	.5	114.5

Red Lion Fm., Sage Member, upper part, continued.	Unit Thick. (feet)	Cumul. Thick. (feet)
29. Mound--½ ft. high, 5½ ft. long--Dolomite--pale yellowish brown (10 YR 6/2), weathers lt. gray (N 7), dense, fine grained--------	.5	114
28. Dolomite--pale yellowish brown (10 YR 6/2), weathers lt. gray (N 7), thin bedded, dense, fine grained------------------------------	1.5	113.5
27. Mound--4 ft. long, 1.8 ft. high--Dolomite--pale yellowish brown (10 YR 6/2), weathers lt. gray (N 7), finely crystalline, dense--	1.8	112
26. Laminae, shaly, dolomitic--greenish gray (5 G 8/1)----------------------------------	.2	110.2
25. Dolomite--pale yellowish brown (10 YR 6/2), weathers lt. gray (N 7), medium bedded, fine to medium crystalline. Locally glauconitic	1	110
24. Dolomite--pale yellowish brown (10 YR 6/2), weathers lt. gray (N 7), thin bedded, fine grained, dense. Laminar partings, silty, shaly--lt. greenish gray (5 G 8/1)---------	1.5	109
23. Mound--1.5 ft. thick, 18 ft. long. Dolomite pale yellowish brown (10 YR 6/2), finely crystalline, dense------------------------	1.5	107.5
22. Dolomite--very pale orange (10 YR 8/2), thin bedded, finely crystalline. Laminar partings, v. pale green--------------------	6	106
Sage Member, lower part:		
21. Dolomite, mottled--like unit 19------------	9	100
20. Dolomite--like unit 18--------------------	7	91
19. Dolomite, mottled--pale yellowish brown (10 YR 6/2), mottled grayish red (5 R 4/2), thin to thick bedded, finely crystalline. Worm trails on bedding surfaces-----------------	4	84
18. Dolomite--pale yellowish brown (10 YR 6/2), medium and thick bedded. Silty laminae to ¼ inch thick between beds---------------	5	80

Red Lion Fm., Sage Member, lower part, continued.	Unit Thick. (feet)	Cumul. Thick. (feet)
17. Dolomite--pale yellowish brown (10 YR 6/2), weathers pale greenish yellow (10 Y 8/2), finely crystalline. Glauconite present. Laminar partings to 1 inch thick--pale greenish yellow (10 Y 8/2)----------------	4	75
16. Dolomite--pale yellowish brown (10 YR 6/2), medium and thick bedded. Silty laminae to ¼ inch thick. Pebble conglomerate at base, 4 inches thick--------------------------	3	71
15. Dolomite--same as unit 17, lower part covered-------------------------------------	17	68
14. Dolomite, silty--like unit 10--------------	7.5	51
13. Dolomite, nodular--silty shale peripheral to nodules------------------------------------	.5	43.5
12. Dolomite, silty--like unit 10--------------	9	43
11. Dolomite--pale yellowish brown (10 YR 6/2), medium bedded, medium crystalline, glauconitic. Fossil hash----------------------	2	34
10. Dolomite, silty--pale yellowish brown (10 YR 6/2), thin bedded, laminated. Weathered face has laminated silt in relief----------	2	32
9. Dolomite, silty, nodular--like unit 7-------	1	30
8. Dolomite, silty--like unit 6---------------	2	29
7. Dolomite, nodular, silty------------------	4	27
6. Dolomite, silty--pale yellowish brown (10 YR 6/2), thin bedded. Weathered face has silty laminae in relief. Intercalated shaly, silty beds--¼ to ½ inch thick-------------------	5	23
5. Dolomite, silty--pale yellowish brown (10 YR 6/2), thin bedded, finely laminated--------	6	18
Dry Creek Member:		
4. Sandstone, quartz, glauconite--medium and thick bedded, fine to medium grained. Lower part has mud chips and dolomite pebble conglomerate----------------------------	4	12

