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# CENOZOIC PALEONTOLOGY, STATIGRAPHY, AND RECONNAISSANCE GEOLOGY OF THE UPPER RUBY RIVER BASIN, SOUTHWESTERN MONTANA

BY

JOHN A. DORR, JR., and WALTER H. WHEELER

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VOLUME XIII

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JOHN A. DORR, JR., and WALTER H. WHEELER

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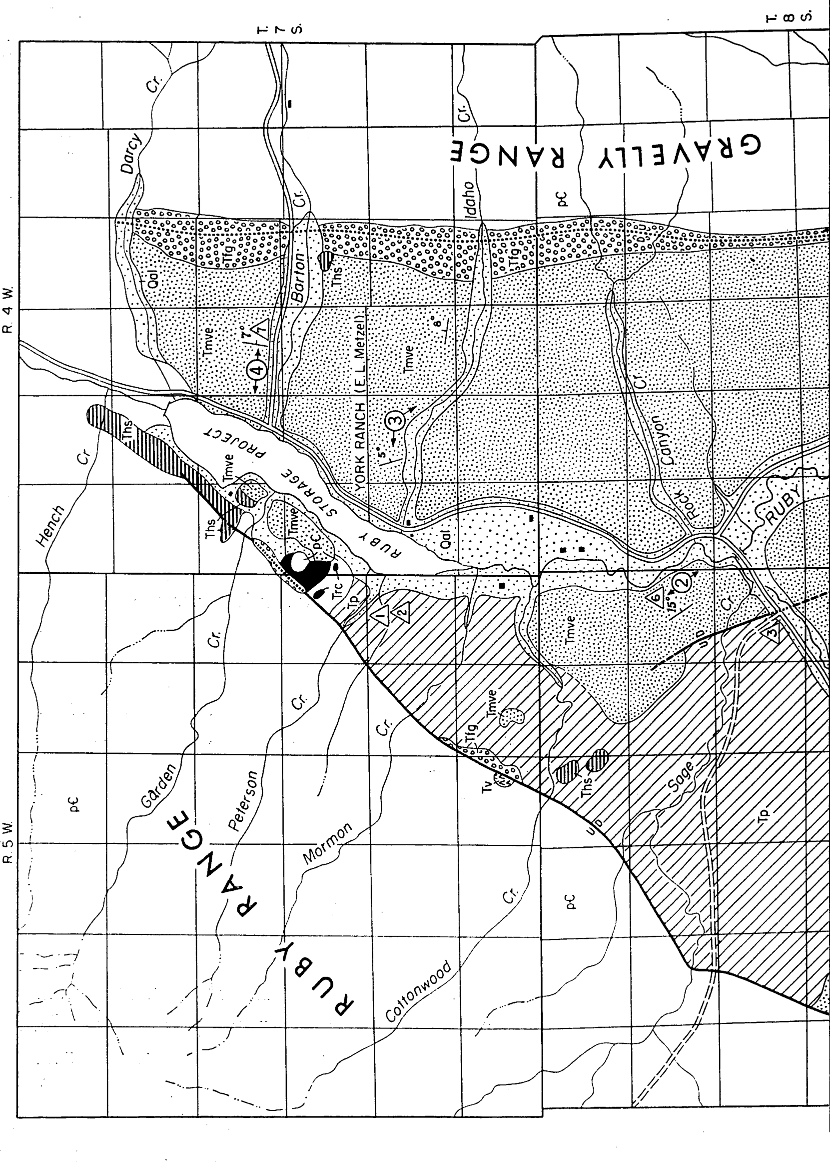
## INTRODUCTION

### *Location of the Area*

THE UPPER RUBY RIVER BASIN lies entirely within Madison County, Montana. It is bordered on the northwest by the Ruby Range, on the east by the Gravelly (or Greenhorn) Range, on the southeast by the Snowcrest Range, and on the southwest by the low divide between the drainage basins of Ruby River and Blacktail [Deer] Creek. This report deals chiefly with the Cenozoic stratigraphy and vertebrate paleontology of the northern two-thirds of this basin.


T. 7 S.
T. 8 S.
R. 4 W.
R. 5 W.
GRAVELLY RANGE
RUBY RANGE
Darcy Cr.
Barton Cr.
Idaho Cr.
Hench Cr.
YORK RANCH (E.L. Metzel)
RUBY STORAGE PROJECT
Canyon Cr.
Rock Cr.
RUBY
Garden Cr.
Peterson Cr.
Mormon Cr.
Cottonwood Cr.
Sage Cr.
Tfg
Qal
Tmve
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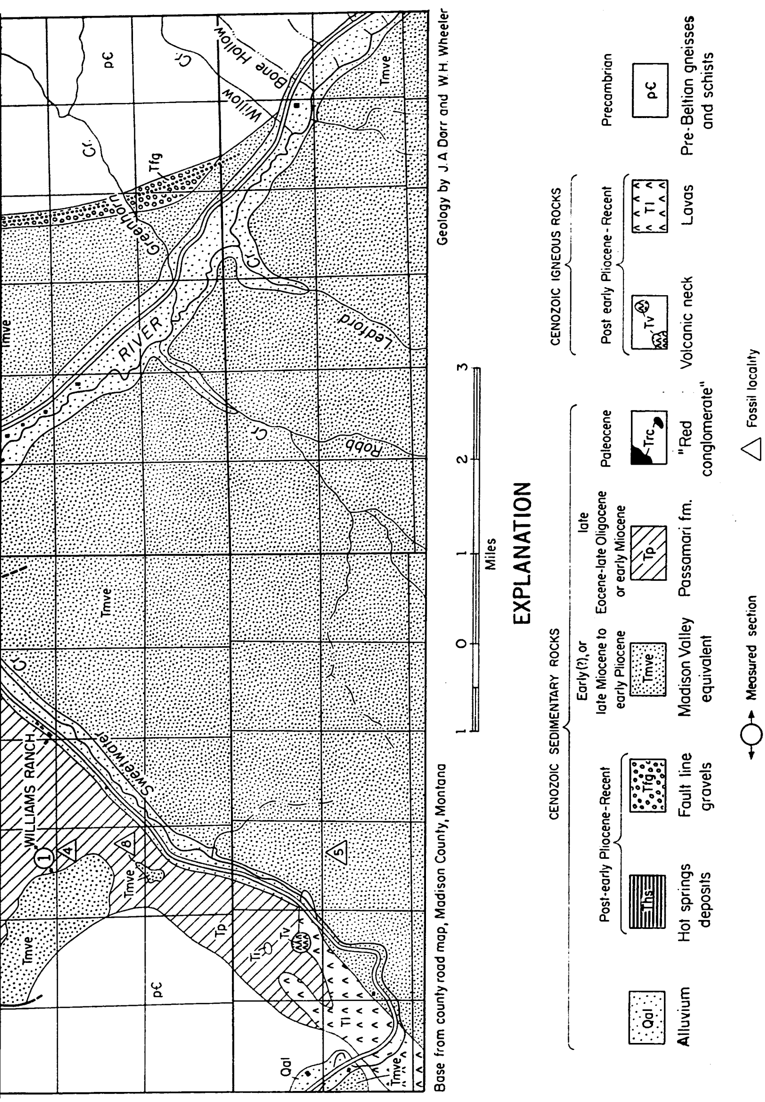



FIG. 1. Geologic reconnaissance map of the Upper Ruby River Basin, Madison County, Montana.

Only the middle third of the northwestward-flowing Ruby River lies within the area designated as the Upper Ruby River Basin. The river enters the basin through the Ruby River Canyon, a water gap in the Snowcrest Range-Gravelly Range. The river leaves the basin through another canyon where this antecedent stream has cut through the knot of crystalline Precambrian rocks formed at the place where the Ruby Range and the Gravelly Mountains are joined together just south of Alder, Montana. It is here that a dam has been built which causes the conspicuous reservoir in the northern portion of the area.

### *History of Investigation*

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).

The occurrence of fossil vertebrates and plants in the area of this study seems to have been well known to early collectors, especially Earl Douglass of the University of Utah and Carnegie Museum of Pittsburgh. However, no systematic description of the Cenozoic rocks nor of their fossil content appears in the literature. If specimens collected by Douglass still exist they have not come to our attention, nor have they been adequately described.

Field mapping and much of the stratigraphic work for this study were completed by the authors during August of 1947, under the direction of Dr. A. J. Eardley of the University of Utah (then of The University of Michigan). Dorr revisited the area briefly in August, 1951, with a party from Carnegie Museum of Pittsburgh, and made additional collections. The long postponement of this paper has allowed Dr. Herman F. Becker, now paleobotanist at the New York Botanical Garden, to complete and publish some of his extensive paleobotanical work on the area. We were fortunate that Mr. Henry P. Zuidema of Detroit accompanied us that summer and discovered some of the fossil vertebrate material described herein. We were able to field check the locality and horizon of those specimens which he called to our attention at the time. After the close of that field season Mr. Zuidema turned over to The University of Michigan Museum of Paleontology some additional specimens he had collected that summer. We rely upon his data concerning the field occurrence of the latter material. Additional material was collected by Professor Claude W. Hibbard and a field party from The University of Michigan during the summer of 1948; the field notes of that group establish the occurrence of their specimens. Fragments of a beaver and a camel, found by H. P. Zuidema in the Madison Valley equivalent in 1949, are included in the collection. During the summer of 1947 Mr. Elwyn L. Metzel, of York Ranch in the Ruby Basin, directed us to several localities rich in fossil plants and fossil insects. These occurred in what we refer to here as the Passamari Formation. Dr. Herman F. Becker, who also was with us that summer, spent several subsequent summers expanding the fossil plant collections from the sites pointed out by Mr. Metzel and from other sites which he later discovered himself. Some of Becker's studies of the fossil floras of the Passamari Formation have now been published in detail (Becker; 1959; 1960*a,b,c,* and *d*; 1961; 1962). We shall simply summarize those contributions in this paper. Dr. Becker also contributed some fossil camel material he found at our locality No. 6. The abundant and beautifully preserved insects from the Passamari Formation remain undescribed although certain groups have been examined by specialists. We feel that the study of the insect material should be left for specialists. Readers are referred to Becker (1961, p. 35–39 and Pls. 31–32) or to Zuidema (1950, 1955) for brief discussions and illustrations of some of that material.

