Univ. of Michigan

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THE GEOLOGY OF A PART
OF THE
RUBY RIVER BASIN OF MADISON COUNTY, MONTANA

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ABSTRACT

The Ruby River basin is in Madison County in southwestern Montana. The part of the basin treated here is south of Alder, Montana. It is a downfaulted trough filled with sediments mostly Miocene in age. These sediments terminate against the pre-Cambrian gneisses and quartzites of the Ruby and Greenhorn ranges. The sediments can be divided into three formations: The Passamari formation, the Madison Valley formation, and the Red Rock conglomerate. The last is exposed only at one limited outcrop. It is probably of Paleocene age. The Passamari is a lake-bed formation of thinly bedded calcareous and tuffaceous, white to gray shales. It is lower or middle Miocene in age and is overlain by the Madison Valley formation. The latter consists of conglomerates, sandstones, and tuffs laid down under conditions of torrential deposition. Fossil ostracods and fossil leaves were found in the Passamari formation, as well as many remarkably well preserved fossil insects. Several teeth of an advanced *Merychippus* or primitive *Neohipparion* were found in the Madison Valley formation, which made it possible to date this formation as upper Miocene or lower Pliocene in age. The Red Rock conglomerate was probably deposited in depressions on an old surface and is now exposed only at one locality in the area. The

Passamari formation was deposited in a basin produced by either downwarping or downfaulting. Block faulting after the deposition of the Passamari formation deepened the basin and caused the deposition of the coarser Madison Valley formation. Subsequent faulting within the basin beds has exposed the Red Rock conglomerate and the Passamari formation. There are four surfaces developed in the area.

INTRODUCTION

Location of area

The basin under discussion is located on both sides of the Ruby River in Madison County in southwestern Montana. See index map, Plate I. It includes Townships 7, 8, and 9 South in Range 5 West, and Townships 7 and 8 South in Range 4 West, and is bounded on the west by the Ruby Mountains and on the east by the Greenhorn Mountains.

Geography

Relief. The relief of the region is considerable with elevations ranging from 5,400 feet on the Ruby Reservoir to about 9,600 feet on the top of Old Baldy Mountain in the Greenhorn Range.

Drainage. The area is drained by the Ruby River, which is only a small stream about twenty feet wide. With the exception of Sweetwater Creek the tributaries of the Ruby River are rarely over three feet wide.

At the northern end of the area the Ruby and Greenhorn ranges come close together and a small cross-structure of pre-Cambrian rock terminates one portion of the Ruby River basin. The Ruby River has cut a deep gorge through the cross-structure. A dam has been built at the head of the gorge creating the large Ruby River Reservoir, which in the summer of 1947 was three miles long and a half-mile to a mile wide.

Vegetation. The valley floor is green with vegetation, both cultivated and wild. Parts of the valley are easily irrigated and well suited to ~~wheat~~ hay raising and cattle ranching. There are many farms in the valley now. Hayden (Hayden, 1872) reported that the valley was well populated even in 1871.

Away from the valley floor the vegetation consists of brownish desert grasses with some cactus and sagebrush. Vegetation fares better on the southern side of gully slopes because this side is less exposed to the direct rays of the sun than the northern side. The resulting conservation of moisture allows more vegetation to grow on these southern sides (Plate 15, Fig. 2). As a result, there are few good rock exposures on the southern sides of gullies.

Nomenclature of major features. The Ruby River has been called the Stinking Water River or the Passamari River in the past. Hayden refers to it as the Stinking Water River. The Dillon Quadrangle topographic map of

1893 refers to it as the Passamari River. Passamari is the Indian name for stinking water.

Some confusion has existed over the name of the mountain range to the east of the basin. Many maps give the impression that it is a continuation of the Snowcrest Range. The Three Forks Quadrangle of 1895 shows it as the Jefferson Range. Shaler (Shaler, 1901) refers Old Baldy Mountain to the Tobacco Root Range. However, the U.S.G.S. preliminary map of Montana of 1944 refers to this range as the Greenhorn Range.

Previous work

In 1871 Ferdinand V. Hayden headed a party through the Ruby River basin and described some of the volcanics along Sweetwater Creek and the Tertiary beds at the junction of Sweetwater Creek with the Ruby River. He also mentioned some of the hot springs deposits and the gorge of the Ruby River at the northern end of the area (Hayden, 1872).

Dr. Earl Douglass of the University of Utah collected vertebrate bones in the basin during the period from 1910 to 1920, but he died before his researches were published.

Preliminary Map No. 25 of the U.S.G.S., "Geologic Map of Montana," compiled by Andrews, Lambert, and Stose in

1944, shows the part of the Ruby River basin described in this report to be filled by Tertiary lake beds with the exception of undifferentiated volcanics at the bend of Sweetwater Creek and near the west side of the reservoir near the dam.

Purpose of the investigation

The purpose of the investigation is to make a study of the Tertiary stratigraphy of this little known area.

Methods of investigation

The methods of investigation of the area were restricted by the lack of some of the usual tools of the geologist. No aerial photographs of the area have been taken. The available maps are the topographic map of the Dillon Quadrangle, a forest service map, and a Madison County road map. The topographic map is of limited use as the scale is one inch equals four miles and the contour interval is 200 feet. The county road map with a scale of one inch equals two miles was the most useful of these maps.

The geologic contacts could not be located with accuracy and detail so the accompanying map (Plate 2) is much generalized. In a few places points were located by the pace and compass method. Many excellent fossils were collected and detailed stratigraphic sections were measured. Numerous rock specimens were collected for thin section study, results of which have been included in the detailed stratigraphic sections.

Acknowledgments

Dr. A. J. Eardley directed the thesis work in the field and in the office. Dr. Eugene Walker visited the party in the field and Dr. Claude Hibbard assisted in the identification of vertebrate material. Dr. J. Speed Rogers and Dr. Theodore H. Hubbell identified the insect material, Dr. Chester A. Arnold examined the plant fossils, Mr. Wallace R. Griffitts studied the thin sections, and Dr. Fred Swain of the University of Minnesota reported on the ostracods.

We are indebted to Mr. Elwin Metzel of Alder, Montana, for pointing out the fossil insect locality and for his help during the field work.

Co-workers and fellow students in the field were Mr. Herman Becker of Brooklyn College and Mr. Henry Zuidema of the University of Michigan.

STRATIGRAPHY

General statement

The rocks in the area are of four main types: the Miocene (and possibly Pliocene) basin beds, the Tertiary volcanic extrusives and hot springs deposits, the pre-Cambrian gneisses and quartzites, and an unusual deposit of conglomerate which is possibly of Paleocene age.

No Paleozoic or Mesozoic rocks are exposed in the area.

The Tertiary rocks of the basin can be divided into two main formations: a lower lake bed formation of lower or middle Miocene age and an upper flood-plain formation of upper Miocene or lower Pliocene age.

Passamari formation

Divisions and lithology. The Passamari formation consists of two members, both deposited under quiet, lacustrine conditions. The lower member is composed of light tan, fine-grained shales. The shales occur in two types. One type is thin-bedded and fissile and contains a small amount of volcanic ash. The other type is silty and blocky and contains no volcanic ash.

The upper member consists mainly of very light buff and very light gray, calcareous, thin-bedded shales. Some beds contain a moderate amount of volcanic ash. There are some layers that contain fine sand mixed with clay. Many units of the upper member contain poorly preserved fresh-water ostracods.

The two members have not been observed in contact with each other. The probable relation between them has been inferred from structural relations. It is possible that the so-called upper member represents a facies change.

Distribution. The lower member occurs in scattered localities on the west side of the basin between Peterson Creek and Mormon Creek.

The upper member was observed and measured in the Sweetwater Creek measured section, which is described under the heading of "measured sections." The upper member extends from the Sweetwater Creek section northeast to the fault along the west edge of the Belmont Ranch section.

Type section and thickness. No measured section was taken of the lower member because the shales were covered in most places.

The type section of the Passamari formation is the Sweetwater Creek section which is described under the heading "measured sections." It includes 130 feet of the upper member of the Passamari formation. (Plate 8, Fig. 2). Neither the base of the upper member nor the base of the formation were observed.

Fossil localities. There are four fossil localities in the Passamari. They are indicated on the map (Plate 2) by triangles. Fossil locality 1 occurs in shales of the thin-bedded type in the lower Passamari. It is in a gully in the NW quarter of Section 25, T. 7 S., R. 5 W. Many excellent insect fossils and many leaf fossils were taken from this locality.

Fossil locality 2 is in the blocky shale of the lower Passamari. It is in a gully about 500 yards south of locality 1. Fossil leaves, largely Taxodium or Sequoia, were found here (Plate 11, Fig. 2).

Fossil locality 3 is in the upper Passamari near the fault along the western edge of the Belmont Ranch measured section in Section 13, T. 8 S., R. 5 W. Poorly preserved ostracods were found here (Plate 12, Fig. 2).

Fossil locality 4 is in the upper Passamari in Section 28, T. 8 S., R. 5 W. near the Sweetwater Creek measured section. Poorly preserved ostracods were found here.

Age and correlation. The Passamari formation is of lower or middle Miocene age as determined from plant fossils. The paleontological reasons for this age determination are discussed under the section on paleontology.

Lake bed deposits are common in the basins of southwestern Montana, but none has been sufficiently described as to lithology and paleontology to permit a correlation with this formation. The possible John Day equivalent and the *Leuciscus turneri* lake beds of the Three Forks area are both possible equivalents, however.

So for the purposes of this report, the lake beds just described are referred to as the Passamari formation. The Passamari River is an old name for the Ruby River, and the Passamari guide meridian passes through this region.

Madison Valley formation

Divisions and lithology. The Madison Valley formation consists of two members both laid down during conditions of flood-plain and torrential deposition. The lower member consists of alternating conglomerates and coarse sandstones with several beds of tuff and a very few beds of tuffaceous limestone.

The sandstones are coarse, calcareous, and well cemented, weathering tan to gray. Unit 14 of the Idaho Creek section is typical.

A conglomerate unit typical of the lower member of the Madison Valley formation is light gray and well consolidated with a matrix of coarse, calcareous sandstone. The pebbles are largely feldspar, pegmatite, pink gneiss, black gneiss, and quartzite of many colors with smaller amounts of granite and rhyolite. A very few pebbles of brown dolomite were found in the first large gully south of Idaho Creek and in a small cliff along the main road about two miles north of Idaho Creek.

Not even the feldspars and mafic minerals have undergone any weathering. The quartzites are generally rounded, but may be sub-rounded. All other minerals are sub-angular to sub-rounded. It is worthy of note that the most resistent rock is the most rounded.

At one exposure of the lower member in Section 12, T. 8 S., R. 5 W. a very unusual conglomerate was found which contains large blocks of unconsolidated, distinctly bedded clay. The blocks range from one-half to three feet in diameter and the internal layers average about three inches in thickness. The blocks have a random orientation in the bed, as shown by the bedding planes. (Plate 6, Fig. 1).

Pebbles of sedimentary rock are rare and are generally absent in the conglomerates of the Madison Valley formation. But on the west side of the Ruby River reservoir, immediately to the north of the hill of Red Rock conglomerate (Plate 4) is a hill of Madison Valley conglomerate which contains many pebbles of sedimentary rock. Here the Madison Valley formation consists of alternating sandstones and conglomerates which are typical in appearance. However, about 25 percent of the pebbles in the conglomerate are sub-rounded, compact, brown dolomite. The other pebbles are feldspar, gneiss, and quartzite. This type of conglomerate does not occur elsewhere in the area.

There are several conspicuous conglomerate beds of the lower Madison Valley formation in the Idaho Creek section which have fifty to seventy-five percent of their bulk in rounded quartzite pebbles of various colors. The pebbles are generally one-half to two inches in diameter. The conglomerate is non-calcareous but is well cemented by a sandy matrix.

The most striking example of the quartz pebble conglomerate is an isolated exposure near the hot springs deposits just north of Garden Creek. Here the conglomerate is seventy-five percent pebbles of quartzite which average one and one-half inches in diameter, but range from one-half inch to four inches. The matrix is non-calcareous.

Conglomerate units of this type make up only a minor part of the formation, but they are important because parts of the mantle of the basin consist largely of pebbles weathered out of quartz pebble conglomerate. The pre-Cambrian exposures to the south and east of the hill of Red Rock conglomerate are largely mantled by rounded quartzite pebbles. In other places throughout the area the mantle has a large percentage of rounded quartzite pebbles.

The upper member of the Madison Valley formation is characterized by a large amount of volcanic ash. Thick beds composed almost entirely of glass shards are present.

The sandstones are tuffaceous and are light gray to light tan or buff in color. Though friable and non-calcareous, they can be cliff forming. They are finer grained than the sandstones of the lower member.

The conglomerates do not alternate regularly with sandstones as in the lower member, but occur in irregularly placed lenses. They are poorly cemented. There is less conglomerate in the upper member than in the lower member, but the conglomerates of the upper member are coarser.

The relation between the two members is well shown in the Idaho Creek section where about 225 feet of poorly cemented tuffs and tuffaceous sandstones rest unconformably on the conglomerates and sandstones of the lower member. However, at every other place the contact is obscure. The individual beds of the Madison Valley formation are lensing and discontinuous, and were deposited under torrential conditions. Consequently, a correlation of beds within the formation is virtually impossible. Therefore, the two members are not mappable. It is useful, however, to consider the formation as having two members, because of the greater ash content higher in the section.

Distribution. The Madison Valley formation is exposed over most of the area. (See map on Plate 2.) The lower member is exposed on the west side of the basin between the Ruby River flats, Sweetwater Creek, and the fault which separates the Madison Valley from the Passamari; and is exposed north of the Red Rock conglomerate area. It is exposed on the east side of the basin from Idaho Creek north nearly to Barton Creek and south to about the latitude of the junction of Sweetwater Creek with the Ruby River.

The upper member is not exposed on the west side of the basin north of Sweetwater Creek. On the east side of the basin it is exposed widely around Barton Creek but is limited to the eastern edge of the Idaho Creek section. It is widely exposed in the light colored hills to the southeast of Sweetwater Creek.