Red Lion Fm., Dry Creek Member, continued.	Unit Thick. (feet)	Cumul. Thick. (feet)
3. Covered----------------------------------	5	8
2. Shale--grayish olive (10 Y 4/2), fissile, clay, v. fine micaceous------------------	2	3
1. Shale--grayish red (5 R 4/2) to blackish red (5 R 2/2), fissile, clay, v. fine micaceous----------------------------------	1	1
PILGRIM FORMATION,		
Upper Member:		
65. Dolomite--same as unit 63. Contact with Red Lion is conformable-----------------------	1	390
64. Dolomite, sandy--same as unit 63, but weathers gray orange (10 YR 7/4)-----------	5	389
63. Dolomite, sandy--moderate orange pink (10 R 7/4), weathers pale red (10 R 6/2), medium bedded. Mottled sand is quartz------------	3	384
62. Dolomite and sandy dolomite interlaminated--much like unit 52-------------------------	7	381
61. Dolomite--same as unit 57-----------------	4	374
60. Dolomite--same as unit 56-----------------	4	370
59. Dolomite--same as unit 57-----------------	6	366
58. Dolomite--same as unit 56-----------------	3	360
57. Dolomite, laminated--similar to unit 51. Contains some wavy laminae, probably mat algae--------------------------------------	6	357
56. Dolomite--weathers medium gray (N 5), knobby weathered surface. Thin bedded------------	9	351
55. Sandstone, dolomitic--cross bedded, tabular, steep. Sand is quartz--------------------	7	342
54. Dolomite, sandy--same as unit 52-----------	3	335
53. Dolomite, sandy--interlaminated with dolomite, medium gray (N 5), thinly bedded------	2	332

Pilgrim Formation, Upper Member, continued.	Unit Thick. (feet)	Cumul. Thick. (feet)
52. Dolomite, sandy--similar to unit 51, but laminae not commonly wavy. Suspect more sand, less dolomite. Local small-scale, cross-bedding-------------------------------	15	330
51. Dolomite, sandy--thin bedded, with wavy laminae. Sand is quartz-------------------	21	315
50. Dolomite, "mud chip"--same as unit 48-------	1.5	294
49. Shaly Laminae, dolomitic--dark yellow orange (10 YR 6/6), forms zone 6 inches thick------	.5	292.5
48. Dolomite, "mud chip"--dark yellowish brown (10 YR 4/2), except chips which are yellowish, thick bedded--------------------------	2	292
47. Dolomite--dark yellowish brown (10 YR 4/2), thick bedded, no structures-----------------	6	290
46. Dolomite--same as unit 43------------------	4	284
45. Dolomite--pale yellowish brown (10 YR 6/2), medium bedded, with some reddish laminae----	4	280
44. Dolomite, silty--pale yellowish brown (10 YR 6/4), medium bedded. Laminar partings--gray yellow (5 Y 8/4), silty, dolomitic----------	3	276
43. Dolomite--pale red (5 R 6/2), thin bedded, nodular to rubbly. Prominent marker unit in immediate area---------------------------	2	273
42. Dolomite, sandy--pale yellowish brown, thin bedded, platy. Laminated--mat algae?--------	3	271
Lower Member:		
41. Dolomite, oolitic, sandy--weathers v. light gray (N 8), thick bedded. Sand is quartz. White twig-like bodies present---------------	3	268
40. Dolomite--similar to unit 34-----------------	10	265
39. Dolomite--like unit 38, but no glauconite or twig-like material---------------------------	9	255

Pilgrim Formation, Lower Member, continued.	Unit Thick. (feet)	Cumul. Thick. (feet)
38. Dolomite--like unit 34, but dolomite is pock-marked with holes from weathered glanconite grains. White twig-like bodies common----------------------------	2	246
37. Dolomite--like unit 36, but laminar zones are 1-2 inches thick and interbedded about every 1 foot. White twig-like bodies appear at 241 feet-------------------------------	7	244
36. Dolomite--same as unit 34-----------------	23.8	237
35. Shaly Laminae, dolomitic--same as unit 13---	.2	213.2
34. Dolomite--pale yellowish brown (10 YR 6/2), mottled grayish orange (10 YR 7/4), weathers v. light gray (N 8) to grayish orange (10 YR 7/4). Mottling not prominent. Medium and thick bedded------------------------------	9	213
33. Dolomite--pale yellowish brown (10 YR 6/2), weathers grayish orange (10 YR 7/4), thin and medium bedded. Contains laminae zones to 2 inches thick, locally----------------	19	204
32. Dolomite, laminated--same as unit 15--------	.5	185
31. Dolomite, mottled--same as unit 14----------	.5	184.5
30. Shaly Laminae, dolomitic--same as unit 13---	.5	184
29. Dolomite, laminated--same as unit 15--------	1.4	183.5
28. Dolomite Pebble Conglomerate--same as unit 16--	.3	182.1
27. Dolomite, laminated--same as unit 15--------	.5	181.9
26. Shaly Laminae--like unit 13, but intermittent--	.2	181.4
25. Dolomite, laminated--same as unit 15--------	.5	181.2
24. Dolomite, mottled--same as unit 14----------	.9	180.7
23. Dolomite--very faint mottling, otherwise like unit 14-------------------------------	.4	179.8

