The geology surrounding the headwaters of Nowlin, Flat, and Granite creeks, Gros Ventre Range, Teton County, Wyoming
by Charles Matteson Love

A thesis submitted to the Graduate Faculty in partial fulfillment of the requirements for the degree of MASTER OF SCIENCE IN APPLIED SCIENCE--PHYSICAL SCIENCE (GEOLOGY)
Montana State University

Abstract:
The geology of the southwestern Gros Ventre Range in Teton County, Wyoming, has been of a reconnaissance nature up to this time. In the 26 square mile area, Precambrian through Pennsylvanian rocks are exposed in two of the southwest-thrust blocks comprising a western portion of this range.

Geomorphic conclusions are based on reconnaissance work. A high level erosion surface exists which may have been formed during late Pliocene. Evidence of two major glaciations was found, with further indications of residual ice. Peculiarly advancing talus tongues are abundant 6 A 2,530 foot section of Cambrian through Lower Mississippian rocks was measured and found to be within the range of regional averages. A previously undescribed Tertiary (?) conglomerate is present. The mid-Cambrian Gros Ventre Formation (Wolsey-Meagher-Park equivalent) is most noted for its complex intraformational incompetencies and susceptibility to deformation under a minimal amount of stress.

The area covers part of the late Laramide Cache block anticline and its connections with the Skyline Trail block. The junction of these discloses two slightly different directions of upthrust, and although their respective erosional fronts are concordant, the southeasterly Skyline Trail block has a greater displacement. Relaxing of upthrust pressures caused an immense down-dropping of the apex of the Cache block, accounting for a major normal fault parallel to the thrust line. Most of the normal faults perpendicular to the range axis exhibit the down-thrown side to the southeast.

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Date *7/16/67*

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MASTER OF SCIENCE IN APPLIED SCIENCE--

PHYSICAL SCIENCE (GEOLOGY)

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ABSTRACT

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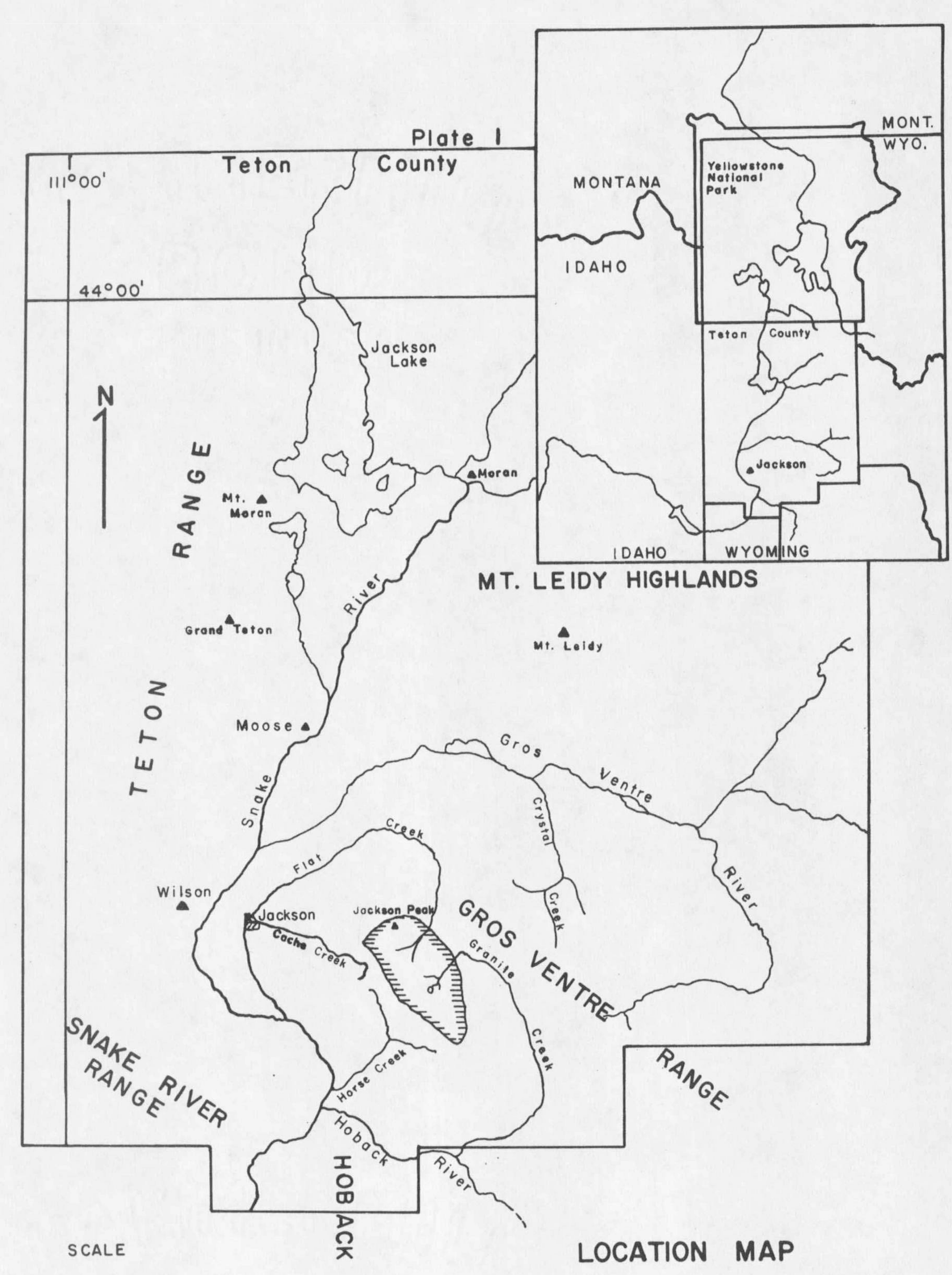
INTRODUCTION

Location and Access

The area under study involves approximately 26 square miles in the Gros Ventre Range of Teton County, Wyoming, and is located mainly in T. 40 N., R.'s 114 and 115 W. (unsurveyed). A minor portion overlaps into T. 41 N., R.'s 114 and 115 W. (unsurveyed). It forms a major section of the southwestern backbone of the Gros Ventre Range, lying on the drainage divides between Flat, Granite, and Horse Creeks, and Nowlin, Flat, and Cache Creeks. Most of the area lies above 8,000 feet, the highest peaks rising to just over 11,000 feet (Plates 1 and 5).

Access is primarily by National Forest Service horse trails which follow most of the major creeks. Two other high altitude trails are usable. These routes can be reached by four non-graded roads in Teton County. The first and most feasible is in the bottom of Cache Creek to the west; second, from a logging road north of Jackson Peak; third, from the Granite Creek recreation road; fourth and least advisable, the Flat Creek road. All but the fourth access road may be driven by ordinary automobile during July and August, and all lead to various trail heads whereby access to the area or specific sections thereof may be gained.

The area is of rugged alpine terrain, and is relatively snow-free from early July through early to mid-September. Good campsites are available almost anywhere with excellent water and wood. Forage for pack animals is only locally plentiful.



LOCATION MAP

Hachured region denotes extent of thesis area

Purpose

The major objective of this study is to produce a detailed geologic map of the area surrounding the headwaters of Nowlin, Flat, and Granite Creeks in Teton County, Wyoming. Because most previous work in this region has been of a reconnaissance nature, a complete explanation of the structure and associated problems is necessary. A lesser objective was to measure a section for general comparison with work done in surrounding regions. It is also intended to summarize the geomorphology of the area based on reconnaissance work, as well as to report other points of interest to the future researcher.

Method

During the summer of 1967, a total of 7½ weeks were spent mapping the geology in the field. An additional 2½ weeks of similar field work was accomplished in the same area during the summer of 1965 for an undergraduate thesis (Love 1966). The present thesis is a rigorous expansion and modification of the earlier work. Field work was done from 2 base camps in 1965, and an additional 4 camps in 1967, spending from 4 days to 2 weeks in each one.

Geologic mapping was accomplished on U.S. National Forest Service aerial photographs, of 1/25,000 scale, and subsequently transferred to advance proofs of the U.S. Geological Survey 1/24,000 quadrangles issued in 1966. The area currently lies in the Jackson 1 NW quadrangle and the Jackson 1 NE quadrangle (now possibly changed to the Turquoise Lake quadrangle).

The stratigraphic sections were measured by the tape and compass method, and the following field descriptions were based on handlens and acid bottle techniques.

All photographs were taken with Kodachrome II color film on a Voigtlander Vitessa 35 mm camera.

Previous Investigations

Orestes St. John (1879, 1883) accomplished the first significant geological observations of a large region in northwestern Wyoming known as the Teton Division, wherein is contained the study area. Indeed, a number of his observations were made from two peaks within the thesis area and some of his evidence has been completely overlooked by all subsequent investigators. Although a great many of his interpretations are now known to be incorrect, the sheer volume of description and resulting correct inferences made is most remarkable. The next researcher, Eliot Blackwelder (1915, 1918) worked on a regional scale and made his closest observations 15 miles to the east, where he measured what is now a standard comparative section.

Since then only five significant published works have been presented which deal in any detail with the area under study. Nelson in 1942 produced a paper entitled "The Structural Geology of the Cache Creek Area, Gros Ventre Mountains, Wyoming" involving the western half of the thesis area. This was expanded in 1943 with Church to include the gross structures of the Gros Ventre and northern Hoback Ranges. Horberg, Nelson, and Church then produced another general paper on the structural trends of Central Western Wyoming in 1949, the Gros Ventres playing a major part. The fourth publication is a somewhat generalized thesis by Swenson, also in 1949, on the northern flank of the Gros Ventre Range. His area lies several miles to the north of the present thesis area. He was not concerned with what happened outside his area to the south, but certain observations were made which are helpful to this study. Some of his stratigraphic sections, it should be noted, are only estimated thicknesses. Van Dyke (1956) has done the work of most importance to this thesis. His research on the structure of the upper Horse Creek area directly involved a portion of the present study, and it is to his intriguing paper that some of the present writer's work will be compared. Eugene Blasdel, a University of Michigan graduate student, is currently mapping a similar area to the southeast. He plans to overlap the present thesis area as far west as Turquoise Lake (personal communication, July 1968).

Stratigraphic work has been non-existent within the thesis area, with the exception of two workers who have measured sections there: Miller (1936), and Denson (1942). Those more important researchers measuring or compiling nearby sections which would pertain to the thesis area are Blackwelder (1918), Miller (1936), Foster (1947), Shaw and Deland (1955), Wanless and others (1955), Lochman-Balk (1956), Benson (1966). Although a multitude of observers have contributed to the stratigraphic picture, including confusion of names, these works have calculated thicknesses and descriptions of importance to the thesis area.

There has been no previous work done in the study area on its geomorphic aspects, however Blackwelder (1915) has studied the Gros Ventre River terraces, glacial deposits, and high altitude erosion surface to the north, with regional conclusions in mind. Swenson (1949) recapitulates a few of these.

The only economic aspect of the thesis area that has been realized or utilized are some iron ore claims which have been filed to the east in the Amsden Formation. No action other than claim staking has been taken.

GEOMORPHOLOGY

Description of Area

The Gros Ventre Range consists of several broadly uplifted and faulted anticlines trending northwest-southeast. The present crests range from 10,000 - 11,500 feet in elevation, with several outcroppings of the Precambrian core along the southwest-thrust flanks. The original elevation of the range, created during late Laramide time, is difficult to estimate as broad eroded areas presently exist above 10,000 feet and the erosional history is unique. Canyons dissecting the range are deep and have undergone intense glacial modification. Cirques are common. The present relief of the thesis area is slightly over 3,000 feet.

Sequence of Events

The oldest geomorphic feature is an immense erosion surface, on which the highest peaks of the range seem to form monadnocks. This surface, only partially included on the north border of the thesis area, extends over much of the range to the north and east. It probably covered the study area at one time. Great undulating flat expanses at an approximate average elevation of 10,500 feet and evenly beveling all strata characterizes this surface. Only two workers have examined this surface in reconnaissance: Blackwelder (1915), and Swenson (1949). Although Blackwelder (1915) mentions this surface under his Union Pass erosion cycle, its features and latitude places it on a par with his Fremont erosion cycle, completed near the end of the Pliocene. However Swenson (1949), whose area overlapped part of this surface, agrees with

Blackwelder in his interpreting it as Union Pass. It does not appear to have been affected by glacial action other than in the cirques eroding into it on all sides. Any ancient stream pattern is unrecognizable, at least from the ground. To the south, many of the Hoback Range peaks just reach the altitude of the erosion surface. None are above it. Similar surfaces exist to the north in the Absaroka Range, to the east in the Wind River Range, and to the south in the Uinta Range.

A conglomerate was found on one of the drainage divides at an elevation of 10,400 feet, and as this has not been described before in the stratigraphy of northwestern Wyoming, its placement suggests several possibilities as to origin. As it overlies the Pennsylvanian Darwin Sandstone, it could be a purely local conglomerate of that age. However, no nearby sections report any conglomerate. This particular one is more than 50 feet thick and has well-rounded late Paleozoic pebbles up to and slightly over an inch in diameter. Its location, size, and composition intimate that it was eroded from a nearby source of Paleozoic strata in which the Precambrian was not yet exposed. Such a situation could have occurred during the cycle of erosion creating the high level surface.

At a date later than the beveling of the Gros Ventre surface, a stream pattern was briefly established on this surface. Because most of the present major drainages originating in the Gros Ventres turn approximately 180^{o} from their source before emptying into another major drainage system, alteration of the original pattern is suspected. Flat

Creek, Granite Creek, and the Gros Ventre River all flow a short distance northeasterly from their source. The other major drainage, Crystal Creek, flows slightly west of north (Plate 1). Most of the tributaries flow in similar directions. Flat Creek, Crystal Creek, and the Gros Ventre River all eventually circle to the west via north, and flow into Jackson Hole. Granite Creek, the one odd exception, flows west by circling around to the east, then south, and finally into the westward-bound Hoback River (Plate 1). The original northeast oriented pattern is suggestive of streams flowing down the dip of the broad northeast flank of the Gros Ventre anticlines. The present pattern is generally indicative of a gradual regional tilting towards Jackson Hole to the west and southwest (Love and Montagne, 1956). These drainages are all affected by faults or flexure zones, although Flat, Granite, and Crystal Creeks are affected only for a small part of their downstream courses. How crucial these sections are to the drainage pattern, particularly that of Granite Creek, will be determined only by much more extensive field work.

The top of the glacially steepened walls in the canyons of the thesis area averages 9,000 feet in elevation. This is 1,200 to 1,600 feet lower than the erosion surface. Thus, these few drainages and their tributaries appear to have deeply dissected the erosion surface before ice helped to modify their canyons.

The pre-glacial streams undoubtedly eroded their way to the Precambrian, for much of the basement complex exposed has the appearance and topography of having been recently stripped of its sedimentary cover. The ensuing glacial erosion has modified the Precambrian only to the point of having created several horn-like peaks along the major, jagged, northwest-trending ridge.

That these mountains have been glaciated more than once is most readily evidenced on the southwest side of the Gros Ventre front in the thesis area. Here there is displayed debris from at least two glaciations which have been mapped as Qg_1 and Qg_2 respectively. Evidence is strong in surrounding regions of at least three glaciations (Montagne 1956; Love 1956). Qg_1 becomes more obvious to the east along the mountain front, for it is extremely widespread and covers all of the near drainage divides south of the mapped area. To the west, however, it is not so ubiquitous and appears to have rather sharp boundaries. In general it is characterized by sporadic large rounded boulders of Precambrian material, and exhibits its thin cover in what little hummocky topography is visible.

Qg_2 is restricted to most of the narrow valley and gully openings in the front of the range. There are many Precambrian boulders and hillocks of debris contained for a short distance within these valleys, none extending more than two miles from the range front. Its fresh appearance and sharp boundaries intimate that it is the younger of the two, there being no overlying debris other than protalus and recent rock glaciers in the cirques of their origin. Loess, which characteristically overlies much of the glacial debris in Jackson Hole, was not noticed. High rates of erosion in this rugged topography have probably never allowed it to accumulate.

On the northeast side of the range crest, there was no immediate and obvious indication of more than one glacial stage, although several must have existed. Most of the valley surfaces have been scoured clean, grooved, and polished by the most recent ice. Only a veneer of fresh debris exists on the canyon rims down stream from the most recent erosional products. In the valleys too, only thin deposits and a few low mounds are evident. With one possible exception, no terminal or recessional moraines were found within the thesis area. As a result, the most recent extensive glacial debris, whose upper limits could not be determined on valley walls, was not mapped on the northeast side of the range front. It did not appear to cover the major northeastern drainage divides except in the area of their headwaters. Striations or debris were found extending completely across the divides between Sheep and Flat Creeks, Flat and Cache Creeks, Flat and Granite Creeks, and Granite and Bunker Creeks. Ice also passed to the south over the major Precambrian ridge west of Pinnacle Peak. Although no other direct indications were observed elsewhere, this ridge is low enough in several places for ice to have easily passed southward. The result of the valley glaciations has transformed the major drainages into the typically broad U-shaped canyons common to alpine glaciated regions.

A single moraine of uncertain origin was found near the toe of the northern-most glacial-landslide debris mapped on the western wall of

Flat Creek. Located at an elevation of 9,280 feet, it is more than 10 feet high, parallel to Flat Creek canyon, and nearly reaches the canyon edge. Three origins seem possible, although the first appears least attractive. It could be a recessional moraine to a small cirque area existing to the west. Its straightness however, hints at a lateral moraine for ice within Flat Creek canyon. As a third possibility it could be a medial moraine between ice in the small western cirque and that in Flat Creek canyon. Either of these last two cases necessitate at least 1,000 feet of ice in Flat Creek canyon. This may have been the situation at one time, for two miles to the southwest there are striations 80 feet above the bottom of the talus on the eastern vertical wall of Jackson Peak, near the Sheep Creek - Flat Creek divide. That this much ice was moving down Sheep Creek at this point rather than into the more precipitous Flat Creek canyon may mean that the latter area was full. It is improbable that ice would have moved in the opposite direction due to the orientation of minor Sheep Creek headwalls. Hence the case for a lateral or medial moraine on the wall of Flat Creek canyon is built. There are undoubtedly others along the tributaries to these main drainages, but specific field work and research will be needed to work out the entire story.

The age of the recent glacial action on the northeast side of the main Gros Ventre ridge must certainly have been Pinedale. Terminal moraines in the mouths of some of the drainages outside the area are considered to be of that age (Montagne 1956: Love 1956). The writer suspects that Qg_2 along the south side of the ridge is Pinedale as well, due to its small, fresh, and limited extent. Extreme exposure to radiation accounts for its lesser development in comparison with other known Pinedale glaciers with northeast exposures.

The last glacial epoch may not have left the Gros Ventre Range entirely, for there are frequent rock glaciers, several with cold late summer streams emanating from them. Four of these are located to the north of the main ridge, and one to the south. All but one northern rock glacier exist in protected downwind positions. Only the southern rock glacier faces southeast, all others in northerly directions. The accumulated debris is generally semicircular in shape, rarely exceeding 200 yards across. They may represent a 'last gasp' of the Pinedale substages.

Related to remaining ice are features mapped as glacial-landslide material. In these cases it was impossible to determine whether the flow had been the result of just gravity, or had been aided by the presence of ice. All of these questionable areas involved the Cambrian shales and limestones, and hence the reverse could be true, glacial action could have been aided by the presence of these incompetent strata. The action has been different on the glacial-landslide debris of the Flat - Cache Creek divide and at the head of Nowlin Creek than it has on the two areas on the west wall of Flat Creek Canyon. The Cache Creek and Nowlin Creek glacial-landslides were probably the result of ice spilling over the divide from Flat Creek. As the Cambrian limestones and shales outcrop along these respectively folded and faulted areas, flow-land-sliding began taking place during and after the ice melted. That ice went through the divides is proven in the Flat-Cache Creek case by glacial debris 100 feet above the saddle of the divide to the north. Both areas display great hummocky topography including juxtaposed house-sized blocks. Additional sliding from a source area does not seem important.

By contrast, the two glacial-landslides on the west wall of Flat Creek canyon are much fresher in appearance, the process probably still continuing. These both were started by ice in minor cirques, which began to form a headwall in the comparatively soft Cambrian rocks. The ice then melted away, helping to "lubricate" the basal shale on which all the debris has since crept down slope. The landsliding process still continues with great blocks of Ordovician dolomite spalling away from the headwall and riding down a dip slope of Cambrian shales.

One landslide area which was mapped as such is on the Granite-Flat Creek divide. In this case, a major portion of Cambrian limestone has been weakened at the bottom of a dip slope by a small fault. With the subsequent removal of support, the limestones have slid by degrees on the shales beneath. The thinness of the slide cover hints at the possibility that ice was not present, although a distinction made on this basis may not be valid.

In the head of the Granite Creek area, a gravity slide block of competent Cambrian quartzite moved prior to the most recent glacial epoch. Sliding north and rotating slightly, it came to rest at a point just above the canyon bottom, and was subsequently covered with glacial debris.

