The Birch Creek area is located slightly north of the geographic center of the state of Oregon. Seventeen square miles lie near the west boundary of Grant county and the remaining thirty-seven square miles are located in eastern Wheeler county. The area occupies the north central portion of the Dayville Quadrangle and is located 6 miles west of Dayville, Oregon.

Paleozoic era marine sediments, marine sediments and intrusive rocks of Mesozoic age, a Paleocene intrusive, and Tertiary volcanic rocks are represented in the area.

The basement complex in the area is Permo-Triassic in age, dated by fossils found on west Birch Creek. The marine sediments are now represented by graywacke, quartzite, argillite, phyllite, and limestone. A meta-andesite flow was observed in the stratigraphic section. Pyroxenite (pre-upper Triassic) intruded the marine sediments. Deformation, with subsequent truncation, occurred prior to undulation and deposition of upper Cretaceous marine shales and sandstone containing lenses of quartzite pebbles. An acidic magma intruded the marine sediments during the uplift and folding at the close of the Cretaceous period. The rocks representing this intrusion are leuco-granite porphyry, rhyolite porphyry and dacite porphyry with associated pseudo-igneous contact rocks.

Tertiary volcanism was initiated in the Eocene epoch where extrusive volcanic breccia and andesite flows of the Clarno formation collected on the folded Cretaceous sediments. Eocene sedimentation ceased with the deposition of tuffaceous sandstone and gravels. Subsequent erosion occurred until upper Oligocene time when aeolian ash fell uniformly over the area and was penecontemporaneously removed from the higher elevations and redeposited in local basins. The John Day pyroclastic showers continued until the close of lower Miocene when fissure eruptions of olivine basalt and normal basalt flows covered the area and blotted out the topography. A slight structural sag which developed in the Columbia River basalts, provided a depositional site for the accumulation of Mascall sediments during upper Miocene. These
lacustrine, (and in part aeolian) tuffs which contain interbedded grits and gravels were folded when regional forces formed the John Day syncline at the close of Miocene. The folded and faulted surface of the former plateau provided both a source area and a depositional basin for the Rattlesnake gravels which collected in the John Day syncline during Pliocene time. A welded-tuff separates the lower and upper gravels. This member is believed to be a "nuees ardentes" type deposit.

Since the John Day River began cutting a channel at Picture Gorge, probably at the beginning of the Pleistocene, erosion has been dominant.
GEOLOGY OF THE BIRCH CREEK AREA
DAYVILLE QUADRANGLE, OREGON

by

JOHN WILLIAM DAWSON

A THESIS
submitted to
OREGON STATE COLLEGE

in partial fulfillment of
the requirements for the
degree of
MASTER OF SCIENCE

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Date thesis is presented March 31, 1951
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THE GEOLOGY OF THE BIRCH CREEK AREA

INTRODUCTION

Systematic mapping of the Dayville Quadrangle was undertaken by the Geology Department of Oregon State College in 1934, under the direction of Dr. W. D. Wilkinson. This work was interrupted during the war years and was not resumed until 1947. Field work culminated in 1950.

A Note on Nomenclature

The Birch Creek area referred to in this report includes that part of the Dayville Quadrangle mapped by the author. It includes approximately 54 square miles. The map is included as Plate II in this thesis. Specific localities referred to in the text of the report include the Birch Creek basin which is located in the west central portion of the area and occupies the SW 1/8 section 16, S 1/2 section 17, N 1/3 section 20, and section 21, all T 13 S, R 25 E. The Clarno basin, situated in the east central part of the area, includes the S 1/2 of section 7, and section 8, T 13 S, R 26 E, also S 1/2 section 12, T 13 S, R 25 E.

The drainage lines referred to are those of Birch, Rattlesnake, and Cottonwood Creeks.
Previous Work

The initial reference to the Birch Creek area appears in a University of California publication of 1902, by J. C. Merriam (13-p.269,314). He mentioned rocks older than the Cretaceous sediments that occur in the general area.

F. C. Calkins (3-p.109,172) described the granites of Birch Creek in "The Petrography of the John Day Basin" published in 1904 by the University of California.

A. J. Collier (6-p.3,47), in 1914, stated that limestone occurs in the older rocks of the region.

In 1925, J. C. Merriam, C. Stock, and C. L. Moody (15-p.43,92) published a paleontological paper dealing with a late Tertiary fauna from the area.

Purpose

The purpose of the field work undertaken by the author was to make an accurate areal geologic map and a detailed study of the area, and thus contribute to the geology of the Dayville Quadrangle. Previous to the field work of Oregon State College, a crude planometric sketch map (6) with limited geologic formations perfunctorily plotted thereon was the only available map.
Detailed work was carried out in the Permian-Triassic area and a stratigraphic section of occurring rock types was compiled to aid in determining the conditions of accumulation of the ancient sediments. Numerous samples of rhyolite porphyry were selected from all outcrops to aid in the determination of its intrusive effects and its mineralogic variations.

As a supplement to the field work approximately one hundred and fifty thin sections were prepared of the varying rock types found in the nine formations of the area.

Methods

Field work was carried out during the summer of 1950, from the Oregon State College Geology Field Camp as a base of operation. All fault and formational contacts were walked and their locations plotted on an enlarged section of the Dayville Quadrangle map as issued by the U S G S, 1932. Bench marks are widely distributed throughout the area and hence relatively accurate vertical control was maintained with the use of an aneroid barometer. Dip and strike recordings were obtained with a Brunton compass and were plotted on the map as they were taken. A fine set of AAF areal photographs was of great assistance.
Size and Location

The Birch Creek area includes some 54 square miles. It is located slightly north of the geographic center of the state. The Wheeler-Grant county line traverses the area in a north-south direction. Seventeen square miles lie in the west-central part of Grant County, and the remainder of approximately thirty-seven square miles is located in southeastern Wheeler County. It occupies the north-central portion of the Dayville Quadrangle and is limited on the north by the northern boundary of this Quadrangle. The area is enclosed by longitudes 119°37' and 119°46' and the parallels of latitude 44°30' and 44°22'. For position in regard to state and county boundaries the reader is referred to Plate I, page 7.

Accessibility

Dayville, located 6 miles east of the area is the nearest community and is accessible by U. S. Highway 28. This highway is a paved all weather road. Six miles west of Dayville it passes within a half mile of the north-east corner of the area. All roads within the area itself are secondary and their use is generally restricted to summer seasons.
Drainage

Drainage within the area is generally northward and is dominated by four streams. Cottonwood Creek drains the eastern part of the area and joins the John Day River near the northeast corner of the area. Birch Creek occupies a similar position in the western section, but it joins east-flowing Rock Creek beyond the northern boundary of the area. The land between these two streams is drained by Little Rattlesnake and Rattlesnake Creeks. All drainage with the exception of Cottonwood and Birch Creeks is intermittent.

Relief

Marked contrast of elevations is evident in the higher regions of the area where the dissected basalt stands as abrupt cliffs. The highest point in the area, 6801 feet above sea level is located near the southwest corner in the SW 1/4, SW 1/4, section 8, T 13 S, R 25 E. The minimum elevation, less than 2400 feet, is located on Cottonwood Creek, NW 1/4, SW 1/4, section 5, T 12 S, R 26 E. Maximum difference in relief is approximately 4425 feet.

Climate

The Climate in this high plateau region is marked
by seasonally contrasting temperatures and limited precipitation. Temperature during the winter often approaches -20°F., but summer heat frequently forces the thermometer to 110°F. Snow accumulates during the winter, especially at higher elevations, but rainfall is usually restricted to spring and early summer months. Thundershowers are common during early summer and locally these storms occasionally gain cloudburst proportions. Annual precipitation averages between 10 and 15 inches a year.
PLATE I

Index map showing location of Birch Creek Area, Oregon
GENERAL GEOLOGY

The structure of the rocks determines the location of outcrops in the Birch Creek area and exposures are restricted to four situations: (1) The oldest formations are limited to two windows exposed by Tertiary faulting and subsequent erosion. Permo-Triassic meta-sediments, a pyroxenite intrusive, Cretaceous marine sediments, a rhyolite porphyry intrusive, Clarno volcanics, and John Day tuffs are thus exposed. (2) The second situation is the result of Tertiary folding, whereby outcrops are restricted to an east-west trending syncline which occupies the northern third of the area. The Mascall sediments and the Rattlesnake formation occur in this area. (3) Columbia River basalt covers the remainder of the area, except (4) for local accumulations of alluvium along creeks.