Type sections and thickness. The type section of the lower Madison Valley formation is the Belmont Ranch section, which is described under the heading "measured sections." Eleven hundred and thirty-six feet of the lower member were measured here (Plate 9, Fig. 2 and Plate 12, Fig. 1).

The type section of the upper Madison Valley formation is the Barton Creek section, which is described under the heading "measured sections." Three hundred and sixty-nine feet of the upper member were measured here.

Fossil localities. There are two fossil localities in the Madison Valley formation. They are indicated on the map (Plate 2) by triangles. Fossil locality 6 occurs in the lower member in unit 2 of the Belmont Ranch section in Section 12 of T. 8 S., R. 5 W. near the junction of Sweetwater Creek and the Ruby River (Plate 9, Fig. 2). Part of a lower jaw of an advanced *Merychippus* or a primitive *Hipparion* was found at this locality.

Fossil locality 5 occurs in the upper member in the light colored hills southeast of Sweetwater Creek in Section 9, T. 9 S., R. 5 W. Two teeth, a cannon bone, and one toe bone of an advanced Merychippus or a primitive Neohipparion were found at this locality.

Age and correlation. The Madison Valley formation is of upper Miocene or lower Pliocene age as determined from vertebrate fossils. The paleontological reasons for this age determination are discussed under the section on paleontology.

The Madison Valley formation was named by Dr. Earl Douglass (Douglass, 1903) from deposits in the Madison Valley south of Three Forks, Montana. He says, "The Loup Fork beds of the Lower Madison Valley are in great part, at least, of stream valley origin. By this is meant such deposits as usually accumulate in valleys of rivers and smaller streams, including channel deposits, mud flats, sand bars, flood plains, and small lakes."

In his monograph of North American Equidae (Osborn, 1918) Osborn describes these same beds as follows, ".... twenty miles south from the Three Forks .... of the Missouri River. Perpendicular cliffs, composed of clays, fine sands, volcanic ash and conglomerate. ....contained referred specimens of *Protohippus*, *Hipparion*, *Merychippus*, *Procamelus*, and *Cosoryx*. The type of *Protohippus minimus* is attributed to the Madison Valley beds in all of Douglass' references to this species."

These descriptions of lithology could apply equally well to the flood-plain formation of the Ruby River basin. Especially important is the mention of volcanic ash and the presence of *Merychippus* and *Hipparion* (probably *Neohipparion*). It seems probable, therefore, that these beds are the equivalent of the Madison Valley formation of the Three Forks district and the formation will be referred to in this report as the Madison Valley formation.

Red Rock conglomerate

On the west side of the Ruby River between Peterson and Garden Creeks a reddish hill lies conspicuously among less colorful hills. The red hill is composed of a conglomerate which occurs nowhere else in the area.

The Red Rock conglomerate here is composed of subangular to angular pebbles of fossiliferous Madison limestone in a red, sandy, calcareous matrix. The weathering of this red matrix gives the entire hill a reddish cast, and even colors the pre-Cambrian gneisses on which the formation rests. A slump block near the road gives the impression that the whole side of the hill facing the reservoir is Red Rock conglomerate, whereas actually the lower part of the hill is pre-Cambrian gneiss.

Lenses of bentonite were noted at two points along the base of the formation.

According to Dr. A. J. Eardley, this outcrop is very similar in appearance to the Red Rock conglomerate of Paleocene age near Lima, Montana, and tentatively will be correlated with it.

A detailed map of the hill of Red Rock conglomerate and the surrounding area is shown on Plate 4.

Hot springs deposits

Hayden, on his trip through the basin in 1871, was much impressed by the extensive hot springs deposits, some of which are probably under the Ruby River reservoir now.

West of the Ruby River reservoir between Garden Creek and Hench Creek there is a large hill composed of brown pre-Cambrian quartzite. This hill has a roughly U-shaped belt of hot springs deposits on three sides of it. They are composed of a pure, fine-grained, white limestone which weathers to a light gray (Plate 6, Fig. 2) The deposits have been extensively eroded. One isolated pinnacle of limestone is nearly 50 feet high (Plate 7). Through most of their extent the deposits rest on the pre-Cambrian. Near Garden Creek there is a hill where the hot springs limestones rest against the Madison Valley formation.

Hot springs are still active, particularly along the part of the quartzite hill that faces the Ruby River reservoir. Recent hot springs activity has resulted in a thin, colorful red and white coating on this face of the hill (Plate 5).

Limestone deposited by hot springs was also noted capping two hills just south of Cottonwood Creek at the edge of the area. Another small deposit was noted near the fault gravels on the southern side of Barton Creek.

Extrusive rocks

Several patches of extrusive rock are found in the basin. Most of them are in the southwest corner of the area around the bend of Sweetwater Creek. Rhyolites and basalts are present. One altered rhyolite possesses color rings and is mined and sold as "Montana agate." Some hills have lava caps and one conspicuous, round, reddish hill resembles a volcanic neck (Plate 8, Fig. 1)

A patch of volcanic rock is present along the Tertiary-pre-Cambrian contact just north of Cottonwood Creek, and a small outcrop of it is situated along the contact of the Red Rock conglomerate with the main pre-Cambrian mass. In the Cottonwood Creek patch massive, blocky basalt, white rhyolite, and a light, soft, highly altered volcanic rock (probably a rhyolite) are present. The altered rhyolite is generally a colorful red. The same altered material is found at the contact of the Red Rock conglomerate with the pre-Cambrian.

There are more extensive exposures of extrusive rocks up Sweetwater Creek out of the area covered in this report.

Mantle of gneissic detritus along fault

Along the east side of the basin there is a belt of thick Quaternary gravel which overlies the large fault. The gravel consists almost entirely of fragments of limonite-stained, black and white, injection gneiss. Gneiss of the type from which the detritus has been derived crops out around most of the basin. It is well shown in the hill of pre-Cambrian rock which lies between the Red Rock conglomerate and the hill of Madison Valley conglomerate of the brown dolomite pebble type.

This type of gneiss pebble was not observed anywhere in the consolidated conglomerates of the basin. The origin of the gravels will be discussed under the section on structural geology.

Measured sections

Sweetwater Creek section. The Sweetwater Creek measured section is indicated on the map as locality No. 1. It is in Section 28, T. 8 S., R. 5 W., one to two miles west of the Williams Ranch buildings. It includes the contact between the Passamari and Madison Valley formations. The contact appears to be conformable in the section, though there is a strong contrast between the thin-bedded, white, calcareous shales of the Passamari formation and the massive tan sandstone of the Madison Valley formation (Plate 8, Fig. 2). The change in sedimentation is further emphasized by the presence of calcium carbonate in large amounts in the underlying Passamari right up to the contact and the complete lack of calcium carbonate in the Madison Valley above the contact.

The shales of the Passamari are generally light gray when fresh, but they weather white. Unless otherwise specified, the shale beds in the section are thin-bedded and calcareous. Thin sections reveal that most of the shale is tuffaceous. The white shales of the Passamari formation contain many poorly preserved ostracods at several levels.

The sandstone of the Madison Valley formation contains many nodules of opal and rare tiny bone and tooth fragments of small vertebrates. The sandstone phase contains only scattered pebbles and is not highly conglomeratic. However, it was definitely laid down under the conditions of flood-plain deposition which characterize the Madison Valley formation. There is no indication of the lake-bed type of deposition. On this basis, therefore, the sandstone is included in the Madison Valley formation.

In the section the beds strike N55W and dip 9° to the southwest. 129.7 feet of Passamari and 252.5 feet of Madison Valley are present. The total thickness of the section is 382.2 feet.

UNIT	LITHOLOGY	THICKNESS (in feet)
30.	Sandstone, brown, weathers brown to buff, sparsely conglomeratic, cliff-forming; contains nodules of opal and scattered tiny bone fragments; contains rock fragments from sand grains up to seven inch cobbles, angular to sub-angular; pebbles are quartzites, gneisses, feldspars, and extrusive rocks.	202.5

UNIT	LITHOLOGY	THICKNESS (in feet)
29.	Sandstone, brown, fine, well-sorted and poorly consolidated with scattered conglomeratic lenses.	7.9
28.	Shale, light brown, weathers tan, slightly arenaceous, thin-bedded, non-calcareous.	10.5
27.	Siltstone, medium brown, weathers tan, non-calcareous; friable, but forms several resistant ledges.	13.2
26.	Shale, medium tan, non-calcareous, blocky and poorly bedded.	18.4

Contact between Madison Valley formation and Passamari formation.

UNIT	LITHOLOGY	THICKNESS (in feet)
25.	Shale, light gray, weathers white, thin-bedded, highly calcareous.	10.5
24.	Limestone, white, weathers white, fine, argillaceous, thin-bedded.	2.0
23.	Shale, light gray, weathers white, soft and calcareous.	9.9
22.	Sandstone, light tan to light brown, weathers medium-brown, cross-bedded and well consolidated; forms a resistant ledge, weathers to an irregular surface, contains several partings of sandy shale.	12.6
21.	Shale, light gray, calcareous, arkosic and poorly bedded; scattered medium to coarse quartzite grains.	4.4
20.	Shale, medium gray, soft and laminated; contains ostracods.	2.6
19.	Argillaceous sandstone and sandy shale, medium gray; well-indurated but poorly bedded; scattered quartzite grains present.	7.3

UNIT	LITHOLOGY	THICKNESS (in feet)
18.	Shale, gray, soft and laminated, sandy, compact and thin-bedded, slightly salty; contains ostracods. A thin section analysis shows that pyroclastics are a minor constituent. The rock consists of basalt fragments and clear, brown glass in shards and in rectangular pieces. The detrital material consists of round quartz grains, sub-rounded microcline grains, and angular grains of augite, hornblende, garnet, and zoisite as well as some plagioclase, montmorillonite pellets, and sericite.	5.8
17.	Shale, grading upward into layered shale and tuffaceous sandstone, gray, massive and calcareous. Thin section shows the sandy layers contain abundant crystalline grains as well as montmorillonite pellets. Here the glass shards are larger and more abundant than in the finer grained material.	4.5
16.	Shale, gray, soft and extremely fine, laminated, calcareous; contains scattered ostracods.	1.3
15.	Sandy limestone, brown, medium-grained. Thin section shows many grains of fine-grained igneous rocks. These constitute about three-fourths of the sand.	1.6
14.	Shale, medium gray, massive and calcareous; scattered reddish fish scales present.	1.4
13.	Tuffaceous sandy limestone, shaly-looking, light gray, weathers white, soft and calcareous. Thin section shows that detrital material is plagioclase, green hornblende, round grains of brown glass, muscovite, andesite, garnet, magnetite, quartz, microcline, and colorless glass shards.	6.8

UNIT	LITHOLOGY	THICKNESS (in feet)
12.	Shale, light to medium gray, well consolidated, arkosic near top, calcareous, poorly bedded; a few ostracods present. Unit is capped by two inch layer of gypsum.	7.5
11.	Shale, medium gray with light gray laminations, fine, calcareous; contains small shreds of organisms, probably plants. Thin section shows this rock is largely isotropic clay material of unknown nature.	3.0
10.	Shale, medium gray with brown limonitic spots, poorly bedded and poorly consolidated, non-calcareous.	7.3
9.	Shale, medium gray with light gray laminations, fine, calcareous; may contain ostracods or some other small organisms.	3.0
8.	Shale, medium to dark gray, soft, nonlaminated, calcareous.	1.8
7.	Sandy tuffaceous shale, dark gray, hard, calcareous, non-laminated. A thin section shows that the matrix is largely an aggregate of clay minerals. The sandy material is concentrated in certain layers accompanied by more abundant shards than in finer grained areas. One large, irregular, calcite nodule was present. The sand consisted mostly of plagioclase, microcline, and garnet with a few grains of fine-grained igneous rocks.	1.0
6.	Sandstone, dark gray with rich brown limonitic streaks, fine, non-calcareous.	7.8
5.	Sandy shale, brown, weathers light gray, fine, non-calcareous, poorly indurated; contains fine bands of siltstone.	1.0
4.	Shale, medium gray with occasional light gray to buff laminae, soft, calcareous.	5.2

UNIT	LITHOLOGY	THICKNESS (in feet)
3.	Argillaceous tuff, brown, weathers light gray, fine, non-calcareous, poorly indurated. A thin section shows large amount of fairly small shards with some sandy material consisting of plagioclase, fine-grained igneous rocks, magnetite, garnet, biotite, and microcline. Matrix is an aggregate of montmorillonitic material.	7.9
2.	Covered slope with fragments of shale, sandstone, and gypsum.	10.5
1.	Argillaceous tuff, light tan, weathers very light gray, medium-grained, calcareous. A thin section shows a fine-grained aggregate of clay minerals with scattered shards and muscovite flakes. Some layers are largely pyroclastic material; others have relatively little. Tuff-rich layers contain much quartz and feldspar; other layers have relatively little.	3.0
		382.2

Belmont Ranch Section. The Belmont Ranch section is indicated on the map as locality No. 2. It is in Section 12 and Section 13 of T. 8 S., R. 5 W., near the junction of Sweetwater Creek and the Ruby River. It is typical lower Madison Valley formation and is composed of coarse sandstones and conglomerates with a few layers of volcanic ash.

This section is continuous but was taken in two courses at right angles to each other, one of which goes up the cliffs and the other goes along the cliffs (See Plate 9, Fig. 2 and Plate 12, Fig. 1). The turning point is at the base of the cliffs along the Sweetwater Creek road one-fifth of a mile southwest of the turn which the road makes at the foot of the cliffs. From this point one leg (beds 6 to 20) was taken up the cliffs and back to the fault which brings up the Passamari formation. The other leg (beds 1 to 6) runs along the front of the cliffs for about a mile to the north-northeast.

The sandstones are coarse and calcareous. The conglomerates are variable with medium to coarse texture and good to poor cementation. The volcanic ash lenses are characterized as extremely friable volcanic glass in shards. A few of the shards are obsidian. One three foot bed of limestone is present. It contains a large amount of shards.