The only other ice or snow related features are the protalus ramparts accumulating in various areas. These are numerous but rarely extensive, and commonly grade into present talus slopes or appear to be remnants of some other precipitation cycle. No attempt to establish relationships to rock glaciers or talus slopes was made.

The last glacial epoch ended so abruptly in the thesis area, that talus slopes are just beginning to form in some areas. The ice, while present, tended to erode the Paleozoic strata off the Precambrian, leaving a narrow bench around the upper ends of the canyons. It is on this bench that the Cambrian Flathead Quartzite is forming extremely active talus slopes. While in some areas almost no talus has formed, in others talus is proceeding at so rapid a rate that the soil is being peeled back by the thrust of the moving blocks. It appears that point-contact pressure between the angular blocks is applied, bulldozing the soil into a mound as much as two feet high in front of the rocks (Figure 1). The rate of movement certainly exceeds the rate of soil erosion in these areas.

The present topography is only a slight modification of that which existed during the glacial stages. Erosion has not proceeded long enough to eradicate the thin cappings of basal Cambrian quartzites from the highest peaks. St. John (1879, 1883) noted Flathead Quartzite on Jackson Peak and on the highest peak (unnamed) in the main ridge. The writer found and mapped 40 feet of this formation on a third peak as well, having found 75 feet on Jackson Peak, and 8 feet on the highest peak in the ridge. Although the Flathead Quartzite on the two unnamed peaks has never been mapped by previous investigators, its presence is important both structurally and geomorphically. The peaks serve as excellent control points to indicate the amount of erosion that has taken place since folding and faulting, and because of their dip, the amount of erosion that has occurred on the front of the uplifted blocks of which they are a part. As erosion continues, the Paleozoic strata will be slowly stripped from the Precambrian core. The remaining aretes and axial ridge may be leveled to form a somewhat more gentle topography.

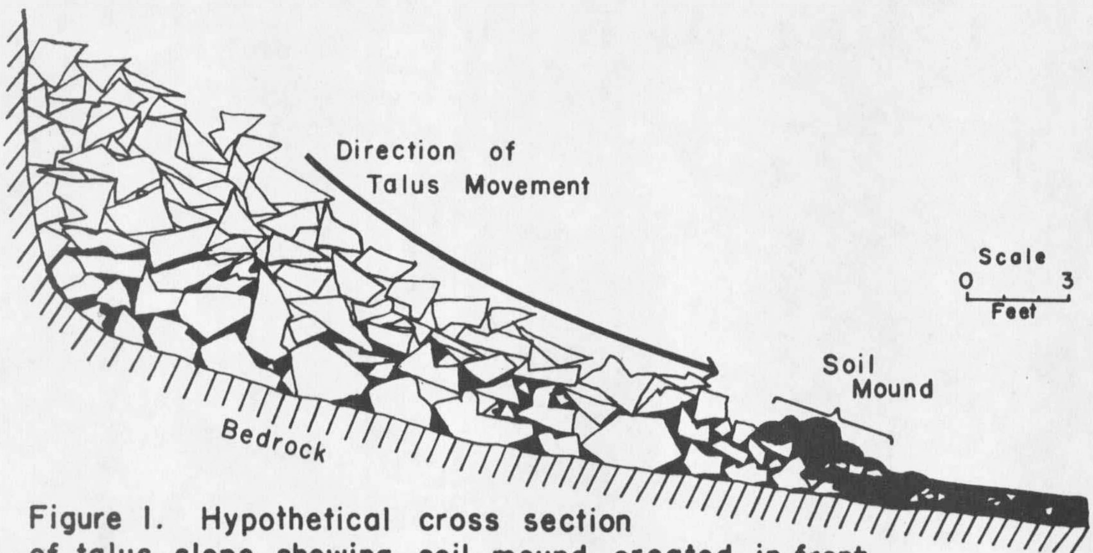


Figure I. Hypothetical cross section of talus slope showing soil mound created in front of advancing tongue.

STRATIGRAPHY

General Statement

This study is concerned with exposed rocks of Precambrian through Pennsylvanian age, excepting Silurian. All of these systems crop out to some degree within the thesis area, and a section was measured from Precambrian through the lower half of the Mississippian rocks. The few other formation thicknesses have been estimated in the field. The writer believes only his thickness of Ordovician rocks to be questionable, due to the necessity of utilizing a large nearly horizontal distance to make the measurement. The complete measured section appended is for the purpose only of basic comparison. Outcrops of Paleozoic rocks are common enough to provide a step by step comparison of excellent measured sections throughout the range by the future stratigrapher.

A review of the literature on the Gros Ventre's stratigraphy, of regional or specific nature, reveals that only the general stratigraphic trends are consistent. The thicknesses and some descriptions vary considerably. It appears that many sections have been measured by stratigraphers without consideration for the structural position of their measurement. Some of the formations are inconsistent in their reactions to stress, and noticeably thicken and thin along certain tightly folded or faulted zones; the Middle and Upper Cambrian units are particularly susceptible. Likewise the structural geologists have paid little or no attention to stratigraphic inconsistencies within their respective areas. The result is that different workers, sometimes having measured sections in the same place, come up with strangely different thicknesses.

Some researchers consistently have a 'short tape', others the reverse. Contacts are in places difficult to recognize and hence have added to the confusion. Positions of unconformities have been hard to pinpoint.

With this in mind, the writer has attempted a description based on what appeared to be the true contacts in the field, and has made special note of arbitrary contacts. The stratigraphic nomenclature generally used in the geologic literature of western Wyoming has been adopted. It most clearly corresponds to that set down by Burk (1956) and Wanless and others (1955). See Table 1.

The appended section will be compared with several areas nearby, some in neighboring mountain ranges. The nearest sections measured are in the Granite Hot Spring area, 7 miles to the southeast, Sheep Creek, 6 miles to the northwest, Sheep Mountain, 6 miles to the north, and Doubletop Peak, 15 miles to the east. Other sections mentioned are in the southern Teton Range, the Snake River Range to the south and west, the Wind River Range to the east, and the Owl Creek Mountains to the northeast.

History of Deposition

Compilation of stratigraphic references (listed under Previous Investigations) provides a basis for summarizing the depositional history of the Gros Ventre area and the surrounding regions.

According to these references, any traces of unaltered sedimentary rocks antedating early Middle Cambrian time do not exist. This substantiates the hypothesis that most of western Wyoming was a highland prior to that time. This highland shed material westward and southward

Table 1. Stratigraphic Units and Thicknesses†

Age	Unit			Thickness (feet)
Quaternary	Scree-talus			0 - 100 *
	Alluvium			0 - 30 *
	Landslide Debris			0 - 80 *
	Glacial-Landslide Debris			0 - 200 *
Tertiary (?)	Conglomerate (Unknown in the stratigraphic section for northwestern Wyoming.)			50 - 75 *
Pennsylvanian	Tensleep-Amsden formations (Undivided) Only lower portion exposed in area.			0 - 120 *
Mississippian	Sacajawea Formation			60 *
	Madison Group			975 **
	Upper Madison Limestone			
	Mission Canyon Formation			
	Lodgepole Formation			
Devonian	Darby Formation			319
Ordovician	Bighorn Dolomite			445
	Leigh Dolomite		97	
	Bighorn Member		348	
Cambrian	Gallatin Limestone			240
	Open Door Member		77	
	Dry Creek Shale		37	
	DuNoir Member		126	
	Gros Ventre Formation			763
	Park Member		296	
	Death Canyon Member		370	
	Upper Death Canyon Limestone	202		
	Mid-Death Canyon Shale	30		
	Lower Death Canyon Limestone	138		
	Wolsey Shale		97	
	Flathead Quartzite			288
Precambrian	Igneous and metamorphic complex			?
Total thickness of Paleozoic strata less Pennsylvanian				3030

† Omitted are Cretaceous and Tertiary rocks mapped as Undivided.
* Estimated in the field.
** Only the lower 475 feet measured in the field. Total thickness extrapolated from measurements by previous workers in surrounding areas.

to an eastward-migrating trough. The basin of deposition spread from west to east throughout the Wyoming area during Middle Cambrian, and remained until the close of the Cambrian Era. The deepest part of this basin lay to the south along the Wyoming-Utah border. During this time a basal sandstone was deposited as the sea transgressed, and above this came a sequence of shales, limestones, and interbedded thin shales. At this point, erosion did occur in sporadic areas, as though islands were gently raised to just above sea level for short periods of time. Following this, regional deposition of limestone ensued, creating local disconformities where the islands used to be, whereas the rest of the section remained gradational. This sea was probably clear while the limestone was being deposited. That one major interval of mixing did occur is seen in a shaly unit which exists mid-section in the limestones. How much deposition occurred or for how long is relatively unknown as the top of the Cambrian is marked by an unconformity. The rocks above are dolomites which have been dated from Late Ordovician to Silurian, and the contact with the Cambrian therefore represents a rather long erosional gap. It is neither an angular nor a deeply scoured disconformity, suggesting that erosion was slow and near sea level. The sea advanced during Late Ordovician and the afore-mentioned grey dolomite was deposited. It would appear from correlation of the stratigraphic charts that one of the Ordovician broad basins centered in west central Wyoming. A pause in deposition eventually occurred, but for how long is again in question. The next sequence of similar whitish thin bedded dolomite has been dated from Late Ordovician to Devonian.

Prior to or during Early Devonian, northwestern Wyoming was eroded and the debris transported into the north, south, and particularly western areas. By Devonian time a local basin in the western continental miogeosyncline had begun to develop strongly along the tri-state border of Utah, Idaho, and Wyoming. The Gros Ventre Mountain area was then on the edge of a foreland bordering the trough, and when inundated it received a much thinner layer of sediments than did the areas south and west. These Devonian sediments consisted of sands, shales, limestones, and dolomites deposited in a somewhat unstable shelf area. The basins of deposition eventually drained toward the end of Devonian time for a brief period of erosion before major inundation by Mississippian seas. This created another unconformity which is extremely subtle in some areas and is best seen in regional studies.

For most of Mississippian time western Wyoming was accumulating great thicknesses of fossiliferous limestone, and in some areas, gypsum interbeds were laid down. The Gros Ventres were still located on the edge of the foreland shelf at this time and received vastly thinner deposits than did regions to the southwest, where the deeply subsiding part of the basin was well developed. The shoreline toward the end of Mississippian time crept westward from southeastern Wyoming, where gentle uplifts had occurred in the area of the present Laramie Range. A period of erosion ensued, sufficient to create a karst topography on the Mississippian limestone over much of northwestern Wyoming. The area was then dropped below sea level just before the end of Mississippian time. Limestones, shales, and sandstones were deposited in the Gros Ventre region in a comparatively less stable environment. These deposits were exposed briefly to erosion just prior to Pennsylvanian deposition.

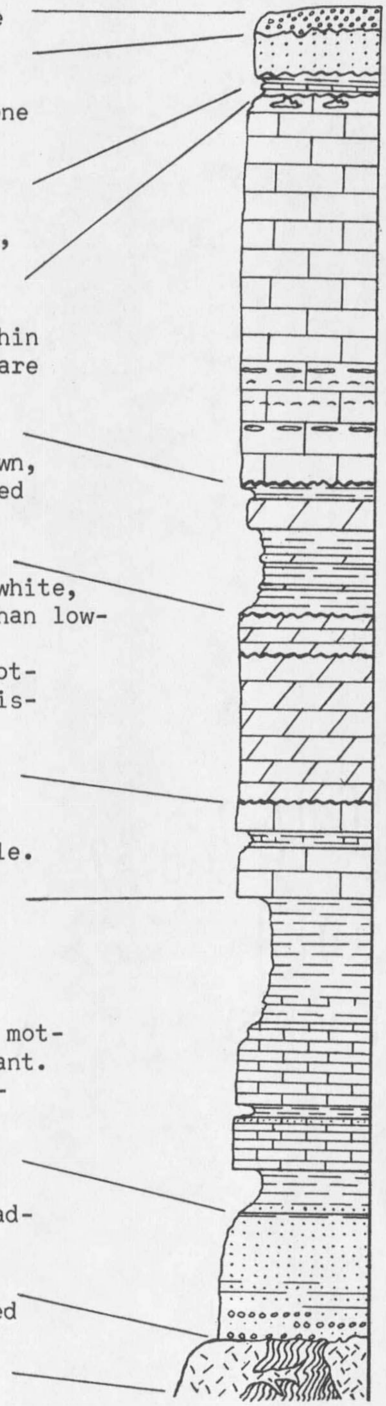
Above this, a sequence of massive sandstones, limestones, gypsiferous shales, dolomites, and more thick sandstones evolved, indicating varying conditions of deposition and climate. The sandstones in the upper and lower portions of this sequence are massive and cross bedded in places, and alternate with thin dolomites. The environment was near sea level, the cross bedded sands indeterminently caused by subaqueous or subaerial erosion. The boundary between Mississippian and Pennsylvanian time is indistinct due to conflicting fossil evidence. It has been placed at the basal unconformity for convenience. See Plate 2.

This sequence gives way to variegated cherty limestones, dolomites, phosphatic shales and thin sands, indicating again an unstable shelf environment. While none of this sequence is exposed within the thesis area, this marks the transition into the Permian.

Although Mesozoic rocks were not of major consideration in the study area, this part of the foreland area was incorporated into the geosyncline at this time, and as much as 13,000 feet of sediment was deposited. Vastly thicker sections were deposited south and west. Most of these deposits are variegated sandstones and shales, interbedded with a few thin limestones and conglomerates. Unconformities occur sporadically

Plate 2. Summarized Stratigraphic Column

Omitted are Cretaceous and Tertiary rocks mapped as Undivided



Tertiary Conglomerate

Thin capping in one area of pebbles of late Paleozoic rocks in a sandy calcareous cement.

Amsden-Tensleep Formations

Only lower portion exposed. Darwin Sandstone member, tan to salmon in color, medium-grained, resistant, disconformity above and below.

Sacajawea Formation

Thin sequence of grey cherts and limestones, interbedded with red shales. Non-resistant.

Madison Group

Limestone, steel blue to grey, massive to thin bedded, resistant. Fossil hash and chert zones are common. Disconformities above and below.

Darby Formation

Dolomites and thin limestones, black to brown, weathering tan to grey, petroliferous, interbedded with cream, yellow, and green shales.

Bighorn Dolomite

Leigh Dolomite member: Dolomite, cream to white, thin bedded, resistant but less resistant than lower member. Disconformity above and below.

Bighorn Member: Dolomite, cream to grey, mottled with grey, thick bedded, resistant. Disconformity above and below.

Gallatin or Boysen Formation

Limestone, dark grey to black, weathering brown, thick bedded, resistant. Contains flat pebble conglomerate zones. Shaly zone near middle. Disconformity above.

Gros Ventre Formation

Park member: Shale, olive, thin bedded and friable, non-resistant. Gradational above and below.

Death Canyon Member: Limestone, blue-grey, mottled with tan to cream, thin bedded, resistant.

Wolsey Shale: Shale, green, micaceous, non-resistant. Gradational above and below.

Flathead Quartzite

Quartzite, tan to salmon in color, medium grained, resistant. Conglomerate stringers. Gradational above.

Precambrian

Biotite gneiss, schist, amphibolite, intruded by granite and pegmatite.

throughout this section. Deposition did not stop at the close of the Mesozoic. While uplift began in some areas, local deposition during early Cenozoic more than equalled Mesozoic thicknesses in other areas. The Gros Ventre region received 19,000 feet of debris eroded from rising areas to the north. Since then deformation and erosion has taken place in the Gros Ventre area. Nearby areas had greatly different local histories.

In summary then, the thesis area is found to have been eroded during late Precambrian time, to be within a basin of deposition during Cambrian and Ordovician, and on an unstable shelf during the Devonian. Mississippian saw more stable conditions on the same shelf, while Pennsylvanian and Permian times were characterized by variation in shallow water deposits. During late Mesozoic time, shelf environment faces gave way to a nearly geosynclinal environment, and a much thicker sedimentary cover was deposited. Uplift and deformation eventually occurred during Late Cretaceous, Laramide and post-Laramide orogeny continuing through Tertiary. Local deposition did take place during uplift.

Precambrian

Precambrian rocks comprise the core of the asymmetric anticline on which the thesis area is located. Although no work other than passing mention has been accorded these rocks, their similarities with those in surrounding areas point to somewhat equivalent origins. The oldest and major portion of the basement complex consists chiefly of biotite gneiss and schists. However, in a few isolated areas large dark greenish-to black amphibolitic blobs were noticed, whose metamorphic lineations were truncated by the gneiss. Another type of inclusion consists of soft, pale greyish-blue steatite-like material. (One place was found where the Indians had utilized some of these soapstone blobs for crude bowls and grinding platforms where they had been scoured out by ice.) The relationship of the steatite and dark amphibolites could not be determined, but they point to the existence of an ancient country rock prior to formation of the gneiss.

Similar to those of the Teton area, the gneisses and schists are cut by granites and pegmatites (Bradley 1956). The light colored, medium-grained granites are massively intruded in only two places: southeast of the Granite-Bunker Creek divide, and on the southern flank of Jackson Peak. Both areas appear to be tabular intrusions several hundred yards across, and roughly parallel to the Precambrian erosion surface. In both cases these granites truncate the gneiss and schist. In other areas the contact appears to be gradational as well. For the most part the granites and pegmatites occur as irregular small bodies and large veins. These in turn are cut by quartz veins, some of them exceeding several feet in thickness. They may be representative of the 'last gasp' of the granitic intrusion.

The next sequence is uncertain, for there is evidence of several large dark diabase dikes which outcrop through the glacial debris. The surface of these is badly weathered and broken up. They are generally softer than the surrounding rock and hence weather as a slight cleft.

The trend of one major dike is northwest-southeast, parallel to the anticline axis, and is best exposed on the divide between Granite and Bunker Creeks. There are hints of several others with similar trends in the upper Bunker Creek area.

The final stage in the Precambrian of this area is that of fracture lining by an epidote-like material. In some areas this becomes thick enough to appear as a small dike-like mass, particularly in the crest of the main ridge. The material is much softer than the host rock and hence weathers out as low areas or sharp clefts. It appeared to the writer that most of the fractures containing epidote have an almost northsouth strike, similar to those in the Tetons (Bradley 1956), but whether this is entirely true in the Gros Ventres is open to question.

Features that are remarkable both on the ground and from the air are the Precambrian lineations. These are well developed and best exploited by erosion in the upper Bunker Creek area. The major and minor lineations appear as small triangles and dots respectively, on the geologic map. Their trend is generally N. 50° E., but cross cutting relations do occur. Whether these are deeply eroded dikes, Precambrian fault zones, or of other origin is questionable.

Except for some massive hand samples of nearly pure magnetite, no mineralization was observed within the thesis area. These were found within the immediate glacial drift and the source was not discovered.

Horberg and Fryxell (1942) note remnants of a Precambrian meta-sedimentary complex in the Tetons to the west. These consist of pink, grey, brown, and white quartzites which they postulate at one time may have exceeded 1,600 feet in thickness. Although none has yet been found in the Gros Ventres, pebbles of similar material are common in the overlying Cambrian orthoquartzites.

Cambrian

Flathead Quartzite

This formation was first named in Montana by A. C. Peale in 1893. This thick sequence of clean-washed, commonly cross bedded, cream to tan, medium to coarse grained sandstones and/or orthoquartzites lies unconformably upon the Precambrian basement complex. In most of northwestern Wyoming this formation consists of orthoquartzites. Within it, particularly toward the base, are lenses or zones of conglomerate, ranging from very coarse sand to smooth cobbles five inches in diameter. All are of a white to pinkish cryptocrystalline quartz or quartzite. Since there is no quartzite of the same type in the Precambrian immediately below, it is possible these cobbles came from a source similar to the remnants of Precambrian quartzites found in the Tetons (Horberg and Fryxell, 1942). In the thesis area, only pea-gravel conglomerates were found on the Precambrian contact itself, but at varying distances up section and in different areas, much coarser conglomerates were discovered (Figure 2).

Although other workers might disagree, the Flathead appears locally to grade up from a near regolith or deeply weathered granite, hence having an arkosic texture and composition at the base. Most areas show a sharp contact truncating the Precambrian at all angles (Figure 3). One of the zones of regolithic material occurs along the southern summit ridge of Jackson Peak.