A list of formations mapped (Plate II) in the field work is combined with a concise formational description in Table I, p. 9.
Formations in the Birch Creek Area

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<th>AGE</th>
<th>FORMATION</th>
<th>DESCRIPTION</th>
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<tbody>
<tr>
<td>Recent</td>
<td>Alluvium</td>
<td>silt, sand and gravel</td>
</tr>
<tr>
<td>Pliocene</td>
<td>Rattlesnake</td>
<td>silt, sand and gravel with welded tuff</td>
</tr>
<tr>
<td>U. Miocene</td>
<td>Mascall</td>
<td>Tuffs of buff, yellow and gray color with interbedded sands and grits</td>
</tr>
<tr>
<td>M. Miocene</td>
<td>Columbia River</td>
<td>Massive flows of olivine and normal basalt with interflow breccia and baked soil zones.</td>
</tr>
<tr>
<td>L. Miocene &amp; U. Oligocene</td>
<td>John Day</td>
<td>Green and buff colored tuffs</td>
</tr>
<tr>
<td>Eocene</td>
<td>Clarno</td>
<td>Andesite flows, volcanic breccia, crossbedded tuffaceous sandstone</td>
</tr>
<tr>
<td>Paleocene</td>
<td>unnamed</td>
<td>Leucho-granite porphyry, rhyolite porphyry, dacite porphyry and pseudo-igneous contact rocks.</td>
</tr>
<tr>
<td>Cretaceous</td>
<td>Antone</td>
<td>Pebble conglomerates, grits, sandstone and sandy shale</td>
</tr>
<tr>
<td>Pre-Upper Triassic</td>
<td>unnamed</td>
<td>pyroxenite</td>
</tr>
<tr>
<td>L. Triassic Per.</td>
<td>Kelsey</td>
<td>limestones, schist, phyllite, argillite, quartzite, gray-wacke, and meta-andesite</td>
</tr>
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TABLE I
PERMO-TRIASSIC

Distribution and Topographic Expression

The Permo-Triassic is the basement complex of the Birch Creek area and is confined to less than 2.5 square miles. Outcrops are restricted to the Birch Creek basin. The limited exposures do not have any typical topographic expression, but the clastic beds of the formation usually form rounded hills which have a thick soil mantle and support dense vegetation. Outcrops are limited to creek banks and areas adjacent to contacts of younger intrusive rocks. The limestone beds are resistant in the arid climate and hence usually stand as abrupt cliffs.

Lithology

A stratigraphic section of rock types was collected on west Birch Creek and several thin sections were cut from each type. A detailed petrographic study was made of all sections and a composite description has been made for each.

Graywacke

Rocks of this class vary considerably in minor constituents.
Exposures of graywacke show various shades of green and brown depending upon the degree of chloritization. Bedding was not apparent in any outcrops examined. Jointing is pronounced and outcrops usually exhibit flat surfaces where erosion has removed material to expose these planes.

The dense green rock fractures irregularly but rectangular shaped pieces part along lines parallel to the jointing system. Minerals are not discernable on fractured or cleaved surfaces; however sawed and polished surfaces of some types show flattened elongated siliceous granules and pebbles that have subangular to subrounded boundaries. Disseminated gray and black fragments and dark carbonaceous streaks (oriented at right angles to flattened pebbles), calcite veins and a chloritic matrix are the only recognizable features.

As seen in all thin sections, angular quartz and rock fragments of the older meta-sedimentary types are dominant. These angular pieces of rock include slates, quartzites of varying grain size, phyllite, vein quartz and limestone. Calcareous material occurs as detrital grains and as secondary vein fillings. Pieces of andesine and basalt are represented by fragments composed of microlites of andesine and labradorite laths. Chlorite has saturated some sections and is
present in all sections. Solution paths are well defined and the chloritoid minerals include pennine, clinoclore, and prochlorite (see Fig. 6,p.19). Octahedra of magnetite are disseminated through all slides and are also present as clusters within the relic outlines of crystals that they have replaced. A clayey matrix is present but limited in most sections. Minerals present in some sections but not common to all include sericite and detrital grains of orthoclase, albite and oligoclase. Vein albite appears in limited amounts and occasionally shows myrmekitic intergrowth. Subhedral augite is common in some but absent in most sections. Small epidote crystals appear in a few vein contact zones.

Argillite

Pieces of the dense black indurated rock that have been loosened along jointing planes are scattered around outcrops. Specimens are usually about 4 inches in length and 2 inches in width. Minerals are not recognizable in the aphanitic rock, but most specimens contain small veinlets of quartz. A mottled appearance on some specimens is caused by varying amounts of included carbonaceous material. Study of thin sections of the rock reveals inclusions of small amounts of micro-quartz fragments disseminated through a siliceous silty groundmass that is occasionally cut by small quartz veins.
Pebble Quartzite

Resistant outcrops of pebble quartzite stand as small knobs where they are exposed. Bedding is not apparent but general attitude is obtainable from flattened pebbles. Durability of the rock limits talus to pieces freed along planes of the pronounced jointing system. The color varies from blue, brown, and red to colorless. Cementing quartz has a blue cast in hand specimens but is clear on thin fractured edges. Pebbles vary in size from 0.5 to 2.5 inches in diameter and are well rounded. The general shape and size of the pebbles indicate a large amount of transportation. The rocks may represent second generation material reworked from older sediments.

Limestone Breccia

Irregular fractures in the limestone breccia causes a diversity of shapes and fresh surfaces contain light colored brecciated fragments up to 0.8 of an inch in length set in a dark calcareous matrix. The included fragments are shattered and the fractures are filled with hematite and limonite. The veinlets pass into but are inconspicuous in the darker matrix.

Microscopic study shows angular limestone fragments set in a carbonaceous calcareous groundmass that is criss-crossed with veinlets of iron oxidation products
derived from clusters of magnetite. Angular micro-quartz fragments are disseminated through the matrix.

Limestone

In the arid climate exposures of limestone are easily located by following the light colored talus and float. Exposures are restricted to single outcrops that appear to be at least in part localized reefs. The rocks at the Lower Triassic fossil locality (described later in the text) contain a pattern identified as that of calcareous algae (1). Because of differential erosion, some outcrop surfaces are covered with brown cherty angular fragments protruding as much as a half inch above the limestone surfaces. Outcrops show calcite cemented fractures and in some exposures the limestone appears shattered.

The rock is white to light gray on weathered surfaces but is dark blue to nearly black along fresh fractures. The dark color is emphasized by white vein calcite cementing the fragments. Weathered surfaces are smooth to the touch but have minor irregularities because of solution.

Under the microscope a similarity in sections from all outcrops is noticeable. They display, in various degrees, the brecciated character of the black limestone cemented with white calcite veins which vary from microscopic size to veins 0.5 of an inch in width. The color
is caused by included carbonaceous material disseminated in sufficient quantity to produce the dark hue. Occasional feldspar and quartz grains occur but are scarce. A few foraminifera are present but tests are not discernible in hand specimens and in the random sections they were unidentifiable.

A sample obtained from a contact zone of rhyolite porphyry is recrystallized. Differential weathering along rhombic cleavages produced a series of alternation depressions and ridges. Under the microscope the twinning and cleavage striae are pronounced in the mosaic textured marble. (see Fig.1, p.16)

A sample from a fault zone is also recrystallized, probably because of pressure at the time of movement. Cleavage traces and twinning striae are present. The pattern formed by the carbonate and the arrangement of included carbon indicates a micro-schistic structure. (see Fig.2, p.16)

Meta-andesite

The meta-igneous rock is chloritic green with smooth parting along cleavage lines parallel to the jointing seen on the outcrops. Minerals are not visible in hand specimens. Because of the chloritic green color, aphanitic texture, and the irregular contact with limestone, the meta-igneous rock closely resembles chloritic graywacke
Fig. 1  Permo-Triassic marble from contact zone of rhyolite intrusion. Crossed nicols, x50. (Rk 75)

Fig. 2  Schistic structure of Permo-Triassic marble from fault zone. Plain light, x50. (Rk 97-b)
and is not distinguishable without thin section study.

A micro-schistic texture superimposed upon the pilotaxitic groundmass is discernible in section study of the micro-porphyry. Aligned oligoclase and andesine laths of the groundmass curve around earlier phenocrysts of augite and twinned andesine and indicate that the rock originated as a lava flow. Ultra-berlin blue of pennine is evident with crossed nicols and octahedra of magnetite are visible in reflected light. Sections cut from the samples obtained from the top of the flow show no alteration of the limestone along the irregular contact.

Other Permo-Triassic rock types present in the basin are carbonaceous slates, brown slates, phyllite, sericite schist, vertically graded sand-granule-pebble quartzite and graphitic quartzite. (see Fig.4, p.18 and Fig.5, p.19)

Mode of Deposition

Permiam seas advanced northward into the United States from the Gulf of Mexico and southward from the Alaska region (10-p.670-674). The transgressing seas joined over the continental area and the meta-sediments accumulated within them. The diversity of rock types indicate fluctuating conditions with periodic subsidence accompanying deposition. Interbedded angular material is indicative of rejuvenation of the positive area which served as a source. The original mud of slates is
Fig. 3  Permo-Triassic meta-andesite-limestone contact. Crossed nicols. x50 (Rk 65)

Fig. 4  Permo-Triassic quartzite sericite schist. Crossed nicols. x25 (Rk 92)
Fig. 5  Permo-Triassic graphite quartzite schist. Crossed nicols. x25 (Rk 95)

Fig. 6  Chlorite saturated Permo-Triassic sediments. Crossed nicols. x50 (Rk 68)
generally thought to accumulate under quiet water conditions while limestone reefs, especially those of organic origin, are typical of the clear shallow zone of the ocean. These rock types are exposed in the Birch Creek basin.

Relative position of the positive area is indeterminable from the limited exposures in the Dayville Quadrangle, but the land mass was composed of older metamorphic sediments of varying types. Igneous activity is evident where fragmental pieces of flow rock are incorporated in the sediments or where meta-andesite is found interbedded with the sediments.

**Stratigraphic Relationship**

Stratigraphic relationship to the presumably younger pyroxenite intrusion is not shown in the area but farther east the effects of this intrusion has been noted (23-p.50-51). The relationship of the Permo-Triassic meta-sediments to the overlying Cretaceous sediments is one of distinct angular unconformity. The older sediments were folded and subsequently truncated by erosion before the advance of late Mesozoic seas. Intrusion effects of the rhyolite porphyry upon the Permo-Triassic sediments are evident in the Birch Creek basin where xenoliths and roof pendants are found.