Of special interest is a siltstone found in unit No. 2. This is a non-calcareous bed colored a striking olive green. A good half of a lower jaw of an advanced *Merychippus* or a primitive *Neohipparion* was discovered in it.

In this section the beds strike N50W and dip 15° to the northeast. The total thickness of this section is 1135.7 feet of which 653.3 feet are covered.

UNIT	LITHOLOGY	THICKNESS (in feet)
20.	Sandstone, light tan to gray, medium to coarse with angular grains, highly calcareous. This bed is not far from the fault which is covered at this point.	5.0
19.	Covered. No outcrops, but slope is covered by material which is derived from conglomerates similar to some lower in the section. Some of the rocks in this interval cap the ridges at the southwest end of these cliffs.	456.0
18.	Sandstone, buff, coarse, calcareous, grains sub-angular, well cemented.	5.7
17.	Sandstone, light tan, fine-grained, non-calcareous, grains sub-angular.	22.8
16.	Sandstone, gray, weathers buff, fine-grained, calcareous; alternating resistant and poorly cemented layers. Upper 18.4 feet is resistant and forms a cliff.	66.6
15.	Limestone, white to light gray, weathers gray, porous and light but well indurated; forms resistant ledge; contains large amounts of splintery volcanic glass.	3.5
14.	Mostly covered. Some layers seen to be cliff-forming to the northeast. Several ledges of fine-grained argillaceous sandstone alternating with a coarse conglomerate lacking any fine matrix. Volcanic glass present in some of the sandstones.	104.6
13.	Conglomerate, fine, cross-bedded with sandy lenses; pebbles range from coarse sand to six inch cobbles; grains angular to sub-angular fragments of quartzite, hornblende-schist, and gneiss; cement calcareous; a few lenses of volcanic ash present.	6.0

UNIT	LITHOLOGY	THICKNESS (in feet)
12.	Siltstone and fine sandstone, light tan, slightly calcareous; cliff forming; thin pebble zones scattered irregularly throughout.	9.0
11.	Conglomerate, fine and poorly consolidated; interbedded with even less resistant argillaceous layers.	27.0
10.	Alternating conglomerates and sandstones with occasional lenses of volcanic ash. Conglomerate is buff, weathers gray, medium-grained, calcareous, occasionally cross-bedded. Sandstone is friable, conglomeratic, occasional bands of large pebbles. Lensing volcanic ash bed is very friable and varies from zero to thirty inches in thickness.	29.0
9.	Covered. Talus derived from conglomeratic material.	63.7
8.	Conglomerate alternating with medium-grained sandstone, tan to gray; conglomerate is calcareous; sands are non-calcareous, poorly cemented; pebbles range from medium sand to ten inch cobbles, angular to sub-rounded; layers are lensing, some are resistant. Unit has a conglomerate cap two inches to one foot thick.	20.6
7.	Fine-grained tan sandstone grading upward into conglomerate. Unit is capped by a resistant conglomerate ledge. Bottom part of unit mostly covered by talus.	58.0
6.	Alternating layers of fine to medium sandstone with conglomerates and conglomeratic sandstones, light tan, weathering dark tan to gray, non-calcareous, cliff forming; pebbles are granites, quartzites, gneisses, and schists. Coarse conglomeratic sandstone forms ledge at top.	29.4

UNIT	LITHOLOGY	THICKNESS (in feet)
5.	Sandstone, tan, fine-grained with a few conglomeratic zones, non-calcareous.	45.6
4.	Sandstone, tan, calcareous but poorly indurated, fine-grained, weathers to a pitted surface; widely dispersed small quartzite pebbles; bed capped by a coarse, hard conglomeratic sandstone 2.2 feet thick.	74.0
3.	Conglomerate, calcareous and well-indurated; forms a ledge; pebbles generally pea-sized, but ranging up to cobbles of granite, quartzite, and feldspar 5 inches in diameter.	3.3
2.	Siltstone. Color is a striking light olive-green. Extremely fine-grained, weathers to a greenish, nodular surface, non-calcareous. A good half of a lower jaw of an advanced <u>Merychippus</u> or a primitive <u>Neohipparion</u> was recovered from this unit.	41.6
1.	Siltstone, light brown, contains some fine sand; weathers to a clayey, mud-cracked slope; forms several ledges with round and pitted surfaces.	64.3
		1135.7

<u>Idaho Creek Section</u>. The Idaho Creek section is indicated on the map as locality No. 3. The section was taken along the walls of the small valley of Idaho Creek on the eastern side of the basin. Idaho Creek lies in the southern fourth of T. 7 S., R. 4 W.

The section starts about a fourth-mile east of the main road at the second gully entering Idaho Creek on the south bank. The section crosses to the north side of Idaho Creek with unit 15 and continues there until reaching bed 42, where the section is taken up the white slope to the north of Idaho Creek and terminates against the pre-Cambrian.

It is from the Idaho Creek section that the best evidence is found for dividing the Madison Valley formation into two members. Here the tuffs and tuffaceous sandstones of the upper member (units 40 through 44) rest unconformably on conglomerates and sandstones of the lower member (units 1 through 39).

Units 42 and 44 are composed of light gray to white tuffs and tuffaceous sandstones. Unit 40 is a tan tuffaceous sandstone of a type widely exposed in the Barton Creek section.

The section from unit 16 through unit 39 is composed mainly of siltstones and fine-grained sandstones, with a few beds of conglomerate, tuff, or limestone. The conglomerates of units 17, 23, and 32 are of the rounded quartz pebble type and are discussed in the section on the Madison Valley formation.

The section from units 1 through 15 resembles the Belmont Ranch section with conglomerates of poorly sorted pebbles alternating with coarse sandstones and a few tuffs.

Units 40 through 44 strike S. 80° E. and dip 7.5° to the north. The remaining units strike N. 23° W. and dip 5° to the east-northeast.

The lower member is 519.4 feet thick and the upper member is 229.5 feet thick. The total thickness of the section is 748.9 feet.

UNIT	LITHOLOGY	THICKNESS (in feet)
44.	This unit consists of three types of deposits as revealed from a study of thin sections. 1. Sandstone, light gray, weathers white, friable, clayey looking; matrix largely a micaceous mineral of low birefringence; coarse particles of plagioclase and quartz are present with less common grains of microcline, garnet, muscovite, altered biotite, and a very few partly devitrified glassy fragments; non-calcareous. 2. Sandy tuff, light gray, weathers white, very friable; insects have bored holes into it; largely glass in shards and rectangular flakes; detrital material is altered biotite, plagioclase, microcline, quartz, garnet, and pellets of sericite and montmorillonite; non-calcareous. 3. Calcareous tuff, light gray, weathers white, friable; about a	152.4

UNIT	LITHOLOGY	THICKNESS (in feet)
	third to a half calcite; detritus consists of microcline, garnet, pyrrhotite, brown biotite, green hornblende, plagioclase, magnetite, quartz, and rare limestone pebbles.	
43.	Conglomerate, color gray at a distance, non-calcareous, fair cementation; coarse; pebbles range from size of coarse sand up to four inches, but pebbles of larger sizes give this unit its coarse character; pebbles are angular to sub-angular pieces of feldspar, pegmatite, and gneiss.	1.8
42.	Like unit 44.	12.5
41.	Covered. Obscures base of unit 42.	37.8
40.	Sandy tuff, light tan, weathers same, friable, non-calcareous, cliff-forming; contains a few scattered pebbles of sub-angular feldspar and rounded quartzite up to a half inch in diameter; a thin section shows that this rock is largely clear glass, in shards and in rectangular flakes, which has been altered at the fringes. Detrital material includes angular brown or green hornblende, angular garnet, sub-angular quartz with lesser amounts of augite, rutile, hypersthene, andesine, montmorillonite pellets, biotite, and sericite. Interstices filled with clay of low birefringence.	25.0
39.	Covered or eroded.	16.0
38.	Tuff, very light gray, weathers white, fine grained, non-calcareous, massive and ledge forming, compact, grains angular or acicular.	1.5
37.	Covered or eroded.	81.0

UNIT	LITHOLOGY	THICKNESS (in feet)
36.	Sandstone, buff, weathers light gray to buff, calcareous, well cemented, fine-grained, thin-bedded but ledge forming.	0.7
35.	Covered.	11.6
34.	Sandstone, buff, weathers light gray to buff, calcareous, well cemented, fine-grained, massive, ledge forming.	2.3
33.	Sandstone, light gray, weathers very light buff, calcareous but friable.	20.3
32.	Conglomerate, appears dark at a distance; excellent marker bed; over 75 percent of the rock consists of pebbles of well-rounded quartzite pebbles of various colors, generally one-half to two inches in diameter; sandy cement. This bed is very conspicuous, and blocks from it are strewn down the slope.	4.4
31.	Covered.	14.6
30.	Sandstone, tan, weathers light tan, fine-grained, highly calcareous; occasional small spots of calcite and tiny cavities lined with calcite are present.	1.2
29.	Covered.	8.2
28.	Siltstone, light gray, weathers very light buff, compact, calcareous, barely friable.	5.9
27.	Sandstone, light gray, weathers same; larger percentage of dark constituents than sandstones higher in the section.	2.2
26.	Covered.	14.2

UNIT	LITHOLOGY	THICKNESS (in feet)
25.	Sandstone, light gray, calcareous, compact, fine to medium-grained; a few scattered pebbles present.	1.4
24.	Covered.	3.3
23.	Conglomerate, well-cemented; largely rounded quartzite pebbles one-half to one-fourth inches in diameter in coarse sandy matrix.	3.2
22.	Covered.	5.5
21.	Limestone, light gray, weathers white, crystalline and compact.	1.2
20.	Alternating layers of conglomerate and sandstone, mostly covered.	39.5
19.	Limestone, white, weathers light gray, porous, fine-grained; probably tuffaceous.	2.9
18.	Volcanic tuff, white, weathers light buff, very friable, non-calcareous, particles acicular; contains a few obsidian particles.	0.4
17.	Conglomerate, sandy matrix, good cementation, non-calcareous; this bed consists of fifty percent by volume of rounded quartzite pebbles one-half to one inch in diameter.	0.9
16.	Tuff. Like unit 18.	4.7
15.	Conglomerate, general appearance is buff weathering to gray; conglomerate material is derived from a mixture of metamorphic and extrusive rocks; few sediments, no pyroclastics. Highly calcareous sandy cement; pebbles are sub-angular feldspars and sub-rounded quartzites and gneisses ranging from size of small sand up to four inches in diameter; ledge former; very similar in gross appearance to unit 11 and unit 13 of the Belmont Ranch section.	13.3

UNIT	LITHOLOGY	THICKNESS (in feet)
	Thin section shows that among the smaller grains the most abundant fragments are trachyte (?), very fine-grained and medium-grained, much microcline, and quartz. Also present are coarse quartz-plagioclase aggregates, green hornblende, pinkish garnet, sericite, basalt (?), and rare siltstone; matrix of medium-grained calcite.	
14.	Sandstone, buff, calcareous; generally coarse angular grains, some sub-rounded particles present; a few conglomeratic bands and scattered pebbles; alternates with conglomerate beds of the type of unit 15. A thin section reveals that this sandstone is argillaceous and contains brown clay veins; particles are quartz-microcline, microcline, plagioclase, biotite, hornblende, garnet, fine-grained igneous rock, siltstone, montronite or montmorillonite, and rare limestone. Matrix is micaceous.	3.3
13.	Conglomerate. Like unit 15.	2.3
12.	Covered.	19.6
11.	Tuff. Like unit 18.	11.8
10.	Sandstone. Like unit 14.	3.5
9.	Covered.	82.2
8.	Conglomerate. Like unit 15. Occasional sandy bands.	61.8
7.	Tuff. Like unit 18.	9.8
6.	Sandstone. Like unit 14.	1.0
5.	Conglomerate. Like unit 15.	13.4
4.	Sandstone. Like unit 14.	2.0

UNIT	LITHOLOGY	THICKNESS (in feet)
3.	Conglomerate. Like unit 15.	14.4
2.	Sandstone. Like unit 14.	1.5
1.	Covered to bottom of gully.	12.5
		748.9

Barton Creek Section. The Barton Creek section is indicated on the map as locality No. 4. This section was measured along the north wall of Barton Gulch in Section 15 and Section 16 in T. 7 S., R. 4 W.

The characteristic feature of this section is the large amount of volcanic ash in nearly pure beds and mixed with sand. However, the presence of many lensing beds of conglomerate and the presence of scattered pebbles throughout the sandstones shows that the section was deposited under the flood-plain conditions characteristic of the Madison Valley formation. The large amount of ash and the smaller amount and poorer cementation of the conglomerate mark this section as part of the upper member of the formation.

The cliffs along the northern side of Barton Gulch are conspicuous, even from a distance. The white color of unit 11 and unit 12 is striking (Plate 10 and Plate 11, Fig. 1).

Bone fragments were found in a small lens in unit 13.

The beds in this section strike N. 10° E. and dip 7° to the east. This measured section is 369.2 feet thick.