A fossil bird, found by Becker in the Passamari Formation, is now at the Princeton University Museum and some fossil plant material is now housed at the U. S. National Museum, at Carnegie Museum of Pittsburgh or is still in the hands of Dr. Becker. However, the majority of the plant specimens described by Becker, the insects, and all of the fossil vertebrate material described herein are now catalogued in The University of Michigan Museum of Paleontology (UMMP).

## STRATIGRAPHY

### *Precambrian and Paleozoic Rocks*

The Ruby Basin may be said to terminate at the normal faults which occur along the margins of the bordering mountain ranges and which separate Cenozoic materials from Precambrian gneisses and schists.

A narrow band of Paleozoic rocks does lie along the Snowcrest-Gravelly mountain trend and crosses the Ruby River in the Ruby River Canyon. The Snowcrest Range lies well to the south of the area under discussion, however, and the Paleozoic rocks of the Gravelly [Greenhorn] Range lie only on the eastern flank of that range (the side away from the Ruby Basin).

There are no Mesozoic rocks flanking the Ruby Basin.

Essentially, none of these rocks lie within the Ruby Basin. The exceptions are some small horsts(?) of Precambrian rock extending out from the base of the Ruby Range into the complex northern end of the basin.

### *"Red Conglomerate" (? Beaverhead conglomerate)*

On the west side of the Ruby River between Peterson and Garden creeks a reddish hill stands conspicuously among less colorful ones. This hill is composed of "red conglomerate" which crops out nowhere else in the Ruby River Basin (Fig. 2).

This formation is similar in appearance to some parts of the Beaverhead Formation, a Laramide orogenic deposit in Beaverhead County (Lowell and Klepper, 1953). They noted (*ibid.*, p. 242) that certain similar conglomeratic rocks occur in the Snowcrest and Gravelly ranges. Eardley (1951, p. 318–19, 324 and Figs. 179, 180) had previously noted red conglomerates around Lima and Armstead in Beaverhead County, Montana, and regarded them as early Cenozoic in age. He seems to indicate (*ibid.*, Fig. 180, lower half) that during the Laramide our area of study would have fallen within an uplifted sourceland composed of Precambrian rocks and not in an area of conglomerate deposition. We are not in a position to resolve this problem.

In the Ruby River Basin the "red conglomerate" is composed of subangular to angular pebbles of fossiliferous Mississippian limestone in a matrix of red, calcareous sand. In fact, this red color has washed down over the surface of the underlying Precambrian gneisses which crop out at the base of the hill. The hills seen in the middle distance in Plate 1 and Plate 3, Fig. 2, of Becker, 1961, include both Precambrian and "red conglomerate" outcrops as shown on our Figure 2.

### *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 are of two types. One type is thin-bedded and fissile and contains a small amount of volcanic ash; the other 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 (Pl. 1, Fig. 1). There are some layers that contain fine sand mixed with clay. Many units of the upper member contain poorly preserved fresh-water ostracods (genus *Candona*).

The two members have not been observed in contact with each other. The probable relation between them has been inferred from structural evidence.

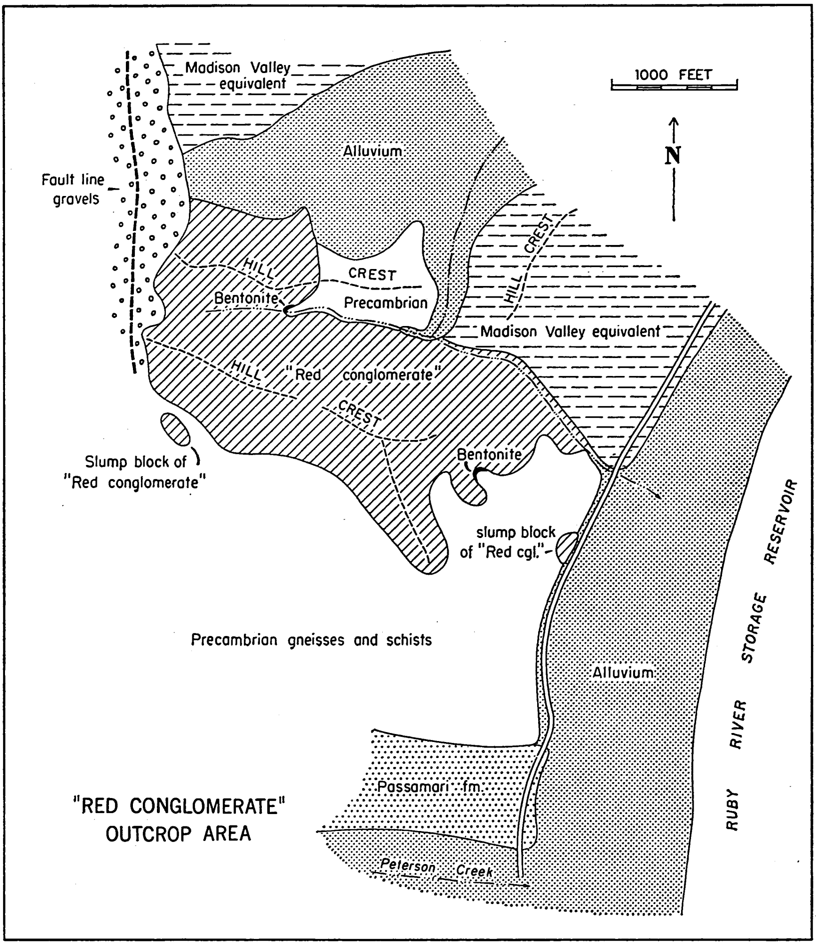



FIG. 2. Geologic sketch map of details in the area of outcrop of the "red conglomerate" (? equals Beaverhead conglomerate, ? Paleocene) in sections 18 and 19 of T. 7 S., R. 4 W. and sections 13 and 24 of T. 7 S., R. 5 W., Madison County, Montana (see map Figure 1).

*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 in the Sweetwater Creek measured section, which is described under the heading of "measured sections." It extends from the Sweetwater Creek section northeast to the fault along the west edge of the Belmont Ranch section.

*Type sections and thickness.*—The type section of the Passamari

Formation is in the Sweetwater Creek Measured Section, beds 1 through 25. This is only the upper member of the formation. The lower member crops out to the northeast, especially in the area between Mormon Creek and Peterson Creek which Becker (1961) has described in some detail. The formation was unofficially named by Dorr and Wheeler (1948, unpublished, p. 8–11) as cited by Becker (1961, p. 12–13). One hundred and thirty feet of the upper member were measured. The total thickness of the formation is unknown.

*Fossil localities.*—The area between Mormon and Peterson creeks has yielded a supply of plant and insect fossils which Becker (1961, Pl. 6) has characterized as "virtually inexhaustible." He has described and illustrated these sites in his GSA Memoir (1961) and in other papers (1959, 1960*a*, 1960*b*, 1960*c*.)

*Age and correlation.*—The age of the Passamari Formation may range from late Eocene (Mormon Creek flora) at least to latest Oligocene (Ruby Paper Shale flora) though this may later be subject to minor modification (see paleontology section of this report). Becker (1963, oral communication) has suggested that an earliest Miocene age for the upper part of the Passamari Formation is a distinct possibility. His suggestion is based upon his newly discovered but as yet undescribed "York Ranch flora" which he has mentioned only briefly in the literature (Becker, 1960*a*).

### *Madison Valley Equivalent*

*Divisions and lithology.*—The Madison Valley equivalent displays two somewhat different lithologic aspects both largely of fluviatile origin. The lower portion 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 portion of the Madison Valley equivalent 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.

The feldspars and mafic minerals have undergone little weathering. The quartzites are generally rounded, but may be subrounded. All other minerals are subangular to subrounded.

At one exposure of the lower portion of the Madison Valley equivalent in sec. 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 strata average about three inches in thickness. The blocks have a random orientation in the bed, as shown by the bedding planes.

Pebbles of sedimentary rock are rare in the conglomerates of the Madison Valley equivalent. But on the west side of the Ruby River reservoir, immediately to the north of the hill of "red conglomerate" is a hill of Madison Valley equivalent which contains many pebbles of sedimentary rock. Here the Madison Valley equivalent consists of typical alternating sandstones and conglomerate. About 25 per cent of the pebbles in the conglomerate are subrounded, compact, brown dolomite. The other pebbles are feldspar, gneiss, and quartzite. This type of conglomerate was not seen elsewhere in the Madison Valley equivalent.

There are several conspicuous conglomerate beds of the lower Madison Valley equivalent in the Idaho Creek section which have fifty to seventy-five per cent of their bulk in rounded quartzite pebbles of various colors. The pebbles are generally one-half to two inches in diameter. The conglomerate is noncalcareous 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 per cent composed of pebbles of quartzite which average one and one-half inches in diameter, but range from one-half inch to four inches. The matrix is noncalcareous.

The fact that pebbles in the conglomerates of the Madison Valley equivalent are almost completely restricted in composition to rock types of Precambrian origin suggests that at the time of accumulation of the Madison Valley equivalent the depositional basin was geographically isolated and closed to introduction of sediment from the outside, that drainage was mainly internal off the Precambrian rocks of the surrounding ranges, and that the Paleozoic and Mesozoic rocks had already been stripped from the region, probably during an early Cenozoic interval of erosion and development of the "red conglomerate" mentioned earlier. If this view is correct, it would imply a lack of original continuity between the Madison Valley "equivalent," as we call it, here in the Upper Ruby River Basin and the true Madison Valley Formation of the Lower Madison River Valley near Three Forks, Montana. This possibility is taken into account in our discussion of the "Age and Correlation" of the Madison Valley equivalent that follows shortly.

The upper portion of the Madison Valley equivalent 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 noncalcareous, they can be cliff-forming. They are finer grained than the sandstones of the lower portion.

The conglomerates do not alternate regularly with sandstones as in the lower portion, 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. At every other place, however, the boundary between the two members is obscured. The individual beds of the Madison Valley equivalent are lensing and discontinuous, and were deposited under fluviatile conditions. Consequently, our brief field study did not permit a correlation of beds within the formation.

*Distribution.*—The Madison Valley equivalent is distributed over much of the area (Fig. 1). The lower member is exposed on the west side of the basin between the Ruby River flats, Sweetwater Creek, and the inferred fault separating the Madison Valley equivalent from the Passamari; north of the "red conglomerate" area; and 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, ash-rich portion noted earlier 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.*—A typical section of the lower portion of the Madison Valley equivalent is the Belmont Ranch section (Pl. II, Fig. 2). Eleven hundred and thirty-six feet of the lower member were measured here.