The lithology is by no means entirely homogeneous. The conglomerates are generally restricted to the lower 30 feet, whereas shale partings are more common further up. The shales are of a finely laminated, green micaceous composition. Some of these, as well as some quartzite beds, were observed to contain fossil worm cast-like structures. No other fossils were found. The shale partings vary from a fraction of an inch to as much as two feet in thickness, and vary in extent as well. Since only

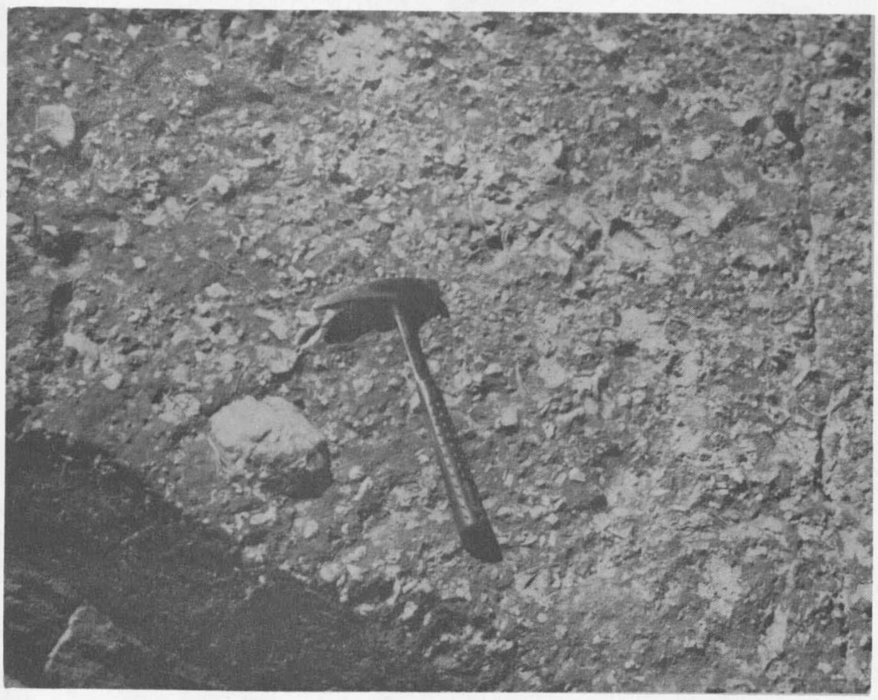


Figure 2. Conglomerate near base of Flathed Quartzite.

Figure 3. Flathed Quartzite lying on Precambrian erosion surface, head of Flat Creek.

one measurement was made in the area, it is not known to what distance the partings extend. Note is made in the appended section of at least locally continuous shale layers. Toward the top of the Flathead, the quartzite grades to sandstone and becomes interbedded with the maroon to green shales of the Wolsey Member above. The contact was arbitrarily put at the top of the last major sandstone bed, i.e. the point beyond which more shale was measured than sandstone.

Although the formation is relatively homogeneous in color, the upper part grades to pink or hematite red. While this distinctive color normally occupies only the upper-most portions, it usually pervades almost the entire formation where extreme folding or faulting occurs. The color appears to be due to the staining from overlying maroon shales rather than to inherency within the sands.

The weathering of this formation produces huge obvious rectangular blocks derived from the joint pattern intersecting bedding planes. The weathered color may vary slightly from cream to tan to a near rust orange. Peculiarly characteristic green, black, and grey lichens abound. This formation is somewhat less resistant than the Precambrian rocks beneath, although it forms cliffs almost everywhere it crops out. Hence a bench or step is formed on the Precambrian in front of the quartzite rise. The talus slopes from these cliffs are the most active, as mentioned in the Geomorphology section. The best outcrops of the Flathead for study are on the highest drainage divides. Pinnacle Peak area is the best, but is rivaled by the drainage divide between Flat and Granite Creeks. Excellent exposures are also found in the head of Flat Creek and on the Granite-Bunker Creek divide.

Under stress, the Flathead is one of the most competent of the exposed formations. Where formations above it may show extreme incompetency, the Flathead remains relatively undeformed.

The thicknesses of the Flathead vary considerably, due to the uneven Precambrian topography on which it was deposited. The measured section shows 288 feet to the gradational contact with the overlying Wolsey Shale. Just beyond the extreme southeast corner of the mapped area, Wanless and others (1955) measure 303 feet. Measurements 15 miles east at Doubletop Peak by Blackwelder (1918) show 200 feet, whereas Swenson (1949) to the north at Sheep Mountain reports 180 feet. Sections in the Tetons to the west range from 175 to 260 feet. In general the Flathead or its equivalent thickens to the east, though certain local areas may be much thinner. Shaw and Deland (1955) give a variation in thickness of 200 - 500 feet for southwestern Wyoming, and it would appear that the variation for northwestern Wyoming would be somewhat less than that, perhaps 60 - 350 feet.

Gros Ventre Formation

This Middle Cambrian formation contains three members, beginning with a thick basal shale unit known as the Wolsey Shale which grades up from the Flathead Quartzite below. Above the Wolsey is a massive limestone labeled the Death Canyon Member, and above this lies the thick Park Shale sequence. The formation was named by Blackwelder (1918) on Doubletop Peak.

Wolsey Shale. This member consists of very fissile green micaceous shale, weathering to a greyish-green color. Some workers mention specific thin sandstone layers in the lower portion; however the writer was more aware of sandy or silty zones within the shales rather than specific beds. Part of this difference may be due to the placement of the arbitrary contact. Worm tracks and cast-like structures appear in the lower portions, whereas fragments of trilobites are rare but recoverable toward the upper gradational contact.

The non-resistant character of this member causes it to weather out as a smooth grassy slope between the limestone talus of the overlying Death Canyon Member and the cliffs of Flathead Quartzite below. The shale always appears to be saturated with water in the thesis area, and in some localities where the overlying limestone is exposed in broad flats, springs occasionally emanate at the top of the weathered shale slope.

The thickness of the Wolsey depends on its proximity to faults and tight folds. In the Flat Creek area, the undisturbed Wolsey measurement is 97 feet. Miller (1936) measured approximately 102 feet within half a mile of the writer's section. It should be mentioned that Miller (1936) takes his thicknesses from the Teton Range and equates them to his measured Gros Ventre section. Swenson (1949) measured 90 feet some 8 miles to the north. Lochman-Balk (1956) shows 120 feet in her column measured at Granite Hot Spring. Foster (1947) reports approximately 86 feet in the Granite Hot Spring section, and 134 feet in the Teton section. Wanless and others (1955) agree, having used Foster's two measurements, but obtain 607 feet of Wolsey in the Sanke River Range to the southwest. Miller's (1936) section in the northwestern Wind River Range describes 107 feet of Wolsey.

The result of comparison shows the Wolsey to thicken greatly to the south, only slightly to the west, and to remain relatively constant on the shelf areas to the north and east.

Death Canyon Member. Within the thesis area this member has three units: a lower massive limestone, a thin shale unit, and a second massive limestone, thicker but similar in character to the first. The upper limestone grades into the overlying Park Member. The Death Canyon Member was named by Miller (1936) for the type locality in the canyon of that name in the Teton Range. According to Lochman-Balk (1956), the Death Canyon limestones are both the age and lithic equivalent to the Meagher Limestone of Montana.

The limestones are similar: dark grey to nearly black, weathering to a grey or blue-grey. They are finely crystalline, and mottling with a rust brown is most common although this may alternate with light grey to cream colors. The limestones are generally thin bedded with the separations between layers in places filled with a calcareous clay-like material that ranges from cream to rust-brown in color. Fossils are not readily apparent. Oolitic zones are present. Varicolored sandy and silty zones occur at the top of both limestones, particularly the upper. These zones are generally thicker bedded than the limestones. The Death Canyon limestones are comparatively resistant, and weather in 100 - 300 foot cliffs, separated in the lower middle by the thin talus covered shale step. Because the thin beds have short undulating planes, these limestones break into mottled flagstone-like plates. Where the weathered joint pattern intersects these plates, cliffs may stand out as a series of tall thinly layered columns.

The middle shale unit is dark green, extremely thin bedded and friable, and contains a trilobite hash in its lower half. In some areas the trilobites weather out as complete hematite-stained fossils on the surface. A bulk sample of trilobites were collected in 1965 and sent to Dr. A. R. Palmer of the U.S. National Museum. He identified them as belonging to the genus Clappaspis. All were of the same species. During the field season of 1967 another type of trilobite was noticed as a rare occurrence with Clappaspis but this was not identified. According to Dr. Palmer, no collecting had been done from this interval before. Numerous tiny brachiopods occur and are tentatively identified as Prototreta by comparison with specimens described by Wanless and others (1955, p. 13). These fossils lend credence to the Middle Cambrian age assigned to this member.

The Death Canyon Member has a thickness of 370 feet in the thesis area, however the contact was placed by comparison of descriptive sections. Foster (1947) obtains 368 feet in the Granite Hot Spring section to the southwest, where as Shaw and Deland (1955) obtain 359 feet and Lochman-Balk (1956) 350 feet at the same locality. Miller (1936) measured 285 feet in the Tetons and compares this exactly with the Gros Ventre section he measured at the head of Flat Creek. The writer finds no possible break in his own description near 285 feet as that measurement was on the side of a couloir with relatively little change in lithology. However Blackwelder's (1918) measurement of approximately 310 feet on Doubletop Peak suggests thinning to the east. It is substantiated by a measurement of 219 feet in the northwestern Wind River Range by Wanless and others (1955). To the north in the Owl Creek Range, the Death Canyon is only 155 feet thick, and to the south in the Snake River Range it is 201 feet (Wanless and others, 1955).

It might be surmised therefore that the Gros Ventre Mountain area was a local basin of thicker accumulation for these limestones, since they thin on all sides except to the northwest. A closer look at the thicknesses of the different units show the local basin to have existed only during deposition of the lower limestone and the intrashale, as these are the units which most actively thin in all directions. The upper Death Canyon limestone becomes much thicker to the northwest, making up nearly the entire member in the southern Gallatin Range.

The shale unit represents a quick change of depositional conditions over a large area. According to Foster (1947), the shale may be thin enough to have been overlooked in the Wind River section, but is thickest in the Gros Ventre Mountains to the west. The shale thins to 14 feet in the Tetons and becomes just recognizable to the north. The writer's measured thickness in the head of Granite Creek was 30 feet. Although Foster (1947) notes 82 feet in her Granite Hot Spring section, she mentions that much of this is covered.

Park Member. First named as a formation by W. H. Weed in 1900 for strata in Montana, the lower portion of this member consists of interbedded weak limestones, non-calcareous sandstones, and shales. Olive to dark green, thin bedded, friable micaceous shale is characteristic above. These upper shales are somewhat more drab than the Wolsey Member, and display a large number of continuous interbeds of limestone and calcareous sandstone an inch or less in thickness. The weathered appearance ranges from dull grey-green for the shales to white for the limestone interbeds. Some shale zones are maroon, and a few thin sandstones range through rust-brown colors. Flat pebble conglomerates or "intraformational breccias" occur in thin beds (Miller, 1936).

The writer noticed several zones of what appear to be limestone algal heads. On the divide between Granite and Bunker Creeks, there are two zones of algal heads. In the lower one, heads about one foot in diameter occur, while the upper zone contains heads from one to four feet across. In a badly contorted area near the junction of the Skyline fault and the Cache thrust, algal heads more than 6 feet in diameter have weathered out on a shale saddle. They are composed of limestone, bulbously lumpy, round or slightly ovoid in outline, and blue-grey in color. Some are tinged with a hematite stain. Internal structure could not be determined.

The Park Shale is a relatively thick unit in the thesis area and is extremely non-resistant and incompetent. In most areas it has been stripped off the Death Canyon Member, leaving wide spaceous dip slopes on the top of those limestones (Figure 4). The upper portion is almost entirely concealed with talus from the scarp of the Gallatin Formation above. Miller (1936) denotes local disconformities between the Park Shale and the Gallatin, which may in part account for the variety of thicknesses. The writer was unable to find a disconformity in his section.

A comparison of measured thicknesses for the Park in the Gros Ventres and surrounding regions show marked discrepancies. The writer measured 206 feet on the Granite-Bunker Creek divide. Foster reports 131 feet at the Granite Hot Spring section, and 107 feet in the Tetons. If the inference is made correctly, Lochman-Balk shows 410 feet in her Granite Hot Spring column. Miller (1936) measured 220 feet in Teton Canyon of the Tetons and postulates a Gros Ventre thickness of 200 - 300 feet. Blackwelder (1918), at Doubletop peak to the east measured approximately 370 feet, and Miller's (1936) northwestern Wind River Range section shows 324 feet. Wanless and others (1955) report a Snake River Range section of 158 feet to the southwest. In the western Owl Creek Mountains, Miller (1936) reports 250 feet.

In summary, the Late Middle Cambrian Park depositional basin was somewhat unstable, and generally deeper towards the east. During some part of this time, low islands must have appeared during a regressive stage. Differential erosion proceeded, resulting in local unconformities with the above formation (Miller 1936).

The Gros Ventre Formation as a whole is the origin of many problems and discrepancies. While some of the members and units are difficult to differentiate, the formation is the least competent of the Paleozoic units. Because of this character, it is found at several places in the thesis area to exhibit anomalously thick and thin units. All three major shale intervals display exceptional thinness where tightly folded or where near faulted zones. The limestones are equally complex in their reactions to stress. Miller (1936) and Denson (1942) measured the same section within the thesis area precisely through one of the anomalous zones at the head of Flat Creek.

Lines or zones of intraformational incompetence are abundant only within the Gros Ventre Formation, and are characterized by small faults, bedding plane slippages, and tight folding. In most places the underlying quartzite and overlying Gallatin Limestone remain undisturbed. It would appear that the structurally weak Death Canyon limestones slither about between the two shales when any directional pressure is applied.

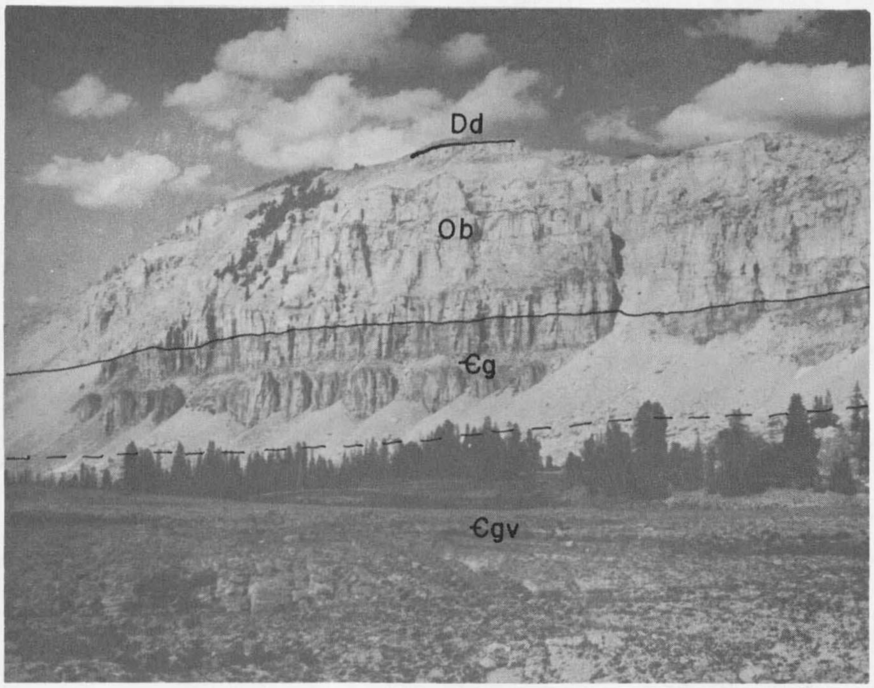


Figure 4. View east. Stratigraphic and erosional relations between the Gros Ventre, Gallatin, Bighorn, and Darby Formations, east wall of Flat Creek.

The Gros Ventre Formation is impossible to measure and describe fully at one location. The Wolsey Member is relatively easy to measure as differential erosion tends to leave it uncovered by talus on top of drainage divides, wherever the Flathead Quartzite and the Death Canyon Member occur in close proximity. The Death Canyon limestones, weathering out as cliffs, are easily measured in many areas. The base and the intrashale are commonly covered with talus. The one good undistorted exposure found of the Death Canyon intrashale is in the head of Granite Creek one-half mile north of Turquoise Lake, and is excellent for collecting trilobites and brachiopods. The Park Member is the most difficult member to measure. The best exposures are located on the Granite-Bunker Creek divide, and the divide between Bunker Creek and an unnamed drainage to the east. Elsewhere it is almost entirely covered or involved in folding and faulting.

Gros Ventre Formation thicknesses vary surprisingly. The writer's measured section totals 763 feet. Foster (1947) found 586 feet at the Granite Hot Spring section, whereas Swenson (1949) approximates 630 feet on Sheep Mountain. Blackwelder (1918) found 770 feet at Doubletop Peak, and Miller (1936) measured 747 for the northwestern Wind River Range. The southern Tetons yielded measurements of 607 feet (Miller, 1936), and 538 feet (Foster, 1947). The Snake River Range shows 967 feet, but 607 feet of that is Wolsey Member (Wanless and others, 1955).

Assuming all calculated thicknesses to be correct, the solution to the problem of such large discrepancies in the Gros Ventre Range, may be found in the place of measurement. Most of the writer's section was measured on the broad northeast flank of a southwest upthrust asymmetric anticline. Blackwelder (1918) measured his section in almost precisely the same position on the anticline to the southeast. The Granite Hot Spring section maintains a nearly axial position with respect to the anticline, yet a fault representing more than 5 miles of displacement lies nearly at the base of the section. Swenson (1949) made his measurements adjacent to a major vertical fault where erosion had exposed the section on the upthrown side.

It would be nice to postulate that the writer's and Blackwelder's (1918) measured sections are in the least disturbed areas. It must be pointed out that these are fairly close to the apex of the asymmetric anticline. The writer's section, incidentally, agrees most closely with Blackwelder's (1918).

Gallatin or Boysen Formation

The term Gallatin was introduced by Peale in 1893 for Montana lithology, and was later changed by Deiss in 1938 to the Boysen Formation in Wyoming. Both are presently used in the literature and refer to the following lithology, which was at first only a part of the strata originally included in the term Gallatin by Peale (1893).

This formation consists of the first massive unit of limestone above the Park Shale, an overlying thin shaly member, and an upper massive limestone unit. These are respectively known as the DuNoir Member, the Dry Creek Shale, and the Open Door Member. Although the Gallatin has this tri-partite character in northwestern Wyoming, it is not often separated into these respective members. In other areas as many as four members are described.

The limestones are essentially the same, dark grey to almost black, weathering grey-brown to tan. They are massive and discontinuously mottled with a yellow or rust-brown. The lower limestone tends to contain layers of flat pebble conglomerates and oolitic zones, where as the Open Door Member can be seen to have faint lighter color bands in the upper part of the section. The Dry Creek Shale in the Gros Ventres is actually a thin-bedded limestone with large greenish or yellow interbeds of limey shale. It is almost without exception covered by talus from the Open Door Member. At the top of the Gallatin is a marked unconformity (Figure 4).

According to Lochman-Balk (1956), who summarized previous work done on the Gallatin and its equivalents, it has been accorded an early Late Cambrian age on the basis of fossil assemblages.

The Gallatin Formation weathers into massive cliffs, separated by the very small talus covered 'step' of the Dry Creek Shale. The DuNoir Limestone appears to be much thicker than the Open Door, though much of the lower member is commonly covered by talus from the above cliffs. It is difficult to estimate how much of the Park shale underlies the talus. The Gallatin cliffs are continuous upward with the thicker, equally massive white dolomite cliffs above (Figure 4).

The writer's measured section includes a 240 foot total thickness for the Gallatin in the Gros Ventres. Blackwelder (1918) found 280 feet at Doubletop Peak. Foster (1947) measured 180 feet at Granite Hot Springs, and her column shows a thicker undescribed section at Sheep Creek to the northwest of the thesis area. Lochman-Balk (1956) shows 250 feet in her Granite Creek column. Shaw and Deland (1955) found 204 feet at Granite Hot Springs, and Swenson (1949) measured 190 feet on Sheep Mountain to the north. Miller (1936) found approximately 300 feet of Gallatin in the northwest Wind River Range and describes a thinning to the east. Foster (1949) shows 102 feet in the Tetons, whereas Miller (1936) found 180 feet there, and compares this exactly with his Gros Ventre section. Wanless and others (1955) found 212 feet in the Snake River Range.

It would appear from these discrepant measurements that the Gallatin is thickest over the junction of the Gros Ventre and Wind River Ranges, with a thinning in all other directions. A close look at the individual members show the DuNoir to be thickening from 40 feet in the Wind River Range to better than 90 feet in the Tetons. The writer measured 126 feet in the Gros Ventres. The Dry Creek Shale remains relatively constant at about 25 - 35 feet, over the same distance. The Open Door Member thins from 229 in the Wind River Range to 65 feet in the Tetons. The writer measured 37 feet and 77 feet respectively for these members. Within the Open Door Member there are two unconformities recognized in both the Teton and Wind River Ranges by Miller (1936). Only the upper contact unconformity is noted by previous workers in the Gros Ventres. The writer is unsure of the second unconformity within his section. A well-defined and highly cross bedded sandstone was found 5 feet below the top of the formation. This would indicate a very shallow water environment. It is not known whether this matches the lower unconformity elsewhere. In the Tetons, the two unconformities might explain the differences in measured sections.