UNIT	LITHOLOGY	THICKNESS (in feet)
14.	Sandy tuff, light gray, weathers buff, poorly indurated, non-calcareous; partly covered slope former; unit contains several conglomeratic layers four inches to two feet in thickness; pebbles are largely sub-rounded or rounded quartzite.	23.7
13.	Conglomerate, dark gray from a distance, sandy matrix, cliff former; pebbles are sub-rounded pebbles of gneiss and quartzite, usually one to two inches in diameter, in the upper part of the bed a few large cobbles up to a foot in diameter; unit contains several sand lenses. At one place, 2.8 feet from the base of the unit, there is a lens of material about six feet long which is 0.3 feet thick at the widest place. A few scattered bone fragments were found in it. A thin section shows that this unusual material is a friable sandstone with grains of fine-grained igneous rocks, glass, quartz, plagioclase, hornblende, and mica; but many of the grains have layers of white clay material around them, which give the bed its unusual appearance.	14.6

UNIT	LITHOLOGY	THICKNESS (in feet)
12.	Tuff, very light gray, very friable, non-calcareous, cliff forming, some cross-bedding; scattered bands of light gray chert. Thin section shows nearly pure ash, consisting almost entirely of colorless glass shards; there are a few crystalline grains of plagioclase, quartz, and zircon.	18.3
11.	Tuff, white, non-calcareous, very friable, cliff forming; unit contains a 0.5 foot bed of gray chert whose base is 0.7 foot from the base of the unit, several scattered thin bands of gray chert. Thin section shows this rock is almost entirely glass shards with a few silt-sized grains of quartz and feldspar.	3.8
10.	Altered sandy tuff, light tan to light gray, weathers buff, non-calcareous, friable. Thin section shows a matrix of yellow clay with abundant shards. Detrital material includes grains of garnet, augite, biotite, microcline, hornblende, plagioclase, sericite, and quartz.	58.2
9.	Conglomerate; pebbles generally small, but a few widely scattered cobbles up to eight inches in diameter are present; pebbles and cobbles are generally gneisses of several types with a few quartzites; matrix is sandstone, probably is tuffaceous; unit lenses and its contacts are poorly defined.	15.5
8.	Conglomerate, light gray, sandy matrix is non-calcareous; pebbles are an eighth to a half inch in diameter in the sandy matrix but range from four inches to a foot in diameter where large cobbles are concentrated along the base of this layer; unit is a cliff-capping layer.	3.2

UNIT	LITHOLOGY	THICKNESS (in feet)
7.	Tuffaceous sandstone, light gray, weathers buff, medium-grained, friable, non-calcareous, cliff-forming.	16.0
6.	Sandy clay (may be a sandy tuff sufficiently altered to destroy tuff structure), light brown, weathers light gray to tan, medium-grained, non-calcareous, friable, cliff-forming; contains a few scattered pebbles; several conglomeratic lenses 0.3 to 1.0 foot thick are present, which contain cobbles up to six inches in diameter; the unit is very similar in gross appearance to the altered sandy tuff of unit 10 of this section and to the sandy tuff of unit 40 of the Idaho Creek section. Thin section shows that the matrix is largely clay of moderately high birefringence; detrital grains are quartz, microcline, plagioclase (some fresh, some slightly sericitized) hornblende, garnet, pyrrhotite, magnetite, biotite, and microcline-quartz aggregates.	69.8
5.	Sandy clay, like unit 6, except in color, light gray, weathers gray.	6.4
4.	Sandy clay. Like unit 6, but not cliff-forming.	21.4
3.	Conglomerate, grayish from a distance; pebbles generally small consisting mainly of gneisses of several varieties with a few quartzites; sandy matrix.	2.7
2.	Tuffaceous sandstone, buff, weathers light tan, non-calcareous, friable; contains a few scattered pebbles.	93.7

UNIT	LITHOLOGY	THICKNESS (in feet)
1.	Alternating layers of conglomerate and tuff; conglomerate is coarse with a wide range of size, shape, and angularity; pebbles are quartzites, gneisses, pegmatites, feldspars, with a few rhyolite porphyries; some cobbles up to a foot in diameter. Volcanic tuff is dark gray and medium-grained with some cross-bedding. Thin section shows that this tuff is largely clear glass with well developed shard structure; smaller amount of brown isotropic glass with shard structure and bubbles, almost a scoria; also present are devitrified glass pellets, montronite pellets and shale (?) pellets; commonest crystalline material is quartz with grains of plagioclase also present.	21.9
		369.2

PALEONTOLOGY

Invertebrata

General. Fossil invertebrates of two classes were collected from the Tertiary sediments of the Ruby River Basin, OSTRACODA and INSECTA. The collections were made in the Passamari formation. No fossil invertebrates were found in the Madison Valley formation or in the Red Rock conglomerate.

Insecta. More than a hundred beautifully preserved fossil insect specimens were collected from a single quarry in the Passamari formation. The locality is shown on the map as fossil locality number one, in the northwest quarter of Section 25, T. 7 S., R. 5 W. The material in which they were preserved is very fissile, in part, paper thin, even textured sandy and silty clay. It was possible to split off easily thin plates of the shale and to examine their surfaces for the impressions or carbonized outlines of the small arthropods. The quarry is located on the south bank of one of the intermittent streams tributary to Peterson Creek (Plate 11, Fig. 2). The same quarry also yielded numerous fossil leaves to be discussed later. The state of preservation of the insects is so perfect as to permit identification in some cases of taxonomic groups as low as genera. Tentative identifications of the best specimens have been made by Drs. J. S. Rogers and T. H. Hubbell of the University of Michigan Museum of Zoology, and there follows a list of the groups represented in the collection:

List of fossil insects from locality 1

(all determinations tentative)

ORTHOPTERA

Acridae (short-horned grasshoppers) 3 specimens, all apparently of the same species, of the subfamily Acridinae, cf. Tybula.

DERMAPTERA (earwigs) one specimen, identification fairly certain.

COLEOPTERA (beetles)

3 specimens of uncertain family, apparently three separate species.

Elateridae (click beetles) 3 specimens including two species.

Scarabaeidae (scarabs) one specimen, fairly certainly a member of the Rutelinae, the same subfamily as the bumble-bee flower-beetles.

HYMENOPTERA

Tenthredinoidea (sawflies) 2 specimens.

Formicidae (ants) possibly one specimen.

HYMENOPTERA (Continued)

Apoidea (bees) one specimen.

2 specimens of a parasitic form of uncertain position.

PLECTOPTERA (Ephemerida) (Mayflies)

Baetidae, subfamily either *Siphlonurinae* or *Metretopinae*, two specimens of two distinct genera.

MEGALOPTERA (dobsons, etc.)

Sialidae (fish-flies) one specimen showing the color pattern of the wings.

DIPTERA

Tipulidae (craneflies)

Tipula, one specimen.

Brachypremna sp., one specimen of subtropical affinities, at present one species being common in Florida and the southeastern states and north to the Ohio River, and related species in the American tropics.

Chironomiidae (midges)

Chironomus? one specimen.

Syrphidae (flower-flies) one specimen.

A Fungus Gnat (either *Myectiphilidae* or *Rhyphidae*), two specimens.

HEMIPTERA (true bugs)

cf. *Coreidae*, one specimen.

HOMOPTERA

Cicadellidae (leafhoppers)?, one specimen.

cf. Fulgoridae (lantern-flies) one specimen.

Another specimen of uncertain position.

Most of the material in the collection was at least cursorily examined, but no other orders were seen. Additional Hymenoptera, Coleoptera, and Diptera were noted, however. (For illustrations of some of the better specimens see Plates 16—20).

Insects have comparatively little use at present as index fossils (Shimer and Shrock, 1944). All of the major and most of the minor taxonomic groups, including most families and many genera, have had unusually long geological ranges. The known Mesozoic and later insects are all essentially modern in appearance and affinities. Specimens are found abundantly in relatively few deposits. Furthermore, the highly specialized background required for their identification makes it difficult to profit from any stratigraphic value they may have. Ordinarily, they are found only in deposits which accumulated with great rapidity, and they are rarely present in wide-spread marine strata. Hence little can be said concerning the age of the Passamari formation from the stratigraphic distribution of the forms included in the above list. The grasshoppers

(Orthoptera) and the earwigs (Dermaptera), as far as is known, appeared in the Eocene (Berry, 1929) which may serve to limit the age of the Passamari to some epoch younger than Paleocene.

Ostracoda. Many poorly preserved ostracod specimens were collected from the Passamari formation. Fossil locality number three in the center of Section 13, T. 8 S., R. 5 W., and fossil locality number four in the northwest quarter of Section 28, in the same township, furnished all of these. Professor Fred M. Swain, of the Department of Geology and Mineralogy at the University of Minnesota, was kind enough to examine the specimens. He writes that they are simple forms which appear to belong to the genus Candona, a genus "found in the later Tertiary rather than the early Tertiary of the western interior," but he does not place much faith in them as index fossils. The genus belongs to the family Cypridae, which includes mostly freshwater forms (Shimer and Shrock, 1944). Little work has been done in this country on Cretaceous and Tertiary ostracods, and the work of European students of the class must be relied upon for information concerning their stratigraphic distribution. Woodward (1877) gives the range of the genus Candona as Carboniferous to Recent, although Glaessner (1945) in a more recent publication, gives its range as Devonian to Recent.

Apparently no conclusions can be reached regarding the age of the Passamari formation on the basis of invertebrate fossils, other than a designation of post-Eocene.

Vertebrata

General. Identifiable vertebrate remains were collected from three localities in the northern portion of the basin, all in the Madison Valley formation. Only one form, a horse, was taken from each locality. Some fragmentary limb and toe bones of camelids were found and a portion of the carapace of a large turtle, but these latter finds are too incomplete to permit further identification. In addition, a few fish scales were found in the Passamari formation (Fossil locality 4), but taken alone have no stratigraphic significance. From a paleontological standpoint they are interesting insofar as they offer evidence of the existence of freshwater fishes in the region at the time. The following discussion will deal solely with the identifiable horse remains. (For illustrations of the various vertebrate specimens in the collection, see Plates 21, 22).

Equidae. Teeth of fossil horses were found in three localities in the Madison Valley formation by Mr. Henry P. Zuidema, a member of the writers' party. An upper left second molar ($LM^{\underline{2}}$) was collected from an exposure of the Madison Valley formation in Section 9, T. 9 S., R. 5 W., (fossil locality number 5 on the map). It now bears University of Michigan Museum of Paleontology Catalogue Number 24335. The enamel pattern on this tooth is very distinct, and conforms closely to the diagnostic characteristics of the genus *Merychippus* as reviewed by Osborn, (1918). It closely resembles the pattern shown on the type specimen of *Merychippus* (*M.*) paniensis. The type figure of this species has been reproduced by Osborn (1918). The tooth in this collection is larger than the type, however, and in this respect is closer to the type specimen of *Neohipparion coloradense*, which also has a similar enamel pattern.

An upper left third molar ($LM^{\underline{3}}$) was taken from another typical Madison Valley exposure in the same section and near the same locality as tooth 24335. It bears the University of Michigan Museum of Paleontology Catalogue Number 24333. It was not possible to develop the enamel pattern by acid etching so it was necessary to cross-section the tooth before identification was possible. The enamel pattern has characteristics in common with both the genus *Merychippus* and the genus *Neohipparion*. The protocone is bulbous and in cross-sections made near the base of the tooth, joins with the protoconule. The plications of the pli-prefossette and pli-postfossette are only moderately complicated. The pre-fossette is incompletely enclosed, opening lingually to the base of the tooth.

A series of cheek teeth were collected from the Madison Valley formation in the northwest quarter of Section 12, T. 8 S., R. 5 W., (fossil locality number 6 on the map), (see Plate 22, figs. 5, 6 and Plate 12, fig. 1), and are catalogued in the University of Michigan Museum of Paleontology collection under the number 24334. The series includes the upper left fourth premolar through the upper left third molar ($LP\underline{4}$ through $LM\underline{3}$), and here acid etching rendered the enamel patterns sufficiently plain to make identification possible. The enamel patterns on the teeth of this series compare closely to the figures of specimens of the species Merychippus (P.) secundus as reproduced by Osborn, (1918), but are somewhat larger. The horizon in the Madison Valley formation from which this specimen was taken is included in the "Belmont Ranch" section discussed earlier in this report under Stratigraphy. The other two localities from which specimens of horses' teeth were taken could not be included in measured sections because of the limited amount of time available for field work. Therefore the stratigraphic positions of the other teeth in the

Madison Valley formation cannot be given exactly. They may have occurred higher in the section than the teeth found in the Belmont Ranch section.

In addition to the specimens discussed above, a metacarpal and associated phalange typical of the genus *Merychippus* were found in Section 9, T. 9 S., R. 5 W., and bear Catalogue Number 24336.

The type specimen of *Merychippus secundus* was taken from the Sheep Creek phase of the Arikaree formation of Western Nebraska. Osborn (1918), placed these beds in the lower middle Miocene. H. J. and M. C. Cooke (1933) considered these beds as middle and upper Miocene. H. E. Wood, et al, (1941), refer to the Sheep Creek fauna as being middle Hemingfordian (middle lower Pliocene) in age.

The type of *Merychippus paniensis* was found in the Pawnee Creek beds of Colorado, which Osborn (1918) referred to late middle Miocene. The species has also been recorded in the Deep River beds of Montana, which were regarded by Osborn as being slightly younger than the Mascall beds of Oregon. The Pawnee Creek beds are considered by Wood, et al, (1941) as being lower Barstovian, (upper Miocene) in age.

The type of *Neohipparion coloradense* was collected from the Sand Canyon beds at the head of Pawnee Creek, Logan County, Colorado. Osborn (1918) regarded the age of these beds as lower Pliocene. Wood, et al (1941), are of the same opinion as Osborn as to their age.

The specimens of horses' teeth collected from the Madison Valley formation are not complete enough to allow definite generic or specific identifications. The enamel patterns on all of the teeth are very similar and the teeth belonged to very closely related, perhaps identical, species. In a general way the patterns resemble more closely those found on teeth of the genus *Merychippus* than those of the genus *Neohipparion*. If enamel pattern alone were the criterion, both generic and specific identifications could be made. Tooth size, shape, and degree of hypsodonty are also important characteristics, though, and all three specimens are too large to be identified as belonging to any of the species of *Merychippus* whose enamel patterns are similar. The specimens are more closely comparable in size to some of the *Neohipparion* teeth. Some primitive species of the genus *Neohipparion* also had enamel patterns somewhat similar to those found on the teeth in the collection. The genus *Merychippus* is now generally accepted as having given rise to the genus *Neohipparion* and a close resemblance can be expected to exist between teeth of these two genera. The teeth in the collection undoubtedly belonged to either an advanced Merychippus or a primitive Neohipparion.

The genus Merychippus is held by Wood, et al, as first appearing in the Clarendonian (middle Miocene), being characteristic of the Barstovian, and last appearing in the Hemingfordian (lower Pliocene). Simpson, on the other hand (1945), considers the genus to have occurred only in the middle and upper Miocene.