A typical section of the upper part of the Madison Valley equivalent is the Barton Creek section (Pl. I, Fig. 2). Three hundred and sixty-nine feet of the upper member were measured here. Both sections are described under the heading "measured sections."

*Fossil localities.*—We list four fossil localities in the Madison Valley equivalent. They are indicated on the map (Fig. 1) by numbered triangles, to distinguish them from the measured section localities shown by numbered circles. Fossil locality 6 occurs in the lower portion in unit 2 of the Belmont Ranch section in sec. 12 of T. 8 S., R. 5 W. near the junction of Sweetwater Creek and the Ruby River.

Fossil locality 5 occurs in the light-colored hills southeast of Sweetwater Creek in sec. 9, T. 9 S., R. 5 W.

*Age and correlation.*—Fossil vertebrate evidence indicates a minimum age range for the Madison Valley equivalent of late Miocene (Barstovian) to early Pliocene (Clarendonian). (See Fig. 3.) This age range is "minimum" for several reasons: (1) The horizons that have yielded vertebrate materials from locality 7 (upper portion of the section) and localities 5 and 6 (lower part of the section) are overlain and underlain respectively by additional strata still within the Madison Valley equivalent. (2) The turtle remains (*Testudo primaeva*) from Locality 8, although they occurred

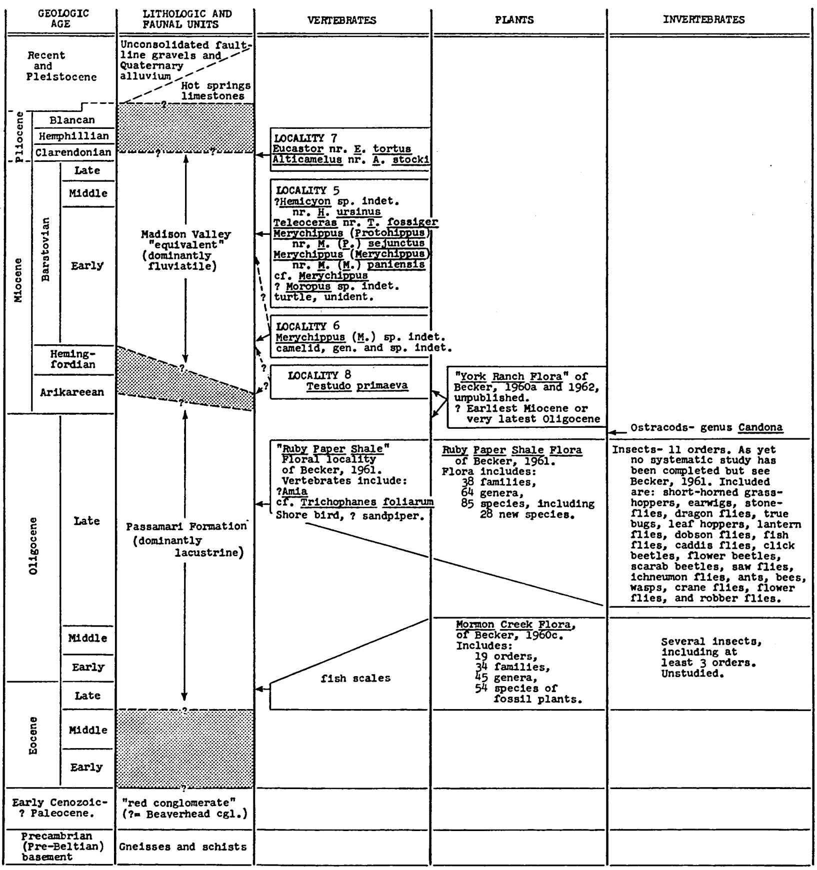



FIG. 3. Cenozoic stratigraphy, and fossil vertebrates, insects, and plants in the Upper Ruby River Basin, Madison County, Montana.

stratigraphically below the level of localities 5 and 6, are inconclusive as to age. Oelrich (1950, p. 44) concluded that the turtle was "probably Lower Miocene" but elsewhere noted (1950, p. 56) that it strongly resembled *T. copei* Koerner from the late Miocene Deep River Formation of Montana. (3) The faunules at localities 5, 6, and 7 are inadequate to indicate exactly where within the Barstovian and Clarendonian they fall. These uncertainties are indicated by the dashed and questioned lines on the stratigraphic chart (Fig. 3).

There are many obvious lithologic similarities between the Madison Valley equivalent in the Ruby Basin and the Madison Valley Formation (recently restudied by Dorr, 1956) to the northeast in the lower Madison River Valley south of Three Forks, Montana. Moreover, the vertebrate faunules from the two (Dorr, 1954, 1956), although not identical, suggest a considerable degree of contemporaneity in time of deposition. The two areas at present are clearly separate geographically, however, and there is evidence (see preceding section on Distribution and Lithology) that the two deposits never were geographically continuous. Their similarities may well have resulted from their having had similar source areas and similar geologic histories in similar settings. We hesitate to assign a new name to the Ruby Basin deposits of this age, because to do so would tend to obscure the obvious relationships. On the other hand, we are reluctant to correlate the two directly, thus implying a former geographic continuity, because this would tend to obscure their possible historical separateness for whatever that might mean to future studies of the history of the region. Therefore, we refer to the Ruby Basin deposits as the Madison Valley "equivalent."

### *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 now under the waters of the Ruby River reservoir.

West of the Ruby River reservoir between Garden Creek and Hench Creek there is a large hill composed of brown Precambrian quartzite. This hill has a roughly U-shaped belt of hot springs deposits on three sides. They are composed of a pure, fine-grained, white tufa which weathers to a light gray. The deposits have been extensively eroded. One isolated pinnacle of limestone is nearly 50 feet high. Through most of their extent the deposits rest on the Precambrian, although near Garden Creek there is a hill where the hot springs limestones rest against the Madison Valley equivalent, hence postdate that 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.

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. These hot springs are thought to be related to zones of recurrent faulting along the basin margins.

### *Extrusive Rocks*

Several patches of extrusive rock occur 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 with distinct color rings is mined and sold as "Montana agate" or "onyx." Some hills have lava caps and one conspicuous, round, reddish hill resembles a volcanic neck.

A patch of volcanic rock is present along the Tertiary-Precambrian contact just north of Cottonwood Creek, and a small outcrop is situated along the contact of the ?Beaverhead conglomerate with the main Precambrian 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 ?Beaverhead conglomerate with the Precambrian.

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

### *Mantle of Gneissic Detritus along Fault*
### (Fault-line Gravels)

Along the east side of the basin there is a belt of thick unconsolidated gravel beneath which we have inferred a 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 Precambrian rock which lies between the "red rock conglomerate" and the hill of Madison Valley conglomerate of the brown dolomite pebble type on the west side of the Ruby River.

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

### *Measured Sections*

*Sweetwater Creek section.*—The Sweetwater Creek measured section is indicated on the map (Fig. 1) as Measured Section No. 1. It is in secs. 21 and 28, T. 8 S., R. 5 W., one to two miles west of the Williams Ranch buildings. It includes the contact between the Passamari Formation and Madison Valley equivalent. The contact appears to be conformable in this section, although 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 equivalent (Pl. I, Fig. 1). The change in sedimentation conditions 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 equivalent just above the contact.

The shales of the Passamari here are generally light gray when fresh, but they weather white. The shale beds in the section are thin-bedded and calcareous, unless otherwise specified. The white-weathering shales of the Passamari Formation contain freshwater ostracods of the genus *Candona* at several levels here.

The overlying sandstone of the Madison Valley equivalent contains many nodules of opal and rare tiny bone and tooth fragments of small vertebrates. This sandstone phase contains only scattered pebbles and is not highly conglomeratic; however, it definitely was laid down under flood-plain conditions of deposition as was all of the Madison Valley equivalent. There is no indication of the lake-bed type of deposition. On this basis, therefore, the sandstone is included in the Madison Valley equivalent. The Passamari Formation and Madison Valley equivalent appear to be conformable here.

In the section the beds strike N55°W and dip 9° to the southwest. Present at this locality are 129.7 feet of Passamari and 252.5 feet of Madison Valley. The total thickness of the section here is 382.2 feet and includes parts of both the Madison Valley equivalent and the Passamari formation.

LITHOLOGY

| *Unit* | | *Thickness* (Feet) |
|---|---|---|
| 30. (top) | 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 subangular; pebbles are quartzites, gneisses, feldspars, and extrusive rocks. | 202.5 |
| 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, noncalcareous. | 10.5 |
| 27. | Siltstone, medium brown, weathers tan, noncalcareous; friable, but forms several resistant ledges. | 13.2 |

LITHOLOGY

| *Unit* | | *Thickness* (Feet) |
|---|---|---|
| 26. | Shale, medium tan, noncalcareous, blocky and poorly bedded. Contact between Madison Valley equivalent (above) and Passamari Formation (below). | 18.4 |
| 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 |
| 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, subrounded 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 |
| 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, noncalcareous. | 7.3 |

LITHOLOGY

| Unit | | Thickness (Feet) |
|---|---|---|
| 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, nonlaminated. 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, noncalcareous. | 7.8 |
| 5. | Sandy shale, brown, weathers light gray, fine, noncalcareous, poorly indurated; contains fine bands of siltstone. | 1.0 |
| 4. | Shale, medium gray with occasional light gray to buff laminae, soft, calcareous. | 5.2 |
| 3. | Argillaceous tuff, brown, weathers light gray, fine, noncalcareous, 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. (bottom) | 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 (Fig. 1) as Measured Section No. 2. It is in sec. 12 and sec. 13 of T. 8 S., R. 5 W., near the junction of Sweetwater Creek and the Ruby River. It is typical lower Madison Valley equivalent and is composed of coarse sandstones and conglomerates with a few layers of volcanic ash.

This section is stratigraphically continuous but was measured in two parts at right angles to each other, one of which goes up the cliffs and the other goes along the cliffs (Pl. II, Fig. 2). 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 by extremely friable volcanic glass in shards. A few of the shards are obsidian. One three-foot bed of limestone is present; shards are abundant.