A dip of 73°, S 55 E, was determined from the
fossil-bearing layers in section 17, T 13 S, R 25 E. This is probably average for the formation although slight local variations were observed in other localities.

**Fossil Locality**

The fossil-bearing outcrops were discovered on a tributary of West Birch Creek. Exact location of the Triassic outcrop is in the SW 1/4, SW 1/4, SE 1/4, SW 1/4 of section 17, T 13 S, R 25 E. The Permian Fossils occur about 300 yards N 50° W along the ridge. The nearest road to the location terminates at the fords of Birch Creek, slightly more than a mile NE of the outcrops. A well marked trail continues from this road and passes within 20 feet of the fossil locality.

**Age**

Age of the formation was determined from the fossils discovered on West Birch Creek. In addition to the two fossil-bearing outcrops previously described, a large piece of fossil-bearing float lithologically different from that of either outcrop was found. A selection of the three assemblages was sent to Dr. G. Arthur Cooper, Smithsonian Institute, Washington, D.C. In his reply (7) he refers to the first two localities as 1 and 2 and the float as 3. He states in part:
"I have examined with considerable care the specimens you submitted to me a short time ago. I regret that I cannot give you any specific identifications. The specimens are so badly squeezed in various directions that specific determinations are quite impossible. The specimens, however, proved to be extremely interesting because, if my observations are correct, they include material of two ages.

I asked Drs. Reeside and Kirk to corroborate this identification and both of them agreed...that the age of the piece (1) is undoubtedly lower Triassic.

The other specimens (2 and 3) are quite definitely of Paleozoic age. Without having any really tangible evidence other than general appearance I suggest that the age of both of these Paleozoic lots are of Permian age."

The stratigraphic association of the fossil occurrences in the field lends support to Dr. Cooper's conclusions.
PYROXENITE

Distribution

The most restricted formation mapped in the area is the ultra-mafic rock located in section 21, T 13 S, R 25 E in the Birch Creek Basin. The small exposure does not exceed 0.05 of a square mile in area.

Lithology

Talus around the outcrop is composed of block-like chunks that average from 4 to 6 inches in size. The irregular fractures of the specimens are caused by cleavages of the variously oriented crystals so that the resulting surface is hackly. Crystals in the hand specimens average about 7mm in length and the cleavage faces have a schiller luster. Fresh surfaces of the rock are deep blue-gray to nearly black, but weathering either lightens the color or alters it to limonitic brown.

A study of several thin sections shows the rock to be composed of approximately 60 percent enstatite. The remainder of the primary minerals, about 35 percent, include magnetite, chromite, diopside, hypersthene, pigeonite and olivine. Secondary minerals are antigorite, chlinochlore, pennine, and limonite. They constitute about 5 percent of the rock. Some secondary magnetite
is noticeable as clusters in relic crystals. (Fig. 9, P.26)

**Age and Stratigraphic Relationship**

The limited exposure of pyroxenite in the Birch Creek area does not afford sufficient evidence to classify this formation in respect to age. The outcrop has the form of a roof pendant and is completely surrounded by younger rhyolite porphyry. It was probably placed in its present relative position by the upthrust of the nearly cooled, viscous rhyolite intrusion.

Similarity in petrographic characteristics to the ultra-mafic formation in the Dayville area is believed sufficient to correlate this with the pyroxenite of that formation. The stratigraphic relationships and contact effects are evident to the east, and Taubeneck (23-p.50,51) believes the ultra-mafics to be pre-Upper Triassic. The pyroxenite of Birch Creek basin is probably comparable in age.

**Mode of Origin**

Umbgrove, in describing the history of geosynclines, indicates that ultra-basic rocks are injected along a weakness caused by downwarp. When the synclinal axis is ruptured, horizontal compressive forces terminate sedimentation. The folded and injected sediments are left as a positive area (25-p.81,82,184,185). The
genesis of the ultra-mafics here can only be surmised but this general sequence coincides with the history of the Birch Creek area during the early Mesozoic era.
Fig. 8  Cretaceous sandstone. Crossed nicols, x50. (Rk 58)

Fig. 9  Pyroxenite. Crossed nicols, x50. (Rk 69)
CRETACEOUS FORMATION

Distribution and Topographic Expression

The main exposures of Cretaceous sediments are limited to the Birch Creek basin and their areal distribution does not exceed 3 square miles. An isolated outcrop is located in the Clarno basin.

Typically, the unconsolidated Cretaceous sediments form rounded hills with smooth contours, but in section 20, T13 S, R25 E coarse sandstone forms an abrupt cliff about 50 feet high. Cliffs of sandstone are common in the Antone area to the west.

Lithology

The basal shale member of the Cretaceous sediments in the Birch Creek basin changes upward to a fine-grained argillaceous sandstone which in turn grades upward into a coarse fossil-bearing sandstone containing lenses and interrupted layers of quartzite pebbles. Locally, grits are evident as interrupted layers in the sandstone. In section 20, T13 S, R25 E fluvial crossbedding occurs near the top.

Because of the friable nature of the rock and the existing soil mantle, outcrops of shale are not exposed except around the rhyolite porphyry. The baked silicified material in these outcrops is classified as hornfels
Sandstones are usually exposed in one of three general forms. Slight induration in some exposures of one of these has aided formation of cliffs. The second type is unconsolidated and its outcrops are indicated by a greenish sandy soil on the smooth topography. Where the sandstones are in contact with the acidic intrusive, a third type is represented by a baked and silicified rock.

Exposures of pebble streaks are limited to indurated igneous contact zones. Outside these local areas the pebbles are scattered through the soil mantle.

The fine-grained sandy shale facies exposed in Clarno basin is shattered. Its talus consists of small blocks slightly more than 2 inches in diameter. Small pelecypods are present but not abundant, although casts of worm borings have weathered free and are scattered over the surface. Bedding is not apparent because of the shattered nature of the outcrops but the structural attitude of the beds may be determined on fossil-bearing layers.

Megascopic Description: Irregular fragments of hornfels have a hackly appearance. Semi-schistic partings are limonite-stained and the rock breaks along these irregularities. Fractures across the lines of parting retain the original light green color common to the
formation. Minerals are not identifiable in hand specimens.

Rounded quartz grains sparsely scattered through a green shaley matrix containing enough bituminous material to cause a dark cast are typical of the sandy shale. Minerals are not distinguishable to the naked eye but with the aid of a hand lens the rounded grains of quartz, feldspar and flakes of white mica are recognizable.

Specimens of sandstone are covered by limonite stain on the exposed parts but the rock is green immediately under the surface. Components identifiable with a hand lens are feldspar, quartz, rock fragments and occasional mica flakes. The sandstones that are altered by the intrusive superficially resemble the finer-grained hornfels because of similar schistic parting. However, mineral grains are visible, and in addition, the rock has a vitreous appearance on fresh fractures.

Grits show local minor variations in texture. Their colors grade from green to black. Angular to subangular material include rock fragments, quartz and scattered feldspar grains in an argilliceous, bituminous clayey matrix. Lighter colored exposures lack the bituminous ingredient.

Well rounded slightly oblong quartzite pebbles of various colors comprise the material in pebble lenses and
layers. Meta-sedimentary rock types are represented in small amounts.

Study of thin sections of the sediments show a dominance of angular quartz and feldspar grains. These are combined with fragments of meta-sedimentary rock comparable to those of the Permo-Triassic sediments, with magnetite and its related oxidation products and with an argillaceous calcareous matrix that forms a cement. Feldspars are acid plagioclase and orthoclase. Clinoclore and pennine are present as alteration products. A grain of rutile with its borders altered to leucoxene was noticed in a single section. (Fig.8,p.26)

**Thickness**

Folding and subsequent erosion prior to deposition of Tertiary volcanics has resulted in an unequal thickness. A measured section was about 450 feet thick.

**Mode of Deposition**

An arm or embayment of the Pacific Ocean occupied the area during the Cretaceous period and marine sediments were deposited in the new seaway. Near shore conditions prevailed in the area as shown by the abundance of macrofossils, carbonaceous material, local stream crossbedding and the association of the several rock types. The most
abundant fossil present in the Cretaceous formation is *Trigonia* which has a characteristic littoral environment. Pebble lenses repeatedly occurring in the sandstone are characteristic of wave or shore current deposition. Angular pieces of Permo-Triassic meta-sediments in the sandstones were derived from the immediate vicinity and were buried without extensive transportation.

**Age and Stratigraphic Relationship**

The Cretaceous sediments lie between rocks of early Mesozoic and early Tertiary ages. Truncated folds of the Permo-Triassic meta-sediments served as a foundation for the late Mesozoic sediments. A variety of Tertiary volcanics overlie the formation. In Clarno basin the correct stratigraphic sequence occurs where the Clarno volcanic breccia unconformably overlies the Cretaceous marine sediments. In Birch Creek basin, depending upon location the outcrops are overlain by John Day tuffs, or by Columbia River basalt, as well as, Clarno volcanics.

Invertebrate marine fossils are abundant in the sandstone and Stanton (13-p.280,284) assigns the formation a position at or near the base of Cretaceous Chico formation. Fossils are not evident locally in the shale member but ammonites have been found at Battle Creek about a mile east of the area. Taubeneck (23-p.81) considered
the shale at this locality to be of Upper Horsetown age and equivalent to similar deposits that have been described from the vicinity of Mitchell.