The genus Neohipparion is considered by Simpson (1945) and Wood (1941) to have had a stratigraphic range of lower to upper Pliocene, inclusive.

The identifications of the species of horses in this report were based upon comparison with figures of type specimens in the literature. Many of the specimens figured have since been re-identified or their taxonomic positions shifted by subsequent revisions of the Equidae, so that while the type figures are still valid, their generic and specific designations have been changed. The generic designations of the three specimens discussed in this report are based upon the recent work of R. A. Stirton (1940) on the "Phylogeny of the North American Equidae." For example, Douglass, (1903), in his early work on the Tertiary mammalian faunas of Montana, frequently records the occurrence of the "genus" *Protohippus* among the horses. It is to be noted that this genus has been reduced to subgeneric rank within the genus *Merychippus* by Stirton, hence the designation *Merychippus* (*P.*) *secundus* is used here. Likewise, *Neohipparion coloradense* was first described as *Hipparion coloradense*. Also to be noted is the fact that *Merychippus* (*P.*) *secundus* was originally described (Osborn, 1918) as a sub-species of the species *M. isonesus*, being referred to as *M. isonesus secundus*. This sub-species has since been elevated to specific rank and the term "*isonesus*" dropped.

Fossil Plants

Numerous excellent leaf and seed impressions and their carbonized outlines were found in the Passamari formation at fossil locality number 1, in the same beds as those in which the insects previously mentioned were found. Another fossil locality, number 2 on the map, in the same section as locality number 1 but about 500 yards south, also yielded many plant fossils. From among the specimens taken at fossil locality 1, the following have been recognized:

Needles of a conifer, found in a group of four. Modern pines have needles grouped in twos, threes, and fives. This specimen probably had five needles originally and indicates the presence of White Pine.

Simple, slender, willow-like leaves possibly of several species.

Ailanthus (Tree of Heaven), one fruit (samara).

cf. Taxodium (Swamp Cypress). May be Sequoia. Most of the complete specimens of this type in the collection consist of a twig of about the same length, the base of which is surrounded by a group of bracts or scales. The consistent length of these specimens indicates a characteristically deciduous conifer and renders the designation Taxodium probably more correct than Sequoia.

Specimens in the collection taken from the pit at locality number 2 are almost all of the Taxodium sort.

Herman F. Becker made a separate collection of fossil plants from both locality 1 and locality 2. He has studied this material independently and his tentative identifications are listed as follows (1947):

Sequoia sp.

Sequoia heeri?

Sequoia haydeni?

A fern - position not stated

A seed pod or tuber - unidentifiable

Nyssa? fruits (or maybe bulbous roots of Equisetum)

A leaf, apparently fagaceous (Beech family)

Populus zaddacki?

Betula multinervis (or Alnus relatus)

Becker remarks that some of the above species are found as early as upper Eocene and are still found in the Miocene.

The use of plants as index fossils in the correlation of Tertiary deposits is uncertain in light of our present knowledge. Many of the early conclusions of paleobotanists as to the stratigraphic range of Tertiary floras are now being subjected to closer scrutiny and to question. The occurrence, however, of Ailanthus in the collection is significant. This genus had a world-wide distribution at one time or another during the Tertiary, but was never abundant in any one place. It is known to have occurred in North America in the Miocene and may have been present in the Oligocene, but the latest known occurrence of the genus on this continent is in the Mascall beds of Oregon. Thus it disappeared from North America in late middle or possibly early upper Miocene and did not reappear here until the year 1820 when it was reintroduced by man, on Long Island. At present it is indigenous only to China.

The problem of the age of the *Taxodium* or *Sequoia*-like plants is less amenable to solution. Both are still found native on this continent, *Taxodium* as a sub-tropical genus in southern United States and *Sequoia* as a genus indigenous to the far West and Northwest. Neither ~~are~~ is found native in the western interior of the United States at the present time, however both are known to have had more extensive geographical distributions earlier in the Tertiary. The time at which *Taxodium* disappeared from the western interior is not well known. *Sequoia* occurred in Montana as late as early or middle Miocene. Since it appears most probable that the specimens in this Montana collection are *Taxodium* rather than *Sequoia*, the known presence of *Sequoia* in the Montana Miocene has doubtful significance. Although *Taxodium* now favors a sub-tropical habitat, it is quite possible that some species of the genus may have been well suited to an environment, in the Miocene, similar to that in which *Sequoia* is found today. Thus, further study of the specimens might show that both genera were closely associated in the Miocene. (For illustrations of fossil plants contained in the collection, see Plates 23—25.)

Age of the Passamari formation

The presence of grasshoppers, earwigs, and late Tertiary ostracods precludes a Paleocene or Eocene age for the Passamari formation. The occurrence of *Ailanthus* possibly restricts its age to early or middle Miocene. Its stratigraphic position below the Madison Valley formation, which is probably upper Miocene to lower Pliocene in age, places an upper limit on its age. It is, therefore, concluded that the Passamari formation is early or middle Miocene in age.

Age of the Madison Valley formation

The presence of horses of an advanced *Merychippus* or primitive *Neohipparion* type in the formation indicates that the formation is probably upper Miocene to lower Pliocene in age. How far the age of the Madison Valley formation extends into the Pliocene cannot be definitely determined at this time. The detailed measured sections did not include the thick sections exposed in the basin south of the juncture of the Ruby River and Sweetwater Creek, so it is not known whether the uppermost beds of the Madison Valley formation were included in any of the measured sections. On the basis of paleontologic evidence and lithologic similarity, this formation is correlated with the Madison Valley formation, which has been described from the region 20 miles south of Three Forks, Montana, (Douglass, 1903). Wood (1941) considers the age of the Madison Valley formation to be upper Miocene and lower Pliocene. Unless further study reveals otherwise, the Madison Valley formation in the Ruby River Basin may also be considered as upper Miocene to lower Pliocene in age.

STRUCTURE

Mapping of the area under consideration was of the crudest sort, and consisted of placing surface outcrops and other observed geologic phenomena on a Madison County, Montana, road map in positions selected by visual inspection of the map and the terrain. Because of the large area of the basin inspected, and the great distances to land marks of known position on the map, resection with the Brunton Compass was found to be less accurate than the visual inspection method as a means of locating positions. Section corners were used as guides in two instances. No benchmarks were found, and conclusions reached with regard to the relationships of outcrops to one another in the vertical dimension were based on estimate for the most part. Leveling with the Brunton Compass was only feasible over short distances, and was not relied upon to any great extent. Lack of time precluded the investigation of regional structure about the Ruby River Basin. Hence, structural conclusions are drawn for the most part on inference in this discussion. The work should be considered purely as a reconnaissance which may serve to suggest the direction more detailed and accurate work might take in the future. It was possible, however, to recognize certain structural and stratigraphic relationships between the Tertiary basin beds and the surrounding pre-Tertiary rocks. The following discussion will present these relationships and attempt to interpret from them a plausible structural history for the basin.

The Tertiary deposits of the Ruby River Basin, within the limits of the area inspected, and as shown on the accompanying map, are confined entirely by pre-Cambrian rocks made up of gneisses and schists of the Cherry Creek group and Pony formations (USGS, 1947). Earlier workers made no distinctions among the various Tertiary deposits of the basin, and referred to them as Tertiary - undifferentiated, Tertiary lake beds, or in some instances as Bozeman lake beds. As has been shown, at least three distinct Tertiary formations can be recognized within the basin, and their sedimentational characteristics imply a long and varied structural history for the basin.

The lowest and also the oldest stratigraphic unit is the Red Rock conglomerate. The significant fact, with respect to this unit, is that in it alone are found any evidences of the earlier existence of Paleozoic and perhaps also Mesozoic rocks in the region now occupied by the northern part of the basin. The conglomerate is composed almost entirely of Mississippian limestone pebbles in a red limestone matrix. Neither of the two later Tertiary formations, the Passamari or the Madison Valley, contain any recognizable amount of material derived from Paleozoic or Mesozoic rocks. They are composed entirely of either volcanic ash of Tertiary age or igneous and metamorphic rocks of the same type as are found at the present in the pre-Cambrian rocks surrounding the basin. It is apparent that a long interval of early Tertiary, perhaps Paleocene, erosion had stripped back the Paleozoic and Mesozoic rocks to such an extent that they lay outside the headwaters of the streams which began to flow into the basin when it formed later in the Tertiary. The Red Rock conglomerate may represent patches of detritus left over the region as a result of this long erosional cycle. It is convenient to postulate moderate regional upwarping in order to satisfactorily explain the removal of the Paleozoic and Mesozoic rocks from the vicinity of the basin, but no direct evidence can be shown to substantiate this assumption at present. Surface outcrops of the conglomerate within the basin are limited to a rather small area between Peterson and Garden Creeks west of the Ruby River Storage Reservoir.

The Passamari formation is restricted in outcrop to the northwest side of the basin between Peterson and Sweetwater Creeks. Along Sweetwater Creek the formation dips gently southwestward at an angle of about 9° (Plate 8, fig. 2). Farther to the northeast the shales are covered by a veneer of detritus and are exposed only in small patches in arroyo bottoms thus rendering a determination of dip difficult. The contact between the Passamari and the Red Rock was not observed, but the Passamari is known to underlie the Madison Valley formation and the latter can be seen to overlap the Red Rock where the Passamari is absent, so it can be concluded that the Passamari is younger than the Red Rock conglomerate and older than the Madison Valley formation. The contact between the Passamari formation and the overlying Madison Valley formation can be seen at only one locality in the basin, north of Sweetwater Creek. This locality is about a mile and a half west of the Williams Ranch, in Section 28, T. 8 S., R. 5 W. Here the two formations parallel one another and both are dipping about nine degrees toward the southwest (see Plate 8, fig. 2). North of Sweetwater Creek and west of its juncture with the Ruby River in the west half of Section 13, T. 8 S., R. 5 W., the light shales of the Passamari formation have been upfaulted so that they now abut the Madison Valley formation rather than underlie it (Pl. 12, fig. 2). The fault trends northwest - southeast and can be traced for about one mile northwestward from the road which runs along Sweetwater Creek. The fault dies out southwestward upon reaching Sweetwater Creek. The fault can be easily recognized and traced for a short distance toward the northwest where the lower Passamari can be seen faulted up against the Madison Valley beds. Farther northwest the Madison Valley beds have been removed by erosion and here the offset relationship between the beds on each side of the fault cannot be seen so the trace of the fault is lost.

Along Barton Creek the Madison Valley beds dip 7° to the east. Along the lower part of Idaho Creek the dip is 5° East while farther upstream the dip changes to about 8° to the Northeast. Near the junction of the Ruby River and Sweetwater Creek the Madison Valley formation dips 15° to the Northeast. South of Garden Creek, along the west side of the reservoir, the beds are essentially horizontal.

The nature of the contact between the basin beds and the pre-Cambrian of the bordering Ruby Range and Greenhorn Mountains is not easy to determine. In most places along the margin of the basin the contact is obscured by a fringing accumulation of late Tertiary to Recent gravels. This is particularly true along the front of the Greenhorn Mountains where the gravels form a broad apron over the Madison Valley formation (Pl. 15, fig. 2). In no place do the basin beds extend past the pre-Cambrian front of the mountains or up along any of the creeks which emerge from the mountains. Furthermore, the basin beds all terminate abruptly at the pre-Cambrian which rises steeply to form the mountains. The pre-Cambrian spurs, between the creeks which emerge from the mountains, are all truncated along the margins of the valley. A fairly straight line may be drawn along these truncated spurs, especially on the eastern side of the basin. The increased inclination of the slope encountered in passing from the basin beds and marginal gravels onto the pre-Cambrian is distinct along both sides of the basin (Pl. 15, fig. 2). In view of the foregoing it seems reasonably safe to conclude that the basin is bounded on both sides by normal faults and has the characteristics of a graben. Some precedent can be found for this view. On the United States Geological Survey Preliminary Map number 25, which is a Geologic Map of Montana (USGS 1947), two faults are shown along the west side of the Snowcrest Range. These faults are shown as paralleling the margin of the southern part of the Ruby River Basin and merging as they approach the Ruby River toward the north. They are doubtfully extended along the east ? side of the Greenhorn Mountains. The Greenhorn Mountains are a northern extension of the Snowcrest Range physiographically, and it seems quite probable that the two groups of mountains are a single structural unit also, separated only by the gap cut by the Ruby River in flowing across them. The writers would extend the fault shown on the USGS map northward along the west side of the Greenhorn Mountains, and the fault is thus shown on the accompanying map. The present elevation of the mountains east of this fault may be due at least in part to movement along this fault.

North of the dam at the head of the basin, the trend of the Ruby Range swings in a gentle curve to the north-northwest and forms the southwestern boundary of another broad valley in which the town of Alder, Montana, is located. On the USGS Preliminary Map number 25, a fault is shown to exist along this portion of the Ruby Range and in the field a well-developed fault scarp or fault line scarp can be seen along the mountain front (Pl. 13, figs. 1, 2). It is evident that the great pre-Cambrian block which forms the present Ruby Range has been uplifted by faulting. The fault along the northwestern margin of the Ruby River Basin may be a southward extension of the fault which is so clearly seen forming the face of the Ruby Range west of Alder, Montana. Certainly the two faults are closely related. Hot springs, hot spring deposits (Pls. 6, 7), lava flows, and old volcanic necks along the margins of the basin (Pl. 8, fig. 1) may provide further evidence in substantiation of the belief that these faults are present here.

In the preceding sections on stratigraphy and paleontology, it was demonstrated that the probable ages of the Passamari and Madison Valley formations are early to middle Miocene, and late Miocene to early Pliocene, respectively. The Madison Valley formation contains large amounts of volcanic ash and tuff. The Passamari formation was deposited in a shallow lake or lakes which occupied the area of the present northern Ruby River Basin, whereas the Madison Valley formation is a fanglomerate composed largely of coarse materials eroded from the surrounding uplifted mountains of pre-Cambrian rock. On the basis of the evidence that has been presented, a series of generalized cross-sections are included (Plate 3). They represent an attempt to recount the geologic and geomorphologic history of the basin, and to explain the mode of deposition and source of the materials which compose the Tertiary formations of the basin.