Pilgrim Formation, Lower Member, continued.	Unit Thick. (feet)	Cumul. Thick. (feet)
22. Dolomite, mottled--same as unit 14----------	.5	179.4
21. Dolomite, fossil fragmental--same as unit 19	.3	178.9
20. Dolomite Pebble Conglomerate--same as unit 16---	.3	178.6
19. Dolomite, fossil fragmental--grayish orange (10 YR 7/4) to pale yellowish brown (10 YR 6/2), thin bedded. Abundant fossil fragments, especially spines. Commonly glauconitic-------------------------------------	.3	178.3
18. Dolomite Pebble Conglomerate--same as unit 16---	.3	178
17. Dolomite, laminated--same as unit 15--------	1	177.7
16. Dolomite Pebble Conglomerate--dark yellowish brown (10 YR 4/2) matrix; pebbles are dusky yellowish brown (10 YR 2/2). Thinly bedded-	.3	176.7
15. Dolomite, laminated--grayish orange (10 YR 7/4) <u>vs</u>. dark yellowish brown (10 YR 4/2) alternating bands of fine laminae. Bands to 1 cm. thick. Differential weathering-------	.4	176.4
14. Dolomite, mottled--pale yellowish brown (10 YR 6/2), mottles are dark yellowish brown, thinly bedded-------------------------------	.2	176
13. Shaly Laminae, dolomitic--grayish orange (10 YR 7/4), shaly, fissile to platy. Finely laminated in part--------------------------	.8	175.8
12. Dolomite--pale yellowish brown (10 YR 6/2), weathers grayish orange (10 YR 7/4), thin and medium bedded. Contains laminae zones to 2 inches thick. Laminae are dolomitic, silty--dark yellowish orange (5 YR 5/6)-----	31	175
11. Dolomite--pale yellowish brown (10 YR 6/2), medium bedded, fine grained. White twig-like bodies uncommon-----------------------	52.8	144
10. Dolomite--same as unit 4-------------------	.2	91.2

Pilgrim Formation, Lower Member, continued.	Unit Thick. (feet)	Cumul. Thick. (feet)
9. Dolomite--same as unit 7------------------	1.5	91
8. Dolomite--pale yellowish brown (10 YR 6/2), thin to medium bedded. Contains "pores" with glauconite in them. Upper surface is undulatory--a scour surface. White twig-like bodies equally abundant above and below scour surfaces----------------------	.5	89.5
z 7. Dolomite--same as unit 3, with local glauconite grains------------------------------	6.5	89
6. Dolomite--same as unit 4------------------	1	82.5
5. Dolomite--same as unit 3, except mottling more prominent----------------------------	4.5	81.5
z 4. Dolomite--yellow gray (5 Y 7/2), weathers dusky yellow (5 Y 6/4), thin bedded, fine grained. Knobby weathering----------------	1	77
3. Dolomite--same as unit 2, but faint mottling evident. Mottles are pale brown (5 YR 5/2), weathering grayish orange (10 YR 7/4)-------	20	76
2. Dolomite--pale yellowish brown (10 YR 6/2), thick bedded, fine grained. Contains small white twig-like bodies. Stylolites---------	6	56
1. Covered--talus----------------------------	50	50

Park Fm.--not measured.

SECTION I

Section I occurs in the McHessor Creek drainage, NW¼SE¼ sec. 19, T. 6 S., R. 5 W. It is north of the creek that trends E-W through the southern half of sec. 19, with its base at about 7200 feet altitude on the ridge that trends NE-SW across this 1/16 part of sec. 19.

Pilgrim Fm.--not measured.

PARK FORMATION:	Unit Thick. (feet)	Cumul. Thick. (feet)
1. Covered--float is shale chips, grayish olive (10 Y 4/2)----------------------------------	175	175