Ordovician

Bighorn Dolomite

This formation, first named by Darton in 1904, is divided into two members: the lower Bighorn Dolomite and the thinner upper Leigh Dolomite (Blackwelder, 1915). It is the most competent formation in the thesis area and the most consistent in character. Cream to grey, white weathering dolomite characterizes almost the entire formation, and everywhere within the lower member there is a slightly greyer, dense mottling. This mottling is three dimensional, that is, it consists of vertically and horizontally branching tube-like structures. Their origins according to Blackwelder (1913) are suggestive of an organic nature, perhaps related to algae. Some zones of this dolomite are pinkish, whereas toward the upper middle portion, markedly darker cream colors exist for a comparatively thick zone. The latter eventually grade back to lighter cream colors. In general the Bighorn Dolomite Member is massive whereas the Leigh tends to be somewhat thinner bedded. The Leigh also is much lighter in color, tending towards white and weathering almost pure white. In some zones the Leigh is of a softer chalky nature. According to Blackwelder (1918) and Wanless and others (1955), one unconformity exists to separate the members, while a second separates the Leigh from the Devonian Darby Formation above.

The weathering properties of the Bighorn are distinctive. It appears in cliffs in most areas, being exceptionally resistant, and covers the lower Gallatin Limestone and Park Member of the Gros Ventre Formation with talus (Figure 4). The joint pattern is such that rectangular blocks are eroded from both horizontal and vertical surfaces. The striking joint pattern can be seen on the dip slopes of Bighorn where the overlying Darby Formation has been stripped away. The major joints strike N. 45° E., are vertical, and approximately parallel the major Precambrian lineations.

Several rockslides show the Bighorn and Gallatin characteristically together, spalling away from the cliff face and sliding out on the Park shale. On a broken surface it is impossible to distinguish bedding planes although weathering processes apparently take keen advantage of them. This is noticed especially in the Leigh Dolomite where the thinner-bedded nature becomes obvious through weathering. Obscure fossil hashes, which appear more commonly in the Leigh dolomite, are brought out by weathering. They are invisible on a broken surface. Occasional horn corals are the most distinctive. A weathered surface of the dolomite appears to be solution pocketed (Figure 5). The darker mottles are more resistant to solution weathering and hence stand out, creating these

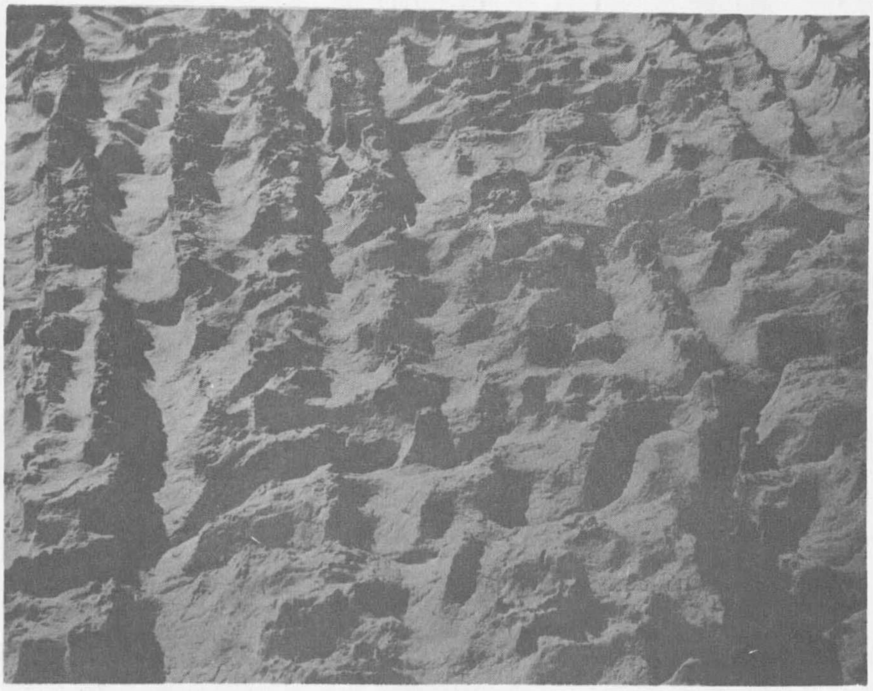


Figure 5. Solution pocketed weathering surface typical of Bighorn exposures.

rough surfaces. Laboratory analyses, indicating a coarser crystalline nature and a slower dissolution of the darker parts, help support this idea (Blackwelder, 1913).

Although age determinations have ranged in the literature from Late Ordovician to Devonian, both members have been commonly accepted as Upper Ordovician through analysis of incomplete fossil evidence. Many of the fossils which Miller (1930) used for age determinations came from a basal sandstone, known as the Lander Sandstone. Its western limit appears to be east of the Gros Ventre area. Miller (1930) noted that 1 - 4 feet are present in the northeastern Wind River Mountains. The writer observed a 1 foot thick cross bedded calcareous sandstone near the top of the Gallatin formation. Unless a mis-interpretation of contacts has occurred, there was no sandstone in the lower part of the Bighorn Dolomite.

Thicknesses were measured in the Gros Ventres in only three places. The writer found 445 feet on the divide between Granite and Bunker Creeks, the upper 98 feet consisting of the Leigh Member. Because much of this measurement by necessity was over broad, gently dipping flats, it may not represent the true thickness though the section was measured with due care. Blackwelder (1918) measured 500 feet at Doubletop Peak, the upper 100 feet comprising the Leigh Member. Wanless and others (1955) mention 288 feet for the Bighorn Dolomite Member in the upper Horse Creek drainage but fail to give a thickness for the Leigh. They also do not note the exact place of measurement, important because some of the Bighorn has been thrust northward in that area. Horberg (1938) approximated 340 - 385 feet for the Bighorn in the Tetons and ventured a range from 300 - 400 feet for the Sheep Creek area. Swenson (1949) measured 290 feet at Sheep Mountain, with the upper 30 feet forming the Leigh Member. Miller (1930) estimates 325 feet for the northeastern side of the Wind River Mountains, the upper 25 feet comprising the Leigh.

In summary, the thickest Ordovician accumulation occurred over the Gros Ventre-Wind River Range junction. How much of the original formation was deposited is unknown as an erosional unconformity separates the Upper Ordovician from the Devonian strata. Differential erosion during that long interval may account for the anomalous thicknesses.

Devonian

Darby Formation

First named by Blackwelder (1918), the Darby formation is primarily a non-resistant sequence composed largely of dolomite and a few limestone interbeds. Its character in the thesis area is one of variation with no cyclic behavior observable. Thick bedded brown to nearly black dolomite, weathering brown, and thin limestones interbedded with thin tan, yellow, or green siltstones, sandstones, and shales comprise this sequence. In places the lower brown weathering dolomites contain abundant Amphipora. No other fossils were readily observed. Many, if not most of the dolomites and limestones give off a fetid petroliferous odor, particularly in the lower part of the formation.

The Darby is commonly covered in the thesis area, being sandwiched between the massive Bighorn Dolomite and the overlying Madison Group limestone. However in some areas it appears in near cliff-like form as along the walls of cirques and along the top of drainage divide ridges (Figure 6). The contact with the Madison Group above appears to be a gradational one, and the writer confesses a lack of certainty in placing the contact in the appended section. This was done only after comparisons with other sections. It is lithologically continuous with the dark brown petroliferous limestones in the lower part of the Madison Group. The thin basal black shale of the Mississippian rocks is easily missed, and was not found by the writer.

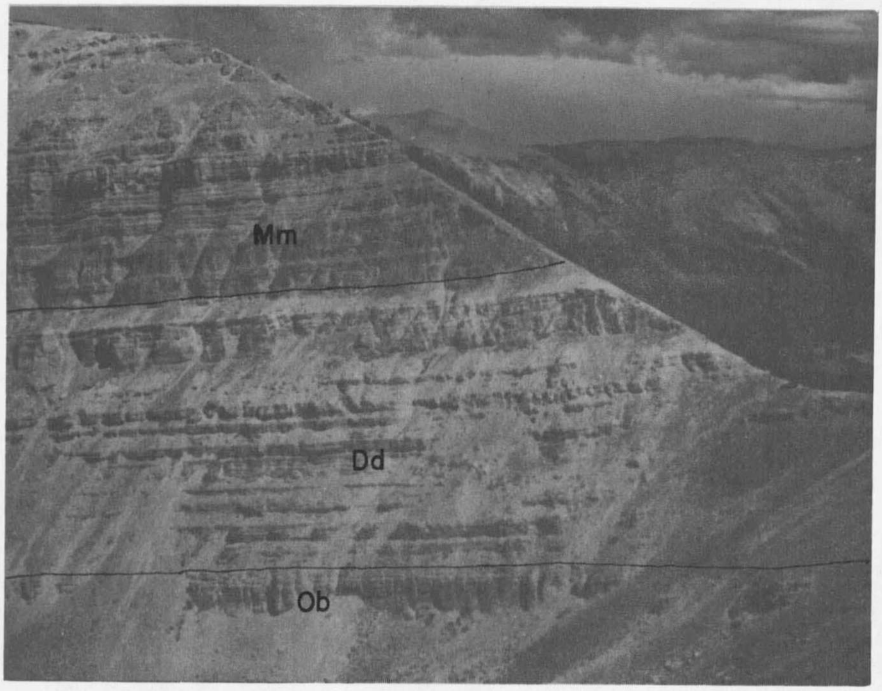


Figure 6. View east. Stratigraphic relations between Bighorn, Darby, and Madison Group on an eastern tributary to Flat Creek. The writer's Darby and Madison (incomplete) sections were measured here.

Correlation of the Darby has been done on a regional scale by Andrichuk (1951, 1956), and Benson (1966). It has been called the Jefferson Formation by Benson (1966), containing an unnamed lower member and the upper massive and dolomitic Birdbear Member. Just north of the Gros Ventre Range, the upper-most part of the Darby becomes more shaly, enough so that it has been correlated with the lower part of the Three Forks Formation of Montana (Andrichuk, 1956; Benson, 1966). This part of the Three Forks Formation comprises the units above the Birdbear Member of the writer's measured section.

The divide between Flat and Granite Creeks contains an excellent section of Darby exposed in a cirque wall, where the formation measures 319 feet thick (Figure 6). Foster (1947) lists 312 feet at the Granite Hot Spring section, and 327 feet in the Tetons. Benson (1966) measured 315 feet at Granite Hot Spring. Farther west the Darby thickens to 2900 feet in east central Idaho in one of two major basins of accumulation (Andrichuk, 1951). Blackwelder (1918) measured 400 feet in the Doubletop Peak area, where a slightly more shaly section occurs.

The Darby was deposited by a west to east transgressing sea, and the limestones in the west grade to dolomites in the Gros Ventres to a more shaly section in the east. Individual beds cannot be distinctly correlated. Although evaporitic sections have been reported elsewhere, no mention of them occurs in other Teton or Gros Ventre measured sections. Fossils are not common in the Darby Formation, and most of those found have not been useful in age determination (Benson, 1966). Through correlation of the Darby with the Jefferson Formation, underlying and overlying strata to the north limit its age to early Late Devonian.

Mississippian

Madison Group

Although a certain amount of confusion exists on the naming and dividing of these rocks in northwestern Wyoming, the name Madison limestone as given by Peale in 1893, refers to the thick massive section of brown to steel-blue limestones beneath the Amsden and overlying the Darby. The color, bedding characteristics, fossil content, and gypsum content differ from section to section, but in general three separations can be made. According to Strickland (1956), it should be divided into a lower Lodgepole formation, a Mission Canyon formation, and an Upper Madison limestone. These divisions change somewhat latterally, enough so that boundaries in various sections become hard to locate.

Benson's (1966) basal dark shale unit, referred to as the Sappington Formation by Strickland (1956) was not found by the writer.

The basal portion of Madison limestones in the thesis area is generally dark grey to brownish in color with zones of somewhat lighter shades. The lower 50 feet contains dark grey chert nodules and some layered chert stringers. Higher in the section the colors change to the typical steel-blue and grey, and fossil hash zones are abundant. Within the lower 120 feet, most of the limestones have a distinct petroliferous odor. Although only the basal 475 feet of the Madison Group was included in the measured section, the description made correlates well with other nearby sections in northwestern Wyoming. Strickland (1956) gives a range of thicknesses for the basal Lodgepole Formation from western to central Wyoming of 800 - 200 feet respectively. Wanless and others (1955) note that only the lower portions of the western Wyoming sections (150 - 250 feet) resemble the Lodgepole. The writer agrees with the latter observation in that the lower 200 - 250 feet of his section more closely fits their Lodgepole description. The Lodgepole is considered to be lower

Mississippian in age.

The Mission Canyon formation, described elsewhere as light colored and thick bedded was seen in several cliff-forming outcrops, and appears in the upper 225 - 275 feet of the writer's section. Although Blackwelder (1918) notes dolomitized zones in the Doubletop Peak area, few other workers and sections agree. However, Strickland (1956) describes the Mission Canyon in northern Wyoming and southern Montana as being dolomitic. He also estimates an average thickness of 250 feet for western Wyoming. The age of the Mission Canyon is considered to be early Middle Mississippian. Strickland (1956) believes a disconformity separates it from the overlying sequence.

The upper Madison limestone, correlative with the Brazer Formation in other areas (Strickland, 1956; Wanless and others, 1955), and thus named by some in western Wyoming, is reported to have a basal breccia. The writer's section was not extensive enough to substantiate this. The upper Madison limestone is composed of finely crystalline, grey to brownish or pinkish massive limestone. It comprises the remainder of the Madison Group and contains numerous veinlets of calcite in the Gros Ventre Range. To the south in the Hoback sections, large quantities of interbedded gypsum are found indicating restrictions of the ocean basin at various times. No gypsum has been found in any of the Teton or Gros Ventre sections. The writer did not notice any gypsum in any of the upper Madison despite the proximity to the Hoback Canyon. The unit is considered to be Middle to Upper Mississippian in age. Wanless and others (1955) give a definite thickness of 243 feet for it in the Hoback Canyon; other authors give no definite thickness. An unconformity exists at the top of this sequence.

Most workers have chosen to map and measure the Madison Group as a single unit, which the writer has done. Foster (1947) reports the Madison Group to be more than 1000 feet thick in the Gros Ventre Mountains. Wanless and others (1955) give 778 feet for combined Lodgepole and Mission Canyon formations in these mountains. Combining this with their Hoback Canyon Brazer section, the total comes to 1021 feet for the Madison Group. Strickland (1956, p. 52) shows a range of 800 - 1000 feet on an isopach map constructed from his studies. It is readily apparent from his map that the Gros Ventre region was on the edge of a shelf in northwestern Wyoming, and received a thinner deposit than did southwestern Wyoming, Utah, Idaho, and much of Montana.

Sacajawea Formation

Named by Branson in 1937, this thin sequence of shale, gypsum, and limestone deposits is of latest Mississippian age. It has been mapped with Pennsylvanian rocks for convenience. It disconformably overlies the top of the Madison Group, filling in a karst topography developed on the limestones during Late Mississippian time. Although not measured in the thesis area, it is estimated to be 50 - 60 feet thick, and is composed of a basal red shale zone, and a few thin, dense, cherty limestones interbedded with red and yellow sandstones and shales. The red shales commonly weather out over the Madison Group, staining the upper portions.

It is disconformably overlain by the basal Pennsylvanian sandstone known as the Darwin Member of the Amsden Formation.

Several sources regard this formation as the lower part of the Amsden sequence (Foster 1947; Wanless and others 1955). Foster (1947) approximates a 60 foot thickness near Sheep Creek. Wanless and others (1955) measured a highly gypsiferous 90 foot section in the Hoback Canyon, mention a thickness of 50 feet in the southern Tetons, and 11 feet in the Snake River Range. According to Strickland (1956) the Sacajawea Formation is correlative with the Big Snowy Group, probably the Kibbey Formation in Montana; its age is Latest Mississippian. He estimates a 100 foot thickness in his columns for the Hoback region. It pinches out farther south.

Pennsylvanian

Amsden-Tensleep Formations

The Amsden and Tensleep formations, originally named by N. H. Darton in 1904, are generally difficult to distinguish within the Teton-Gros Ventre area, and have commonly been mapped as one unit. Only the lowermost portion is exposed in the area. In other areas the Amsden Formation consists of a basal sandstone overlain by 200 - 300 feet of red shales, siltstones, and mottled limestones (Foster 1947, p. 1557). Some of these contain oolitic iron ore (Wanless and others, 1955). The Tensleep Sandstone though not exposed in the thesis area, consists of 300 feet of cleanwashed, light colored, well cemented quartz sandstone, interbedded in places with equally light colored limestones and dolomites. To the north, limestones predominate over dolomite, whereas in the Hoback region dolomite is more abundant than limestones. The Tensleep is correlative with the Quadrant Formation of Montana (Scott, 1935). Only the basal Darwin Sandstone Member of the Amsden Formation is present on the borders of the thesis area, with perhaps a thin covering of red and yellow sandy shales. The Darwin Sandstone is light salmon colored and cross bedded. It weathers in castellated form where exposed as a ridge on drainage divides, which is the common topographic position in the study area. Although in most exposures it has been eroded to less than its original thickness, the outcrop northeast of Jackson Peak may provide the future stratigrapher with a complete measureable section. Thickness of the Darwin in the Gros Ventres are 97 feet at Sheep Creek (Foster, 1947), 88 feet at Granite Hot Springs (Wanless and others, 1955), and 100 feet at Doubletop Peak area (Blackwelder, 1918). Wanless and others (1955, p. 32) note 106 feet in the Snake River Range, 118 feet in the Northern Hoback Range, 76 feet in the Tetons, and 54 feet on a butte in Jackson Hole. The writer estimates a maximum of about 75 feet in the study area, within the lower 120 feet of the exposed Amsden Formation.

In summary, the Darwin Member is found to thin to the north and west, with the center of accumulation to the south.

Tertiary

A conglomerate possibly undescribed in the stratigraphy of northwestern Wyoming occurs as a capping of one of the ridgetops. This conglomerate unconformably overlies the Darwin Sandstone on the northwestern drainage divide between Flat and Granite Creeks. It consists mainly of pebbles of chert and limestone, and some of sandstone. No Precambrian metamorphic or igneous pebbles were observed. The largest pebbles are more than an inch in diameter and are cemented by sandy calcium carbonate. Its observable thickness was estimated to be 0 - 75 feet where it capped a broad knoll. This enigmatic unit was not noticed elsewhere in the area. Since this undue thickness does not fit any local Amsden descriptions, it is fair to speculate that this conglomerate might be part of the products eroded from the high level erosion surface which exists in the adjacent area of the northern Gros Ventres. This means the deposits might be as young as late Pliocene. The need for more extensive field work on this unit in the Gros Ventres is obvious.

Quaternary

Quaternary deposition has been mainly of thin glacial and alluvial sands and gravels. Glacial drift is common. Protalus ramparts, talus, and scree are also common but not extensive.

STRUCTURAL GEOLOGY

Introduction

A surprising amount of conflict will be found in the volume of literature concerning both age and position of the Gros Ventre structures. As there have been few researches since 1956, and these have generally not been published, new information invalidating old hypotheses has not gained public notice. Earliest works covering the present study area were general and many of the initial hypotheses are still correct. However all of the structural conclusions concerning the thesis area based on the latest regional work by Horberg, Nelson, and Church (1949), have been assumed to be true by the only subsequent worker who has published. Van Dyke (1956) mapped an area overlapping the present study to the south and east. Some of his findings and conclusions are based on stratigraphic information now obsolete. Others have worked 15 miles to the east in the Gros Ventres, to the north and to the south, but none have been concerned with any part of the area this study covers.

The writer's map will be seen to differ markedly from any available published map. The detail accomplished within this study has shown tremendous deviations from previous general studies. The objective of this section on structure is not to resolve the conflicts within the literature on this particular area. Rather, by substantiating formerly correct hypotheses and verifying new ones it is hoped that certain previous conceptions may be abandoned.