GEOMORPHOLOGY

Paleozoic and Mesozoic rocks in the Cretaceous and early Tertiary were probably present in the region now occupied by the Ruby River Basin. Upwarp of the region, accompanied by folding of the pre-Tertiary rocks occurred during the Laramide orogeny and was followed by a long interval of erosion in the early Tertiary. The Paleozoic and Mesozoic rocks were stripped back from the area of the basin, exposing the pre-Cambrian except where it was covered by a veneer of Red Rock conglomerate (Paleocene?). The Red Rock conglomerate consists, to the greatest extent, of materials that were derived from pre-existing rocks of the region during the erosional interval. In the following Eocene and Oligocene much of this conglomerate may have been removed but remnants of it at least are still found in the basin. In early to middle Miocene the site of the present basin began to sag with perhaps some faulting along the margins of the sag. Regional volcanic activity dammed the Ruby River downstream and lakes formed in which accumulated the sandy and silty clays of the Passamari formation. In upper Miocene normal faulting along the present basin margins carried the pre-Cambrian to considerable heights and accelerated erosion resulted in the dumping of large amounts of poorly sorted material in the basin. Continued regional vulcanism contributed ash and thus the Madison Valley formation was formed during the upper Miocene and lower Pliocene. Volcanoes and hot springs developed along the faults, the hot springs continuing to flow to the present in some places. Later in the Tertiary, following the consolidation of the Madison Valley sediments, faulting recurred along the margins of the basin cutting the Madison Valley formation and resulting in the spread of gravels over the fault line onto the Madison Valley formation. These gravels, shown as "fault line gravels" on the map, are best developed along the eastern side of the basin, and are as yet unconsolidated whereas the Madison Valley formation is rather well consolidated and cemented throughout.

Since the deposition of the Madison Valley formation, minor faulting within the basin has taken place. As a result, the basin beds have been tilted and in one place the Passamari formation has been brought up against the overlying Madison Valley formation (Plate 12, fig. 2). The exposure along the western side of the Ruby River Storage Reservoir of the Red Rock conglomerates may be a result of uplift due to the same minor faulting.

Four surfaces have developed in the basin. All but one, the highest, are post-Miocene in age since they, significantly, were formed on or over the Madison Valley formation. In chronologic order, the highest and oldest of these surfaces is an erosion surface, the remnants of which form the level tops and skyline of the Ruby and Greenhorn Ranges (Plate 15, fig. 2). This erosion surface is probably early Tertiary in age and formed during the long erosional interval which removed the Paleozoic and Mesozoic rocks from the region and exposed the pre-Cambrian (Plate 15, figs. 1, 2; Plate 14, fig. 1). On cross-section 6 (Plate 3), this surface is referred to as the "high erosion surface." The next oldest surface within the basin is a pediment cut on and beveling the beds of the Madison Valley formation. It is best developed along the eastern side of the basin and forms a gently sloping surface from the margin of the more recent fault line gravels basinward to the bluffs along the present Ruby River flood plain (Plate 15, figs. 1, 2). This pediment formed following a recurrence of movement along the marginal faults which further uplifted the mountains and rejuvenated the tributaries to the Ruby River. At present this pediment surface is drained by small intermittent streams which flow across the pediment surface in very shallow gullies and drop down over the bluffs from the pediment onto the present flood plain. They either flow directly into the Ruby River or join one of the main tributaries of the Ruby River. The main tributaries of the Ruby River, such as Barton and Idaho Creeks, have incised themselves deeply into the Madison Valley formation below the pediment, indicating that they probably were in existence and had developed extensive headwaters prior to the recurrent faulting. The recurrence of faulting along the margins of the basin, followed by recession of the fault scarp, has resulted in the deposition of a blanket of gravels which extend from the pre-Cambrian rocks at the mountain fronts out over the Madison Valley formation. These gravels form what is probably a depositional surface, topographically higher but chronologically younger than the pediment. The pediment and this higher surface are shown on (Plate 3, fig. 6) and (Plate 15, figs. 1, 2). The present flood plain of the Ruby River forms what may be considered a fourth surface.

The Ruby River is an antecedent stream which occupied its present course prior to the faulting and uplift of the Snowcrest and Greenhorn Ranges. Within the basin, the tributaries of the Ruby River developed subsequent to and as a result of the basin faulting. Their courses have been determined by the conformation of the basin so that, typically, they flow directly outward from and normal to the mountain fronts, entering the Ruby River, which flows parallel to the ranges, at right angles.

No evidence of glaciation was found within the basin and limited work by others has failed to indicate any glaciation within the surrounding ranges. Shaler (1902) reported the occurrence of a gravel high on Old Baldy Mountain in the Greenhorn Range which had the appearance of glacial drift but proved to be stream gravel.

Shaler (1902) has suggested that the broad valleys of this region may be entirely the result of erosion by the existing river and their tributaries. Since faults that bound the Tertiary deposits are definitely known to occur along both sides of the Ruby River Basin, they must be considered in the evolution of the basin. It seems that the Ruby River occupied its present course across the Snowcrest Range before the Ruby Basin faulting occurred, and was able to maintain its course as the Snowcrest and Greenhorn Ranges rose across its path. The basin resulted first by erosion, and later by faulting in the middle and upper Miocene and lower Pliocene.

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PLATE 1

EXPLANATION OF PLATE 1.

Regional map of southwestern Montana showing the location of the northern part of the Ruby River Basin in red.

PLATE I

E. Raisz

INDEX MAP

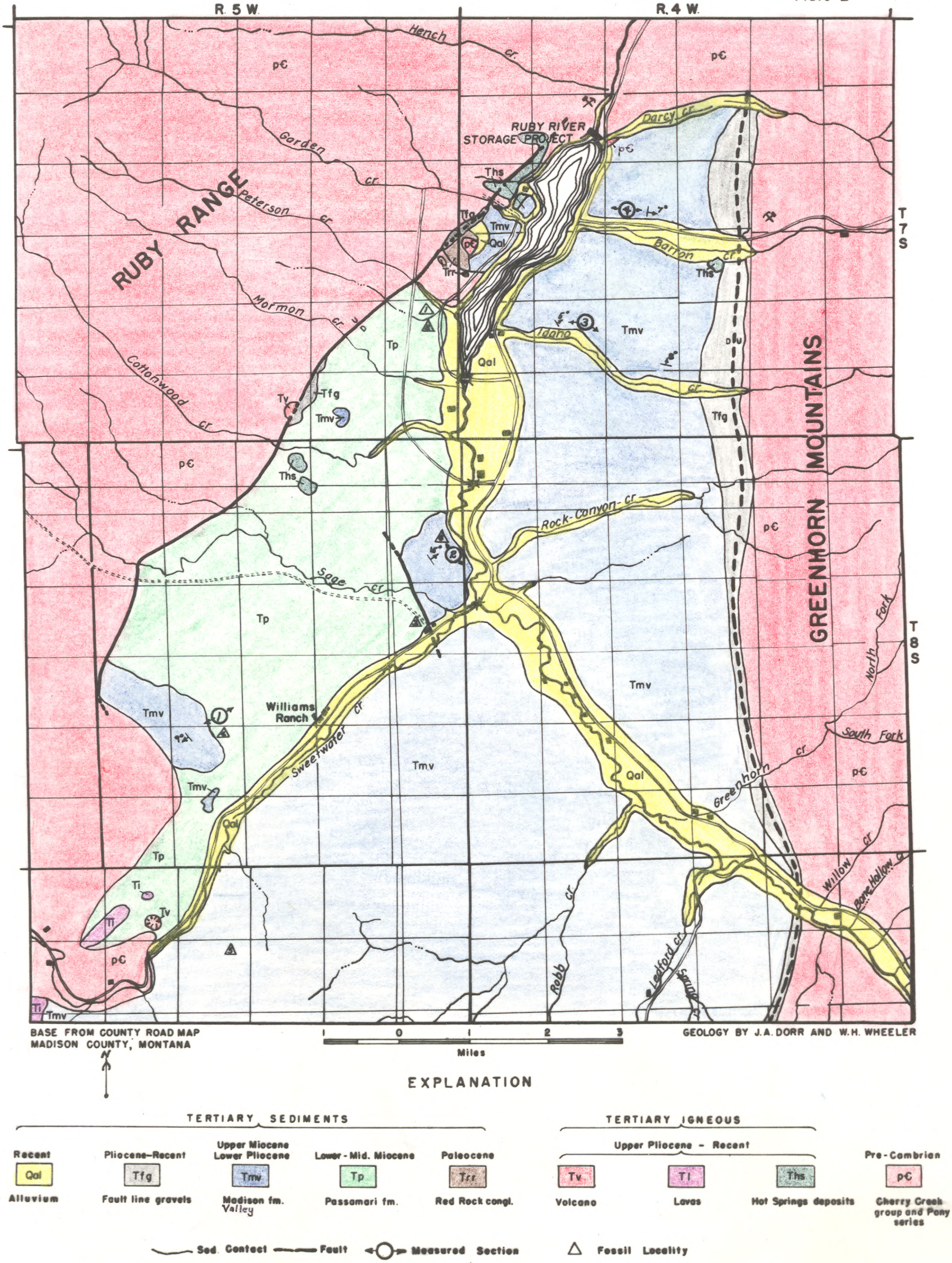
EXPLANATION OF PLATE 2.

Geologic map of the northern part of the Ruby River Basin.

PLATE 2

GEOLOGY OF THE RUBY RIVER BASIN

Plate 2



EXPLANATION OF PLATE 3.

Cross-section 1 - Possible pre-Tertiary aspect of the region. Paleozoic and Mesozoic rocks shown as extending over the area of the present basin.

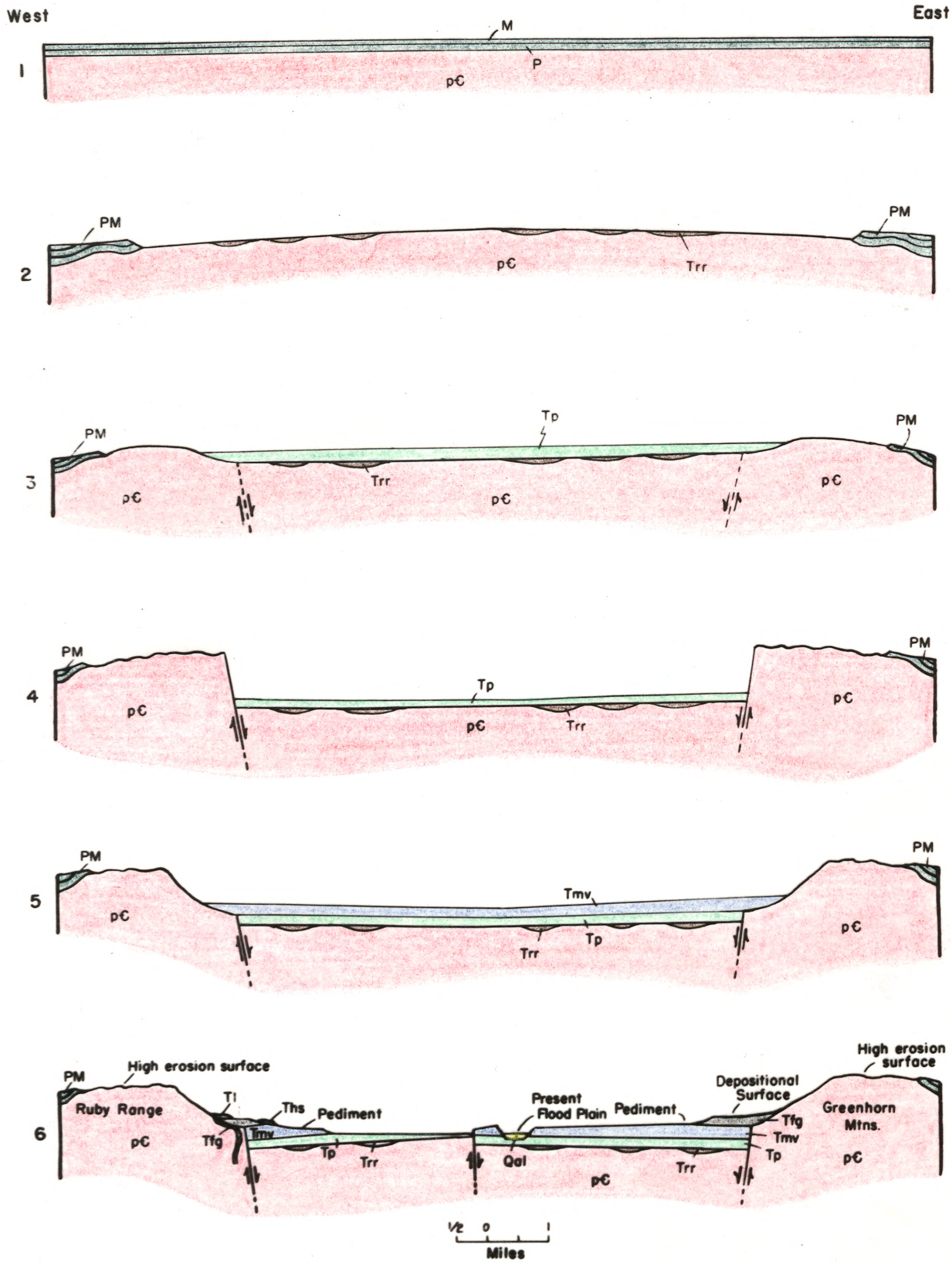
Cross-section 2 - Regional upwarping and folding during Laramide orogeny, followed by long period of Early Tertiary erosion. Paleozoic and Mesozoic rocks stripped back exposing the pre-Cambrian with patches of Red Rock (Paleocene ?) conglomerate left on the irregular surface. The "high erosion surface" formed at this time.

Cross-section 3 - Early to middle Miocene sagging of portion of uplifted region. Inception of regional volcanic activity with resultant downstream damming and deposition of the Passamari formation as lake beds in the basin. Possibly some faulting beginning along flanks of the sag. Pre-Cambrian and Red Rock conglomerate covered.