MEAGHER FORMATION:	Unit Thick. (feet)	Cumul. Thick. (feet)
31. Dolomite--dark yellowish brown (10 YR 4/2), weathers pale yellowish brown (10 YR 6/2) to grayish orange (10 YR 7/4), medium bedded. Locally has mottles, moderate reddish brown (10 YR 4/6). Only (Park) shale above this unit------------------------------------	15	745
30. Covered------------------------------------	15	730
29. Dolomite--dark yellowish brown (10 YR 4/2), thin bedded, medium crystalline------------	1	718
28. Covered--greenish shale chips in float. Dolomite nodules in float--pale red brown (10 R 5/4) and dark yellowish orange (10 R 6/6)------------------------------------	6	717
27. Dolomite Pebble Conglomerate--dark yellowish brown (10 YR 4/2), weathers pale yellowish brown (10 YR 6/2) to grayish orange (10 YR 7/4), medium bedded. Most pebbles are flat but a few are edgewise. Differential weathered, with pebbles being the more resistant------------------------------------	1	711
26. Covered--A few greenish shale chips in float------------------------------------	5	710
25. Dolomite--same as unit 21----------------	1	705
24. Covered------------------------------------	4	704
23. Dolomite--same as unit 21----------------	18	700
22. Covered------------------------------------	22	682
21. Dolomite--dark yellowish brown (10 YR 4/2), weathers grayish orange (10 YR 7/4) to pale yellowish brown (10 YR 6/2), thin and medium bedded, finely crystalline. Mottled. Contains white twig-like bodies. Not fetid	14	660
20. Covered------------------------------------	9	646
19. Dolomite--same as unit 18, but mottling is very prominent on weathered surface--------	20	237

Meagher Formation, continued.

		Unit Thick. (feet)	Cumul. Thick. (feet)
18.	Dolomite--pale yellowish brown (10 YR 6/2), weathers some to grayish orange (10 YR 7/4) and yellowish orange (10 YR 8/6), thin and medium bedded, finely crystalline. Mottled. Parting laminae, silty--pale yellowish orange (10 YR 8/6) to dark yellowish orange (10 YR 6/6)----------------------------------	27	617
17.	Dolomite--same as unit 15-------------------	28	590
16.	Dolomite--same as unit 12-------------------	4	562
15.	Dolomite--dark yellowish brown (10 YR 4/2) to dusky yellowish brown (10 YR 2/2), weathers pale yellowish brown (10 YR 6/2) to dark yellowish brown (10 YR 4/2), thick bedded. Fine to medium crystalline. Fetid. Mottling is faint to absent. No twig-like bodies---	28	548
14.	Dolomite--same as unit 12-------------------	35	520
13.	Dolomite--dark yellowish brown (10 YR 4/2), weathers grayish orange (10 YR 7/4) to pale yellowish brown (10 YR 6/2). Thin and medium bedded. Weathered surface is mottled, but fresh surface does not appear mottled. Base forms recession in cliff. Fetid, no twig-like bodies------------------	21	485
12.	Dolomite--same as unit 11, but no pisolites and unit is mottled-------------------------	25	464
11.	Dolomite--dusky yellowish brown (10 YR 2/2), weathers pale to dark yellowish brown (10 YR 6/2 to 4/2), medium and thick bedded. White twig-like bodies appear, then pistolites with them. Dolomite is vuggy and fetid--	1	439
10.	Dolomite--dusky yellowish brown (1o YR 2/2), weathers pale yellowish brown (10 YR 6/2). Vugs common. Locally mottled. Twig-like bodies present between 426 and 428 ft. Pale yellowish brown rock has dark yellowish brown mottles and mottles have whitish to tan twig-like bodies in centers. Rock is fetid--	12	438

Meagher Formation, continued.	Unit Thick. (feet)	Cumul. Thick. (feet)
9. Dolomite--dark yellowish brown (10 YR 4/2), weathers dusky yellowish brown (10 YR 2/2), thin to thick bedded. Some white twig-like bodies present. Pisolitic (may be obscure). Locally petroliferous----------	12	426
8. Dolomite--dark yellowish brown (10 YR 4/2), weathers medium yellowish brown (10 YR 5/2), medium and thick bedded. No mottles or twig-like bodies----------------------	30	414
7. Dolomite--dark yellowish brown (10 YR 4/2), locally mottled pale yellowish brown (10 YR 6/2). Weathered surface is finely suggary. Low angle cross bedding present. Soft sediment deformation present. White twig-like bodies are present and cause rock to be vuggy--------------------------------	5	384
6. Dolomite--pale yellowish brown (10 YR 6/2) to dark yellowish brown (10 YR 4/2), weathers grayish orange (10 YR 7/4), thin and medium bedded. Weathered surfaces range from smooth to suggary. Locally there is evidence for current action--beds are laminated. Fine and medium crystalline. Parting lamination, silty, dolomitic--moderate reddish brown (10 R 4/6)----------	20	379
5. Dolomite--same as unit 4, but mottling less distinct--------------------------------	19	359
4. Dolomite--dark yellowish brown (10 YR 4/2), mottled pale yellowish brown (10 YR 6/2), weathers pale yellowish brown (10 YR 6/2) to v. pale orange (10 YR 8/2). Thin and medium bedded, massive outcrop. Medium crystalline. Differential weathering of mottles produces crenulated outcrop surface. Bedding surfaces have parting laminae, silty--yellowish gray (5 Y 7/2), pale yellowish orange (10 YR 8/6), or dark ywllow-orange(10 YR 6/6)-------------	70	340
3. Covered--talus----------------------------	115	270