Of special interest is a siltstone found in unit No. 2. This is a noncalcareous bed colored a striking olive green. The fossil vertebrate material described from Fossil Locality No. 6 largely comes from this horizon.

In this section the beds strike N50°W and dip 15° to the northeast. The total thickness of the following partial section of the Madison Valley equivalent is 1135.7 feet of which 653.3 feet are covered.

LITHOLOGY

| *Unit* | | *Thickness* (Feet) |
|---|---|---|
| 20. (top) | 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 subangular, well-cemented. | 5.7 |
| 17. | Sandstone, light tan, fine-grained, noncalcareous, grains subangular. | 22.8 |
| 16. | Sandstone, gray, weathers buff, fine-grained, calcareous; alternating resistant and poorly cemented layers. Upper 18.4 feet are resistant and form 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 subangular fragments of quartzite, hornblende-schist, and gneiss; cement calcareous; a few lenses of volcanic ash present. | 6.0 |
| 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 |

| Unit | Lithology | Thickness (Feet) |
|---|---|---|
| 9. | Covered. Talus derived from conglomeratic material. | 63.7 |
| 8. | Conglomerate alternating with medium-grained sandstone, tan to gray; conglomerate is calcareous; sands are noncalcareous, poorly cemented; pebbles range from medium sand to ten inch cobbles, angular to subrounded; 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, noncalcareous, cliff forming; pebbles are granites, quartzites, gneisses, and schists. Coarse conglomeratic sandstone forms ledge at top. | 29.4 |
| 5. | Sandstone, tan, fine-grained with a few conglomeratic zones, noncalcareous. | 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, noncalcareous. Fossil Locality 6—Vertebrates. | 41.6 |
| 1. (bottom) | Siltstone, light brown, contains some fine sand; weathers to a clayey, mud-cracked slope; forms several ledges with rounded and pitted surfaces. | 64.3 |
| | | 1135.7 |

*Idaho Creek section.*—The Idaho Creek section is indicated on the map as Measured Section No. 3. The section was measured along the walls of the small valley of Idaho Creek on the eastern side of the basin. Idaho Creek lies in the S¼ of T. 7 S., R. 4 W.

This measured section was begun about one-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 Precambrian.

It is in the Idaho Creek section that the lithologic differences between the upper and lower portions of the Madison Valley equivalent are best seen. Here the tuffs and tuffaceous sandstones of the upper member (units

40 through 44) rest 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 measured 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.

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.

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

LITHOLOGY

| *Unit* | | *Thickness* (Feet) |
|---|---|---|
| 44. | This unit consists of three types of deposits as revealed from a study of thin sections.<br>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; noncalcareous.<br>2. Sandy tuff, light gray, weathers white, very friable; modern 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; noncalcareous.<br>3. Calcareous tuff, light gray, weathers white, friable; about a third to a half calcite; detritus consists of microcline, garnet, pyrrhotite, brown biotite, green hornblende, plagioclase, magnetite, quartz, and rare limestone pebbles. | 152.4 |
| 43. | Conglomerate, color gray at a distance, noncalcareous, 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 subangular 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, noncalcareous, cliff-forming; contains a few scattered pebbles of subangular 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 angu- | 25.0 |

LITHOLOGY

| Unit | | Thickness (Feet) |
|---|---|---|
| | lar brown or green hornblende, angular garnet, subangular quartz with lesser amounts of augite, rutile, hypersthene, andesine, montmorillonite pellets, biotite, and sericite. Interstices filled with clay of low birefringence. | |
| 39. | Covered or eroded. | 16.0 |
| 38. | Tuff, very light gray, weathers white, fine-grained, noncalcareous, massive and ledge-forming, compact, grains angular or acicular. | 1.5 |
| 37. | Covered or eroded. | 81.0 |
| 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 per cent of the rock consists 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 |
| 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, noncalcareous, particles acicular; contains a few obsidian particles. | 0.4 |
| 17. | Conglomerate, sandy matrix, good cementation, noncalcareous; this bed consists of fifty per cent by volume of rounded quartzite pebbles one-half to one inch in diameter. | 0.9 |
| 16. | Tuff. Like unit 18. | 4.7 |

LITHOLOGY

| Unit | | Thickness (Feet) |
|---|---|---|
| 15. | Conglomerate, general appearance is buff weathering to gray; conglomerate material is derived from a mixture of eroded metamorphic and extrusive rocks; few fine-sediments; no primary pyroclastics. Highly calcareous sandy cement; pebbles are subangular feldspars and subrounded 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. 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 rarely siltstone; matrix of medium-grained calcite. | 13.3 |
| 14. | Sandstone, buff, calcareous; generally coarse angular grains, some subrounded 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 rarely 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 |
| 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 Measured Section 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 or mixed with sand. The presence of many lensing beds of conglomerate and the presence of scattered pebbles throughout the sandstones, however, shows that the section was deposited under the flood-plain conditions characteristic of the Madison Valley equivalent. The large amount of ash and the smaller quantity and poorer cementation of the conglomerate mark this section as part of the upper portion of the formation. This is confirmed by the occurrence of a beaver (*Eucastor*) and camel (*Alticamelus*) somewhat younger than the faunules from fossil localities 5 and 6 in the lower part of the Madison Valley equivalent (Fig. 3).

The cliffs along the north side of Barton Gulch are conspicuous, even from a distance. The white color of unit 11 and unit 12 is striking (Pl. I, Fig. 2).

Bone fragments were found in a small lens in unit 13. Unfortunately the exact level of occurrence of the beaver and camel material mentioned above is unknown to us. It was collected by Mr. H. P. Zuidema the summer following our field work, and deposited in The University of Michigan Museum of Paleontology at a still later date, with data sufficient only to establish that the material came from the Barton Creek section.

The beds in this section strike N10°E and dip 7° to the east. This measured section is 369.2 feet thick.

### Lithology

| *Unit* | | *Thickness* (Feet) |
|---|---|---|
| 14. | Sandy tuff, light gray, weathers buff, poorly indurated, noncalcareous; partly covered slope; unit contains several conglomeratic layers four inches to two feet in thickness; pebbles are largely subrounded or rounded quartzite. | 23.7 |
| 13. | Conglomerate, dark gray from a distance, sandy matrix, cliff former; pebbles are subrounded 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 |
| 12. | Tuff, very light gray, very friable, noncalcareous, 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, noncalcareous, 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 | 3.8 |

| Unit | Lithology | Thickness (Feet) |
|---|---|---|
| | shows this rock is almost entirely glass shards with a few silt-sized grains of quartz and feldspar. | |
| 10. | Altered sandy tuff, light tan to light gray, weathers buff, noncalcareous, 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 noncalcareous; pebbles are one-eighth to one-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 |
| 7. | Tuffaceous sandstone, light gray, weathers buff, medium-grained, friable, noncalcareous, 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, noncalcareous, 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.<br>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, noncalcareous, friable; contains a few scattered pebbles. | 93.7 |
| 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.<br>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

### *General Statement*

Previously cited published works of Becker have indicated that the age of the Passamari Formation may range from late early Eocene (Mormon Creek flora) to latest Oligocene (Ruby Paper Shale flora). Becker, however, has recently indicated to us (oral communication, Dec. 1963) that he may need to reconsider the age significance of the Mormon Creek flora because it now appears to be younger than described, probably Late Eocene. Becker also is in possession of a new flora to which he has referred briefly (Becker, 1960*a*) as the "York Ranch flora" but which he has not yet described or completely studied. He now believes (Dec. 1963, oral communication) that the age of this flora is very latest Oligocene or earliest Miocene. Conclusions regarding the significance of this latter flora must remain tentative pending completion of Becker's study. The uncertainties involved in dating the Passamari by fossil plant material are indicated by question-marked arrows and dashed diagonal lines on the stratigraphic chart (Fig. 3). The field evidence does, however, indicate that the Passamari Formation underlies the Madison Valley equivalent and that the latter contains late Miocene and possibly even older Miocene fossil vertebrates in its lower portions.

The Madison Valley equivalent includes late Miocene (Barstovian) and early Pliocene (Clarendonian) levels. If the turtle described from Locality 8 is actually as old as Oelrich (1950, p. 44) has inferred, then the base of that formation would be at least as old as early Miocene. The turtle by itself offers dangerously little evidence for a firm conclusion, although its stratigraphic level is below that of Locality 6. The mammalian faunule from Locality 5 clearly is Barstovian in age; moreover, it probably is early Barstovian. The age significance of the material from Locality 6 is uncertain. Certainly the horse from that locality is no younger than early Barstovian, both because of its taxonomic relations and because the material comes from a stratigraphic level no higher, and probably lower, than the vertebrates from Locality 5. The material is not sufficiently good to rule out the possibility of a late middle Miocene (late Hemingfordian) age, however. The camelid from that locality is indeterminate. The occurrence of the beaver, *Eucastor,* commonly considered to be an early Pliocene form, in the Barton Creek section indicates that the upper portion of the Madison Valley equivalent is at least as young as that. The locality data for the beaver, submitted by H. P. Zuidema who found the fossil, are not adequate to place the find exactly in our Barton Creek measured section, but seem adequate to show that there are beds in the section above the level of the beaver occurrence and therefore still younger but from which no fossils are available. The uncertainties of dating of faunules within the Madison Valley equivalent are indicated by question-marked arrows on the stratigraphic chart.

The geologic and geomorphic relationships seem to indicate that the fault line gravels, hot spring deposits and of course the Quaternary alluvium all are, at least in part, Recent or near-Recent in age. We have no fossil evidence, however, bearing on the time of beginning of accumulation of those deposits.

### *Fossil Lists*

The annotated lists of fossils that follow are arranged according to formations and localities within formations, from oldest to youngest. The relative positions of the faunules and floras were established by geologic and stratigraphic field evidence but are largely confirmed or at least not denied by the apparent ages of the fossil assemblages themselves. All identifications are by the authors unless otherwise stated. University of Michigan Museum of Paleontology (UMMP) catalogue numbers are shown for the specimens. Localities are shown on an accompanying map (Fig. 1). Fossil locality numbers, when used, are those assigned by the authors (not Becker) and as shown on the map.

PASSAMARI FORMATION

*Mormon Creek flora:* Fossil locality of Becker (1960*c*). Age uncertain. Becker's conclusion from his original study was late early Eocene but he now believes (oral communication, 1963) that the age of the flora is late Eocene.