Cross-section 4 and 5 - Upper Miocene and lower Pliocene block faulting. Passamari formation cut by faults. Pre-Cambrian upfaulted in Greenhorn, Ruby, and Snowcrest Ranges. Erosion causes fault scarps to recede rapidly, the material derived filling the basin with fanglomerates of the Madison Valley formation. Extensive regional volcanic activity. Early Tertiary erosion surface uplifted and left forming "high erosion surface" on top of ranges bordering basin.

Cross-section 6 - Pliocene (upper) to Recent recurrent movement along marginal faults, cutting Madison Valley formation. Further erosion of pre-Cambrian with fault line gravels obscuring the fault and spreading out over the Madison Valley formation. Possibly contemporaneous faulting and tilting of the basin beds with subsequent erosion exposing the Passamari and in a restricted area the Red Rock conglomerate. Small volcanoes, lava flows, and hot spring deposits develope along faulted margins of the basin. Erosion truncates Madison Valley beds to form pediment. Possible depositional surface formed on top of fault line gravels. Present flood plain of Ruby River last surface to come into existence.

PLATE 3



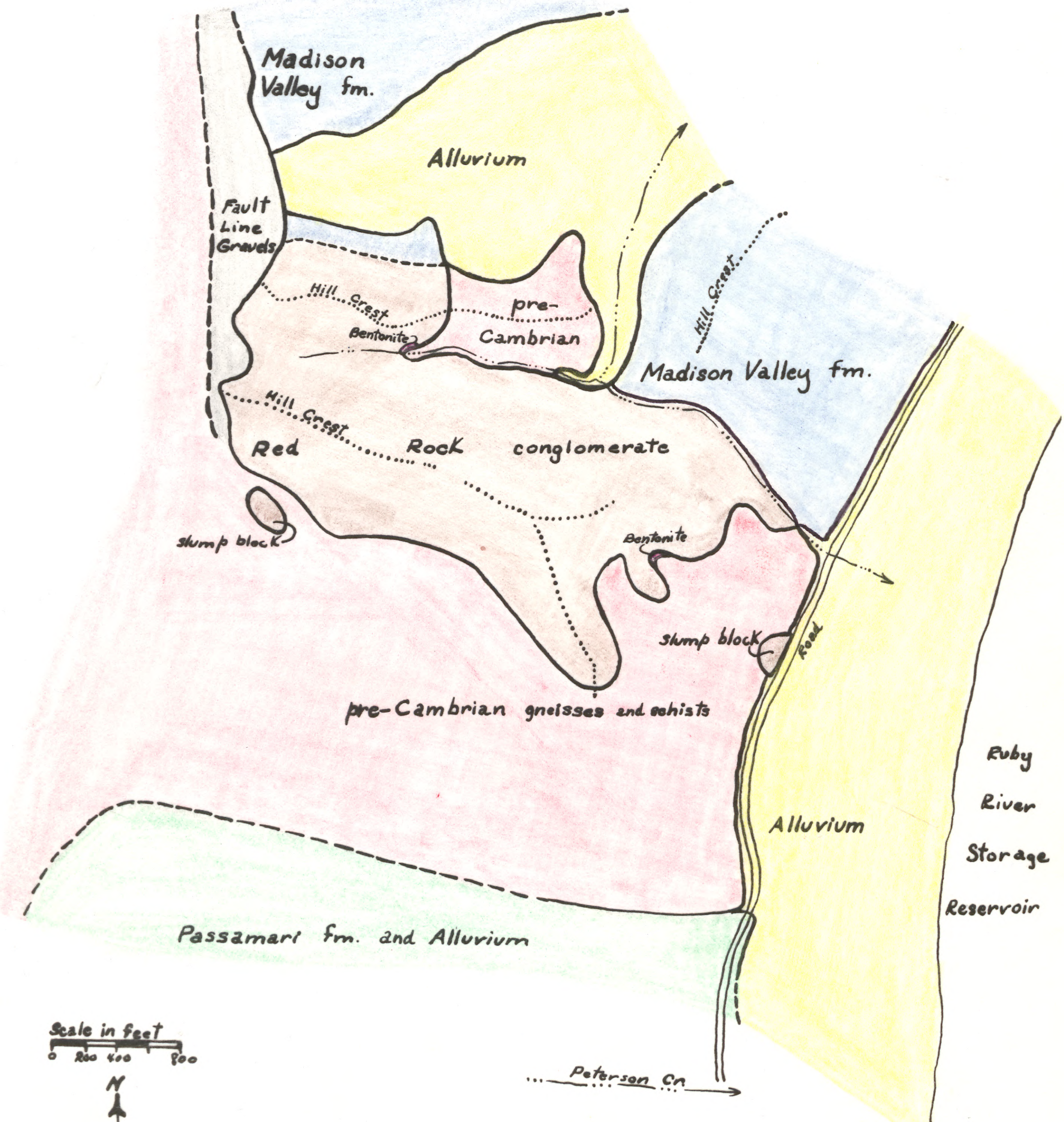
GENERALIZED CROSS-SECTIONS SHOWING GEOLOGIC HISTORY OF RUBY RIVER BASIN

Ta	Recent Alluvium	Tmv	Madison Valley fm.
Tl	Lavas	Tp	Passamari fm.
Ths	Hot Springs Deposits	Trr	Red Rock conglomerate
Tfg	Fault-line gravels	PM	Paleozoic and Mesozoic
		pЄ	pre-Cambriam

PLATE 4

EXPLANATION OF PLATE 4.

Detailed map of the hill of Red Rock conglomerate and vicinity.



Pace and Compass Map of
Outcrop Area of Red Rock Conglomerate, and Vicinity

EXPLANATION OF PLATE 5.

Kodachrome picture showing colorful hot springs deposits between Garden and Hench Creeks.

PLATE 5

Plate 5

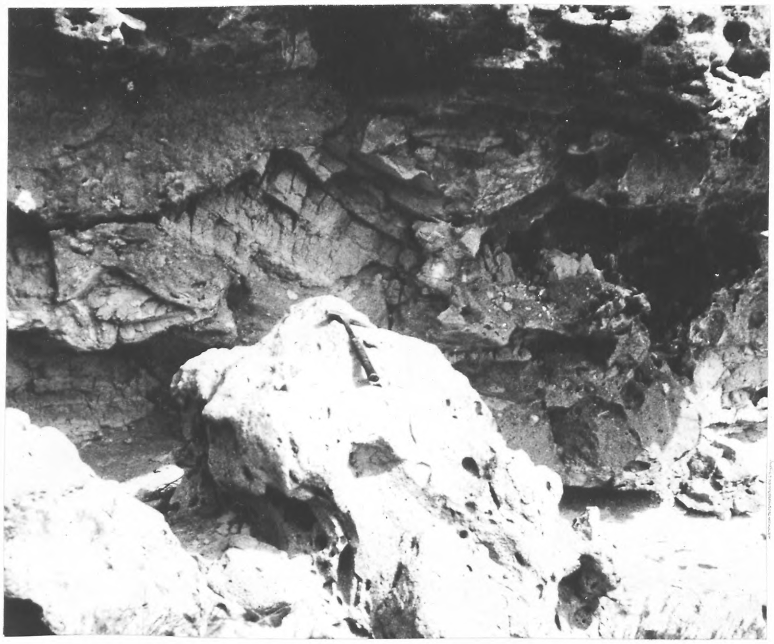
EXPLANATION OF PLATE 6.

Figure 1 - Unusual occurrence of clay boulders in the Madison Valley conglomerate, between Cottonwood Creek and the Belmont Ranch measured section.

Figure 2 - Eroded hot springs limestones near Hench Creek.

PLATE 6

Plate 6



1.

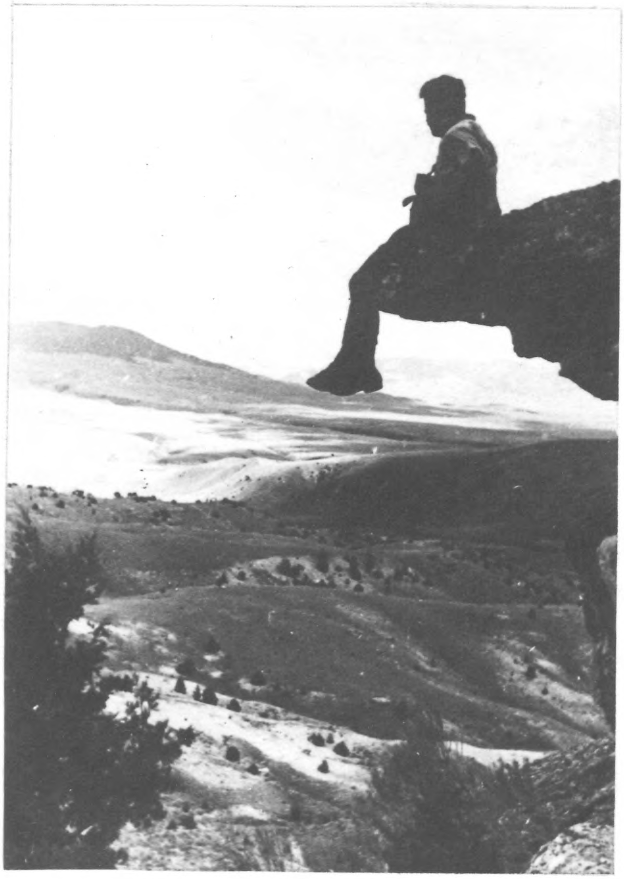
2.

EXPLANATION OF PLATE 7.

Unusual erosion remnant of hot springs limestone near Garden Creek. Ruby River floodplain and pediment surface on the Madison Valley formation can be seen in the distance.

PLATE 7

Plate 7



EXPLANATION OF PLATE 8.

Figure 1 - Volcanic neck near bend of Sweetwater Creek.

Figure 2 - View showing Sweetwater Creek measured section. Tan sandstone of the Madison Valley formation overlies white shale of the Passamari formation.

PLATE 8

Plate 8

1.

2.

EXPLANATION OF PLATE 9.

Figure 1 - Cliffs of Madison Valley conglomerate along main road about three miles south of Idaho Creek.

Figure 2 - Typical exposure of the lower Madison Valley formation in the Belmont Ranch measured section.

PLATE 9

Plate 9

1.

2.

EXPLANATION OF PLATE 10.

Cliffs along northern side of Barton Creek showing the Barton Creek measured section. Typical upper Madison Valley formation.

PLATE 16

Plate 10

EXPLANATION OF PLATE 11.

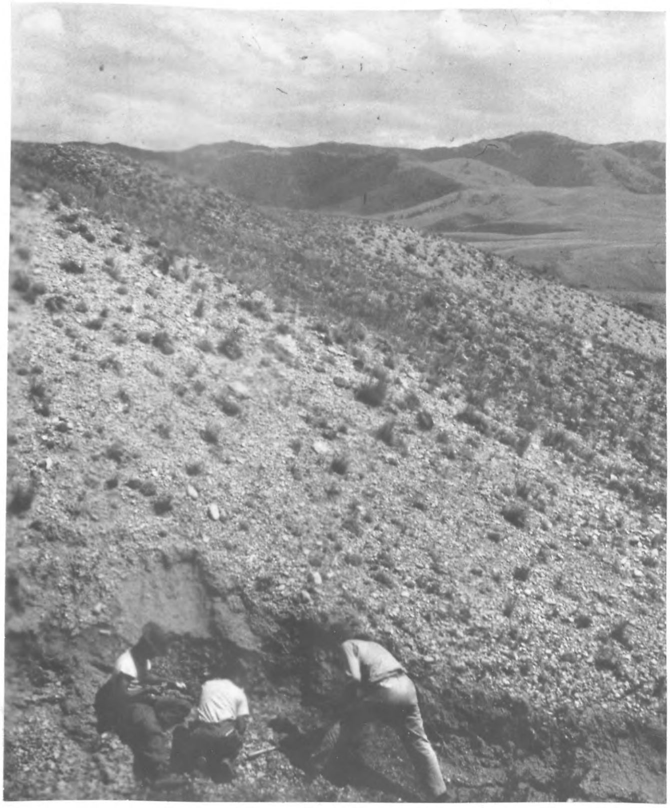
Figure 1 - Barton Creek measured section as seen from a distance. White tuffs are prominent.

Figure 2 - Fossil locality 2 in blocky non-tuffaceous shale of the lower Passamari formation. Plant fossils only were found at this locality.

PLATE 11

Plate II

1.



2.

EXPLANATION OF PLATE 12.

Figure 1 - Fossil locality 6 in lower Madison Valley formation of the Belmont Ranch measured section. A series of upper cheek teeth of an advanced *Merychippus* or primitive *Neohipparion* was found here.

Figure 2 - View showing fault along western edge of the Belmont Ranch measured section. Passamari formation on the left lies against the Madison Valley formation on the right.

PLATE 12

Plate 12

1

2.

EXPLANATION OF PLATE 13.

Figure 1 - View of fault-line scarp southwest of Alder, Montana along northwest side of Ruby Range. This scarp is outside of the Ruby River Basin and is seen here from a hill within the basin north of Barton Creek, looking northwest.

Figure 2 - View of same fault-line scarp as seen in figure 1. This picture was taken from a point north of the Ruby River Storage Project dam near the north end of the gorge through which the Ruby River flows in leaving the Ruby River Basin.

PLATE 13

Plate 13

1.

2.

EXPLANATION OF PLATE 14.