Meagher Formation, continued.	Unit Thick. (feet)	Cumul. Thick. (feet)
2. Dolomite--medium yellowish brown (10 YR 5/2), weathers pale yellowish brown (10 YR 6/2), massive outcrop, v. fine grained. Mottling locally--faint. Brecciated (tectonic). Rock surface intricately dissected on small scale due to weathering of breccia----------------------------------	35	155
1. Covered--talus------------------------------	120	120

Wolsey Fm.--not measured.

SECTION J

Section J is on the west side of the Ruby Range, NE¼NW¼ sec. 36, T. 6 S., R. 6 W. The section is in the Trout Creek drainage, north of the creek, and between 7200 and 7500 feet in altitude. The section was measured northeast, up the slight ridge nose present in the western part of the 1/16 fraction of sec. 36.

Three Forks Fm.--not measured.

JEFFERSON FORMATION, Birdbear Member:	Unit Thick. (feet)	Cumul. Thick. (feet)
38. Dolomite--pale yellowish brown (10 YR 6/2), evaporite breccia---------------------------	45	250
37. Dolomite--pale yellowish brown (10 YR 6/2), thin bedded, fine grained, dense------------	9	205
Lower Member:		
36. Dolomite, shaly--pale reddish brown (10 R 5/4) to grayish orange (10 YR 7/4)----------	4	196
35. Dolomite--pale yellowish brown (10 YR 6/2), medium bedded, fine grained----------------	5	192
34. Dolomite, shaly--pale yellowish brown (10 YR 6/2), thin bedded, book-like---------------	7	187
33. Dolomite--dark yellowish brown (10 YR 4/2), mottled pale yellowish brown (10 YR 6/2), thick bedded, suggary, fetid---------------	2	180

Jefferson Formation, Lower Member, continued.	Unit Thick. (feet)	Cumul. Thick. (feet)
32. Dolomite--dark yellowish brown (10 YR 4/2), thick bedded, suggary, fetid----------------	20	178
31. Covered------------------------------------	15	158
30. Dolomite--dark yellowish brown (10 YR 4/2), medium bedded, suggary, fetid---------------	2	143
29. Dolomite--same as unit 27------------------	.5	141
28. Dolomite, shaly--grayish orange (10 YR 7/4)-	1.5	140.5
27. Dolomite--pale yellowish brown (10 YR 6/2), medium bedded, fine grained, dense----------	.5	139
26. Dolomite--dark yellowish brown (10 YR 4/2), medium and thick bedded, laminated, suggary, fetid-------------------------------------	1.5	138.5
25. Dolomite--pale yellowish brown (10 YR 6/2), stained pale red (5 R 6/2), medium bedded---	1	137
24. Dolomite--dark yellowish brown (10 YR 4/2), medium and thick bedded, suggary, fetid-----	1.5	136
23. Dolomite, shaly--grayish orange (10 YR 7/4), thin bedded-------------------------------	1.5	134.5
22. Dolomite--pale yellowish brown (10 YR 6/2), medium and thick bedded--------------------	2	133
21. Dolomite--pale yellowish brown (10 YR 6/2), thin bedded, rubbly, evaporite breccia------	2.5	131
20. Dolomite--pale yellowish brown (10 YR 6/2) to dark yellowish brown (10 YR 4/2), thick bedded, fine grained----------------------	21.5	128.5
19. Dolomite, shaly, silty--grayish orange (10 YR 7/4)----------------------------------	2	107
18. Dolomite--pale yellowish brown (10 YR 6/2), medium bedded, fine grained, dense----------	2.5	105
17. Dolomite--same as unit 15------------------	1.5	102.5