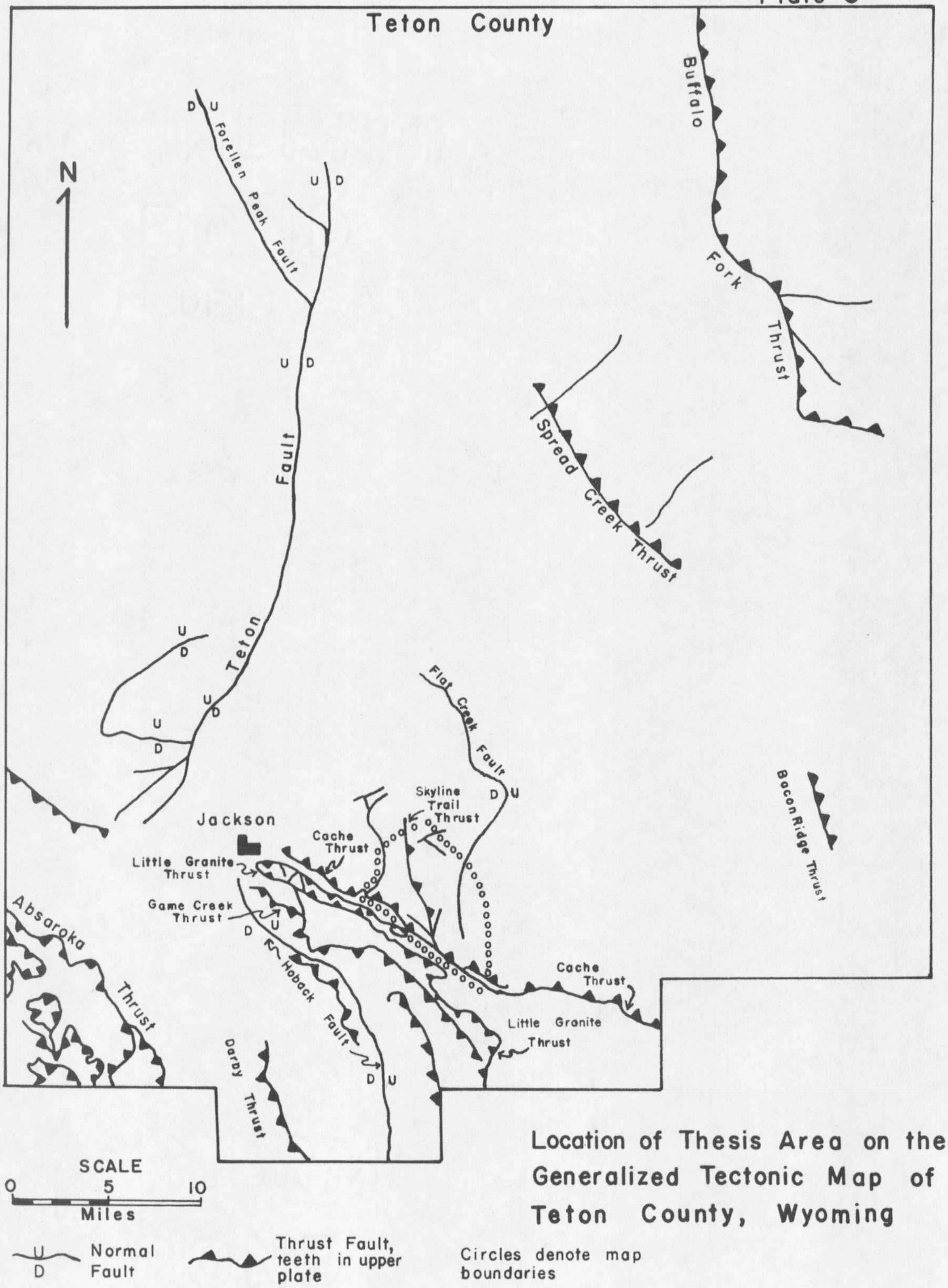
Regional Setting

The Gros Ventre Range is a comparatively small range lying within the northern part of the Middle Rocky Mountain Province. Structures created during Laramide time dominate the regional relations, and have been subsequently modified by Tertiary faulting. The regional structures are related to the two environments which existed in the region prior to Laramide time. A geosynclinal area lay to the southwest of the present Gros Ventres, with an axis roughly parallel to the Wyoming border, and containing up to 90,000 feet of sediment (Froidevaux, 1968). To the north and east lay the foreland area with its much thinner sedimentary cover. In the Gros Ventre region, remnants of the Paleozoic and Mesozoic formations total about 15,000 feet.

With the onset of the Laramide revolution, uplift, folding, and overthrusting developed within the geosynclinal area, comprising the start of what was to become known as the overthrust belt of that region. Seven major eastward-rising thrusts are recognized today in the Caribou, Wyoming, Salt River, Hoback, and Snake River ranges, with a myriad of smaller thrusts and associated faults. None bring the Precambrian to the surface. The primary deformation began as early as late Jurassic in the geosynclinal area, with progressively younger overthrusting to the east and north. The most recent of these structures lies only several miles to the southwest of the Gros Ventre structures. They are commonly considered part of the range, although their origins differ. To the south and east, deep tectonic basins were also formed, into which great thicknesses of sediment was deposited.

In the north and east, the foreland platform reacted in a similar manner although on a different scale. Uplift, folding, and thrust faulting characterizes several of the mountain ranges, exemplified by the Bighorn, Wind River, and Gros Ventre ranges. The Precambrian basement has played an important part in each. Unlike the north and east thrust belt to the south, many of the foreland region's asymmetric anticlines were thrust or reverse faulted to the southwest. These structures are not as common as those in the geosynclinal area, nor are they thought to approach the same magnitude in activity or dimensions. The foreland deformation commenced during early Laramide; however several of the thrust faults did not become active until after Paleocene time. Basins were also formed on the shelf during this time, and reworked sediments were poured into them.

The two types of structures oppose each other in the western Gros Ventres so closely that they may have abutted each other at one time (Horberg, Nelson, and Church 1949) (Plate 3). The distinctiveness of the two deformational types lies in the angle of thrusting and the rocks brought into play. The southern geosynclinal thrust zones involve only the sedimentary rocks, forming elongate imbricate patterns. The thickness of the individual low angle thrust sheets never exceed 25,000 feet (Froidevaux, 1968). To the north, thrusts are of a much higher angle, ranging from 35° to high angle reverse faults. The sedimentary cover of these northern structures was so thin that forces within the



Location of Thesis Area on the Generalized Tectonic Map of Teton County, Wyoming

Generalized from the Wyoming Geological Association Guidebook 11th Ann. Field Conf., 1956: p. 141.

Precambrian basement controlled the development of the ranges. Subsequent erosion has exposed the basement rocks in the core of these ranges in several cases.

The earliest thrusting began in the geosynclinal basin, and a contemporaneous bulging occurred in the regions of today's foreland ranges. During Paleocene and early Eocene most of the present mountain ranges in both the geosynclinal and foreland areas were uplifted and thrusted. Later orogenic spasms occurred in both areas but never on as great a scale as in late Laramide. Throughout early Tertiary time, thrusting, folding, and differential uplifting took place. This contrasts with late Tertiary time when fault block structures were created and general massive collapsing of eroded mountain cores occurred.

The mountain ranges of the foreland area tend to have rectangular block-like proportions, and may be divided into smaller blocks by associated cross faults. The later Tertiary normal faults have been superimposed across these ranges, modifying their original structures. The normal fault block ranges of this age are exemplified by the Teton mountains.

Gros Ventre Range

The Gros Ventre Range exhibit typical foreland structures, though its history may not be as easily classified. The range is composed of a broad anticline trending northwest-southeast, asymmetrical to the southwest. It has been thrust and reverse faulted in separate blocks to the southwest, creating a steep slope on that side. Several smaller asymmetric anticlines have been superimposed on it (Horberg, Nelson, and Church, 1949). One of these anticlines is present in the northwest part of the thesis area and is called the Nowlin Creek anticline. Another, comprising the western front of the range, is called the Cache Creek anticline.

An initial uplift began during middle Paleocene to the north of the Gros Ventre Range, and tremendous quantities of Mesozoic debris were shed and reworked to the south. Over 14,000 feet of Hoback Formation, composed mostly of sandstones with some limestones and conglomerates, were deposited at this time in a broad sheet. This extended over the southeastern part of Teton County and beyond into a tectonic basin to the southeast. The earliest Eocene Pass Peak Formation, consisting mainly of conglomerates was shed slightly to the east, so that some of its 5,000 foot section narrowly misses being included within the thesis area. Just prior to Pass Peak deposition but continuing into that time, an unnamed sequence of similar conglomerates were deposited throughout the western Gros Ventre region. These were at one time considered to be part of the Pliocene Camp Davis Formation, but have since been found to intertongue with the Eocene Pass Peak conglomerates on the east, and the Pliocene classification was dropped (J. D. Love, personal communication, June 1968). The materials of this 5,000 foot sequence have been derived from Mesozoic rocks, probably from those rising to the north during the initial stages of uplift. The wedge shaped thickness of these rocks were folded into the Little Granite Creek anticline and now dip to the north in the thesis area at angles up to 50 degrees. The angle of dip becomes less steep to the east and is nearly horizontal at the mouth of Granite Creek Canyon where it emerges from the Gros Ventre Mountains. The Little Granite Creek anticline may have been formed by initial pre-thrust compression between the opposing geosynclinal and foreland thrusts. The thrusts are farther apart to the southeast where the angle of dip on the conglomerates near the Gros Ventre side is least.

Several thrust sheets of geosynclinal origin cover the Paleocene-Eocene rocks to the southwest, and four thrust and reverse faulted blocks of the Gros Ventre Range have overridden them from the northeast. These major thrust faults along the southwest side of the Gros Ventre Range have been termed the Cache thrust system, and represent a case where the faulted blocks have overridden their own erosional debris from an antecedent stage (Plate 3). Evidence in the thesis area indicates that the Cache thrust and Skyline Trail faults, which comprise the two western segments of the Cache thrust system, were initially active during early Eocene. It is still uncertain whether major movement continued through later Cenozoic time.

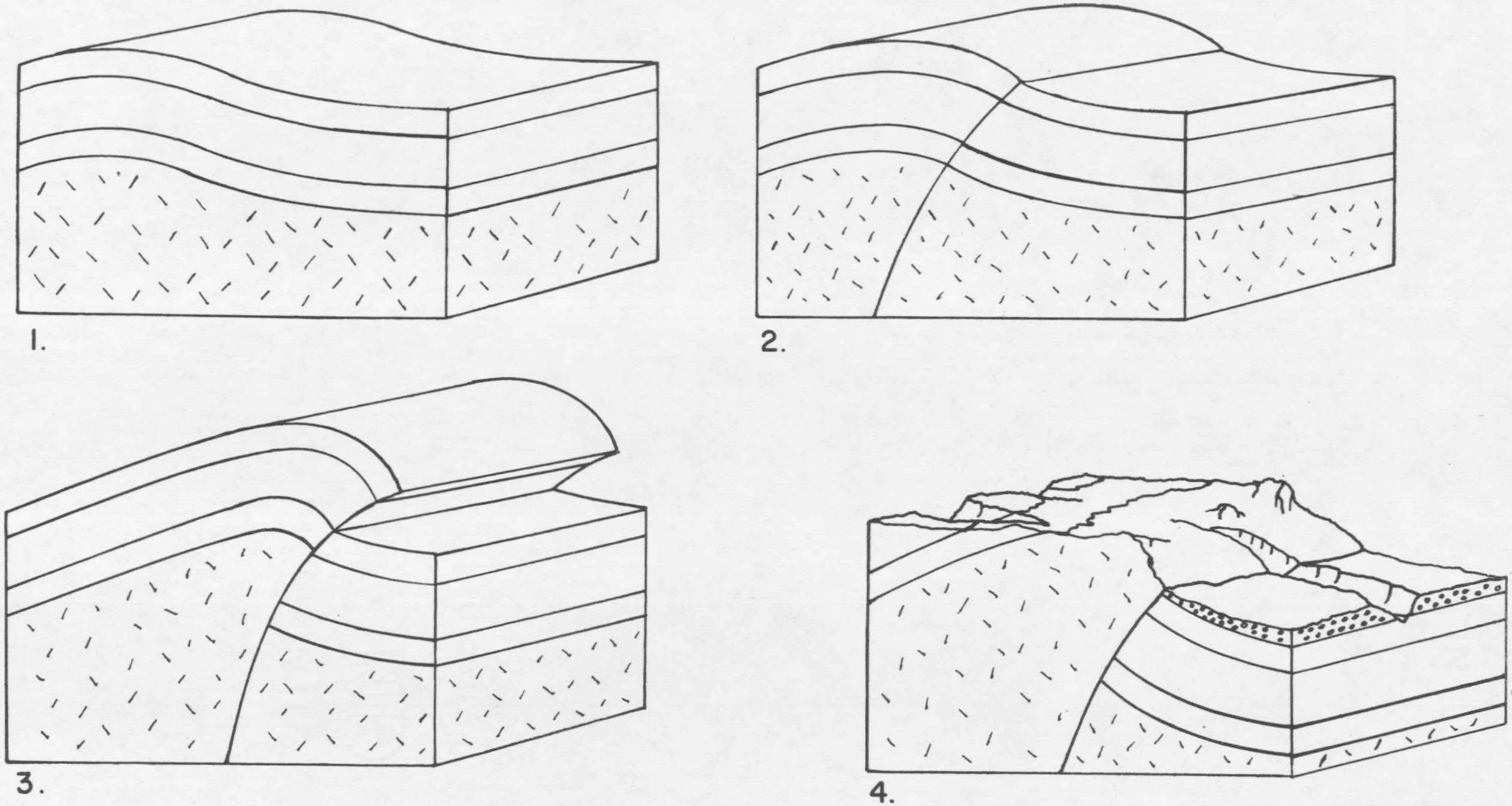
Local Structure

The thesis area lies on two of the four blocks comprising the Gros Ventre Range (Plate 3). The boundary between them lies south of the center portion of the geologic map near Turquoise Lake, where the western Paleozoics abut the Precambrian (Plate 6; in pocket). The southeastern block has by far the simpler structure and has been traditionally called the Skyline Trail block. The northwestern block has been previously referred to as the Cache Thrust block or Cache block. Nelson and Church (1943), and Horberg, Nelson, and Church (1949) have termed both of these blocks 'trap door' phenomena. In their case the fault line assumes a sled runner profile in cross section, curving to a low angle at depth under the thrust plate. Although the Cache thrust fault has a much shallower initial dip than its southeast neighbor, it is considered an advanced stage of 'trap door' structure. These authors imply that the Cache block has moved farther than the Skyline Trail block.

That there are two interpretations of 'trap door' faults is seen in the cross sections of Nelson and Church (1943). Their explanation of the advanced stage of the Cache thrust is not given. The two similar publications on these interpretations are general enough so that evidence for these important ideas is eliminated. Van Dyke (1956) chose to believe these interpretations and published accordingly, again foregoing the evidence.

The writer prefers the interpretation of 'trap door' and 'upthrust' structures as developed by Bengtson (1956) (Plate 4). In this case, vertical uplift occurs first from deep seated pressures in the basement complex. The first stage produces a steep monocline in the sedimentary cover. With slight lateral pressure, a curved overthrust fracture appears dipping towards the upthrown block. The dip of the fault increases with depth. It is possible that vertical fractures may appear above the thrust on the upthrown block, which may or may not connect with the

Plate 4



Stages in theory of upthrust, modified after Bengtson (1956), and adapted in part to the Gros Ventre Range. 1. Initial uplift. 2. Curved fracture forms by uplift with slight lateral pressure. 3. Uplift causes thrusting. 4. Subsequent erosion reveals thrust plane to steepen at depth.

nearly vertical thrust fault at depth. By strong uplift, the sediments are thrust over the adjacent area, hence the name of 'upthrust'. The plane of the thrust, therefore, becomes steeper with subsequent exposure by erosion of the upper block (Plate 4). This interpretation of structures is used in all of the included cross sections on the geologic map (Plate 6, in pocket).

The cross section of the western Cache thrust segment by Nelson and Church (1943) begins to follow this interpretation, which is vastly different than their 'trap door' explanation of the adjacent Skyline Trail segment cross sections. Their Skyline Trail thrust angle becomes shallower at depth. This major contrast in cross sections is not discussed in the description. It seems that Horberg, Nelson, and Church (1949) chose to perpetuate the previous Skyline Trail interpretation for 'Trap Door' phenomena, and the Cache block is seen as an advanced state of Skyline Trail block movement in their cross sections.

The field evidence seems to support Bengtson's (1956) analyses of 'upthrust' interpretation. The writer believes that the time-honored interpretation of Horberg, Nelson, and Church (1949) should be revised for this area. The following discussion of specific structures will attempt to show the validity of the upthrust hypothesis for this area.

Skyline Trail Block

It cannot yet be proven in the thesis area that the major fault line bordering this block on the southwest is a very high angle reverse fault. Evidence for a somewhat steep angle occurs in its relatively straight trace with slight indention towards the upthrown side where it crosses large drainages. This pattern continues to the southeast some 10 miles where it abuts the Shoal Creek block. All previous conclusions on the movement of this block are based solely on this pattern. The writer believes different conclusions on the type of movement can be drawn from evidence concerning the junction of the Skyline Trail and Cache blocks as well.

Stratigraphic displacement is much greater in actuality than previous literature would suggest, as more complete knowledge of stratigraphy has been made available. In order to place Precambrian on latest Paleocene in this region, a dip slip of at least 29,000 feet is needed. More than 14,000 feet of this is required by Paleocene deposits alone. Horberg, Nelson, and Church (1949) were unaware of this when their estimates limited displacement to 11,000 feet. Since the upper part of the 5,000 feet thick unnamed latest Paleocene-earliest Eocene conglomerate has been eroded off in the thesis area, displacement would total less than 35,000 feet. The extra 1,000 feet accounts for the projected Precambrian-Cambrian contact on the upthrown side over the Tertiary conglomerates (cross section E-E', Plate 6).

Farther to the southeast in the Gros Ventres, this displacement may be correct (Keefer, 1964). However calculating the actual displacement in the thesis area is complicated by structures within the downthrown block. The Geologic Map of Teton County (Love, 1956b) shows the presently unnamed Tertiary conglomerate to be in fault contact with Cretaceous sediments to the north. In the field, the fault appears to be a southward thrust with vertical (?) Cretaceous shales overriding the Tertiary conglomerate. The Cache thrust overrides this undescribed thrust southeast of Cache Peak. How far this thrust has moved, what thicknesses of conglomerate and other formations it involves, and how far it extends to the east and north under the Cache thrust is unknown. It seems possible to conclude therefore, that the Skyline Trail block has moved as much as 35,000 feet. This would at least place Precambrian on top of the Tertiary conglomerate, although movement may have been much more. This would have to happen after earliest Eocene thrusting of vertical Cretaceous rocks over the unnamed Tertiary conglomerate.

If a sled runner form were assumed for a fault having a stratigraphic displacement of this magnitude, crustal shortening would certainly be considerable. It seems doubtful that the foreland shelf would develop large thrust plates in the competent Precambrian of small ranges of magnitude nearly equal to geosynclinal thrust displacements. Even if the angle of thrusting were to average 45^{o}, a minimum of 5-6 miles of shortening would have to take place in the basement complex. The roots of this ramp thrust may then have to be in the Gros Ventre River area, the northern limit of Gros Ventre structures. In this region there is no hint of the four part block structure the southwest front exhibits. The range is narrow in comparison with its length and the backslope of the major asymmetric anticline dips 15^{o} - 20^{o} northeast. That a low angle thrust could have produced such a high narrow uplift in so short a distance seems improbable. Large scale vertical faulting in the Gros Ventres involving Precambrian rocks raises difficult questions about the intersection of the ramp-like thrust with the vertical faults. This entire situation, though unwieldy in a foreland environment, is conceivably possible and has been accepted by previous workers.

Bengtson's (1956) theory is more practical under the foreland environment (Plate 4). The Skyline Trail block has been uplifted much more along its southwest front than the northeast flank. The overlying sediments were at one time probably on the crest of a large fold, asymmetric to the southwest, and possibly overturned along the marginal thrust fault. Cross section E-E' (Plate 6) suggests that this fold was caused mainly by drag along the thrust fault, and may not be an anticline caused solely by uplift. Only the remnants of northeastward dipping Flathead Quartzite are exposed high on the peaks above the fault contact. They have not become involved with the tremendous drag fold that once existed along the front. The magnitude of this drag fold can be seen in areas to the southeast.

If a northwestern adjacent block had not moved as far, and erosion had not proceeded as rapidly as on the higher block, drag folded sediments with a lower thrust angle might still be exposed. Such appears to be the case for the adjacent Cache block (See area surrounding the junction of the Cache and Skyline Trail blocks southeast of Cache Peak, Plate 6).

The Skyline Trail fault at its southeast extension appears to separate several times. Van Dyke (1956) has mapped the northern split of the main fault as the eastwardly continuous Skyline Trail thrust. His southern split was mapped as the Cache thrust. According to his paper they coincide for nearly two miles to the west where they divide and the Skyline Trail thrust traces north, separating the Skyline Trail block from the Cache block. Van Dyke (1956) theorizes a nearly horizontal thrust plane for the superimposed Skyline Trail thrust, and a steeper plane for the Cache Thrust. The writer found four graphic natural cross sections of the northern split of the Skyline Trail fault on its south-east extension. All cross sections display a vertical fault plane for Van Dyke's (1956) Skyline Trail thrust. Drag folding was not discernable. The writer believes a wedge of Madison Group limestone to have been caught along the main Skyline Trail upthrust fault plane, and overturned during movement. Its proximity to drag folded Cambrian rocks immediately southeast suggest that the Madison Group wedge is not related to the major drag fold along the front of the upthrust.

The farthest southeast split of the Skyline Trail fault (Plate 6) encloses a block of Cambrian rocks illustrating drag on the front of the upthrust. The writer estimates the axis of the Skyline Trail block has been down-dropped as much as 200 feet with respect to the drag folded block. Although field work was minimal in this border area, that part of the crest of the Skyline Trail block appears slightly down-dropped is significant, as discussion of the Cache block structure will reveal.