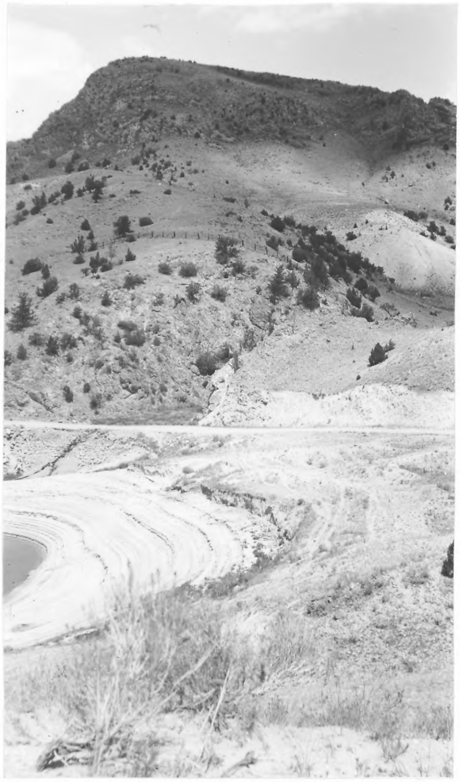
Figure 1 - View looking west across the valley from upper Idaho Creek toward the Red Rock Conglomerate exposure west of the reservoir. Shows extensive pediment developed on the Madison Valley formation in the foreground, and the " high erosion surface" topping the Ruby Range in the background.

Figure 2 - Pre-Cambrian- Tertiary contact as seen in road cut near dam at northern end of the Basin.

PLATE 14

Plate 14

1.



2.

EXPLANATION OF PLATE 15.

Figure 1 - Dumps from placer gold mining operations along Barton Creek. Pediment surface on the Madison Valley formation shown in the middle distance. "High erosion surface" topping the Ruby Range in the Background. Picture taken looking toward the southwest from the north side of Barton Creek.

Figure 2 - View Showing three physiographic surfaces in the basin. Pediment surface on The Madison Valley formation in the foreground, the High erosion surface along the crest of the Greenhorn Range in the background, and the depositional surface seen indistinctly about one third of the way up the flanks of the mountains. Note the vegetation growing on the south bank of the gully only. Three mule deer in the foreground.

PLATE 15

Plate 15

1.

2.

EXPLANATION OF PLATE 16.

Fossil insects from locality 1.

Figure 1 - Order Orthoptera
Family Acrididae (short-horned grasshopper). Natural size.

Figure 2 - Order Orthoptera
Family Acrididae X2

Figure 3 - Order Orthoptera
Family Acrididae X2

Figure 4 - Order Coleoptera
family uncertain X3

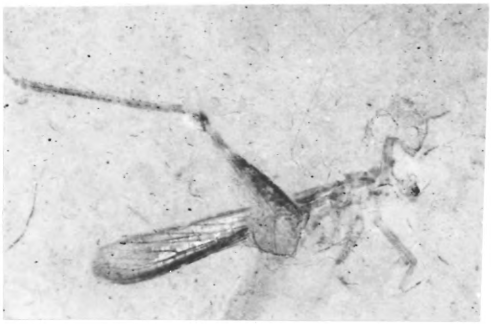
Figure 5 - Order Coleoptera
family uncertain X3

Figure 6 - Order Coleoptera
family uncertain X3

PLATE 16

Plate 16

1.



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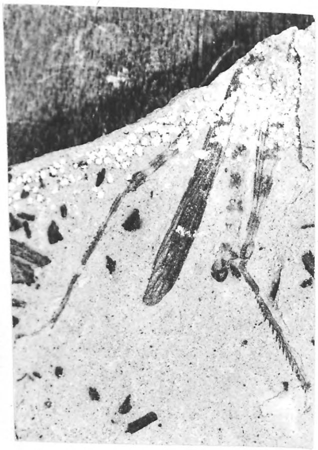

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EXPLANATION OF PLATE 17.

Fossil insects from locality 1.

Figure 1 - Order Coleoptera
Family Elateridae
(click beetle) X2

Figure 2 - Order Coleoptera
Family Elateridae
(click beetle) X2

Figure 3 - Order Coleoptera
Family Elateridae
(click beetle) X3

Figure 4 - Order Coleoptera
Family Scarabaeidae X2

Figure 5 - Order Hymenoptera
Family Tenthredinoidea X3
(sawfly)

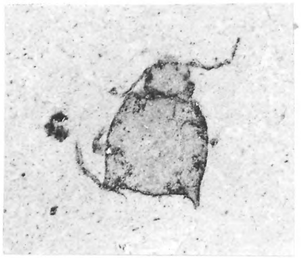
Figure 6 - Order Hymenoptera
Family Formicidae(?)
(ant) X3

PLATE 17

Plate 17

1.

2.



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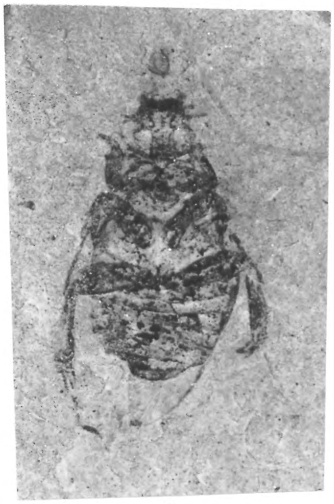

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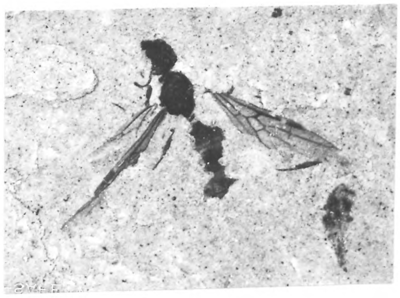

6.

EXPLANATION OF PLATE 18.

Fossil insects from locality 1.

Figure 1 -	Order Hymenoptera Family Apoidea (bee)	X3
Figure 2 -	Order Hymenoptera (parasitic form)	X3
Figure 3 -	Order Hymenoptera (parasitic form)	X3
Figure 4 -	Order Plecoptera (mayfly nymph)	X3
Figure 5 -	Order Plecoptera (mayfly nymph)	X3
Figure 6 -	Order Plecoptera (?)	X3

PLATE 18

Plate 18

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EXPLANATION OF PLATE 19.

Fossil insects from locality 1.

Figure 1 - Order Megaloptera
Family sialidae
(fish-fly) X2

Figure 2 - Order Diptera
Family Tipulidae
Genus *Tipula*
(crane-fly) Natural size

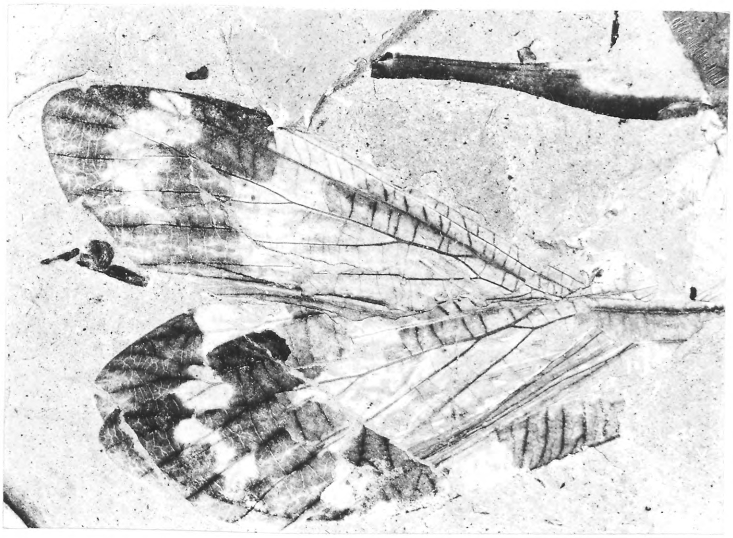
Figure 3 - Order Diptera
Family Tipulidae
Genus *Brachypremna*
Natural size

Figure 4 - Order Diptera
Family Chironomiidae
Genus *Chironomus* (?) X3

Figure 5 - Order Diptera
Family Syrphidae
(flower-fly) X3

PLATE 19

Plate 19



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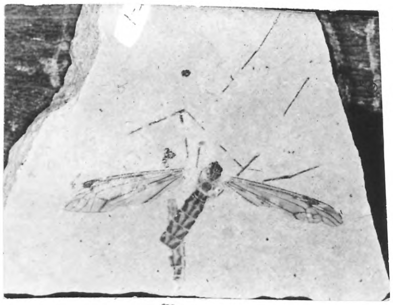

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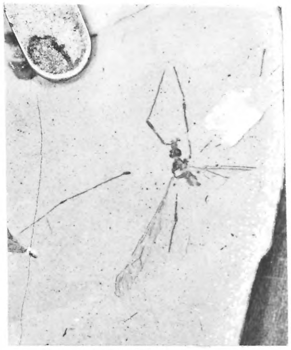

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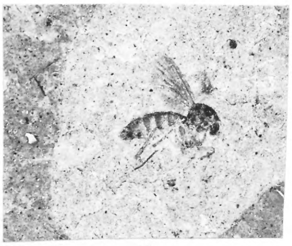
EXPLANATION OF PLATE 20.

Fossil insects from locality 1.

Figure 1 -	Order Diptera Family Myectiphilidae (or Rhyphidae) (fungus gnat)	X3
Figure 2 -	Order Hemiptera Family Coreidae	X3
Figure 3 -	Unidentified insect	X3
Figure 4 -	Unidentified insect	X3
Figure 5 -	Unidentified insect	X3
Figure 6 -	Unidentified insect	X3

PLATE 20

Plate 20



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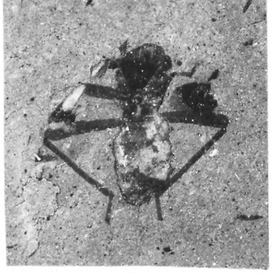

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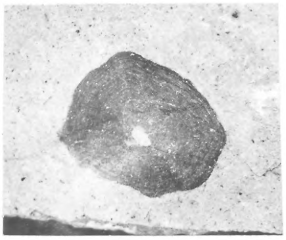
EXPLANATION OF PLATE 21.

Figure 1 - Fish scale from locality 1. X3

Figures 2, 3, and 4 - Front, lateral, and rear views, respectively, of the cannon bone and a toe bone of cf. *Merychippus*, from fossil locality 5. U. of Mich. Mus. of Paleontology Cat. No. 24336. X½

PLATE 21

Plate 21



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EXPLANATION OF PLATE 22

Figures 1 and 2 - Crown and side views, respectively, of the upper left premolar of an advanced *Merychippus* or primitive *Neohipparion* from fossil locality 5. U. of Mich. Mus. of Paleontology Cat. No. 24333. Natural size.

Figures 3 and 4 - Crown and side views, respectively, of an upper left molar from a horse cf. *Merychippus* or Neohipparion. From fossil locality 5. U. of Mich. Mus. of Paleontology Cat. No. 24335. Natural size.

Figures 5 and 6 - Crown and side views, respectively, of a series of upper left cheek teeth, cf. *Merychippus* or *Neohipparion*. From fossil locality 6. U. of Mich. Mus. of Paleontology Cat. No. 24334 Natural size.

PLATE 22

Plate 22

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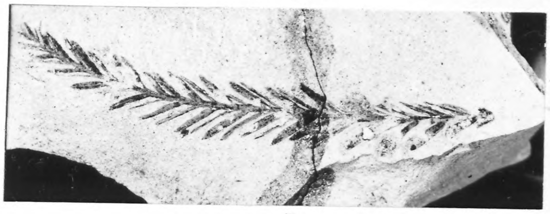
EXPLANATION OF PLATE 23.

Figures 1 through 5 - <u>Taxodium</u> (or <u>Sequoia</u> ?) Specimens from fossil locality 2. Natural size.

PLATE 23

Plate 23

1.



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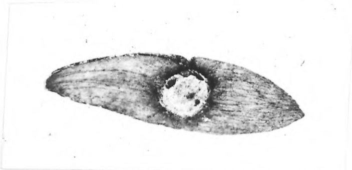
EXPLANATION OF PLATE 24.

Fossil plants from the Passamari formation

Figure 1 - *Ailanthus* fruit (samara).	Natural size
Figure 2 - Needles of a White Pine	Natural size
Figure 3 - Simple, willow-like leaf	Natural size
Figure 4 - Unidentified plant	Natural size

PLATE 24

Plate 24



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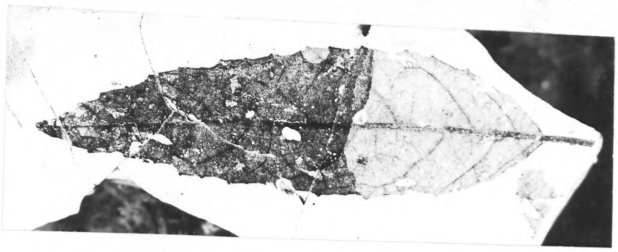

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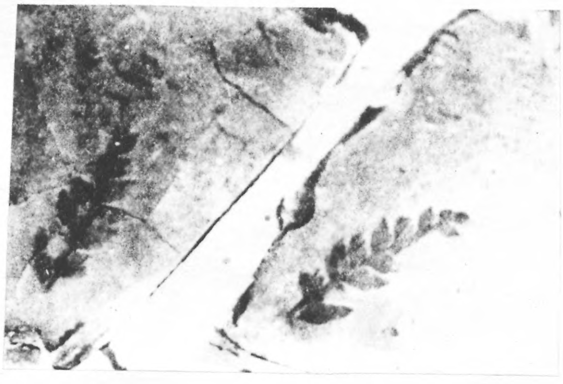

4.

EXPLANATION OF PLATE 25.

Fossil plants from the Passamari formation

Figure 1 - *Nyssa* fruits or bulbous roots of *Equisetum*. Natural size.

Figure 2 - Fagaceous. Some member of the Beech family. Natural size.

Figure 3 - Beech family (?). Natural size.

Figure 4 - Possibly *Betula multinervis* or *Alnus relatus* . Birch family. Natural size.

PLATE 25

Plate 25

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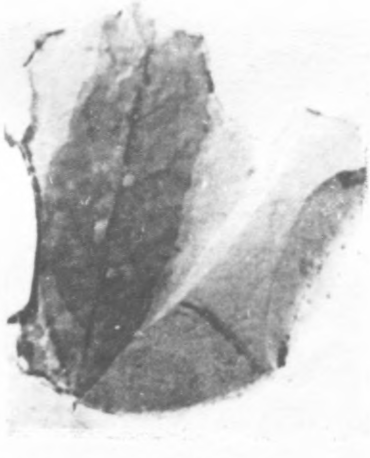
2.



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