Jefferson Formation, Lower Member, continued.		Unit Thick. (feet)	Cumul. Thick. (feet)
16.	Dolomite--pale yellowish brown (10 YR 6/2), thick bedded	2	101
15.	Dolomite--dark yellowish brown (10 YR 4/2), medium and thick bedded, suggary, fetid. *Amphipora* from 92-93 and 95-96 feet	10	99
14.	Dolomite--pale ywllowish brown (10 YR 6/2), weathers yellowish gray (5 Y 7/2), tends to be nodular	1	89
13.	Dolomite--dark yellowish brown (10 YR 4/2), medium bedded, suggary, fetid. Upper one foot contains *Amphipora*	3	88
12.	Dolomite--pale yellowish brown (10 YR 6/2), medium bedded, fine grained, dense	1	86
11.	Covered	13	85
10.	Dolomite--dark yellowish brown (10 YR 4/2), medium and thick bedded, suggary, fetid	9	72
9.	Covered	1	63
8.	Dolomite, shaly, silty--grayish orange (10 YR 7/4)	1.7	62
7.	Dolomite--pale yellowish brown (10 YR 6/2), medium bedded, fine grained, dense	.3	60.3
6.	Dolomite--same as unit 2	2	60
5.	Dolomite--same as unit 2, except appears brecciated--evaporite?	1	58
4.	Dolomite--same as unit 2	2	57
3.	Dolomite--dark yellowish brown (10 YR 4/2), thin and medium bedded, appears laminated, fetid	2	55
2.	Dolomite--dark yellowish brown (10 YR 4/2), medium and thick bedded, fine grained, suggary, fetid	3	53
1.	Covered--contact with Pilgrim is concealed	50	50

PILGRIM FORMATION, Upper Member:	Unit Thick. (feet)	Cumul. Thick. (feet)
36. Covered--contact with Jefferson is concealed	3	365
35. Dolomite, sandy--dark yellowish brown (10 YR 4/2), mottled pale red (5 R 6/2) to pale yellowish brown (10 YR 6/2), medium and thick bedded-------------------------------	6	362
34. Dolomite, sandy--pale yellowish brown (10 YR 6/2), thin to medium bedded, laminated------	6	356
33. Dolomite--pale yellowish brown (10 YR 6/2), weathers yellowish gray (5 Y 7/2), thinly bedded, finely crystalline, nodular---------	3	350
32. Dolomite, sandy--similar to unit 30. Sandy cross-beds in upper part-------------------	13	347
31. Covered--probably sandy dolomite-----------	4	334
30. Dolomite, sandy--pale yellowish brown (10 YR 6/2), thin bedded, surface weathers with wavy laminations. Sand is quartz. Exposures are poor, commonly------------------------	25	330
29. Dolomite--yellowish gray (5 Y 7/2), thin bedded------------------------------------	1	305
28. Dolomite--pale yellowish brown (10 YR 6/2), thin bedded to shaly-----------------------	1	304
27. Dolomite--pale yellowish brown (10 YR 6/2), thin to medium bedded, dense---------------	5	303
26. Dolomite--pale yellowish brown (10 YR 6/2), thin bedded and rubbly (nodular), mottled pale reddish brown (10 R 5/4)--------------	3	298
25. Dolomite--pale yellowish brown (10 YR 6/2), medium and thick bedded, fine grained-------	3.5	295
24. Dolomite--grayish red (5 R 4/2), thin bedded to rubbly, sandy (quartz)------------------	3.5	291.5
23. Dolomite, sandy--pale yellowish brown (10 YR (6/2) to pale red (5 R 6/2), thin and medium bedded. Sand is quartz--------------------	5	288

Pilgrim Formation, Upper Member, continued.	Unit Thick. (feet)	Cumul. Thick. (feet)
22. Dolomite--pale yellowish brown (10 YR 6/2), thin and medium bedded, mottled (forming "knots"), wavy laminations, fossil hash in lower 6 inches----------------------------	5	283
Lower Member:		
21. Dolomite--pale yellowish brown (10 YR 6/2), thick bedded, fine grained, faintly mottled-	22	278
20. Dolomite--pale yellowish brown (10 YR 6/2), mottled grayish red (5 R 4/2), medium and thick bedded, fine grained, dense----------	6.7	255
19. Dolomite--grayish red (5 R 4/2), silty shaly laminae------------------------------------	.3	248.3
18. Dolomite--pale yellowish brown (10 YR 6/2), medium bedded, fine grained, dense, mottled, with coarser grains on weathered surface----	4	248
17. Dolomite--pale yellowish brown (10 YR 6/2), mottled grayish red (10 R 4/2), medium bedded fine grained, dense. Trilobite fragments---------------------------------------	6	244
16. Dolomite--pale yellowish brown (10 YR 6/2), medium and thick bedded, fine grained, dense, mottled------------------------------------	18	238
15. Dolomite--dark yellowish brown (10 YR 4/2), thin and medium bedded. Beds locally separated by thin laminae, dolomitic, silty, grayish orange (10 YR 7/4)----------------	4	220
14. Covered------------------------------------	1	216
13. Dolomite--pale yellowish brown (10 YR 6/2), medium bedded, finely crystalline----------	2	215
12. Dolomite--pale yellowish brown (10 YR 6/2), medium bedded, finely crystalline. Weathers grayish orange (10 YR 7/4)----------------	2	213
11. Dolomite--dark yellowish brown (10 YR 4/2), thin and medium bedded, suggary. Beds separated by silty dolomitic laminae, grayish orange (10 YR 7/4)----------------	5	211