Small cross faults exist displacing the Flathead Quartzite where it crops out as erosional remnants on the southeast peaks. Whether these faults are related to the Precambrian lineations in that area remains to be solved. The sedimentary cover here is nearly on the apex of the drag fold, and to the southeast of the thesis area it can be seen to curl over and compose the front of the asymmetric uplift. This means the displacement decreases progressively to the southeast along the major fault line. This agrees with the interpretation of Horberg, Nelson and Church (1949).

The crest of the Skyline Trail block anticline seems to have been exceptionally uplifted along its central axis. The projected apex of the fold is somewhat southwest of the main ridge of Precambrian peaks. To the northeast, the dip of the sediments steepens to as much as 24° in places. Two miles farther northeast the dip becomes less steep and gradually stabilizes at about 16 degrees. This situation is exemplified on the Granite-Bunker Creek divide.

Four of the five small faults on the northeast slope of the Skyline block show a slight down-dropping on their southeast sides. The four eastern faults have displacements of less than 50 feet, and all are filled with tremendous multicolored secondary calcite crystals. These faults are clean breaks, several tens of feet wide, and may represent the release of minor tensional stresses within the Skyline block. The dating of their occurrence may be impossible. The western fault was determined on the elevation differences between Precambrian-Cambrian contacts in the field. The writer could not justify landslide-block origins for the western downthrown tongue of Flathead Quartzite. It was not traceable to the Death Canyon Limestone of the Gros Ventre formation. Its displacement was seen to increase to the south.

Cache Block

The Cache thrust extends more than 10 miles west to the town of Jackson, and may have continued further at one time. The entire block has had a complex history and only a discussion of the simpler, mapped portion in this study will be attempted here. The Cache block is an uplift of the foreland type, similar to the Skyline Trail block, but with complications.

If the profile of the thrust fault in cross section were of sled runner form, as Horberg, Nelson, and Church (1949) believe, it is difficult to understand how it can then be an 'advanced stage' of their Skyline Trail movement. Precambrian rocks do not overlap Cretaceous or Tertiary sediments as they do in the Skyline Trail block, hence it cannot have moved as far stratigraphically.

In actuality, the Skyline Trail block is an advanced stage of the Cache block, both types of uplift and movement are essentially the same. The Cache block has not been upthrust as far as the Skyline Trail block, and hence it has not been eroded to the point of displaying a steeper fault plane. Although their erosional fronts are concordant, the Skyline Trail block has been upthrust farther, as is readily apparent from the map relations and cross section F-F' (Plate 6).

The Cache thrust trace is sinuous. According to Nelson and Church

(1943) and Horberg, Nelson, and Church (1949), it probably dips at an angle approximating 35 degrees. The asymmetrical anticline at the southeast end must have overturned before thrusting, for remnants of the overturned flank are visible along the southeastern 4 miles of the thrust. In the cross sections D-D' and C-C' (Plate 6), it can be seen that the anticline may have overturned less towards the northwest. However if the trend of the anticline is projected northwest, it nearly matches the faulted Nowlin Creek anticline on the northwest border of the map. The Geologic Map of Teton County (Love, 1956b) in conjunction with the writer's map suggests possible merging. This also agrees with Horberg, Nelson, and Church (1949).

That another anticline from the western Cache Creek area has not yet merged can be seen in cross section A-A' (Plate 6). A question then remains unanswered: should the Cache Creek anticline be named for its western portion, or the southeast extension of the Nowlin Creek anticline? The writer suggests that the axial anticline for the Cache block was originally the Nowlin Creek anticline. The Geologic Map of Teton County (Love, 1956b) implies the western Cache Creek anticline to be faulted off at its eastern border. This corresponds to the northwesternmost fault of the writer's geologic map. The original conclusion of Horberg, Nelson, and Church (1949) was that the Nowlin Creek anticline merged with the Cache Creek anticline.

Sometime after thrusting and before the anticline had been eroded to the Bighorn Formation, the apex of the anticline collapsed. This dropped the crestal part of the fold. The displacement may be different than the interpretation shown in cross section D-D' (Plate 6), but is probably on the order of 4,000 - 6,000 feet in the area of Cache Peak (Figure 7). This normal fault abuts the Skyline Trail fault on the southeast end and parallels the Cache thrust for 4½ miles to the northwest. Here it swings north and dies out as it merges with the fault southwest of Jackson Peak. Much of the upthrust area to the northeast of this fault, possibly including Jackson Peak, has been down-dropped with respect to the former crest of the anticline. It also has been down-dropped with respect to the present axis of the Skyline Trail block.

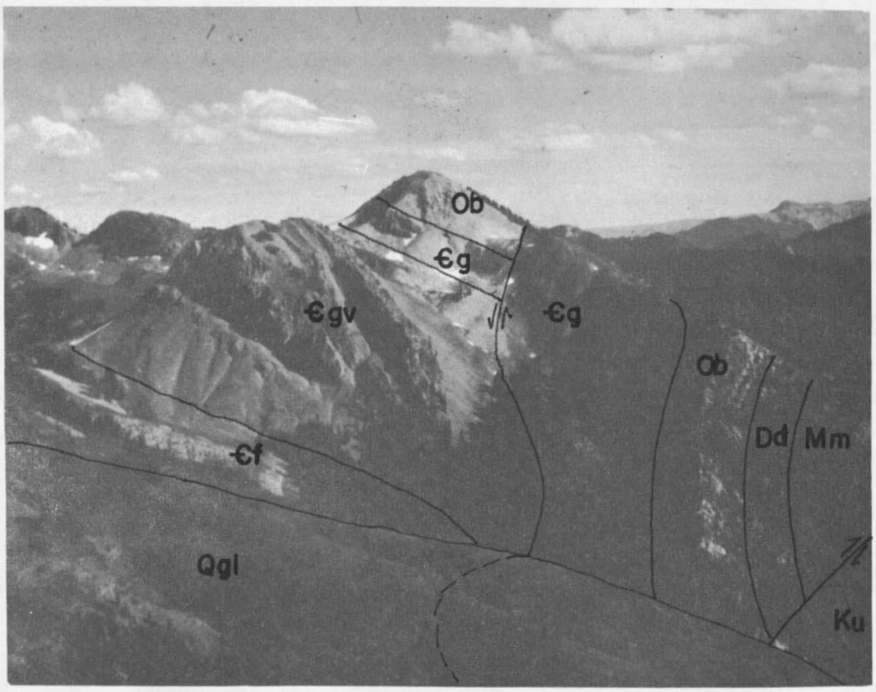


Figure 7. View southeast of Cache Peak. Natural cross section of the front of the Cache block, showing the approximate position of the Cache thrust, and the major normal fault down-dropping the crest of the Cache block.

Herein lies a possible explanation for the origin of Jackson Peak. Initially it was included within the northeast flank of the anticlinal crest as part of the major upthrust block. When the crest foundered, the Jackson Peak block may have begun to drop, but not as far as the blocks around it. That the Jackson Peak block dropped at all is suggested only by comparison of the southward projected capping of Flathead Quartzite onto the apex of the northwestward projected anticline in cross section C-C' (Plate 6). However, because the anticline becomes less acute to the northwest, the present Jackson Peak might not be down-dropped with respect to it. The southeast 18^{o} dip on the quartzites capping Jackson Peak is most likely not the original dip on the southwest limb of the fold.

The idea that Jackson Peak is a remnant of the original crest is helped by the following: The map relations show that all of the rocks southeast of the western border faults have been greatly up-faulted. It is possible that the rocks on the west could have been down-faulted from the original height of the anticline, or that both movements could have occurred. The comparable changes in the anticline form, as one moves northwest through the cross sections, implies that all of this anticline was at roughly the same structural height during formation. If one or both of the two western border blocks had been that high, production of the inferred map pattern by later down-faulting would be difficult. It would seem therefore that the southeast anticline, closer to the core of the block, was uplifted more than the structurally and topographically lower western border areas. Even after down-faulting of the crest in the southeast anticline, the Precambrian-Cambrian contacts are more than 500 feet higher than on the northwestern border block. Also, the northwestward projected Madison-Darby contact in cross section B-B' (Plate 6) appear to match those on the western border. This suggests that the initial forming of the axial anticline began before extreme uplift of the southeast portion. The field relations of the west border have obviously not been worked out in detail. Hence conclusions drawn from this sketchy knowledge will undoubtedly undergo revision by further investigations.

Possible Underthrusting

That underthrusting or reverse faulting occurs in the upper plate of the southwest thrust is shown in cross section A-A' (Plate 6). The field relations suggest that great friction, or an impediment encountered by the front of the thrust block, caused a marginal wedge of sediments to override the block beneath. Horberg, Nelson, and Church (1949) suggest that the Cache thrust area may have abutted geosynclinal thrusts from the south, creating such an impediment.

The cause of the down-dropping of the northeastern sedimentary block in this cross section is uncertain. Drag folding along the southwestern side of this block infers a steep southwest dipping fault plane, with the up-side to the southwest. All the northwestern formation and fault contacts are covered. The writer believes the separate blocks in this cross section to be the result of a translation of forces. As the continuous Nowlin Creek anticline was being upthrust, this block of sediments broke away from the slowly overturning southwest limb. As a result it was structurally uplifted higher than its neighbors to the southeast. Because it was now detached from the rest of the fold, its relation to the front of the Cache thrust became unique. Both lateral and upward pressure was acting upon it from the rising Nowlin Creek anticline to the northeast. Upward pressure dominated southwest lateral movement, and the block broke in half. The northeast half became tilted, raising that side along the upthrust Nowlin Creek anticline. This may have dropped the opposite side along the middle fracture. The steeper dips on the down-dropped block are thus accounted for. Lateral pressure transmitted through this half forced the southwest counterpart to override it slightly as they both thrust to the southwest. This might steepen the dips on the northeast side of the overriding block. Friction along the front of the thrust plate as mentioned previously, could produce the frontal overriding wedge.

This idea, though tenuous, is far more attractive than other solutions. That this pattern could be the result of pure friction along the thrust line, or an abutment of an opposing thrust does not seem possible. Purely lateral pressure would probably not create high angle reverse faults. These particular blocks are separated from the down-dropped crest of the anticline to the southeast. Since they are structurally raised above the adjacent overturned limb to the southeast, a relation with the crestal collapse seems unlikely.

Cross section B-B' (Plate 6) shows the Flathead Quartzite to be faulted off by the uplifting Jackson Peak. This would have occurred during the formation of the southeast axial anticline. The fault may or may not have reached the surface during formation because of the thickness of overlying strata. It is obvious that this end of the anticline did not collapse. Erosion has removed the apex of the fold, exposing the existing fault line along the originally upthrust Jackson Peak.

On the east side of Jackson Peak is a large north-trending normal fault. Displacement decreases very rapidly to the south. The fault line is marked in several places by a wide gouge zone weathering out as a ravine or scarp. The freshness of some of these scarps may be due to recent glacial or landslide action.

The northernmost sector of the Cache block has been cut by several northeast-trending faults. These generally show the down-dropped side to the southeast as did those in the Skyline Trail block. If these are similar faults related to tensional stresses, they are not as obviously marked as those on the Skyline Trail block. In this case movement exceeds 150 feet in all but the small fault displacing the tongue of Flathead directly east of Jackson Peak. The relations of these long faults to structures outside the area to the north is not yet known. However, it would seem that the pattern of these faults helps substantiate the idea that the northwestern end of the anticline collapsed least.

The down-dropped crest of the major anticline has been crossed in the west central part of the map by a small tear fault which dies out in the Gros Ventre Formation. These intraformational incompetencies arise from up-drag on the down-faulted crest. This seemingly minor 'overthrusting' from the south occurs throughout this crest only within the Gros Ventre Formation. Only the major faults and slippages were mapped, although myriads exist. That these would affect the thickness of a measured section can best be illustrated on Cache Peak. Here the dips range from 32° on the Flathead to 38° for the Bighorn. The Gros Ventre Formation between ranges from 46° to 70°. It was at this spot that Miller (1936) and Denson (1942) measured their sections. See Figure 7.

In the southern headwaters of Flat Creek, a spectacular normal fault down-drops the crest even further. The topographic scarp at the maximum displacement is more than 500 feet high (Figure 8). It dies out within

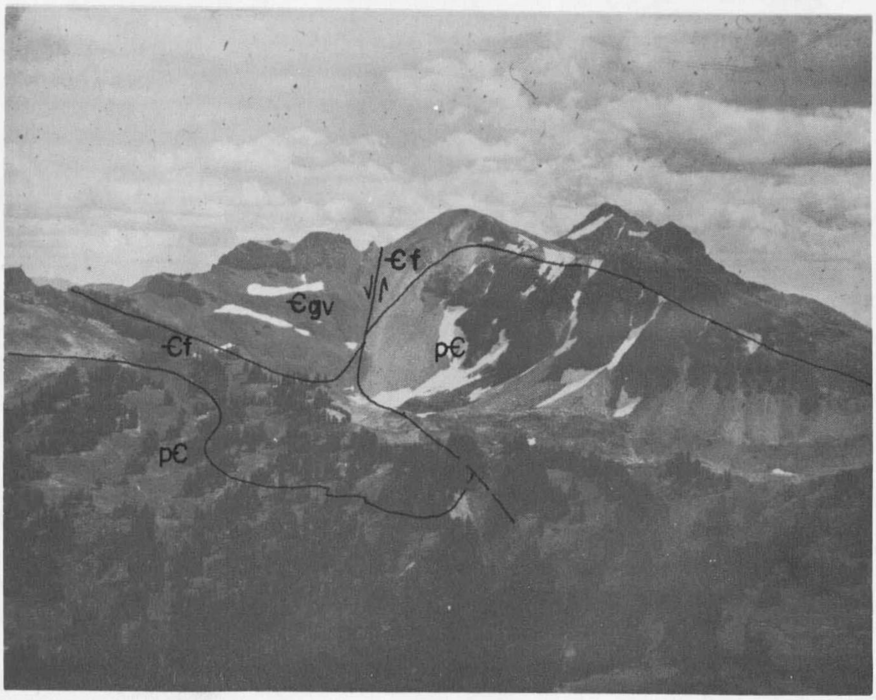


Figure 8. View southeast on the Cache block, head of Flat Creek. The northernmost normal fault, down-dropping the crest of the Cache block, is seen faulting off the Flathead and Gros Ventre formations.

half a mile to the northwest. The fault splits to the southeast, both prongs abutting the northern extension of the Skyline Trail fault. The incompetence of the tightly drag folded Gros Ventre Formation is illustrated in the triangular wedge caught in the junction of these three faults. The Wolsey shale has thinned from 97 feet to about 25 feet. Only gross bedding is visible in the lower part of the Death Canyon Limestone. The Flathead assumes a brilliant maroon staining on all of its strained zones. The Gros Ventre Formation has been beautifully drag folded on the Flat-Granite Creek divide, and the incompetence of that formation near the fault line is again well illustrated (Figure 8). Conversely the competence of the Flathead is displayed, for on the upthrown block, the lower part of the formation changes dip 40^{o} in 20 feet without fracturing.

Most previous maps show the Skyline Trail fault to branch, or head off in a northwesterly direction. Exactly what has been previously interpreted as the northern extension of the Skyline Trail fault is unclear. The only two faults branching in that direction are both normal faults, one along the down-faulted crest, the other a short intense break. This northern fault seems to have been interpreted and mapped as continuing northwest in the Precambrian through the Sheep-Flat Creek divide, where it is reputedly responsible for the east wall of Jackson Peak. At the divide it supposedly is met by the 'Jackson Peak Fault' which has its origins in a confused area to the north and west. Most of these previous maps similarly do not show the normal fault of the collapsed anticline.

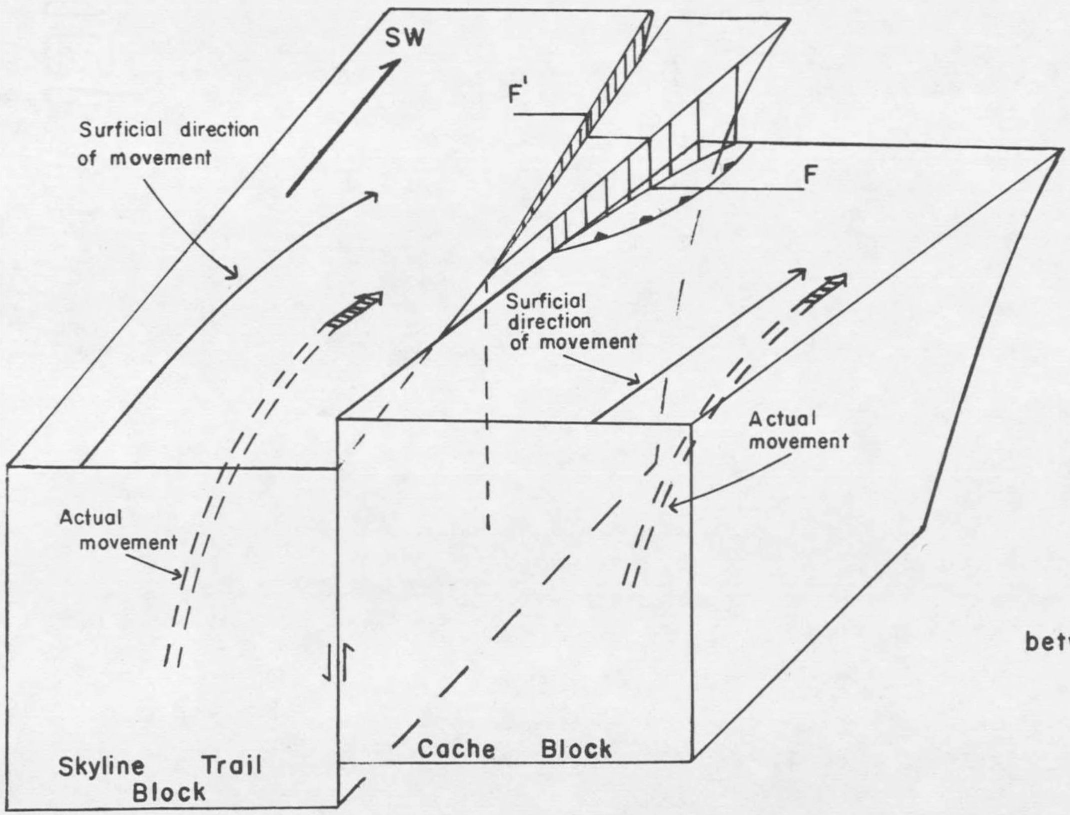
The map relations show only a tiny elevation difference between continuous tongues of Flathead Quartzite on the Sheep-Flat Creek divide. Although faults have taken place in this area, they are not very extensive nor do they suggest common origins with faults 3 miles to the southeast. It would appear that previous investigator's 'Sheep Creek Fault' is actually the fault on the east side of Jackson Peak. The writer's southwestern Jackson Peak fault connects with the eastern Jackson Peak fault at the head of Nowlin Creek and not on the Sheep Creek divide, as shown on previous maps.

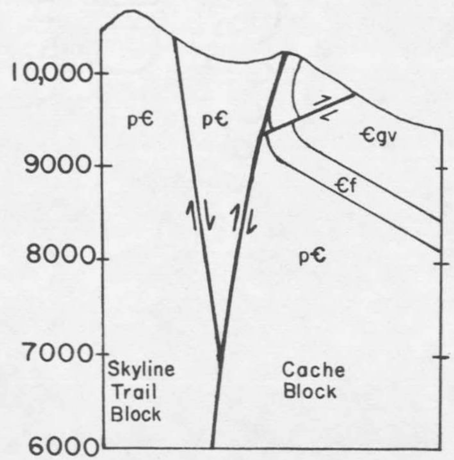
Previous investigators do not mention what evidence there was for mapping the northern extension of the Skyline Trail fault through the Precambrian. Nor is there mention of collapsed anticlines. The mechanism of creating high Precambrian peaks on the ramp-like thrust sheet is also unexplained.

Junction of the Skyline Trail and Cache Blocks

It first appears that the great schism between the Skyline Trail and Cache blocks is perpetuated to the north. Although the pattern of the southeast-dropped side is accentuated somewhat, on all of these faults the majority of the displacement is gone by the time the Madison Group is reached. Some of them imply tensional stresses with wide clear cut breaks choked with secondary calcite. These faults come together southward and reverse displacement, indicating that the southwest crest of the Skyline Trail block has been upthrusted more than the present Cache block (Plate 5). At this point it could be called the northern extension of the Skyline Trail fault. That these faults are not complex or of great

Variation in Upthrust Movement Illustrated by the Skyline Trail and Cache Blocks





Cross section F'–F across zone between thrust blocks. See also Plate 6.

magnitude, and do not extend any great length to the north suggests that the Cache and Skyline Trail blocks were upthrusted initially together. If this had not happened, folding or complex faulting between the blocks should be observed along them to the north.

The writer observed from a distance what appears to be Swenson's (1949) Flat Creek fault tracing southward from Sheep Mountain towards the thesis area. However, several miles north of the thesis area it appears to bend eastward and cross over into the main canyon of Granite Creek. The up-side is to the north. Whether the system of faults comprising the northern extension of the Skyline Trail fault connects with the Flat Creek fault remains an open question.