It is suggested the Upper Cretaceous sediments exposed in the north end of the Dayville Quadrangle be given local formational names. This has been done in part by Dr. E. L. Packard (17). He refers to the sandstone-pebble facies containing the *Trigonia* fauna as the Antone formation. As yet the remainder of the Cretaceous sedimentary section is unnamed.
RHYOLITE PORPHYRY

Rhyolite porphyry best describes the average texture and composition of the intrusive acidic rock of the area although several petrographic varieties are represented.

Distribution and Topographic Expression

The rhyolite porphyry, typical of pre-Columbia River basalt formations, occurs in very limited extent. Outcrops are restricted to the Birch Creek basin and their total areal distribution does not exceed 0.3 of a square mile. Outcrops are found in sections 16, 17, 20 and 21, T 13 S, R 25 E.

Surface exposures are not extensive, but this resistant rock is responsible for the ridges and knolls in the basin. Outcrops usually occur along or near the crests of the hills and they form small knolls and ridges with steep slopes. Talus and pieces of float 6 to 8 inches in diameter are scattered over the surface, thus exposures are easily located by following the loose material.

Lithology

Outcrops exhibit a jointing pattern which strikes parallel to a major east-west fault and one system dips about 70° to the north the other 60° to the south. A later injection of quartz has cemented most of these
fractures. Weathering has been severe in some outcrops while others appear fresh. Around some of the more extensively weathered exposures, doubly terminated beta quartz crystals are scattered over the soil mantle.

The color of the rocks grades from limonitic tinted cream to dark green; alteration of mafic minerals contributed to the yellow stain. Darker colors are directly related to contact effects.

The following petrographic descriptions represent a gradational facies from the center of the exposures to contact zones at the exterior. This order is also representative of a darkening color gradation. All textures are porphyroid seriate. The described types are leuco-granite porphyry, rhyolite porphyry and dacite porphyry.

Leuco-Granite Porphyry

The granite porphyry is an irregularly fractured, limonite tinted, cream-colored rock. Weathered surfaces contain numerous small depressions produced by the alteration of biotite and the freeing of quartz crystals. Euhedral phenocrysts of orthoclase and acid plagioclase are abundant and occasionally reach 5mm. in length. Subhedral quartz phenocrysts are present but are not abundant. Biotite is noticeable on fresh fractures.

Study of thin sections show the rock to be composed
of 60 to 70 percent phenocrysts set in a fine crystalline groundmass. The larger crystals were found to be about 30 percent twinned and untwinned orthoclase. Albite and oligoclase approximately equal orthoclase. Small quartz crystals and occasional biotite crystals, sometimes altered to antigorite and limonite, comprise the remainder of the phenocrysts. The fine-grained groundmass is composed of essentially the same suite of minerals. Feldspars and especially quartz crystals show deuteric effect. Secondary sericite is abundant on the surface of feldspars in weathered sections. Minor amounts of accessory minerals include zircon, apatite and magnetite. (see Fig. 10,p.36)

This is probably the granitic rock described by Calkins (3-p.109,172).

Rhyolite Porphyry

This facies is a gradation from the leuco-granite porphyry, becoming darker as sedimentary rock contacts are approached. The lighter varieties are similar to the leuco-granite porphyry except for fewer phenocrysts. Darker facies show an appreciable increase in size and frequency of euhedral beta quartz crystals. Small biotite flakes increase in amount.

Under the microscope it was found that phenocrysts
Fig. 10 Leuco-granite porphyry. crossed nicols, x50. (Gr 1)

Fig. 11 Rhyolite porphyry crossed nicols, x50. (Gr 2)
comprise only about 30 to 50 percent of the rock. The ratio of orthoclase to plagioclase is unchanged. Sericite is not evident but kaolinization has clouded the feldspars. A slight decrease in groundmass size is noticeable and micro-mafic minerals in the groundmass contribute to the darkening color (see Fig. 11, p. 36).

Dacite Porphyry

The dacite porphyry is a dark greenish-gray rock with the uneven fracture common to the intrusion. It is irregular and pitted on weathered surfaces. The dark color of the rock is apparently due to inclusion of mafic minerals in the cryptocrystalline groundmass. Feldspars include orthoclase twins and striated plagioclase. Some euhedral quartz crystals are 5mm wide across the "a" axis. These crystals are twinned rhombs that simulate pyramids and on some a trace of a prism is noticeable. Biotite increases in frequency and size of crystals.

Study of thin sections reveal phenocrysts are set in a micro-crystalline groundmass that comprises about 50 percent of the rock. Euhedral to subhedral orthoclase and plagioclase occur in about 1 to 3 ratio. Beta quartz crystals and early feldspars show deuteric effects. Green biotite flakes sometimes show alteration to limonite and
chlorite.

**Contact Effects**

Contact effects vary in different locations and are probably directly related to the viscosity and the cooled state of the magma at the time of intrusion.

Xenoliths apparent in some locations indicate that the Permo-Triassic sediments were stoped by the magma. A zone between the intrusive and the limestone was dug out and no contact metamorphic minerals were found; however the limestone was recrystallized at the immediate contact. Induration of the sediments by baking and silicification is the main contact effect noted at surface exposures.

Pebbles of the Cretaceous formation were likewise indurated by silicification and baking. Finer sediments were more extensively altered and hornfels fragments are scattered over the surface near contact zones.

The contact effect of the sediments upon the intrusive was the addition of ferruginous material to the leuco-granitic magma. This is evident in some outcrops where colors become progressively darker and the content of biotite increases as contacts are approached.

**Metasomatism**

Where excessive juices from the intrusive saturated
the sediments the contact effects, in addition to those described, included formation of pseudo-rhyolite porphyry and pseudo-dacite porphyry (20-p.256). The pseudo-rhyolite was formed from a fine grained, slightly chloritized Permo-Triassic arkosic sandstone. Phenocryst-like crystals of beta quartz and twinned feldspars have euhedral form. The rounded quartz and feldspar grains and the chloritized mafics of the finer matrix are crowded around the edges of larger crystals. The rock is light colored but can be distinguished from igneous varieties by the rounded grains, inclusion of occasional rock fragments, and a higher percentage of quartz, both as large crystals and as vein fillings. (see Fig.12,p.40)

A trench dug in a contact zone of the Cretaceous sediments yielded the following three rock types. The descriptions represent progressively greater distances from the igneous contact.

The pseudo-dacite porphyry sample occupied a lense or vein 2.5 inches in width and was found about 2 feet from the intrusion. The rock as a whole is colored deep green but along contacts are usually less than 0.1 of an inch wide and are composed of a chloritic shaley matrix enclosing very small rounded quartz and feldspar grains. The rock proper contains large euhedral beta quartz crystals which sometimes have rounded edges, subhedral
Fig. 12  Psudo-rhyolite porphyry. Crossed nicols, x50. (Cr.1,46)

Fig. 13  Quartz enclosing groundmass in rhyolite-Cretaceous contact rock. Crossed nicols, x50. (Cr.3)
biotite crystals 0.1 of an inch in diameter and feldspars.

The sections are composed of about 50 percent phenocrysts in a micro-crystalline groundmass. The quartz and feldspar are completed to euhedral form. Many quartz crystals, in growing, have surrounded or embayed part of the finer groundmass (see Fig.13, p.40). Pseudo-hexagonal green biotite flakes often show chloritic alteration.

A nodule occurring about 6 feet from the intrusive is composed almost entirely of material similar to the lighter green border of the previous sample. Edges of the concretion are friable. Larger crystals are restricted to beta quartz that sometimes reach 0.7 of an inch in length, pseudo-hexagonal euhedral biotite crystals 0.15 by 0.3 of an inch wide, and smaller subhedral feldspar crystals. Small rock fragments are apparent with the aid of a hand lense. The groundmass is composed of a chloritic clayey material that is crowded around the edges of larger minerals.

A third specimen of the Cretaceous sediments was collected at the outer edge of the altered zone, and the rock is light green. Minute quartz, feldspar, and rock fragments are visible with the aid of a hand lense. Microscopic examination of the sample shows nodules up to 0.2 of an inch in diameter that are composed of very fine grained material resembling the crystalline
groundmass of the pseudo-dacite porphyry. The phenocryst-like nodules grew in situ and the matrix is pushed around their edges (see Fig. 14, p. 43). Ferruginous material contained in the sediments have been oxidized along solution paths and these paths are bordered by magnetite, hematite, and limonite.

**Age and Stratigraphic Relationship**

The rhyolite porphyry is believed to be the marginal facies of a larger granitic mass and the irregular outcrop pattern is formed by cupolas from this intrusion. Its relationship to the Permo-Triassic sediments is well shown in section 20, T 13 S, R 25 E where two outcrops of the sediments form roof pendants completely surrounded by rhyolite. Contact effects of the Cretaceous sediments are noted in some localities and in addition the structural relationship between the Cretaceous sediments and the rhyolite porphyry suggests that the intrusion was contemporaneous with folding of the Cretaceous beds. The field relationship to the acidic intrusive by the younger Clarno extrusive is present in the southeastern part of the Birch Creek basin. This indicates the age of the rhyolite porphyry to be Paleocene. The following evidence is presented to support this conclusion.
Fig. 14  Cretaceous sediments from edge of rhyolite contact zone. Nodules grew in situ. Crossed nicols, x50. (Cr 3)

Fig. 15  Oxidation of ferruginous material in sediments by vein injection. Plain light x50. (Rk 96)
1. The occurrence of localized induration of the Cretaceous sediments around contacts of the rhyolite porphyry. The finer sediments are altered by baking, oxidation of mafic minerals, some metasomatic action and silicification. This occurs, among other places, in the SW 1/4 section 17, T 13 S, R 25 E on the north side of Birch Creek. The Cretaceous pebbles are indurated by baking and silification. Excellent examples of this phenomenon exists in NW 1/4, SW 1/4, section 17, and SW 1/4, NW 1/4 section 20, both T 13 S, R 25 E. Except in contact zones, the pebbles are loose and scattered over the surface and through the soil mantle.