Pilgrim Formation, Lower Member, continued.		Unit Thick. (feet)	Cumul. Thick. (feet)
10.	Dolomite--same as unit 7------------------	1	206
9.	Dolomite--dark yellowish brown (10 YR 4/2), weathers pale yellowish brown (10 YR 6/2), thin and medium bedded. Beds separated by grayish silty dolomitic laminae------------	11	205
8.	Dolomite--pale yellowish brown (10 YR 6/2), medium bedded------------------------------	8.5	194
7.	Dolomite laminae--grayish orange (10 YR 7/4). Silty laminae zones are to °" thick and separate pale yellowish brown (10 YR 6/2) dolomite beds ¼" to ⅓" thick. Beds and laminae are wavy-------------------------	.5	185.5
6.	Dolomite--dark and pale yellowish brown (10 YR 4/2 and 6/2), thin and medium bedded; beds separated by thin dolomitic silty laminae that is grayish orange (10 YR 7/4)--	13	185
5.	Dolomite--dark yellowish brown (10 YR 4/2), weathers pale yellowish brown (10 YR 6/2), medium and thick bedded, fine grained, dense	14	172
4.	Dolomite--pale yellowish brown (10 YR 6/2), weathers lt. gray (N 7), medium and thick bedded. Few white twig-like bodies---------	27	158
3.	Dolomite--pale red (5 R 6/2), medium bedded, fine grained, dense, suggary---------------	1	131
2.	Dolomite--pale yellowish brown (10 YR 6/2), weathers lt. gray (N 7), thick bedded, fine grained. White twig-like bodies locally----	50	130
1.	Covered--Park-Pilgrim contact concealed-----	80	80

Park Fm.--not measured.

SECTION K

Section K occurs in the SW¼NW¼ sec. 28, T. 5 S., R. 5 W. It was measured north of the creek, with its base at about 7000 feet in altitude.

Jefferson Fm.--not measured.

RED LION FORMATION, Sage Member, upper part:	Unit Thick. (feet)	Cumul. Thick. (feet)
21. Dolomite--same as unit 20, but is medium and thick bedded----------------------------	45	146
20. Dolomite--pale yellowish brown (10 YR 6/2), weathers lt. gray (N 7), thin bedded--------	4	101
19. Covered-------------------------------------	6	97
Sage Member, lower part:		
18. Dolomite, mottled--same as unit 16----------	6	91
17. Dolomite--same as unit 15-------------------	1.5	85
16. Dolomite, mottled--pale ywllowish brown (10 YR 6/2), mottled moderate red (5 R 5/4), medium bedded-------------------------------	2.5	83.5
15. Dolomite--pale yellowish brown (10 YR 6/2), medium bedded. Beds separated by silty laminae, grayish orange (10 YR 7/4)---------	12	81
14. Dolomite--same as unit 11-------------------	2	69
13. Dolomite--pale yellowish brown (10 YR 6/2), thin and medium bedded. Beds separated by silty laminae, grayish orange---------------	12	67
12. Covered-------------------------------------	4	55
11. Dolomite float--pale yellowish brown (10 YR 6/2) to medium dark gray (N 4), thinly bedded. Laminar partings, pale greenish yellow (10 Y 8/2)---------------------------	10	51
10. Dolomite--same as unit 6--------------------	2	41
9. Dolomite--same as unit 5---------------------	2	39
8. Dolomite--same as unit 6---------------------	4	37
7. Dolomite--pale yellowish brown (10 YR 6/2), weathers moderate reddish orange (10 R 6/6), medium bedded. Medium crystalline----------	3	33