Teleost fish scales constitute the only vertebrate material recovered so far.

*Ruby Paper Shale flora:* Fossil sites of Becker (1959, 1960*a–d,* 1961).

### Teleost Fishes

(*fide* Becker, 1961, p. 38, Pl. 32)

*?Amia*

Bowfin, consisting of isolated scales.

cf. *Tricophanes foliarum* Cope

### Bird

Nearly complete skeleton or impressions of the skeleton with feather impressions. Becker (1962, letter) says that the specimen, now deposited in the museum at Princeton University, has been examined by both Dr. Glenn L. Jepsen and Dr. Alexander Wetmore but has not yet been positively identified. Becker says that a letter from Jepsen stated as follows, "The fine ashy shroud of the bird has been altered to opaline silica and montmorillonite, and the feathers and most of the bone have disappeared, leaving impressions and stains and holes where they were. Only a few fossil birds with associated feathers have been found. This bird is especially remarkable because the contents of its gizzard, with tiny quartz grinding stones and some bits of insects are preserved. The fossil represents a tiny sandpiper-like bird, about two-thirds as large as the smallest living sandpiper. Its exact classification will be determined by further study." A photograph of this specimen was published by Becker (1960*a*, p. 13).

"*York Ranch flora*" of Becker (1960*a*): Not yet studied or described in detail. Becker (oral communication, 1963) *tentatively estimates* that its age is very latest Oligocene or earliest Miocene but final conclusions must await conclusion of his work. No fossil vertebrate material recovered from this site.

MADISON VALLEY EQUIVALENT

*Fossil Locality No. 8* (of present authors, not Becker): This locality is described by Oelrich (1950, p. 44) as "west side of Sweetwater Creek, approximately two miles southwest of the Belmont Park Ranch house in the NE.¼ sec. 32, T. 8 S., R. 5 W., Madison County, Montana." A re-check of field notes, catalogue card, and field map has convinced the authors that Oelrich, through no fault of his own, mislocated this locality which should be placed on the center of the boundary between sections 28 and 33, T. 8 S., R. 5 W., Madison County, Montana. Exact stratigraphic level is uncertain, but the relative position of beds at this locality is lower than the beds at Localities 5 and 6.

## Turtle

*Testudo primaeva* Oelrich, 1950

UMMP 25758. Collected by Professor C. W. Hibbard and University of Michigan field party July 6, 1948. A nearly complete plastron and carapace and several other skeletal elements. Oelrich states (1950, p. 44) that this specimen is "probably Lower Miocene," but he later notes (p. 56) that the specimen "is similar in general form to *Testudo copei* Koerner, from the late Miocene, Deep River formation, Meagher County, Montana." This specimen was found and field checked by one of the authors (Wheeler) but the evidence from the turtle alone is insufficient to establish an early Miocene age for the beds at that locality. Our field studies, however, indicate that the Madison Valley equivalent beds exposed here lie stratigraphically below those at fossil Localities 5 and 6 and probably near the base of the formation.

*Fossil Locality No. 6* (of present authors, not Becker): Along gully in bluffs west of Ruby River approximately in the NW¼, sec. 12, T. 8 S., R. 5 W., Madison County, Montana. About one mile northwest of the junction of the Ruby River and Sweetwater Creek. Probably early Barstovian, but possibly late Hemingfordian. The fossil material is insufficient for more exact dating. The horse material is not in itself adequate to rule out the possibility of a late Barstovian age also, but field evidence seems to indicate the deposits at this locality are slightly lower than, or at least no higher than, the beds at Locality 5 where the faunule is more clearly early Barstovian in age.

### Horse

*Merychippus* (*Merychippus*) sp. indet.

UMMP 24334 is a little worn but badly fractured and weathered series of upper cheek teeth, $LP^4$–$LM^3$, collected by H. P. Zuidema, August, 1947, and subsequently cross-sectioned for study. The locality was field checked by the authors and the specimen occurred in Unit 2 of Belmont Ranch Measured section, hence low in the Madison Valley equivalent. Teeth are definitely merychippine, not protohippine. Resemblances in size, crown height, and tooth proportions are closest to *M. seversus* (Cope), 1879 (incl. *M. isonesus* according to Downs, 1956, p. 267; Mascall fauna); *M. quintus* Osborn, 1918, of the Hemingfordian-Sheep Cheek fauna; and *M. sphenodus* (Cope) 1889 from the early Barstovian (*fide* Galbreath, 1953, p. 105). Salient features include large size (about as in *M. quintus*), isolated protocone on worn $M^1$ and on premolars, distinct spurs on premolar protocones and a doubling of the pli caballin on $M^1$. Primitive characters include a moderate crown height about as in *M. seversus* and *M. californicus,* a relatively simple enamel pattern, and open prefossettes on $P^2$–$P^3$.

UMMP 26415 includes numerous fragments of at least two individuals of a form close to that represented by the material described above. Collected by H. P. Zuidema, August, 1947, but not field checked by the authors. Locality data of Mr. Zuidema indicates sec. 2 of T. 8 S., R. 5 W., but our mapping does not show any Madison Valley equivalent in that section. Matrix on specimens is that of Unit 2 of our Belmont Ranch Measured Section and specimens probably came from the same horizon and general locality as specimen 24334 above, that is, sec. 12, not 2. Material includes: associated $RI^{1\text{-}3}$; associated $LI_{1\text{-}3}$ and $RI_{1\text{-}2}$; a distal epiphysis of a tibia; 2 phalanges; associated $RP_3$–$M_2$; associated $RM_{1\text{-}3}$; 1 isolated right lower molar; and $RP^2$–$RM^3$. All teeth badly fractured and weathered.

## Camel

Genus and species indet.

Fragmentary, uncatalogued portions of camel limb bones including parts of incompletely fused metapodials. Correspondence with the collector, Dr. H. F. Becker, indicates these are from the same general locality and horizon as the horse material described above. The fragments indicate a creature larger than *Stenomylus* but otherwise unidentifiable.

*Fossil Locality No. 5* (of present authors, not Becker): Specimens from this general locality are surface finds which came from several sites near one another in the exposures in gullies along the margin of the high bench east of the right-angled bend of Sweetwater Creek, sec. 9, T. 9 S. R. 5 W., Madison County, Montana. Although all specimens are considered part of a single faunule, special location information is given for certain specimens listed below. Those specimens whose field occurrence was checked by the authors are so listed; otherwise the locality data are those of the particular collector named. The known stratigraphic ranges of the several categories represented in this faunule, taken together, indicate an early Barstovian (early late Miocene) age for the deposits at this general level in the Madison Valley equivalent. The assemblage appears no older than the material from Locality 6 and is probably slightly younger. This is in agreement with our conclusion from geologic and stratigraphic evidence discussed earlier in this paper.

## Amphicyonodontid Carnivore ("Bear-dog"), an Ursid *fide*

Erdbrink (1953, p. 552–53)

*?Hemicyon* sp. indet., near *H. ursinus* (Cope)

UMMP 44580 is a left astragalus collected by C. W. Hibbard and University of Michigan Field Party, 1948, from "third draw running east-west, north of onyx mine." Locality not field checked by authors. Specimen found on surface in close proximity to a Metatarsal III of ?*Moropus* (see UMMP 34376 below). The specimen compares closely with both *H. ursinus* and *Daphaenodon superbus* Peterson in general form, but is much longer than the latter and slightly larger than the former. Unfortunately, there are no comparable parts known for *H. barstowensis* Frick, *H. californicus* Frick or *H. barbouri* Colbert. The deep, narrow groove between the calcaneal facets is much as in *D. superbus* but is terminated posteroexternally by a zone of strong exostosis. The specimen also lacks the vertical sulcus which interrupts the internal tibial condyle in *D. superbus,* thus resembling *H. ursinus*. The specimen is larger in anteroposterior dimension than *H. ursinus* and the astragalar neck is slightly longer and more angulated anteromediad. The lateral and medial faces, and dorsal side of the astragalar neck, all are very rugose, and pitted. The anterior end of the internal tibial condyle ends in a sharp, overhanging lip, likewise the posteromedial edge. The groove between calcaneal facets is very deep, pitted and rugose, with overhanging margins. Thus the indications are that the animal represented was a large, heavy-bodied form. *H. ursinus,* to which the specimen seems nearest, occurs in the late Miocene (Barstovian) and questionably in the early Pliocene (Clarendonian).

## Rhinoceros

*Teleoceras* sp. indet., near *T. fossiger* (Cope)

UMMP 26372 is the proximal half of a right ulna lacking the olecranon process, collected by C. W. Hibbard and the University of Michigan Field Party, July 6, 1948. The occurrence of this specimen was not field checked by the authors. The bicipital hollow below the semilunar notch is deeply excavated, strongly pitted and very rugose in the manner of *Teleoceras* and suggesting a heavy-bodied animal in which the free ulna must necessarily have been strongly bound to the radius by interosseus ligaments. The specimen is too fragmentary for certain specific identification but is very closely similar to the same element in *T. fossiger* as figured in Cope and Matthew (1915, pl. 138, Figs. 5 and 5*a*). This genus is most common and widespread in the late Miocene (Barstovian) although ranging into the early Pliocene.

## Chalicothere

?*Moropus* sp. indet.

UMMP 24376 is the distal two-thirds of a Metatarsal III. Maximum A–P diameter 48 mm., Maximum Tr. diameter 52 mm. Collected by C. W. Hibbard, July, 1948, in "third draw running east-west, north of onyx mine." Occurrence not field checked by authors. A surface find in close proximity to ?*Hemicyon* listed above. Very similar to *M. elegans* Holland and Peterson, but larger. Specimen is approximately same size as a specimen from near Pawnee Buttes, N.E. Colorado, described by Holland and Peterson as *Moropus matthewi* but subsequently (1929) removed by Matthew to ?*Macrotherium.* Galbreath (1953, p. 106–7) indicates there is doubt concerning the stratigraphic position of the Colorado material heretofore referred to this species. The specimen listed here is clearly closer to *Moropus* than to *Macrotherium;* the anterior face especially is flat as in *Moropus. Moropus* is usually considered an early to middle Miocene genus, however, Merriam (1911) has recorded a large *Moropus* in the Virgin Valley fauna of California. Downs (1956, p. 327–28 and Fig. 44) considers the Virgin Valley fauna to be late middle Miocene or transitional middle to late Miocene. The present specimen may represent a slight extension of the time range of that genus into the early late Miocene (early Barstovian) if our interpretation of the faunule as a whole is correct, but the fragmentary nature of the specimen and uncertain identification leave this weakly supported.