2. The structural relationship between the Cretaceous sediments and the intrusive is evident on the ridge separating east and west Birch Creeks. The sediments assume a south plunging anticlinal attitude and the rhyolite crops out in a linear arrangement along the axis of the fold. This arrangement is apparent for approximately a half mile and the relationship is believed to be more than a coincidental occurrence.
3. Pebbles and fragments of rhyolite porphyry are absent from the Cretaceous sediments.

4. The intrusive is in contact with Clarno andesite in section 20, T 13 S, R 25 E and the andesite has flowed around a cupola. This would indicate erosion had exposed the intrusive rhyolite porphyry prior to extrusive volcanism during Eocene time.
CLARNO FORMATION

Distribution

The Clarno formation represents the initial extrusive volcanism in the dominantly volcanic Tertiary period. Pyroclastic material is combined with a sedimentary facies. It does not exceed 0.3 of a square mile in areal extent. Outcrops of significance are exposed along a fault and are restricted to the Clarno basin. An isolated occurrence of breccia is exposed in the east end of Birch Creek basin and a flow is visible at the south edge of section 21, T 13 S, R 25 E.

Lithology

The Clarno formation consists of basal volcanic breccia with interbedded andesite flow, tuffaceous sandstone and unconsolidated tuffs and gravels.

Breccia

Where weathering has been sufficient, the outcrops spall off and smooth exposures commonly show cross sections of boulders 3 to 4 feet in diameter. The weathered clay residue retains original color and exposures are generally gray, with brighter spots of red, buff and purple representing the weathered rock fragments.
Hornblende is apparently the only unweathered mineral. Unweathered exposures are resistant and usually stand above the surrounding erosional surface. Rounded quartzite pebbles from the underlying Cretaceous formation are scattered through the breccia and generally become more abundant near the top of the section.

Irregular shaped specimens fracture across included fragments and the pieces include matrix, as well as angular rock fragments. Identifiable minerals are fractured euhedral hornblende crystals of varying size which are present in the matrix and most rock fragments.

Thin sections show the matrix to be composed of a tuffaceous groundmass enclosing phenocrysts of zoned feldspars that are dominatly andesine, fractured hornblende crystals of varying sizes, occasional angular quartz grains and many rock fragments. The matrix appears welded in some sections. (Fig.16,p.48) Rock fragments in the breccia are mainly porphyritic hornblende andesites varying in texture and size of phenocrysts. Feldspar phenocrysts contain as many as 30 separate zones and many show corrosion and reversal of composition (see Fig.17,p.48). Euhedral hornblende crystals, some with peripheries altered to magnetite,
Fig. 16 Matrix of Clarno volcanic breccia. Note hornblende twin. Crossed nicols, x50. (Rk 4)

Fig. 17 Large plagioclase twin in Clarno andesite. Crossed nicols, x50. (Rk 5)
compose the remainder of larger crystals set in a ground-
mass of pilotaxitic feldspar laths.

Sections of basalt fragments contain phenocrysts of
andesine and labradorite, as well as smaller crystals
of olivine and augite. A pilotaxitic groundmass of
plagioclase laths contain dusty magnetite that composes
nearly 10 percent of the rock.

A fine grained andesite, conspicuous by the absence
of hornblende crystals, is present in limited amounts.
It is composed of a felty mass of micro-feldspar laths.

Flow

Parallel cleavage causes the andesite flow at Clarno
basin to simulate a sedimentary rock. Areas around out-
crops are covered with the soft weathered gray pieces
that average 4 to 6 inches in length and 0.5 of an inch
in thickness. Minerals visible in hand specimens of the
aphanitic rock are limited to a few feldspar laths. Thin
sections show phenocrysts of andesine and hornblende
slightly larger than the pilotaxitic groundmass. Flow
structure is evident in the relationship of the ground-
mass to the phenocrysts. Magnetite is present but not
abundant.

The andesite flow in the Birch Creek basin is in con-
tact with rhyolite porphyry. Contact zone consists of
24 to 36 inches of clay derived from the rhyolite. The clay zone often contains nodules of rhyolite, especially near the intrusive. The clay zone changes to a zone of glassy textured rock that becomes progressively coarser grained away from the contact and the glassy material grades into a hornblende andesite flow. Textural and mineralogic differences are found in the flow rather than in the intrusive.

Pieces of the flow taken near the contact are aphanitic, dark gray, vitreous appearing rocks. A few reflecting feldspar laths and an occasional dark mineral are visible with the aid of a hand lens. Some specimens contain small quartz veins that average 0.1 of an inch in width and some of these veins altered the andesite up to a distance of 0.3 of an inch on either side of the vein. Thin sections of the micro-porphyry have a microlitic groundmass of andesine with slightly larger crystals of the same mineral, hornblende that is mostly altered to biotite, and very limited amounts of quartz. Thin sections from the contact vein alteration zones show the veins are quartz. Hornblende and biotite were altered to actinolite and the actinolite extends in radiating acicular groups into the vein and through the affected zone (see Fig.18,p.51).
Fig. 18  Hornblende altered to actinolite in quartz vein cutting Clarno andesite flow. Crossed nicols, x50. (Rk 72)

Fig. 19  Crossbedding in Clarno sandstone.
Sandstone

White sandstones crop out on the west side of Cottonwood Creek at Blarno basin. Slight induration makes possible steep slopes in most exposures. Locally pebble lenses and interrupted layers are evident through the section. The majority of these pebbles are well rounded quartzites similar to and probably derived from the Cretaceous sediments. A scattering of pebbles of subangular hornblende andesite and basalt are noticeable. The white sandstone locally rests on mudstone and the irregular contact fluctuates up to 2 feet. At the base of the sandstone, fine grits grades into a sandstone which in turn changes to tuffaceous banded sandstone. Specimens of the sandstone show irregular bands of tuff separating layers of sand grains imbedded in a tuffaceous matrix. Material identifiable with the aid of hand lense are quartz and feldspar grains, rock fragments, hornblende and biotite. Thin section study shows the quartz is angular to subangular, feldspars are orthoclase and acid plagioclase. Hornblende and rock fragments are present that were derived from earlier Clarno volcanics. Green biotite completes the minerals seen in the thin sections.
Tuffs and Gravels

The contact between tuffaceous banded sandstone and the overlying tuff is not exposed. The tuffs are light tan with a slight pink tinge caused by colored calcite. The rock is somewhat friable. Fragments disseminated in the tuffaceous material are small euhedral quartz crystals, most of which are fractured and very angular, subangular to subrounded rock granules, a few pumice shards and very limited amounts of biotite and hornblende. Some fractures in the rock are cemented by calcite, which is also present as detrital grains. The rock effervesces vigorously in hydrochloric acid.

The overlying tuffs are stained red by hematite. Specimens are shattered and have a hackly surface caused by removal of pieces along the fractures. Fragments prominent in the underlying material are absent and identifiable material include only fragmental feldspars and calcite veins. This tuffaceous material changes at a sharp contact to a purplish tuff and the darker color is the only significant difference from the brighter underlying bed. The following series exposed in a single outcrop completes the Clarno section known in the area.

10 feet Semi-consolidated gravels in a tuffaceous sandy matrix. The layer is irregularly stained with manganite, hematite and
limonite. They are unconformably overlain by John Day tuffs.

2 inches Red hematite-stained tuff inclosing cobble of basalt and andesite.

4 inches Soft brown tuffaceous clay.

**Thickness**

A complete section is not exposed in a single area as faulting interrupts the formational sequence. An estimated thickness of 600 feet is made up of 100 feet of unconsolidated tuffs and gravels and 300 feet of tuffaceous sandstone in a continuous outcrop. A second exposure of approximately 200 feet of breccia with 50 feet of interbedded andesite flow completes the section.

**Mode of Deposition**

The lower Clarno pyroclastics initiate extrusive volcanism during early Tertiary time. The breccia is believed to be, at least in part, ejected material as ashy matrix, absence of bedding, inclusion of boulders 3 to 4 feet in diameter, petrographic character and widespread occurrence indicate quick deposition and burial with a probable pyroclastic origin. Similar deposits were observed in the Battle Creek area 2 miles east of the locality and in the vicinity of Mitchell, some 30 miles west. Rounded quartzite pebbles included in the
volcanics indicate exposed Cretaceous beds or penetration of these beds by the source vent. It is not apparent in the limited exposure whether the andesite flows originated from a cone or fissure but the field association is suggestive of the former. Color and nature of the sandstone indicate secession of volcanic activity. Ash fell over the existing topography and was eroded into the depositional basin. A source area of different lithology is evident in the sand grains of the deposit. This is borne out in section study where minerals foreign to Clarno volcanics are evident. The sandstone deposit is probably of fluvial origin as excellent stream cross-bedding is displayed in some outcrops. (Fig.19,p.51)

Stratigraphic Relationship and Age

The Clarno volcanic breccia was ejected onto a eroded surface of folded Cretaceous marine sediments. Deformation and erosion in turn terminated Clarno accumulation. The formation is overlain by John Day tuffs or by Columbia River basalt depending upon location in the area.