Sage Member, lower part, continued.	Unit Thick. (feet)	Cumul. Thick. (feet)
6. Dolomite, silty--pale yellowish brown (10 YR 6/2), thinly bedded (about ¼ inch thick). Pale greenish laminae between beds----------	1	30
5. Dolomite--pale yellowish brown (10 YR 6/2), thin and medium bedded, some beds nodular. Silty laminae weather in relief on outcrop face--	17	29
4. Limestone--pale yellowish brown (10 YR 6/2), medium bedded------------------------------	1	12
Dry Creek Member:		
3. Limestone pebble conglomerate--pale yellowish brown (10 YR 6/2), medium bedded, glauconitic. Flat pebbles-----------------	1.5	11
2. Shale--pale olive (10 Y 6/2), soft clay chips	9	9.5
1. Shale--grayish red (10 R 4/2), clay chips, finely micaceous-------------------------	.5	.5
PILGRIM FORMATION, Upper Member (partial section):		
6. Dolomite, sandy, mottled--moderate orange pink (10 R 7/4) to gray orange (10 YR 7/4), thin and medium bedded. Sand is quartz-----	12	93
5. Dolomite--(same as unit 3) and sandy dolomite (like unit 1) interbedded as units 3 to 6 ft. thick--	25	81
4. Dolomite, sandy--same as unit 1------------	4	56
3. Dolomite--pale yellowish brown (10 YR 6/2) to medium gray (N 7), thin and medium bedded------------------------------------	6	52
2. Sandstone, quartz, dolomitic--pale yellowish brown (10 YR 6/2), medium bedded, cross-bedded------------------------------------	6	46
1. Dolomite, sandy (quartz)--pale yellowish brown (10 YR 6/2), thinly bedded. Wavy laminae-----------------------------------	40	40

Fault. Remainder of upper Pilgrim member not present.

SECTION L

Section L occurs on the east side of the Ruby Range, SE¼SW¼ sec. 24, T. 6 S., R. 5 W. It is located on the north wall of Taylor Canyon, its base about 50 feet above the canyon floor and 1000 feet ENE (downstream) of the juncture of South Fork with Taylor Canyon.

		Unit Thick. (feet)	Cumul. Thick. (feet)
Wolsey Fm.--not measured.			
FLATHEAD FORMATION:			
17.	Sandstone, quartz--pinkish gray (5 YR 8/1), medium bedded, fine to medium grained, subrounded grains. Only shale occurs above this unit----------------------------------	3	52
16.	Sandstone, quartz--lt. brown (5 YR 6/4), medium bedded, fine grained, well cemented--	4	49
15.	Covered-------------------------------------	2	45
14.	Sandstone, quartz--same as unit 12----------	1.5	43
13.	Covered-------------------------------------	1.5	41.5
12.	Sandstone, quartz--lt. brown (5 YR 6/4), medium bedded, friable. Fine grained, subangular to subrounded. Slightly calcareous-	7	40
11.	Covered-------------------------------------	3	33
10.	Sandstone, quartz--light brown (5 YR 6/4), thick bedded, v. fine grained---------------	8	30
9.	Sandstone, quartz--v. pale orange (10 YR 8/2), medium bedded, friable. Grains are fine, subrounded. Upper 3 inches contains angular quartz clasts, most are ½-1 inch diameter, but some are 3 inches and one is about 6 inches in diameter-------------------------	1	22
8.	Sandstone, quartz--same as unit 6, but medium and thick bedded---------------------	5.8	21
7.	Zone of white, angular quartz clasts--to 2 inches in diameter--------------------------	.2	15.2

Flathead Formation, continued.	Unit Thick. (feet)	Cumul. Thick. (feet)
6. Sandstone--dark yellowish orange (10 YR 6/6), thick bedded. Quartz is fine grained, rounded. Limonite and some hematite spots throughout----------------------------------	5	15
5. Sandstone--same as unit 3-----------------	3.5	10
4. Sandstone, quartz--moderate orange pink (5 YR 8/4), mottled moderate reddish brown (10 R 4/6). Fine grained, subrounded to rounded grains. A few quartz pebbles to 1 inch diameter--angular---------------------------	1	6.5
3. Sandstone, quartz--light brown (5 YR 6/4), thick bedded, v. fine to fine grained. Well cemented-------------------------------	4.5	5.5
2. Sandstone, quartz, conglomeratic--same colors as below. Clasts are quartz, pebble- and cobble-size, subangular to subrounded-------	.5	1
1. Sandstone, quartz--dusky yellowish brown (10 YR 2/2) to brownish black (5 YR 2/1) and dark yellowish orange (10 YR 6/6). Medium and coarse-grained, subangular to subrounded quartz grains. Manganese and limonite stained---------------------------	.5	.5

Precambrian Metamorphic Rock.

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