## Horses

*Merychippus* (*Protohippus*) near *M.* (*P.*) *sejunctus* (Cope)

UMMP 24333 is an isolated $LP^2$ (sectioned for study), collected by H. P. Zuidema, August, 1947. Locality field checked by authors. Definitely a protohippine; the round-oval protocone joins broadly with the protoselene. The enamel pattern is nearly identical with that of an $RP^2$ of *M. sejunctus* (Amer. Mus. 8254) figured by Osborn (1918, Fig. 86, p. 113). The specimen is slightly larger, however, than the tooth figured by Osborn. *M. sejunctus* is an early Barstovian (early late Miocene) form.

*Merychippus* (*Merychippus*) near *M.* (*M.*) *paniensis* (Cope)

UMMP 24335 is an isolated $LM^2$ collected by H. P. Zuidema, August, 1947. Locality field checked by authors. This little-worn tooth has a crown height as in *Merychippus* and a clearly isolated protocone with a mere vestige of a protoconal spur. In size, proportions, and enamel pattern it not only bears a close resemblance to *M. paniensis* but is also very similar to some of the variants of the Mascall *Merychippus seversus-californicus* complex described by Downs (1956). The specimen is definitely merychippine, thus indicating the presence of a second group of horses in the faunule. The closest resemblance is to species of early Barstovian (early late Miocene) or Mid-Miocene-late Miocene transitional age.

UMMP 24374, an isolated $LM_2$ collected by Zuidema in 1947 and field checked by the authors is also merychippine and near *M. paniensis* but really inadequate for certain specific identification.

cf. *Merychippus*, sp. indet.

UMMP 24375 includes two astragali (a right and left) collected by Zuidema in August, 1947, but not field checked by the authors. Notes of Zuidema regarding the locality read, "near crest of mound, south of blowout in sand northeast of onyx mine." Specimens are of same size and form and probably are from a single individual. A phalange may also be associated with them.

## Turtle

Unidentifiable, uncatalogued fragments of plastron and carapace.

*Fossil Locality No. 7:* Barton Creek. Fossils were discovered at this locality by H. P. Zuidema two summers after the completion of our field study hence we could not field check the specimens. Had this been possible, their level of occurrence in our Barton Creek Section (described in this paper) might have been determined. Our work was sufficient, however, to establish in conjunction with the notes of Zuidema that the two specimens listed below are from the upper portion of the Madison Valley equivalent in the Upper Ruby Valley and stratigraphically above the fossil vertebrate material from Localities 5, 6, and 8. The locality is given by Zuidema as, "one mile east of Ruby River Road, SE¼, Sec. 16, T. 7 S.–R. 4 W., Madison County, Montana." This could only be somewhere in the bluffs on the north side of Barton Creek although not so stated by Zuidema. The two specimens, but particularly the beaver, are especially significant in spite of their fragmentary nature because they establish the presence of an early Pliocene (probably early Clarendonian) level in the Madison Valley equivalent.

## Beaver

*Eucastor* sp., near *E. tortus* Leidy

UMMP 26416 is an isolated $LP^4$ collected by H. P. Zuidema in the summer of 1949. The tooth is subhypsodont. The base, though damaged, indicates some closing of the roots. External striae do not extend to the base and the triturating surface is nearly triangular. The posterior stria is restricted to the upper part of the crown. In the foregoing characters the specimen is clearly *Eucastor* as diagnosed by Stirton (1935, p. 428). The specimen is slightly smaller than the type of *E. tortus* but falls within the range of materials referred to that species by Stirton (1935, p. 429–31). The specimen also resembles *E. dividerus* Stirton, 1935, in its short metastria, although the tooth is slightly smaller than the type of that species. Compared with presently described species of *Eucastor* the specimen seems unique in the following *combination* of characters: $P^4$ widest at base; metafossette open externally through the metaflexus; parastria intermediate in length, mesostria longest, metastria shortest, and none of striae extending to base of tooth. Thus it is not definitely referable to any presently described species, but is really insufficient material upon which to base a new species. Its early Pliocene age seems assured, however.

## Camel

*Alticamelus* sp., near *A. stocki* Henshaw, 1942

UMMP 26417 is an isolated, worn $RP_4$ collected by H. P. Zuidema in the summer of 1949. Its field relations to the beaver tooth listed above are not known beyond the fact that they both occurred in the area described in the field notes of Zuidema. The configuration of the tooth is that of *Alticamelus* but it is not specifically referable. Its nearest resemblance is to *A. stocki* but the specimen is slightly larger than the same tooth in that species; also the posterointernal enamel inflection in the specimen is more anteriorly placed than in that species. The tooth is longer than in *A. alexandrae* Davidson and has a more pronounced posteroexternal enamel inflection. *A. altus* Matthew and *A. priscus* are not represented by comparable parts. The specimen also differs in size and/or form from *A. procerus* and *A. leptocolon.* The stratigraphic range of the genus is uncertain. The Tonopah local fauna of Nevada which contains *A. stocki* has been considered late Barstovian but the genus has been questionably reported as ranging up into the early Pliocene. The fact that we cannot prove the association of our specimen with *Eucastor* does not help.

## STRUCTURE AND HISTORY OF BASIN

Mapping of the area was of reconnaisance nature on a Madison County, Montana, road map, hence the locations of formational and structural boundaries shown on Figure 1 are only approximate. It was possible, however, to recognize certain structural and stratigraphic relationships between the Tertiary basin beds and the surrounding pre-Tertiary rocks.

The Tertiary deposits of the Ruby River Basin, within the limits of the area inspected, and as shown on the accompanying map (Fig. 1), are confined entirely by Precambrian rocks made up of Pre-Beltian gneisses and schists (Montana Bureau of Mines and Geology, Geologic Map of Montana, 1955). Earlier workers made no distinctions among the various Tertiary deposits of the basin, and referred to them as "Tertiary—undifferentiated," "Tertiary lake beds," "Tertiary sediments," or in some instances as "Bozeman lake beds." As has been shown, several distinct Tertiary deposits can be recognized within the basin, and their characteristics imply a long and varied structural history for the basin.

The lowest and also the oldest Tertiary stratigraphic unit is the "red conglomerate" probably referable to the Beaverhead conglomerate of the Beaverhead Formation. Only in this unit is there any evidence 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 the Passamari Formation nor the Madison Valley equivalent contain significant amounts of material derived from Paleozoic or Mesozoic rocks; they are composed almost entirely of either volcanic ash of Tertiary age or igneous and metamorphic rocks and minerals of the same types as compose the Precambrian rocks surrounding the basin. It is apparent that long erosion during the early Tertiary, or perhaps during the pre-Tertiary, had stripped away 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 conglomerate" may represent local patches of detritus left in the region during this long erosional interval. 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. Surface outcrops of the "red 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 outcrops only on 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°. Farther to the northeast the shales are strongly deformed, covered by a veneer of detritus, and exposed only in small patches in arroyo bottoms thus making it difficult to determine the dip. The contact between the Passamari Formation and the "red conglomerate" was not observed, but the Passamari Formation is known to directly underlie the Madison Valley equivalent in some places; and the latter can be seen to overlap the "red conglomerate" where the Passamari Formation is absent, so it can be concluded that the Passamari Formation is younger than the "red conglomerate" and older than the Madison Valley equivalent. The contact between the Passamari Formation and the overlying Madison Valley equivalent can be seen at only one locality in the basin, north of Sweetwater Creek (Pl. I, Fig. 1). This locality is about one and one-half miles west of the Williams Ranch, in sec. 28, T. 8 S., R. 5 W. Here the two formations parallel one another and both are dipping about nine degrees toward the southwest. North of Sweetwater Creek and west of its juncture with the Ruby River in the west half of sec. 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 equivalent rather than underlie it (Pl. II, Fig. 1). 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 southeastward upon reaching Sweetwater Creek, but 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 equivalent. Farther northwest the Madison Valley equivalent has been removed by erosion, the offset relationship between the beds on each side of the fault becomes obscure, and the trace of the fault was lost.

Along Barton Creek the Madison Valley equivalent dips 7° to the east. Along the lower part of Idaho Creek the dip is 5° east while farther up-stream 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 Precambrian of the bordering Ruby Range and Gravelly Mountains is obscure. In most places along the margin of the basin the contact is covered by a fringing accumulation of late Tertiary? to Recent gravels. This is particularly true along the front of the Gravelly (Greenhorn) Range where the gravels form a broad apron over the Madison Valley equivalent. Nowhere do the basin beds extend past the Precambrian front of the mountains nor up along any of the creeks which emerge from the mountains; instead they appear to terminate abruptly at the Precambrian which rises steeply to form the mountains. The Precambrian 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 slope encountered in passing from the basin beds and marginal gravels onto the Precambrian is distinct along both sides of the basin. Some lava flows, hot spring deposits and hot springs occur near the basin margins. Thus it seems that the basin is bounded on both sides by faults and has the characteristics of a graben. Some precedent can be found for this view. On the Geologic Map of Montana (Montana Bureau of Mines and Geology, 1955) 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 Gravelly Range. The Gravelly (Greenhorn) Range is a northward physiographic extension of the Snowcrest range, and it seems quite probable that the two ranges are parts of a single structural unit as well, separated only by the gap cut by the Ruby River as it flows across them. We would extend the fault shown on the USGS map northward along the west side of the Gravelly (Greenhorn) Range, and the fault is thus shown on the accompanying map (Fig. 1). The present elevation of the mountains east of this fault may be due at least in part to movement along it.

North of the dam at the head of the basin, 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 is located. On the Geologic Map of Montana (Montana Bureau of Mines and Geology, 1955) 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. It is evident that the Precambrian 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. Certainly the two faults are closely related. Hot springs, hot spring deposits, lava flows, and old volcanic necks along the margins of the basin all provide evidence of the presence of these faults.