This stratigraphic position limits its age to a post-Cretaceous pre-upper Oligocene interval. Paleontological evidence is entirely lacking in the area but the formation is generally accepted as having accumulated during Eocene time. (24)
JOHN DAY FORMATION

Distribution and Topographic Expression

Significant outcrops of John Day tuffs are restricted to the Clarno basin and distributed over an area not exceeding 0.5 of a square mile. A trace too small to map is located on the west side of Day basin, section 22, T 13 S, R 25 E. Restricted outcrops occur in the west end of Birch Creek basin and along the west fork of Cotton wood Creek.

The tuffs form low rounded hills in the Clarno basin but elsewhere the exposures are not of sufficient extent to have a typical form. Interbedded indurated layers like those exposed in Turtle Cove are missing from the area and the characteristic badland topography with erosional hoodoos and fluted pillars likewise is absent.

Lithology

The John Day formation is essentially an aeolian and water-lain tuff. The surface exposures in Clarno basin are oxidized red but grade to light cream 2 to 5 inches under the surface. The red surface is produced by conversion of ferruginous material to hematite. Moisture promotes slumping and soil wash but when dehydrated the clay mass becomes very hard.
Minerals identifiable in the rock include limited amounts of angular quartz fragments and scattered feldspar laths. Microscopic analysis reveals that the rock is composed of about 65 percent bentonite and montmorillonite (18-p.379). Glass shards compose about 15 percent, while the remainder consists of magnetite, hematite, biotite, quartz, andesine and oligoclase. (see Fig.20,p.58)

The green tuffs of Birch Creek basin contain about 50 percent glass shards. Magnetite with oxidation products, angular quartz and plagioclase total 30 percent, while clayey material comprises the remainder of the rock. (see Fig.21,p.58)

Comparison of the rocks from the two localities show compositional and textural differences. Grain size of the green aeolian tuff is uniform. The feldspars are angular, and a higher percentage of glass shards appear welded because of compression. Uniformity of grain size is lacking at Clarno basin, the material is unconsolidated, glass shards are few, and subangular feldspars are not abundant.

Thickness

The thickness of the John Day formation varies from 50 feet in Birch Creek basin to approximately 300 feet in
Fig. 20  Sedimentary John Day tuff from Clarno basin. Plain light, x50. (Rk 2)

Fig. 21  Aeolian John Day tuff from Birch Creek basin. Plain light, x50. (Rk 48)
Clarno basin.

Origin and Mode of Deposition

Two theories have been advanced to explain the origin of the John Day tuffaceous beds. Early writers favored a lacustrine mode of deposition, while Coleman (5-p.126,129) favors an aeolian origin. Neither method alone will account for the origin of the John Day formation as observed in the Clarno basin. Here evidence is favorable for a combination of the two modes of deposition.

Although limited in the area studied, the widespread occurrence of the formation in the region suggest a source some distance away. Source vents were probably to the west in the vicinity of the Cascade Range and intermittently erupted masses of pyroclastics were likely transported and deposited by prevailing west winds over wide areas of central Oregon. Ash fell uniformly over the existing topography and was eroded from the higher elevations and deposited in local basins. This is substantiated by the unequal thickness as well as by the absence of some members in different localities. The Battle Creek area (22-p.92) contains upper and lower beds while the Birch Creek basin contains only the green middle member. The Clarno basin exposures are believed to
belong to the upper member. These upper beds thin to the west and pinch out to the east so as to indicate a probable depositional basin during John Day times.

Stratigraphic Relationship and Age

The beds in the Birch Creek basin lie unconformably on the folded Cretaceous sediments and in turn are overlain unconformably by the Columbia River basalts. In the Clarno basin the formations occur in regular stratigraphic sequence. The underlying Clarno was folded and eroded prior to deposition of the pyroclastic John Day tuffs and they in turn were severely eroded before extrusion of overlying Columbia River basalt.

On the basis of fossil evidence it is believed the lower John Day beds accumulated during the upper Oligocene period, and the upper member during the lower Miocene period (20-p.328).
COLUMBIA RIVER FORMATION

Distribution and Topographic Expression

Basic lava flows of the Columbia River basalt constitute the most extensive formation in the Birch Creek area, covering approximately 30 square miles. The main outcrops of basalt are limited to the southern part of the area and the only occurrences in the northern end are along the upthrow block on the west side of a fault in a syncline.

Lava flows not only have the greatest distribution but exert the dominant control on physiography. Two distinct land forms are evident in the area. The first includes that part represented in the area around Day basin. This type of topography is evident where erosion has produced even hills with smooth contours. Several tilted blocks, formed by erosion of the disrupted basalt in a fault, are located in the same general area. (see Fig.23,p.62) The second topographic type is represented in the southern end of the area and generally lies within the Ochoco National Forest boundary. The terrain is rugged and stream incision, in conjunction with a mosaic-like fault pattern, has led to the development of cliffs and deep steep-walled canyons.
As mapped, the Columbia River basalt may include some younger lavas capping the Ochoco scarp in the southern part of the area.

**Lithology**

The Columbia River basalt consists of a series of superimposed basalt flows each 50 to 100 feet thick. Field occurrence is usually restricted to one of three general forms. One type develops pentagonal or hexagonal columnar jointing perpendicular to the cooling surfaces. Talus accumulates as "brick bats" or pieces of columns. A second type is represented by the dense massive basalts. Outcrops show irregular jointing, and talus accumulates as irregular rubble. A third type is produced by weathering. The yellow sandy residue is loose and incoherent and the jointing pattern is not preserved. This probably represents the weathered equivalent of a prior type but a gradation was not found.

In low non-timbered regions interflow scoria and former soil zones are oxidized to a conspicuous red, but along the margins of the timbered areas such zones support vegetation, and trees are aligned on the contacts between flows (see Fig. 22 and 23, p.63).

Weathered surfaces of the rock are stained by limonite to shades of brown but fresh fractures are dark
Fig. 22  Resistant basalt dike. Reproduced from AAF areal photograph.

Fig. 23  Tilted fault block, west end of Clarno basin. Reproduced from AAF areal photograph.
gray to black. Fracture is conchoidal to subconchoidal and the resulting hand specimens are usually irregularly shaped. Flashing feldspar laths, occasional augite crystals and a few olivine phenocrysts are the only minerals identifiable in the aphanitic rock. Although magnetite is not usually seen with a hand lens it is often present in sufficient amounts to affect a compass needle. Many scoriaceous samples contain amygdules of calcite and zeolites.

Thin section study shows a wide textural variation but only minor variations in composition. Textures vary from hypocrystalline to diabasic, both between separate flows and as a gradation horizontally and vertically in large single flows. Compositional changes are the presence or absence of olivine, and the ratio of andesine to labradorite.

A representative thin section shows a hypocrystalline groundmass with intergranular plagioclase laths enclosing rounded grains of augite. Larger phenocrysts of euhedral to subhedral labradorite, as well as scattered clusters of magnetite, are present. Rounded olivine crystals, many with red altered edges, are common to abundant in the olivine-bearing facies. Interstitial glass is present in varying amounts.

A later injection of quartz altered the Columbia
River basalt in section 21, T 13 S, R 25 E. Veins cutting the igneous rock vary in size. The larger veins are 0.4 of an inch wide and these veins have altered the basalt to form actinolite along the knife edge contact. This post-basalt injection probably occurred during Pliocene time as it is associated with faulting in the area.

Mode of Deposition

Numerous small feeder dikes scattered throughout the area show the derivation of the lava flows. The dikes are small, averaging 4 to 6 feet in width but large volumes of lava have been known to issue from fissures of this limited size (24-p.106). The dikes have the usual columnar jointing, oriented perpendicular to the cooling surfaces, and hence resemble stacked cordwood. The dikes are more resistant than surrounding flows and frequently stand above the eroded surface (see Fig.22,p.63). Each single flow was probably limited in extent but overlapping flows from widespread igneous activity contributed to the accumulated thickness. Volcanic quiescence is indicated by the baked soil layers that exist at some of the contacts between successive flows.

Thickness

The lava flows were poured out upon rough erosional
surface and consequently the thickness of the basalt is variable from place to place. A section measured on lower Cottonwood Creek between Clarno basin the the Mascall formation proved to be about 2500 feet thick. A thickness of about 3500 feet was observed near West Birch creek in the south-western part of the area.

Stratigraphic Relationship and Age

The Columbia River basalts lie unconformably upon an erosional surface and they are in contact with all underlying formations, at various localities in the area. In Birch Creek basin the flows lie on the Permo-Triassic metamorphics, Cretaceous sediments, rhyolite porphyry and some John Day tuffs. In the Clarno basin the basalt overlies either the Clarno volcanics or the John Day tuffs.

The upper contacts vary almost as widely as the basal contacts. The Mascall formation is conformable on the Columbia River basalt, but where erosion has removed the Mascall tuffs, the Rattlesnake formation lies unconformably over the basalt.

Age of the formation is determined by these stratigraphic relationships. The upper John Day tuffs were deposited during lower Miocene time, while the overlying Mascall accumulated during upper Miocene time. The
Columbia River basalt is established as middle Miocene age.
MASCALL FORMATION

Distribution and Topographic Expression

The Mascall sediments are restricted to the syncline in the northern third of the area. Their total area does not exceed 3 square miles. The type section of the Mascall formation borders the area on the north, near Cottonwood Creek, and the outcrops in the northeastern part of the area are continuations of this type section.