The map relations at the junction between the Cache and Skyline Trail blocks on the southwest front indicates the Cache block movement terminated first. The down-faulting of the Cache block anticline must have occurred before the Skyline Trail block stopped all movement. The evidence for this is seen in the section of Flathead Quartzite which is almost entirely faulted off and overturned along the Skyline Trail fault. In this area the fault zone is wide and commonly includes the Gros Ventre Formation which has been thrust west (Plates 5 and 6, cross section F-F'). Down-dropping of the crest of the Cache anticline and slight western pressure from the Skyline Trail block would cause this situation. Further evidence is seen in the southwest limb of the Cache block anticline. It was not overturned along the junction, and the large segment southeast of the glacial debris displays offset relations with its northwest continuation. This hints that it has been pushed out along the Cache thrust plane by the continuing force of the upthrusting Skyline Trail block.

A 40 foot thick zone of Flathead-Precambrian fault gouge and breccia mark where the Skyline Trail fault crosses the northeast-southwest drainage divide. To the east, a branch of the Skyline Trail fault was mapped through the Precambrian ridge on the basis of similar fault gouge and the existence of definite Flathead breccia on the saddle through which it passes. No Flathead could be found anywhere on the surrounding ridges or in the nearby glacial debris. Since the main mountain mass of this block is further east, this marginal western sliver of Precambrian was arbitrarily shown as being down-dropped. That the northern Skyline Trail fault extension is continuous is seen in the field in the outcrop relations, and obvious fault zones. In a natural cross section of the vertical fault plane in the Precambrian rocks, Flathead Quartzite boulders were found within the fault breccia.

Although the outcrops east of the slide block in the head of Granite Creek are somewhat covered, the three major faults from the north all lead to a series of springs at the appropriate junction with the Skyline Trail fault. Several small cross faults choked with Flathead and Precambrian breccia occur between them near the junction.

Summary of Structure

The present Gros Ventre mountains began to be uplifted to the north as a gentle middle Paleocene uplift, which shed its sedimentary cover southward. As uplift developed after early Eocene time, the underlying sediments bulged over the more elevated southwest side. Along a rising northwest trending anticline, a small sector of tilted sediments broke instead of folding over the asymmetrically steep southwest limb. As upthrusting increased, this smaller block was incorporated along the thrust plane adjacent to the overturned limb of the fold. During this time differential uplift divided the range into separate blocks which continued to upthrust at different rates. The Cache block uplifted and thrust furthest on the southeast. The Skyline Trail block attained its greatest height at its junction with the Cache block on the northwest. The forces upthrusting the Cache block eventually relaxed, while the Skyline Trail block forged ahead. With continued relaxation in the Cache block, the crest collapsed, leaving Jackson Peak on the northwest as a remnant of the original anticline. Cross faults appeared at the same time, up-side to the northwest, adjusting the flank to the collapsing of the crest. The Skyline Trail block briefly continued to upthrust along its southwest crest. Unlike the Cache block, it did not founder upon cessation of movement.

SUMMARY OF THE GROS VENTRE RANGE HISTORY

The Gros Ventre Range was subtly forming through Paleozoic and Mesozoic time. With a geosynclinal trough developing to the southwest, the Gros Ventre area lay on the edge of the nearby foreland. Their history was one of alternating deposition of marine sediments and brief lowland erosion. Unstable shelf environments alternated with marine quiescent stages, but in total the major deposition took place to the southwest. By mid-Cretaceous time the geosynclinal development incorporated the bordering Gros Ventre foreland, and a thick sequence of geosynclinal sediments were deposited. Toward the end of this time, the Laramide revolution began to affect this area and the Cretaceous shales were exposed to erosion.

Different parts of the northwestern Wyoming foreland began to uplift, shedding debris into the basins between. Thrusting along the border of the geosyncline displaced weak sediments toward the north. Differential uplift continued through Paleocene with tremendous thicknesses of eroded sediments and occasional Precambrian material creating fans off the highlands to the north. In middle Paleocene the beginnings of the ancestral Gros Ventres domed up and shed some of these recent sediments to the south. Some of these were overridden by approaching thrust sheets from the geosynclinal area. The Wind River Range and other large foreland ranges were uplifted and thrust in various directions.

During earliest Eocene the geosynclinal thrusts may have caused enough compression within the foreland area to create thrust movements and folding within these late Paleocene sediments. Some time after this the Gros Ventre Range began actively upthrusting, overriding the closest Paleocene-Eocene rocks and structure. With this came the formation of the major asymmetric folds and thrusts in opposition to geosynclinal elements thrust from the southwest. Segmentation of the Gros Ventre Range occurred, and each block moved a little differently than the others, reacting to differing pressures. When most of the upthrusting finally ceased, collapse of at least one of the asymmetric thrust anticlines took place. An adjacent block remained elevated, its movement terminating at a later date.

Subsequent Tertiary faulting may not have affected the Gros Ventres, though it modified other areas in northwestern Wyoming. Erosion continued throughout the remainder of Tertiary time. By Pliocene time an eroded level surface had formed, beveling the crest of the Gros Ventre Range. Perhaps prior to or during this time regional uplift brought the Gros Ventres to their present elevation. Before new streams could be well entrenched, tilting of this surface may have readjusted their drainages. Subsequent glaciation helped to modify the Gros Ventre's topography to its present alpine character.

Suggestions For Further Study

The need for detailed stratigraphic and structural research in the Gros Ventre Range is acute. The entire range and its associations with nearby areas needs to be explored. The result may be a better understanding of the complex history of northwestern Wyoming. Detailed study of the Precambrian complex is needed for comparison with other areas. The investigations of the geomorphic problems connected with the area may throw light on nearby structural readjustments. Recent floral and faunal relations in this area have never been studied, and offer new avenues of research.

APPENDIX

All formations and thicknesses were described and measured within the thesis area. Thickness is in feet.

MADISON GROUP incomplete

Section measured in a cirque on the east wall of Flat Creek. Measurement includes only the lower 475 feet of this group. No distinction has been given formations or members.

Unit	Cumulative Thickness	Thickness	Lithology
26	475.4	6.5	Limestone, dark grey, resistant; calcite stringers and tabs.
25	468.9	32.4	Limestone, light grey, thick bedded, resistant; numerous layers of fossil hash, a few large light brown chert nodules.
24	436.5	22.1	Limestone, grey, massive, resistant.
23	414.4	17.9	Limestone, light brown to grey, grading to top to dark brown, resistant.
22	396.5	38.1	Limestone, brownish-grey, grading to dark grey at top, blocky, resistant; some layers almost coquina-like.
21	358.4	21.1	Limestone, dark grey, blocky, resistant.
20	337.3	25.8	Limestone, grey-pink, thin bedded, nonresistant.
19	311.5	57.7	Limestone, light brown to dark grey-blue, some with greenish tint, thin bedded comparatively, resistant, series of fossil zones.
18	253.8	16.6	Limestone, blue-grey, massive and resistant; brachiopod zone grading slightly to corals but a dominance of brachiopods.
17	237.2	8.2	Limestone, blue-grey, weak and thin bedded.

Unit	Cumulative Thickness	Thickness	Lithology
16	229.0	4.0	Limestone, blue-grey, massive and resistant; fossil hash of brachiopods and unidentifiables.
15	225.0	5.9	Limestone, blue-grey, massive and resistant.
14	219.1	3.0	Limestone, light blue-grey, massive and resistant.
13	216.1	4.0	Limestone, blue-grey, massive and resistant.
12	212.1	17.0	Limestone, blue-grey, massive and resistant; Chert zone, each nodule is from .1 to .5 ft. thick, tabular and 10 to 15 yards long. Small zones of coral common, each zone .5 ft. thick.
11	195.1	6.5	Limestone, blue-grey, massive and resistant; scattered coral zone.
10	188.6	12.9	Limestone, blue-grey, massive and resistant.
9	175.7	26.4	Limestone, dark grey, thin bedded, some thin fossil zones.
8	149.3	7.0	Limestone, blue to brownish-black, slightly less resistant, thin layers of fossil hash.
7	142.3	7.6	Limestone, brownish-grey, blocky appearance, resistant.
6	134.7	14.7	Limestone, blueish to brown, grading to brown above, massive.
5	120.0	2.0	Limestone, brown, thick bedded, resistant, petroliferous odor.
4	118.0	10.4	Limestone, blueish-brown, thick and thin bedded, resistant.
3	107.6	39.7	Limestone, steel blue, grades upward into grey-brown and dark brown; thin bedded but blocky and resistant; some large chert nodules; coralline fossils; some petroliferous odor in upper parts; a few geodes present.

Unit	Cumulative Thickness	Thickness	Lithology
2	67.9	20.0	Limestone, variegated grey to brown, some layers weather white, massive, resistant; small amounts of chert in nodules and stringers; petroliferous odor.
1	47.9	47.9	Limestone, variegated light grey to almost black, massive and resistant; some dolomitic zones; some dark grey chert nodules and layered chert stringers; a few small calcite geodes; slight petroliferous odor.

DARBY FORMATION 319.4 feet

Section measured in a cirque on the east wall of Flat Creek.

Unit	Cumulative Thickness	Thickness	Lithology
36	319.4	15.7	Sandstone, grey-white, thin bedded, resistant; partly dolomitic and partly calcareous; black chert nodules evident; nodules of sandy grey limestone. Caps unit below.
35	303.7	16.6	Shale, rust to green with some pink laminae, thin bedded, non-resistant, very sandy, partly calcareous and dolomitic. Excellent ripple marks evident.
	Birdbear Member		
34	287.1	4.0	Dolomite, grey-tan, weathers whitish-grey, thick bedded, resistant, calcareous; weathers out as the cap of a toadstool-like feature.
33	283.1	8.0	Dolomite, grey-white to brown, thin bedded, less resistant than unit above or below, calcareous. Weathers out as the top of the stem of a toadstool-like feature with the units above and below.

Unit	Cumulative Thickness	Thickness	Lithology
32	275.1	53.1	Dolomite, darkish-brown, but may vary from tan to dark brown, thick bedded, base is non-resistant but grades immediately into resistant; calcareous, slight petroliferous odor; riddled with small calcite geodes; weathers in an odd way: 4 to 8 inch blocks with almost conchoidal fracture, breaks vertically as well as horizontally; forms major part of stem of toadstool-like feature with above two units.
	Lower Member		
31	222.0	15.0	Shale, greyish-green, weathers to tan, very sandy, thin bedded, non-resistant; nodules of hematitie, limestone, and dolomite present.
30	207.0	2.6	Limestone, brownish-tan, thin bedded, non-resistant, appears to be sandy, some crystal of calcite present.
29	204.4	11.8	Limestone, tan grey-pink, thick bedded grading to thin bedded, non-resistant; upper 2.6 ft. very thin bedded.
28	192.6	10.4	Sandstone, light salmon grading to tan at top, thin bedded grading to thicker at top, non-resistant.
27	182.2	13.6	Sandstone, light tan, thick bedded, resistant, weakly dolomitic.
26	168.6	5.7	Shale, greenish-brown, thin bedded, non-resistant, weakly calcareous.
25	162.9	11.3	Dolomite, dark brown, thick bedded, resistant, petroliferous odor; thin bedded zone in middle of measurement.
24	151.6	12.0	Thin interbedded sandstones, shales, dolomites, limestones; colors for sandstones and limestones vary from tan to pink, grey, cream, and white; shales are greyish yellow to cream; Dolomites are grey to brown. Non-resistant.

Unit	Cumulative Thickness	Thickness	Lithology
23	139.6	1.0	Dolomite, dark brown, composes a single bed.
22	138.6	3.0	Sandstone, light tan, slightly non-resistant.
21	135.6	11.6	Dolomite, dark brown, massive, resistant, petroliferous odor.
20	124.0	4.3	Dolomite, dark brown, thin bedded, non-resistant, fetid.
19	119.7	0.7	Limestone, light cream to cream-tan, very thin bedded, non-resistant.
18	119.0	3.5	Limestone, black, thick bedded, resistant, petroliferous odor.
17	115.5	9.1	Dolomite, dark brown, thick bedded, resistant, some sand, one or two thin interbeds of limestone.
16	106.4	9.8	Sandstone, buff-tan, alternating weak and thin bedded with resistant and thick bedded; some dolomitic and calcareous laminae; fine-grained, almost a siltstone.
15	96.6	9.1	Siltstone, tan, thin bedded, non-resistant, slightly calcareous to dolomitic.
14	87.5	2.8	Dolomite, black, thick bedded, resistant, calcareous.
13	84.7	10.5	Limestone, rusty tan, very sandy, thin bedded, non-resistant, dolomitic to calcareous.
12	74.2	3.5	Limestone, pink-grey-brown, thick bedded, resistant.
11	70.7	12.3	Limestone, grey-black, thick bedded, resistant, silty light tan base, grades upward to brown.
10	58.4	9.0	Limestone, light tan, silty, non-resistant, thin bedded.

Unit	Cumulative Thickness	Thickness	Lithology
9	49.4	3.0	Dolomite, deep brown-black, resistant, thick bedded, calcareous.
8	46.4	15.8	Dolomite, dark brown-black, massive, resistant, strongly fetid, slightly calcareous; grades to lighter brown and more thin bedded above.
7	30.6	3.8	Siltstone, light cream-tan, non-resistant, thin bedded, tends to become dolomitic towards top.
6	26.8	6.0	Dolomite, dark brown, thin bedded; grading to grey-brown and more calcareous towards top.
5	20.8	6.8	Dolomite, dark brown, massive, resistant.
4	14.0	3.0	Sandstone, light tan, resistant; interbedded toward top with dark brown fetid dolomite.
3	11.0	2.0	Limestone, grey, resistant, fetid.
2	9.0	3.0	Dolomite, dark brown, slightly more resistant than lower unit.
1	6.0	6.0	Covered, float indicates calcareous and dolomitic shaly stringers, brown to tan, thin bedded.

BIGHORN DOLOMITE 445 feet

Section measured on the divide between Granite and Bunker Creeks.

Unit	Cumulative Thickness	Thickness	Lithology
			Disconformity with Darby Formation above
	Leigh Member		
4	445	98	Dolomite, very white, soft, more calcareous than lower member; becomes less calcareous in upper parts; weathers more quickly to talus than does lower member.
Bighorn Dolomite Member			
3	347	37	Dolomite, slightly lighter grey cream than lower unit, mottled with light grey, dense, very resistant.
2	310	141	Dolomite, noticeably darker grey-cream than lower unit, mottled with light grey, dense, very resistant.
1	176	176	Dolomite, cream to grey-cream, mottled with light grey; dense, very resistant.

GALLATIN FORMATION 240 feet

Section measured on the divide between Granite and Bunker Creeks.

Unit	Cumulative Thickness	Thickness	Lithology
			Disconformity with Bighorn Dolomite above.
	Open Door Member		
11	240.0	3.9	Limestone, grey-buff, massive, resistant; tends to be dolomitic.
10	236.1	1.0	Sandstone, grey-tan, non-calcareous, highly cross bedded and laterally continuous.
9	235.1	3.5	Limestone, grey-buff, massive, resistant; tends to be dolomitic.
8	231.6	7.0	Limestone, grey buff to pinkish, thin bedded; slightly dolomitic.
7	224.6	40.1	Limestone, dark grey, grading to lighter grey, massive, resistant.
6	184.5	21.0	Limestone, buff grey to cream to dark grey, sandy and thinner bedded than DuNoir; upper parts display cross bedded zones, chert zones, limestone nodule zones and white calcareous sandstone stringers.
	Dry Creek Shale		
5	163.5	3.5	Limestone, grey to dark grey, very weak and thinly interbedded with green mudstone.
4	160.0	11.7	Limestone, grey-green, blocky, 2 ft. thick beds alternate with greenish cream shaley layers, less resistant than members above and below; turbidity current marks in some of the limestones, small color gradations to grey-pink; upper parts have thin maroon shales alternating with tan sandy shales.

Unit	Cumulative Thickness	Thickness	Lithology
3	148.3	13.8	Limestone, grey-green, non-resistant, sandstone interbeds, flatpebble conglomerates and thin wavey shale layers; overall appearance is slightly green.
2	134.5	8.0	Sandstone, rust cream-brown, resistant, calcareous, grades by interbedding to limestone above.
	DuNoir Member		
1	126.5	126.5	Limestone, grey to dark grey, weathers to brown; thin bedded with seams of mottling yellow-brown; base shows 13 ft. sandstone stringers, mottling of cream-tan, tan, and red-tan, weathering to cream-tan; several flat pebble conglomerate seams over 1.0 ft. thick only within 30 feet of the base; films of sandy shale numerous and less than 0.1 ft. thick.

GROS VENTRE FORMATION 763.2 feet

Park Member and upper limestone of the Death Canyon Member measured on the divide between Granite and Bunker Creeks. The shale unit (14) separating the Death Canyon limestones measured ½ mile north of Turquoise Lake in the head of Granite Creek. The lower Death Canyon limestone and Wolsey Shale measured in the head of Flat Creek, southeast wall.

Unit	Cumulative Thickness	Thickness	Lithology
Park Member 295.8 feet			
34	763.2	38.9	Shale, light green to olive, non-resistant; included are a few stringers of grey, brown, and white limestones.
33	724.3	83.9	Covered; float indicates mostly green shale with a few interbeds of grey, brown, and white limestones and sandstones.
32	640.4	1.0	Limestone, grey, very sandy, slightly more resistant than underlying and overlying units.
31	639.4	48.6	Shale, green, friable; with interbeds of maroon shale, sandy shale with light cream to tan stringers, and rusty-tan sandstone layers. These interbeds are inconsistently calcareous and less than .5 feet thick.
30	590.8	2.0	Shale, light brown, sandy, slightly more resistant than underlying and overlying units.
29	588.8	8.1	Shale, green, friable.
28	580.7	0.5	Limestone, white, thin bedded, resistant.
27	580.2	8.0	Shale, green, friable.
26	572.2	6.8	Shale, green to light olive, non-resistant; several thin stringers of grey and white limestones and brown sandstone; the sandstone and shales tend not to be calcareous.
25	565.4	3.2	Limestone, grey, framboidal algal head appearance, main layer at base; some heads up to 4 feet in diameter.

Unit	Cumulative Thickness	Thickness	Lithology
24	562.2	10.2	Shale, green, interbedded with limestone layers, grey, 1.0 feet thick; uppermost limestone is framboidal, grapefruit-sized algal head blobs.
23	552.0	9.6	Shale, green, friable, soft and very thin bedded; limestone stringers occurring in upper portion.
22	542.4	18.9	Covered; float indicates light grey and white sandstones and limestones with a few brown to light tan interbeds of sandy limestone; all are thin bedded, some have coarse grey mottling.
21	523.5	16.1	Limestone, blue-grey mottled light tan.
20	507.4	10.7	Limestone, dark grey-blue, mottled with light and dark red-tan; interbedded with thin white sandy layers.
19	496.7	13.6	Limestone, dark blue to grey with light tan, tan, or red-tan mottling; sandstone stringers present.
18	483.1	15.7	Limestone, steel blue to light grey, mottled with cream or reddish-tan, thin bedded; interbedded with sandstone, reddish-tan, very thin bedded, highly calcareous.
	Death Canyon Member 370.1 feet thick		
17	467.4	64.4	Limestone, blue grey mottled with light tan, mixed resistant and non-resistant beds varying from 1.0 to 8.0 feet thick.
16	403.0	100.5	Limestone, steel blue with light tan mottling, bedding .5 to 2.0 feet thick.
15	302.5	36.8	Covered by talus.

Unit	Cumulative Thickness	Thickness	Lithology
14	265.7	30.4	Shale, dark green, weathers grey-green, soft, non-resistant; extremely abundant trilobites and braciopods in lower half, relatively few fossils in upper portion; majority of trilobites are Clappaspis; upper 6 - 8 feet are lighter green to brown and very friable; grades upward to brown sandy limestone of the upper Death Canyon limestone.
13	235.3	4.0	Limestone, grey, grading upwards to a silty nodular limestone, white to green, thin bedded and lumpy; transition to green shale unit above; excellent marker bed in thesis area.
12	231.3	13.0	Limestone, grey, mottled with rust-brown or cream.
11	218.3	5.0	Limestone, dark brown, weathers to a lighter brown, thick bedded, very sandy; gradational with the limestone above and below.
10	213.3	52.8	Limestone, grey, mottled with rust-brown or cream, dark brown towards top of measurement; a few thin sandstone stringers.
9	160.5	63.2	Covered by talus in measured section; other areas show base to be a sandy limestone, brown, weathering to rusty- or orange-brown, 6 to 8 feet thick. Limestone above is similar to unit 10.
	Wolsey Member	97.3 feet thick	
8	97.3	2.0	Shale, light green to grey, very friable, becomes calcareous upwards as it grades to sandy limestone of the Death Canyon Member.
7	95.3	52.4	Shale, green, weathers grey-green, becomes more friable upwards.
6	42.9	2.0	Shale, green, slightly resistant, silty, thin bedded.