In the preceding sections on stratigraphy and paleontology, it was demonstrated that the most probable age ranges of the Passamari Formation and Madison Valley equivalent are late Eocene to latest Oligocene or earliest Miocene, and late Miocene to early Pliocene, respectively, although the dashed and questioned diagonal lines on Figure 3 indicate the uncertainties of dating and possible age extensions. The Madison Valley equivalent 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 Upper Ruby River Basin, whereas the Madison Valley equivalent is a fluviatile fanglomerate composed largely of coarse materials eroded from the surrounding uplifted mountains of Precambrian rock. Based on the evidence presented, we include a series of generalized cross-sections (Fig. 4) depicting our interpretation of the geologic and geomorphologic history of the basin, and indicating a mode of deposition and source of the materials which compose the Tertiary formations of the basin.

It is probable that during the late Cretaceous and early Tertiary, Paleozoic, and Mesozoic rocks were present in the area now occupied by the Ruby River Basin. Laramide upwarp and folding of the pre-Tertiary rocks were followed by a long interval of early Tertiary erosion. The Paleozoic and Mesozoic rocks were stripped back, exposing the Precambrian except where it was covered by residual patches of "red conglomerate." This conglomerate consists largely of materials that were derived from pre-existing rocks of the region during that erosional interval. Much of this conglomerate may have been removed by subsequent erosion but remnants of it still occur in the northeastern part of the basin. In the late Eocene the site of the present basin began to sag, possibly accompanied by faulting along the margins. Some event, possibly regional volcanic activity, dammed downstream drainage, and lakes formed in which accumulated the sandy and silty lacustrine clays of the Passamari Formation. Early or middle Miocene normal faulting along the present basin margins carried the Precambrian to considerable heights so that accelerated erosion carried large amounts of coarse material into the basin, continued regional vulcanism contributed ash, and thus the fluviatile Madison Valley equivalent was formed during the late Miocene (or possibly earlier) and early Pliocene. Lava vents and hot springs developed along the faults, the hot springs continuing to flow today in some places. Later in the Tertiary, following the consolidation of the Madison Valley equivalent, faulting recurred along the margins of the basin cutting the Madison Valley equivalent and resulting in the spread of gravels over the fault line onto the Madison Valley equivalent. 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 equivalent is better consolidated and cemented throughout.

Since the deposition of the Madison Valley equivalent, minor faulting within the basin has occurred. As a result, the basin beds have been tilted and in one place the Passamari Formation has been faulted up against the overlying Madison Valley equivalent (Pl. II, Fig. 1). The exposure of the "red conglomerate" along the western side of the Ruby River Storage Reservoir may be a result of uplift due to similar minor faulting. Recent faulting in this part of Montana continues to the present—*witness* the recent Hebgen earthquake and faulting.

Four surfaces of construction or destruction have developed in the basin. All but one, the highest, are post-Miocene in age because they were formed on or over the Madison Valley equivalent. 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 Gravelly ranges. This erosion surface is probably late Cretaceous and/or early Tertiary in age and formed during the long interval of erosion which removed the Paleozoic and Mesozoic rocks from the region and exposed the Precambrian. On cross-section 6 (Fig. 4), 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. 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 equivalent below the pediment, indicating that they probably were in existence and had developed extensive headwaters prior to the post-Miocene faulting. The recurrence of faulting along the margins of the basin and subsequent erosional recession of the fault scarp provided the source for an apron of fringing gravels which were carried from the Precambrian rocks at the mountain fronts out over the Madison Valley equivalent. These gravels form a depositional surface, topographically higher and chronologically younger than the pediment. The erosional pediment and this higher but younger gravel surface both are shown on cross section 6 of Figure 4. The present flood plain of the Ruby River may be considered a fourth surface.

FIG. 4. Generalized geologic cross sections showing Cenozoic historical sequence in the Upper Ruby River Basin, Madison County, Montana.

Cross section 1 (top)—Pre-Cenozoic aspect of region. Paleozoic and Mesozoic rocks extend over and beyond area of Upper Ruby River Basin.

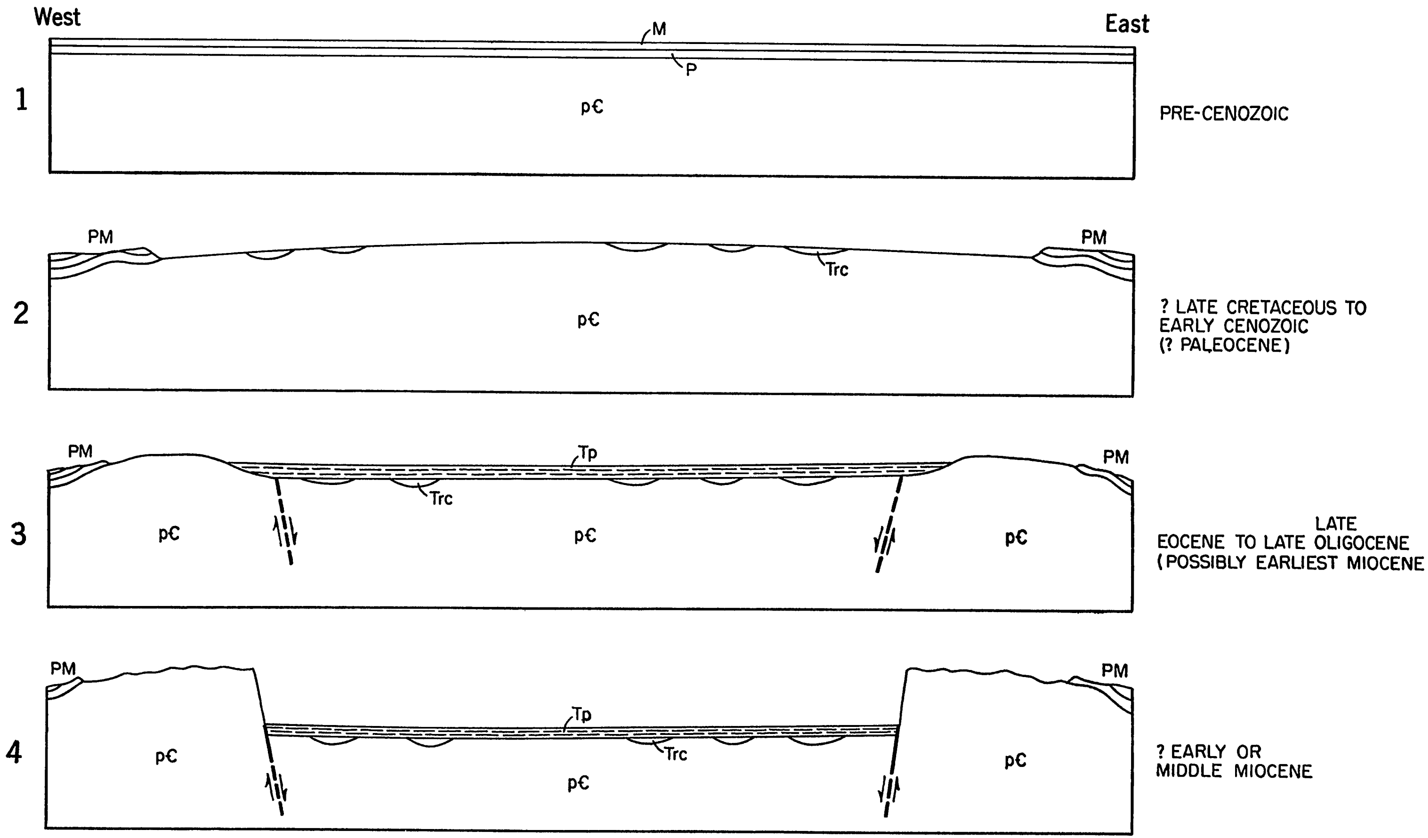
Cross section 2—Laramide regional upwarping, followed by long period of ?late Cretaceous and early Cenozoic (?Paleocene and early and middle Eocene) erosion. Paleozoic and Mesozoic rocks stripped back exposing Precambrian (PreBeltian). Patches of "red conglomerate" (?Paleocene, ?equals Beaverhead conglomerate) left on irregular surface. The "high erosion surface" (see cross section 6 below) formed at this time and was later uplifted.

Cross section 3—Late Eocene sagging of portion of uplifted region. Possibly some faulting beginning along flanks of sag. Deposition of Passamari Formation lake beds during late Eocene, Oligocene, and possibly earliest Miocene times. Inception of regional volcanic activity may have been partly responsible for downstream damming of basin. Precambrian and "red conglomerate" covered in basin.

Cross sections 4 and 5—Early or middle Miocene faulting. Passamari Formation cut by faults. Precambrian upfaulted in Gravelly and Ruby ranges. Erosion causes fault scarps to recede rapidly, the derived material filling the basin as the Madison Valley equivalent. Deposition of Madison Valley equivalent continues at least into early Pliocene. Extensive regional volcanic activity produces ash to form tuffs, especially during later part of Madison Valley equivalent deposition. Early Cenozoic erosion surface now uplifted and topping bordering ranges as "high erosion surface."

Cross section 6—Post early Pliocene to Recent time. Recurrent movement along marginal faults, cutting Madison Valley equivalent. Tilting of basin beds. Subsequent erosion of bordering Precambrian producing fault-line gravels which now obscure faults and spread over Madison Valley equivalent at basin margins. Contemporaneous faulting and tilting of basin beds and subsequent erosion expose Passamari Formation and, in a restricted area, the "red conglomerate." Lava flows, hot springs, and possibly some small volcanic vents, form anew along faulted basin margins. Erosion truncates tilted Madison Valley equivalent and Passamari Formation to form pediments merging toward basin margins with depositional surfaces of fault line gravels. Relatively recent stream erosion (due either to late uplift or to climatic changes) has incised the fault line gravels and pediments; present flood plain of Ruby River came into existence as a result (prior to modern artificial damming).