Where the protective Rattlesnake formation has been removed, low rounded hills soon develop. Clay minerals in the tuffs provide lubricant during wet seasons and so landslide masses are not uncommon. Included in the lower portion of the formation is a white indurated layer that lends support of the outcrops and forms a cuesta along lower Rattlesnake Creek. Although this layer is not exposed in the immediate area it is typical of Mascall topography elsewhere.

Lithology

The Mascall sediments are made up of beds of tuff, tuffaceous silts, sands and granules. In a single outcrop basalt granules and pebbles are present. Outcrops of Mascall sediments show pastel shades of gray, buff, yellow and red. Solifluction and wash often form a
compact surface that obscures bedding. This crust is usually limited to less than a half inch in thickness and the underlying material is incoherent. Colors usually grade into each other without sharp contacts, but bedding is determinable by the different degree of induration of the different layers, by layers of granules and by particle size gradation.

Except at Pine Gulch the rocks of Mascall age in the basin are relatively uniform in composition. The beds are made up of (1) friable tuffs that appear vitreous and fresh, (2) massive tuffaceous silts that are sometimes locally cemented by manganese oxide, (3) tuffaceous sandstones, and (4) granule conglomerates. Near the type locality, the sub-rounded pea-sized granule conglomerates are reworked tuffs set in a tuffaceous matrix that contains a ferruginous cement. The fresh appearing tuffs are composed almost entirely of glass and pumice shards with a scattering of white feldspar and angular quartz fragments. The silty sandy facies is present in nearly all gradations from massive silty layers to fine-grained and coarse-grained tuffaceous sandstone. Minerals comprising the sandstones are subangular quartz and feldspar set in a tuffaceous matrix of glass and pumice shards.

The basal part of the outcrop on the east side of
Pine Gulch consists of massive and thin layered tuffs overlain by about 100 feet of granule and pebble conglomerates composed almost entirely of subrounded basalt. Crossbedding, and to a lesser degree, cut and fill structures are evident. Interlayered in these beds is a carbonaceous seam that averages 1.5 feet thick. Sufficient organic material is present to form a binder for the subrounded grits and pebbles.

**Thickness**

The Mascall formation is irregularly exposed across the northern end of the area and its maximum thickness occurs only along lower Cottonwood Creek. Tuffs at this locality are about 650 feet thick. This figure includes only that part of the formation within the area although the outcrop continues northward to Picture Gorge. Thickness of the entire Mascall formation at this locality is approximately 1500 feet.

**Mode of Deposition**

A basin, probably formed by coalescing basalt flows and later enlarged by structural sagging, provided a depositional site for the Mascall sediments. The formation is somewhat localized in occurrence and probably accumulated under conditions similar to the playa lakes
now existing in eastern Oregon. Tuffaceous layers, alternating with crossbedded grits indicate that intermittent pyroclastic showers fell over the immediate region. The ash was eroded from the plateau surface and, combined with detritus from weathered basalt to make up the bulk of the Mascall sediments. Silt, leaf prints and beds that contain a high percentage of organic material indicate soil accumulated and plant life survived between pyroclastic showers.

Stratigraphic Relationship and Age

There are indications that subsidence accompanied deposition. Coleman (4-p.41) and Taubeneck (25-p.109) found evidence of an unconformable relationship with the underlying basalt. Such an unconformity would be evident around the periphery of a basin and yet not be distinct at the contact zone within the basin proper. In this area the basal contact is conformable. Along the east side of Pine Gulch a residual hill of Mascall beds now shows Rattlesnake gravels and ignimbrite abutting against it on three sides. The remaining side has been dissected and a cross section of the unconformable relationship between Mascall tuffs and Rattlesnake formation is visible. (see Fig.24,p.73)

Merriam and Sinclair (11-p.171,205) describe an
assemblage of vertebrate fossils from the type section at the Mascall ranch and assign the formation to upper Miocene.
Fig. 24 Residual hill of Mascall sediments nearly surrounded by Rattlesnake gravels, tuffs and ignimbrite.

Fig. 25 Concordant surface of Rattlesnake alluvial fans. Incised streams in foreground.
RATTLESNAKE FORMATION

Distribution and Topographic Expression

The distribution of the Rattlesnake formation include approximately 14 square miles and is exceeded in extent only by the Columbia River basalt. The formation accumulated in a syncline as did the Mascall formation and so its outcrops are also limited to the northern third of the area.

The three members of the formation have distinct topographic expressions. The gravels in the lower part form low hills with smooth contours. Welded tuff in the middle member exhibits flat surfaces which are often isolated mesas. Alluvial fans in the upper part are usually smoother than the welded tuff and are incised by present streams. (see Fig.25,p.73) Where the welded tuff has been removed by erosion or never did exist, both upper and lower gravels show the same expression. Occasionally large sections of the welded tuff become unstabilized, sagging and frequently sliding so that landslide topography is present locally.

Lithology

The Rattlesnake formation is made up of torrential and stream deposited sediments, with interbedded welded
tuff member. The sedimentary members are treated as a unit since evidence indicates uninterrupted deposition.

Alluvial facies of the Rattlesnake formation are represented, in part, by torrentially deposited material that ranges in size from silts to boulders 2 feet in diameter. Little stratification is shown by this part of the formation. Fluvial deposition is evident locally where stratified silts, grits and carbonaceous beds show crossbedding.

The localized silts are tuffaceous in character and probably represent, in part, reworked Mascall sediments while the associated grits are composed of rounded basalt granules. The basal torrential gravels consist almost entirely of subangular to subrounded basalt, but near the top of the lower gravels rock types older than the basalt are apparent. The upper fanglomerates are continuations of the lower gravels, areas adjacent to windows of pre-basalt formations are approached, the frequents of older rock types increases. The most noticeable material of these older types is the rounded quartzite pebbles from the Cretaceous formation but pieces of fossiliferous Cretaceous sandstone, Permoc-Triassic meta-sediments and Clarno volcanics occur. Some ignimbrite is present in the upper part of the deposits.
Ignimbrite

Color of the welded tuff or ignimbrite varies from tan to gray and occasionally pink. A rough columnar jointing pattern is combined with subconchoidal fracture to produce talus composed of large blocks. Erosion of the underlying unconsolidated sediments along exposures aids in disruption of the welded tuff.

The ignimbrite is roughly divisible into three units that grade upward into each other without sharp contrast (see Fig. 26, p. 77). The lowest part contains nests and lines of subrounded basalt cobbles and is slightly porous. This grades into the harder middle part where induration is sufficient to cause fracture across included basalt pebbles. The top portion near the rim is usually more vesicular and the uppermost 12 to 18 inches usually shows platey cleavage across the rough columnar joints. Thin sections show the rock to be composed almost entirely of glass and pumice shards. The curved vesicular fragments show crude alinement and sinuous flow structure. Incorporation of basalt granules in the glass shards is not uncommon. (see Fig. 27, p. 77) Primary crystalline minerals are restricted to a few acid feldspar laths and scattered quartz fragments.

The water-laid equivalent of the rim occurs in a single outcrop. Although field evidence in the area is
Fig. 26  Rattlesnake welded tuff member

Fig. 27  Glass shard around granule in Rattlesnake welded tuff. plain light, x50. (Rk 1)
insufficient to correlate the white layered material, Taubeneck (23-p.119,120) found evidence that it is equivalent to the welded tuff. The single outcrop consists of a series of layers that average 0.3 of an inch and is less than a foot in total thickness. Hand specimens are semi-cleavable along bedding planes and break in stair step fashion on the edges. Minerals are not recognizable in the white tuffaceous layers but interlayered cementing material contains limited amounts of quartz fragments, acid feldspars, glass and pumice shards. As near Dayville, the outcrop is associated with silts and crossbedded gravels. (Fig.28,p.79)

Thickness

The sediments of the Rattlesnake formation vary from a trace on the flanks of the syncline to a maximum of 300 feet along the synclinal axis. A local basin was formed when post-ignimbrite faulting blocked the drainage along lower Cottonwood Creek and the sediments accumulated therein to a thickness of about 900 feet.

The ignimbrite rim averages about 50 feet in thickness.

Mode of Deposition

Diastrophism that closed the Miocene epoch provided
Fig. 28 Crossbedding in Carbonaceous sediments of Rattlesnake formation, at Rattlesnake Creek.

Fig. 7 Drag-fold in Permo-Triassic meta-sediments.
both a source area and a depositional basin for the pluvial Rattlesnake gravels. A dissected anticline at Clarno basin and a retreating scarp at Birch Creek basin attest to the large volume of material transported from these locations.

The floor of the syncline probably served as a flood plain for the stream. The even surface is preserved at the lower contact of the rim rock which locally does not fluctuate more than a few inches. The site of a small pond or perhaps the location of a former stream is shown at Rattlesnake Creek where the water-laid equivalent of the ignimbrite is associated with silts, graded granules and carbonaceous beds. Massive silts locally underlie the welded tuff.

The ignimbrite is believed a "nuees ardentes" type of deposit that was deposited as a hot gaseous flow. Slight inclination in relief is sufficient to provide momentum and these gaseous flows often reach a velocity of 50 to 60 miles per hour (8-p.205). The deposit was thus formed in a short length of time, probably not exceeding a few days. Ignimbrite abuts against the basalt on the sides of the syncline and is restricted to the basin. Location of the source vent for the material is not known and is probably covered by overlying fan-glomerate.
Stratigraphic Relationship and Age

The Rattlesnake formation rests upon Mascall tuffs or Columbia River basalt, depending upon the locality. An angular unconformity is evident at this contact. The fanglomerate represents the peak of sedimentation in the basin.