Unit	Cumulative Thickness	Thickness	Lithology
5	40.9	16.3	Shale, green, weathers grey-green, friable; silty zones present which tend to be more resistant.
4	24.6	4.0	Shale, grey-green, dense, sandy, slightly resistant.
3	20.6	3.0	Shale, green, weathers grey-green, soft, non-resistant; worm tracks evident.
2	17.6	10.5	Shale, mostly maroon, grading upward to green, soft, non-resistant; worm tracks evident.
1	7.1	7.1	Shale, green, grading upward to maroon, becomes sandy in upper portions, thin bedded, friable.

FLATHEAD QUARTZITE 288.4 feet

Section measured in the head of Flat Creek, southeast wall.

Unit	Cumulative Thickness	Thickness	Lithology
12	288.4	11.2	Sandstone, orange-maroon, dense, resistant, grades upward to green shale.
11	277.2	8.8	Sandstone, reddish-maroon, non-resistant; contains several maroon shale stringers .1 feet thick.
10	268.4	.7	Sandstone, orange-rust, dense, resistant, massive.
9	267.7	3.4	Sandstone, maroon, non-resistant; contains three thin orange shale stringers.
8	264.3	4.0	Sandstone, dark tan, resistant, beds 1.0 feet thick.
7	260.3	5.8	Mixed shales and shaly sandstone, red to dark maroon, soft, thin bedded; contains one thin stringer of resistant tan sandstone.

Unit	Cumulative Thickness	Thickness	Lithology
6	254.5	5.4	Sandstone, tan-orange, dense, resistant, thin bedded.
5	249.1	3.3	Shale, maroon, soft, non-resistant, thin bedded, very sandy.
4	245.8	2.5	Sandstone, dark orange-brown, resistant, medium-grained.
3	243.3	48.8	Covered; float suggests quartzite, tan to buff, with a few scattered maroon shale layers. Quartzite seems to grade to sandstone upward. Color becomes darker, nearly maroon at top of measurement. Bedding varies from .5 to .1 feet thick thinning upward.
2	194.5	10.6	Quartzite, dark rust-tan, grading upward from light tan-buff, resistant; hematite points visible on weathered surface.
1	183.9	183.9	Quartzite, cream to tan to buff in color, thick bedded, resistant. Contains the following interbeds of shale and conglomerate. Shales green, micaceous, very thinly laminated, and non-resistant.
		183.9	Discontinuous shale layer, less than .1 feet thick at 183.9
		171.7	Discontinuous shale layer, less than .1 feet thick at 171.7
		166.8	Quartzite, thin bedded; contains three .2 feet thick shale layers; 4 feet thick beginning 162.8
		154.3	Continuous shale layer .5 feet thick at 154.3
		90.3	Continuous shale layer .5 feet thick at 90.3; contains lens of sandstone
	83.3		Discontinuous shale layer, less than .1 feet thick at 83.3

Unit	Cumulative Thickness	Thickness	Lithology
	65.8		Continuous sandy shale layer 1.0 feet thick beginning 64.8
	45.6		Discontinuous shale layer, .1 feet thick at 45.6
	40.2		Discontinuous shale layer, less than .1 feet thick at 40.2
	40.1		Zone of scattered thin conglomerate lenses, some cross bedding; 7.9 feet thick beginning 32.2
	32.2		Continuous sandy shale layer, .3 feet thick beginning 31.9
	27.2		Discontinuous shale layer, less than .1 feet thick at 27.2
	24.0		Continuous shale layer, .2 feet thick at 24.0
	21.2		Continuous shale layer, .1 feet thick at 21.2
	21.1		Zone of conglomerate stringers and cross bedding; 8.9 feet thick, beginning 13.2
	13.2		Continuous shale layer, .2 feet thick beginning 13.0
	11.3		Discontinuous green shale layer, less than .1 feet thick at 11.3
	3.5		Conglomerate zone, quartzite stringers, grades upward to quartzite, pebbles are up to pea-gravel size; 3.5 feet thick resting on Precambrian granite and gneiss.
			Angular unconformity with Precambrian rocks below.

REFERENCES CITED

Andrichuk, J. M., 1951, Regional stratigraphic analysis of Devonian system in Wyoming, Montana, southern Saskatchewan and Alberta: Amer. Assoc. Petrol. Geol. Bull., V. 35, P. 2368-2408.

_______________, 1956, Devonian stratigraphy in northwestern Wyoming and adjoining areas: Wyoming Geol. Assoc. Guidebook, 11th Ann. Field Conf., Jackson Hole, 1956, p. 43-50.

Bengtson, C. A., 1956, Structural geology of the Buffalo Fork area, northwestern Wyoming, and its relation to the regional tectonic setting: Wyoming Geol. Assoc. Guidebook, 11th Ann. Field Conf., Jackson Hole, 1956, p. 158-168.

Benson, A. L., 1966, Devonian stratigraphy of western Wyoming and adjacent areas: Amer. Assoc. Petrol. Geol. Bull., v. 50, p. 2566-2603.

Blackwelder, E., 1913, Origin of the Bighorn Dolomite of Wyoming: Geol. Soc. America Bull., v. 24 p. 607-624.

_______________, 1915, Post-Cretaceous history of the mountains of central western Wyoming: Jour. Geol., v. 23, p. 97-117, 193-217, 307-340.

_______________, 1918, New geological formations in western Wyoming: Wash. Acad. Sci. Jour., v. 8, p. 417-426.

Bradley, C. C., 1956, The Precambrian complex of Grand Teton National Park, Wyoming: Wyoming Geol. Assoc. Guidebook, 11th Ann. Field Conf., Jackson Hole, 1956, p. 34-42.

Branson, C. C., 1937, Stratigraphy and fauna of the Sacajawea formation, Mississippian, of Wyoming: Jour. Paleon., v. 11, p. 650-660.

Burk, C. A., 1956, Wyoming stratigraphic nomenclature chart: Wyoming Geol. Assoc. Guidebook, 11th Ann. Field Conf., Jackson Hole, 1956, p. 33.

Darton, N. H., 1904, Comparison of the stratigraphy of the Black Hills, Bighorn Mountains and Rocky Mountain Front Range: Geol. Soc. America Bull., v. 15, p. 379-448.

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

Denson, N. M., 1942, Late Middle Cambrian trilobite faunas and stratigraphy of Alberta, Montana, Wyoming, and Utah: Unpublished doctoral dissertation, Princeton University, 1942.

Foster, H., 1947, Paleozoic and Mesozoic stratigraphy of northern Gros Ventre Mountains and Mount Leidy Highlands, Teton County, Wyoming: Amer. Assoc. Petrol. Geol. Bull., v. 31, p. 1537-1593.

Froidevaux, C. M., 1968, Geology of the Hoback Peak area in the Overthrust Belt, Lincoln and Sublette Counties, Wyoming: Unpublished Masters thesis, University of Wyoming, 1968.

Horberg, L., 1938. The structural geology and physiography of the Teton Pass area, Wyoming: Augustana Library Publication, no. 16. p. 1-86.

Horberg, L. and Fryxell, F., 1942, Precambrian metasediments in Grand Teton National Park, Wyoming: Am. Jour. Sci., v. 240, p. 385-393.

Horberg, L., Nelson, V., and Church, V., 1949, Structural trends in central western Wyoming: Geol. Soc. America Bull., v. 60, p. 183-216.

Keefer, W. R., 1964, Preliminary report on the structure of the southeast Gros Ventre Mountains, Wyoming: U.S. Geol. Survey Prof. Paper 501-D, p. D22-D27.

Lochman-Balk, C., 1956, The Cambrian of the Rocky Mountains and southwest deserts of the United States and adjoining Sonora Province, Mexico: 20th International Geological Congress, p. 529-653.

Love, C. M., 1966, Geology surrounding the headwaters of Flat Creek, Teton County, Wyoming: Unpublished Senior Thesis, Bates College, Lewiston, Maine.

Love, J. D., 1956a, Summary of Geologic History of Teton County, Wyoming, during late Cretaceous, Tertiary, and Quaternary times: Wyoming Geol. Assoc. Guidebook, 11th Ann. Field Conf., Jackson Hole, 1956, p. 140-150.

__________, 1956b, Geologic map of Teton County, Wyoming: Wyoming Geol. Assoc. Guidebook, 11th Ann. Field Conf., Jackson Hole, 1956.

Love, J. D., and Montagne, J., 1956, Pleistocene and recent tilting of Jackson Hole, Teton County, Wyoming: Wyoming Geol. Assoc. Guidebook, 11th Ann. Field Conf., Jackson Hole, 1956, p. 169-178.

Miller, A. K., 1930, The age and correlation of the Bighorn formation of northwestern United States: Amer. Jour. Sci., 5th Ser., v. 20 (1930) p. 195-213.

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

Montagne, J., 1956, Review of glacial studies in Jackson Hole: Wyoming Geol. Assoc. Guidebook, 11th Ann. Field Conf., Jackson Hole, 1956, p. 29-32.

Nelson V. E., 1942, The structural geology of the Cache Creek area, Gros Ventre mountains, Wyoming: Augustana Library Publications, no. 18, p. 1-46.

Nelson, V. E., and Church, V., 1943, Critical structures of the Gros Ventre and northern Hoback ranges, Wyoming: Jour. Geol. v. 51, p. 143-166.

Peale, A. C., 1893, The Paleozoic section in the vicinity of Three Forks, Montana: U.S. Geol. Survey Bull. 110, p. 1-56.

St. John, O., 1879, Geological report of the Teton Division: 11th Ann. Report of the U.S. Geol. Survey of the Terr., p. 321-508.

____________, 1883, Report on the geology of the Wind River district: Hayden, 1883, 12th Ann. Report of the U.S. Geol. and Geogr. Survey, Pt. 1.

Scott, H. E., 1935, Some carboniferous stratigraphy in Montana and northwestern Wyoming: Jour. Geol., v. 43, p. 1011-1032.

Shaw, A. B., and Deland, C. R., 1955, Cambrian of southwestern Wyoming: Wyoming Geol. Assoc. Guidebook, 10th Ann. Field Conf., Green River Basin, 1955, p. 38-42.

Strickland, J. W., 1956, Mississippian stratigraphy, western Wyoming: Wyoming Geol. Assoc. Guidebook, 11th Ann. Field Conf., Jackson Hole.

Swenson, F. A., 1949, Geology of the northwest flank of the Gros Ventre Mountains, Wyoming: Augustana Library Publications, no. 21, p. 1-75.

Van Dyke, L. H., 1956, Structure of the upper Horse Creek area: Wyoming Geol. Assoc. Guidebook, 11th Ann. Field Conf., Jackson Hole, 1956, p. 184-187.

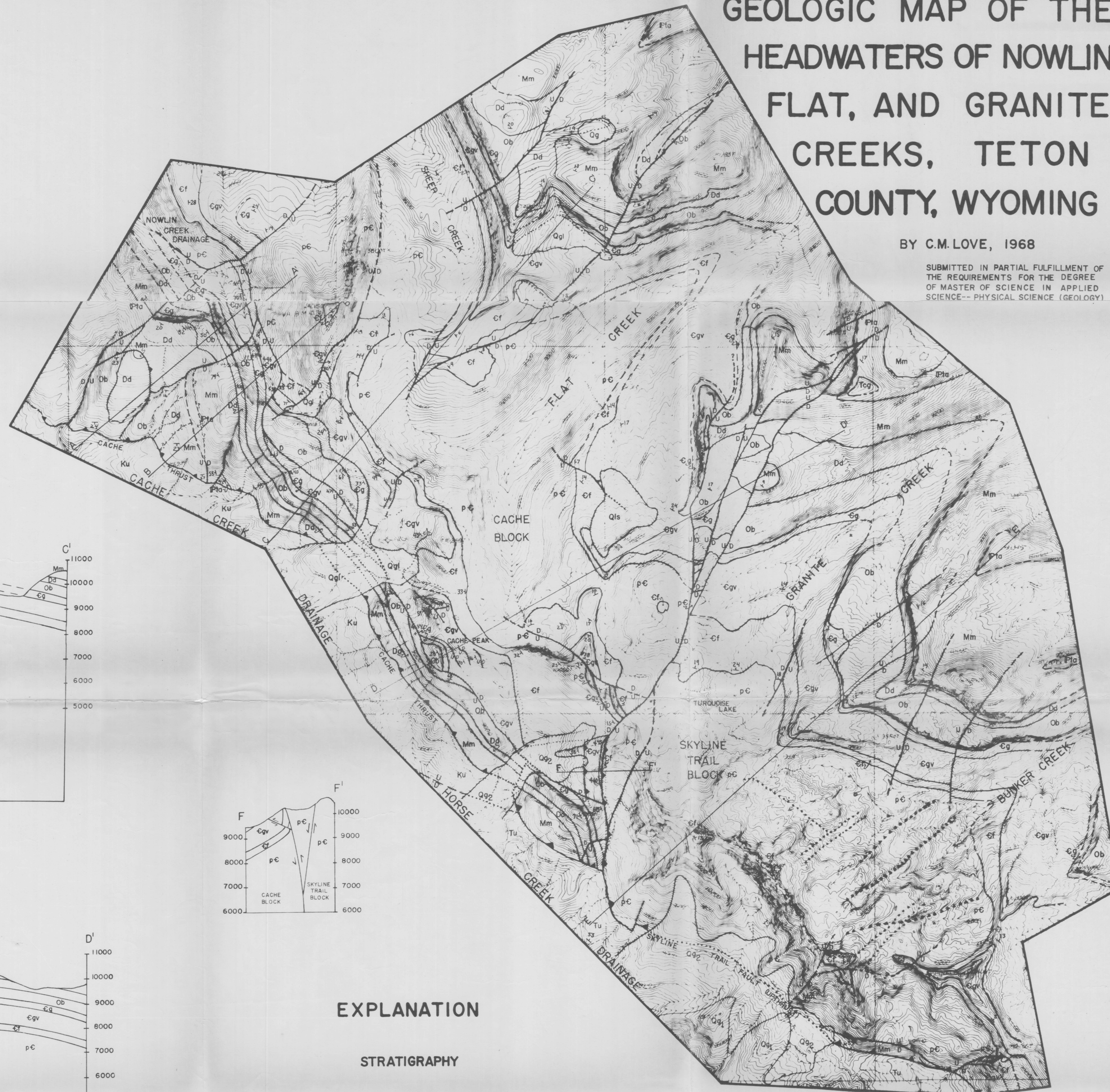
Wanless, H. R., Belknap, R. L., and Foster, H., 1955, Paleozoic and Mesozoic rocks of the Gros Ventre, Teton, Hoback and Snake River Ranges, Wyoming: Geol. Soc. America Memoir 63, p. 1-90.

Weed, W. H., 1900, Geology of the Little Belt Mountains, Montana: U.S. Geol. Survey 20th Annual Rept., Pt. 3, p. 257-416.

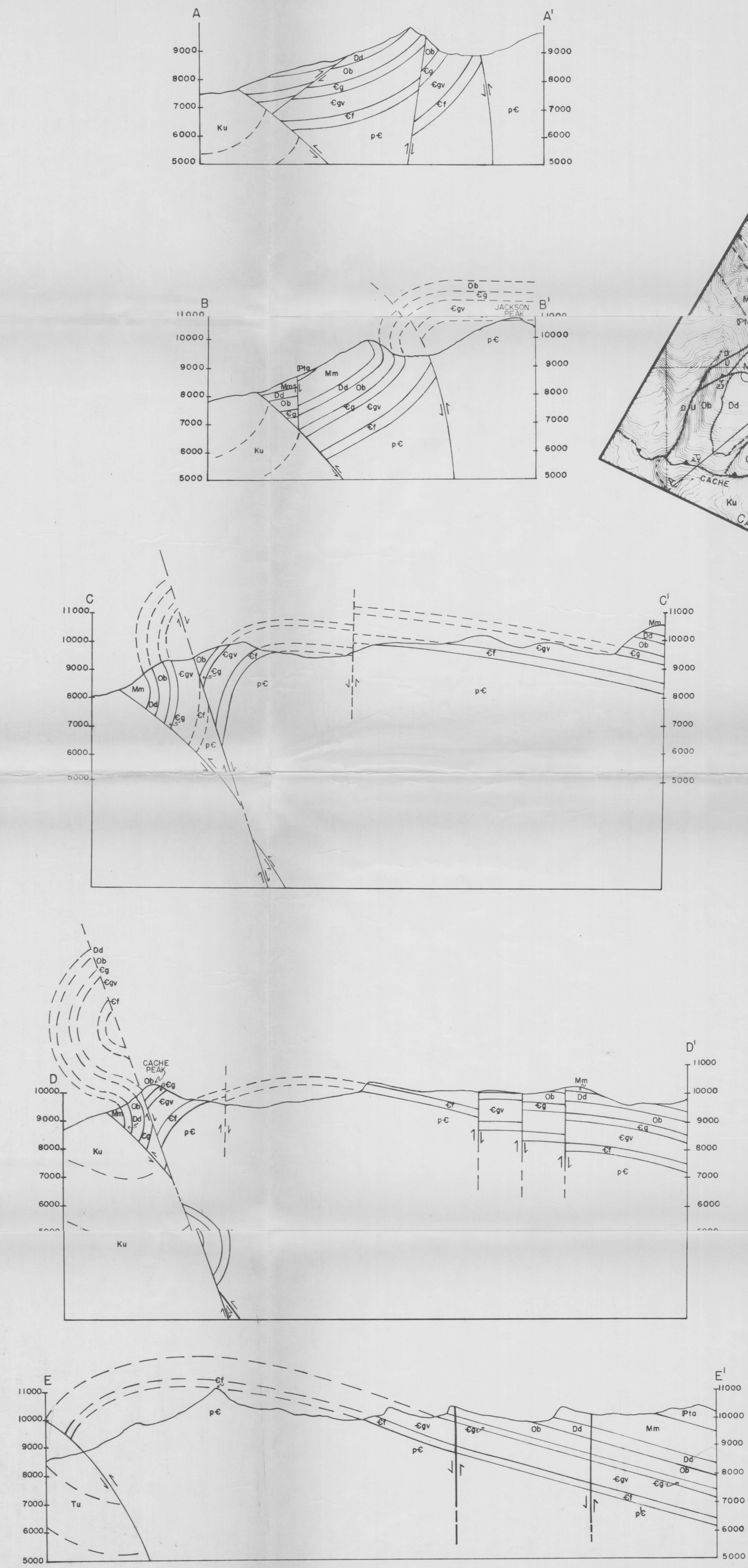
GEOLOGIC MAP OF THE HEADWATERS OF NOWLIN, FLAT, AND GRANITE CREEKS, TETON COUNTY, WYOMING

BY C.M. LOVE, 1968

SUBMITTED IN PARTIAL FULFILLMENT OF THE REQUIREMENTS FOR THE DEGREE OF MASTER OF SCIENCE IN APPLIED SCIENCE-- PHYSICAL SCIENCE (GEOLOGY)



STRUCTURE SECTIONS



EXPLANATION

STRATIGRAPHY

Quaternary	Qgl	Glacial-landslide debris
	Qg	Latest Glacial debris
	Qg_2	Pinedale (?) drift
	Qg_1	Earliest Glacial drift
Tertiary	Tcg	Tertiary conglomerate
	Tu	Tertiary Undivided
Cretaceous	Ku	Cretaceous Undivided
Pennsylvanian	IPta	Tensleep-Amsden Formations
Mississippian	Mm	Madison Group
Devonian	Dd	Darby Formation
Ordovician	Ob	Bighorn Dolomite
Cambrian	€g	Gallatin or Boysen Formation
	€gv	Gros Ventre Formation
	€f	Flathead Quartzite
Precambrian	p€	Precambrian granite, gneiss, and schist

STRUCTURE

Dashed where concealed or inferred

Dotted where stratigraphically covered

- Thrust fault or upthrust as marked. Teeth in upper plate
- U / D — Normal fault
- Mm / Dd — Contact between formations
- Major Precambrian Lineations
- Minor Precambrian Lineations
- 44 — Strike and dip of strata
- Vertical strata
- 77 — Overturned strata

SCALE

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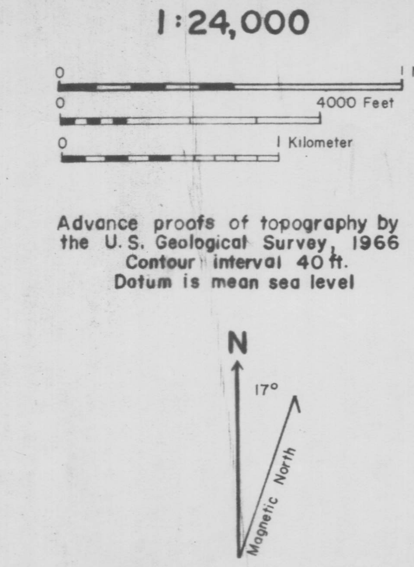

Advance proofs of topography by the U.S. Geological Survey, 1966
Contour interval 40 ft.
Datum is mean sea level

Love, C.M, 1968
Map & Cross-sections

C.M. LOVE