NOTE.—Cross sections are generalized and do not represent any actual single line of section across the depositional basin.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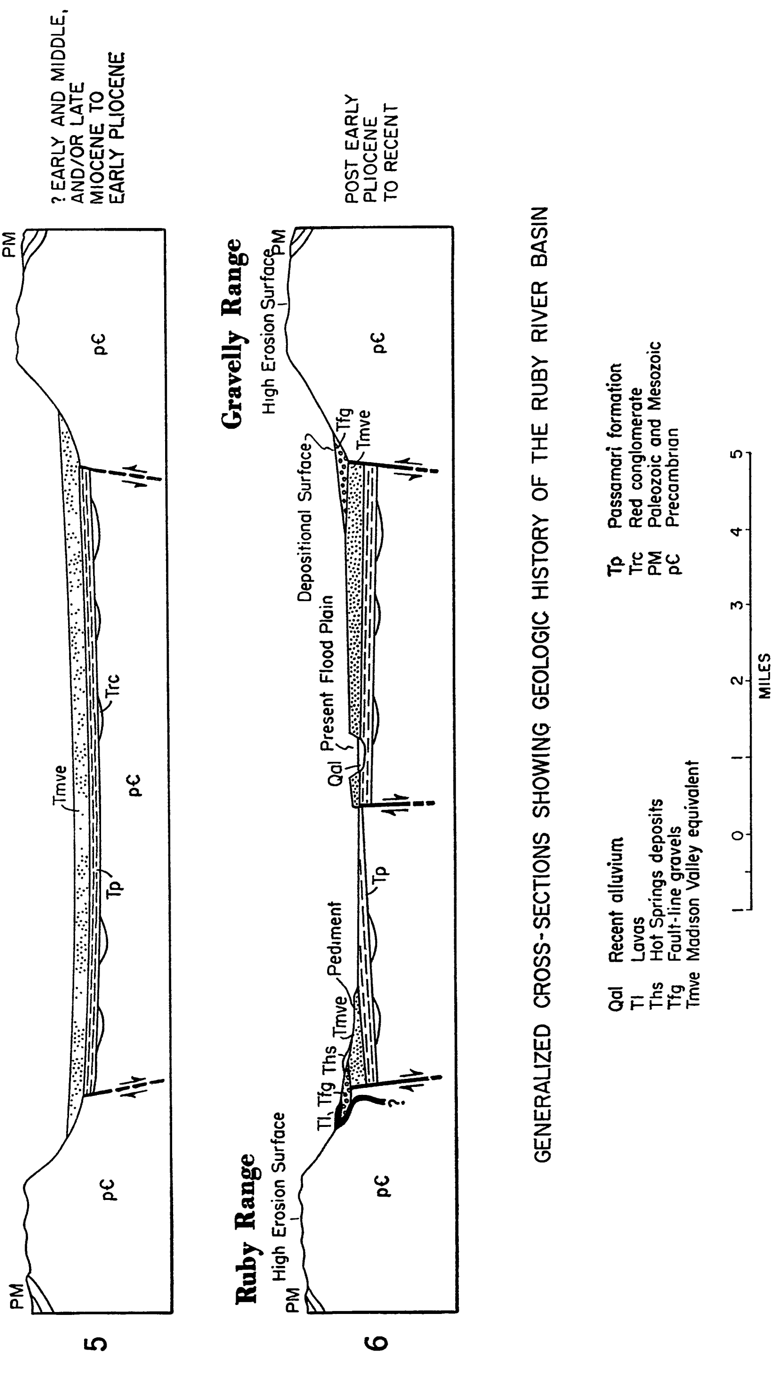


GENERALIZED CROSS-SECTIONS SHOWING GEOLOGIC HISTORY OF THE RUBY RIVER BASIN

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PLATES

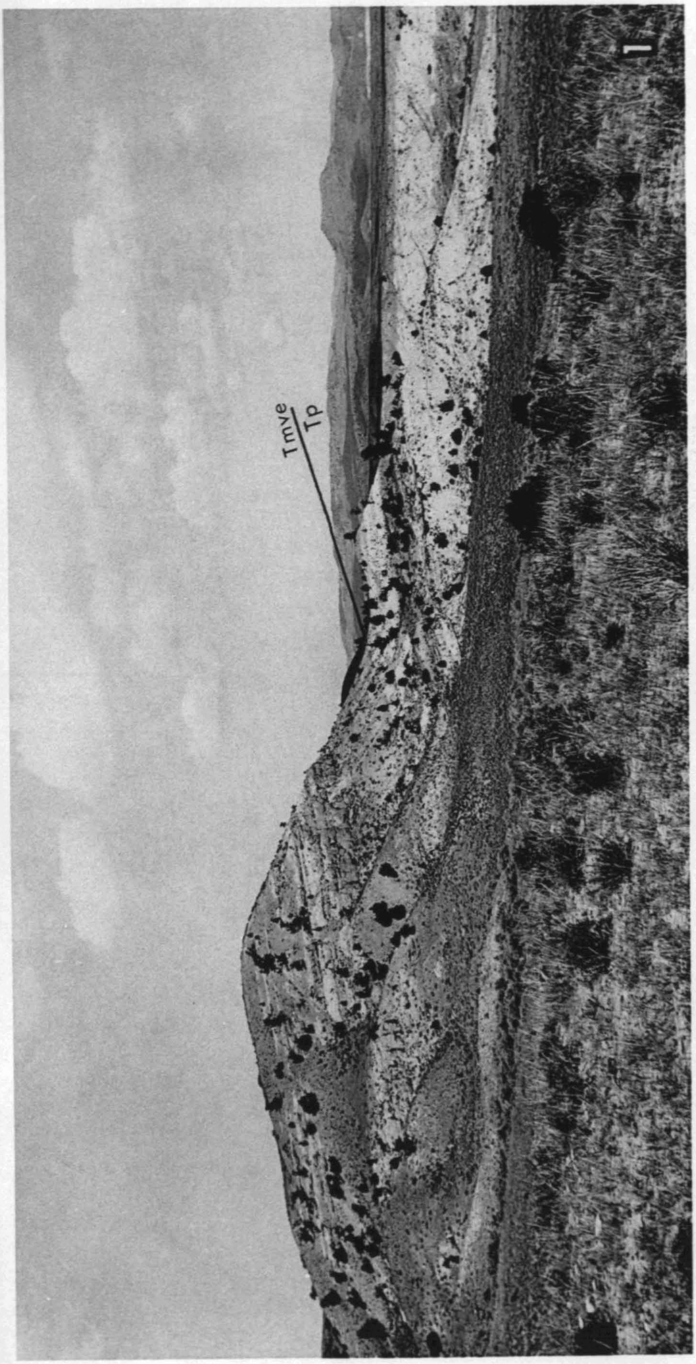
## EXPLANATION OF PLATE I

Sedimentary strata of ?Eocene, Oligocene, Miocene, and Pliocene age in the Ruby River Basin, southwestern Montana.

FIG. 1. Sweetwater Creek Measured Section Locality No. 1 (see map). Looking northwestward. Tan sandstones and siltstones of the Madison Valley equivalent (Tmve) conformably overlying white-weathering shales of the Passamari Formation (Tp).

FIG. 2. Exposures of the Madison Valley equivalent along the north side of Barton Creek. This is the locality of Barton Creek Measured Section No. 4.

PLATE I



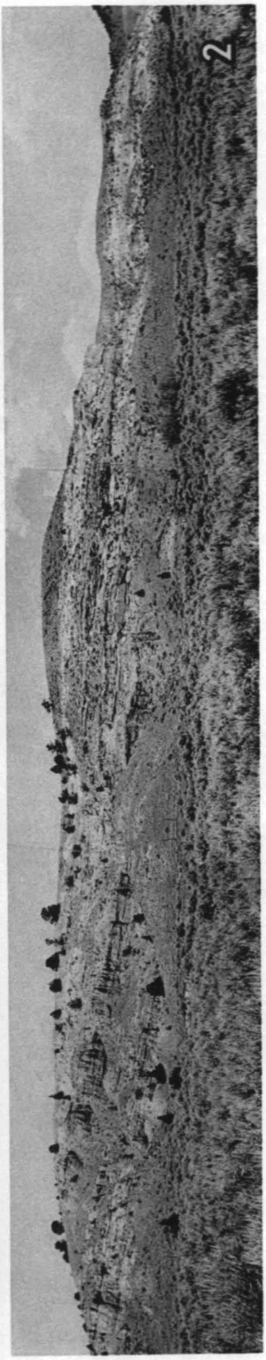
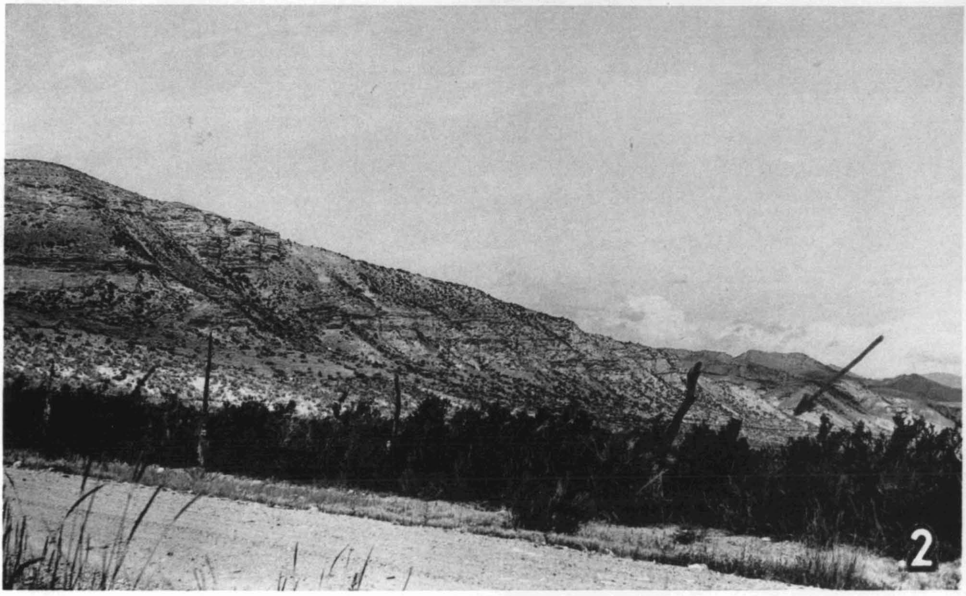



PLATE II

## EXPLANATION OF PLATE II

Sedimentary strata of ?Eocene, Oligocene, Miocene and Pliocene age in the Ruby River Basin, southwestern Montana.

FIG. 1. Darker colored Madison Valley equivalent on right (east) downfaulted against lighter shales of the Passamari Formation. Looking northward from about one-half mile southwest of the junction of Sweetwater Creek and the Ruby River.

FIG. 2. Exposures of the Madison Valley equivalent at the Belmont Ranch Measured Section Locality No. 2. Looking northward from road near junction of Sweetwater Creek and the Ruby River. Arrow indicates mouth of ravine up which fossil vertebrates were collected from Fossil Locality No. 6 in the Madison Valley equivalent.