Merriam and associates describe vertebrate material and assign the formation to Pliocene (14-p.42,43).
QUATERNARY ALLUVIUM

Quaternary alluvium shown on the accompanying map (Plate II) represents only the larger accumulations. Deposits of varying amounts are found along all creeks. Locally deposits of white friable ash are found in the alluvium. The deposits are restricted to lenses and pockets and represent a recent fall of ash that has been eroded from the surrounding terrain and deposited in favorable locations.
Details discussed under structure are early Mesozoic deformation, post-Cretaceous pre-Miocene folds, post-Columbia River basalt folds, Dayville-Antone faults and post-Rattlesnake ignimbrite faults.

Structure Related to Early Mesozoic Deformation

The exposed Permo-Triassic meta-sediments in Birch Creek basin indicate at least one period of major deformation before subsidence and deposition of Cretaceous marine sediments. The attitude of the bedding, 73° S 55° E, in conjunction with the metamorphic character which include drag folds, schistosity and silicification, indicates that early Mesozoic deformation was of regional magnitude. Some beds of the formation show schistosity and cleavage oriented parallel to the bedding planes, while in other layers the schistosity and cleavage parallels the more pronounced joint set.

Two distinct joint sets are evident in the Permo-Triassic meta-sediments. The more pronounced joint set has an average attitude of 70° N 25° E. The second joint set has an attitude of 60° S 25° W. The strike of the jointing system generally parallels the trace of a fault in the Birch Creek basin area.
Post-Cretaceous Pre-Miocene Fold

The Cretaceous sediments have been deformed into a south plunging anticline. The crest of the fold is located on a general north-south line near the center of sections 17 and 20, T 13 S, R 25 E. The west limb of the fold is exposed on the west side of Birch Creek ridge and on the west side of West Birch Creek. The attitude of this segment is 28° S 50° E. The other limb is evident east of the ridge and dips 18° S 25° E. Tertiary faulting has interrupted the fold locally.

The rhyolite intrusion is considered to be contemporaneous with folding and was probably instrumental in the formation of the local flexure. The acidic rock crops out along the anticlinal axis of the fold.

The Clarno formation is not exposed in sufficient extent for regional structural determination. The beds had been folded prior to extrusion of John Day tuffs.

Post-Columbia River Basalt Folds

Post-Columbia River basalt folding, in conjunction with faulting, has produced the prominent structural features of the area. They are the John Day valley syncline, Ochoco anticline with related scarp and the Clarno basin anticline.

The John Day syncline trends in a general east-west
direction across the northern third of the area. The flexure is asymmetrical in shape and the steeper southern limb dips 25° N 10° E at Cottonwood Creek. The fold is not as pronounced to the west, having a dip of only 11° at Pine Gulch. The northern limb of the fold is exposed along the southern edge of the Picture Gorge Quadrangle; the dip at Picture Gorge is 18° S 10° W.

The Ochoco anticline is located in the southwest fourth of the area. Post-Mascall faulting interrupts the structure to the east and faulting of the same age has increased deformation in the general area. Dip on the southern limb of the anticline averages 9° South.

The Clarno basin anticline is slightly over a mile in linear extent along the axis. It dies out near the western boundary of the Dayville area and is terminated by post-Mascall faulting at Cottonwood Creek. Dip of the southern limb is 10° S 7° W and of the northern leg 25° N 10° E.

Dayville-Antone Fault

The Dayville fault or fault zone trends in a general east-west direction from the eastern boundary of the area at Clarno basin to Rattlesnake Creek in the center of the area. The major fault of this zone is the east portion of a hinge. A local variation was found at Clarno basin.
Here the southern limb of the anticline is broken along the south edge of the basin by a secondary fault, while the major fault tends to parallel the anticlinal axis. The broken segment between the anticlinal axis and the secondary fault is a horst. Several secondary faults are oriented at right angles to the major fault trace. Rattlesnake and Little Rattlesnake Creeks flow along two of these faults. There is evidence of faulting at irregular intervals along Cottonwood Creek, as shown by the fault-terminated anticline at Clarno basin and the disrupted nature of the basalt near the forks of Cottonwood Creek.

The Antone fault trends in a general S 65° E direction from section 17, T 13 S, R 25 E, and leaves the area near the forks of Cottonwood Creek. The fault in the south-western part of the area is located on the axis of the Ochoco anticline. The southern upthrow block has resulted, in part, in the formation of Birch Creek basin. Dip of the fault in this area is 70° N 25° E, and throw was about 1500 feet. The vertical displacement becomes less to the east. Several small faults trend at odd angles from the major fault.

The Dayville and Antone faults are probably the same age, but they have opposite orientations. The Dayville fault has the upthrow block to the north side
whereas the block south of the Antone fault has been upthrown. This attitude probably is the result of a hinge, and the pivot point of the hinge is located between Clarno basin and Birch Creek basin.

Post-Rattlesnake Ignimbrite Faults

The welded tuff member of the Rattlesnake formation serves as a reference plane for this movement. A fault is located in the northeast corner of the area, and trends from section 32, T 12 S, R 26 E, northwest to Rattlesnake Creek. A fault of similar age and orientation trends WNW from Birch Creek to the northwest corner of the area. The faults generally parallel the Dayville-Antone faults and they have a similar orientation. At Cottonwood Creek the north block has been upthrown, while the south side is upthrown at Rattlesnake Creek. Vertical displacement at Cottonwood Creek is about 300 feet, measured from the offset ignimbrite rim. The opposite hinge was vertically displaced about 150 feet at Birch Creek, just off the north edge of the area.

There were two separate movements along this fault. The original movement probably coincided in time with the Dayville-Antone faulting. Later movement disrupted the Rattlesnake ignimbrite. Evidence for the two
movement is shown at Birch Creek where Rattlesnake ignimbrite abuts against Mascal tuffs and is nearly in contact with Columbia River basalt. If the initial movement along this fault was post-Rattlesnake ignimbrite in age, the rimrock would not be in contact with the tuffs and nearly in contact with basalt in this synclinal position. The post-ignimbrite faulting probably represents late structural adjustment caused in part by loading of the area with Rattlesnake gravels.
GEOMORPHOLOGY

The physiographic features discussed are Ochoco fault line scarp, fault blocks, fans, and terraces.

Ochoco Fault Line Scarp

The outstanding physiographic feature in the area is the retreating fault scarp in the southwest part of the area. Steep-walled canyons of incised streams cutting the scarp in places reach a depth of 400 to 500 feet. The scarp was placed in its present position by the Antone fault, in conjunction with the Ochoco anticline. The material eroded from the retreating scarp provided gravels for the Rattlesnake formation.

A concordant surface is noticeable as a rock terrace on north-trending ridges along the scarp. It is not known whether the terrace is caused by a particularly resistant basalt flow or by younger lavas capping the scarp.

Fault Blocks

Isolated tilted blocks of basalt are located in the hinge zone of the Dayville-Antone fault zone. The blocks are large, covering up to a square mile each. They are generally shaped like an inverted V, with the flanks
eroded to steep cliffs, and the dip slope represented by the sloping lee side. Trees are alined on the interflow baked soil and breccia zone along the flanks. (see Fig. 23, p. 62)

The forces involved in forming the hinge fault probably disrupted the basalt flows, and erosion since the close of Miocene time has completed the development of the isolated blocks.

Fans

Coalescing alluvial fans built upon the ignimbrite surface from the south side of the syncline are evident where the present streams are incised below the concordant surface (see Fig. 25, p. 73). The ends of these fans are alined in a general east-west direction along a line about a mile north of the boundary separating townships 12 and 13. The line extends to Birch Creek. The deposition of the upper-Rattlesnake gravels in these fans probably forced the John Day River to the north side of the synclinal basin.

Terraces

An interrupted terrace is located in the S 1/2, section 29, T 12 S, R 26 E, S 1/2 sections 27 and 34,
T 12 S, R 25 E, and the N1/2 section 21, T 12 S, R 25 E. These areas are represented by the recent alluvium on the accompanying map, Plate II. The terrace is located at about the same elevation in the three places.

A more pronounced terrace is evident just off the northeast corner of the area where U. S. Highway 28 is constructed on a former flood plain of the John Day River.

The cause of the interruptions in erosion which produced these terraces is not evident in the Birch Creek area.
GEOLOGIC HISTORY

Interpretation of the geological history of the region is based on evidence found in the Birch Creek area.

The known geologic record in the Birch Creek area begins in Permian time when warm shallow seas were receiving sediments and limestone reefs of possible organic origin were formed in quiet waters. The diversity of sediments indicate fluctuating conditions and subsidence accompanied deposition. The sea into which the sediments were deposited was probably a part of the Cordilleran geosyncline. This sea transgressed northward from the Gulf of Mexico and southeastward from Alaska and joined over the present continental region. So far as known from the local field evidence, the conditions existing during Permian time continued uninterrupted until the close of the lower Triassic period.

The history of geosynclines, as recorded by Umbgrove (5-p.81,82,184,185), fits the sequence of events in the Birch Creek area during late Paleozoic and early Mesozoic time. His findings are: Geosynclinal downwarp as the sediments accumulate, followed by horizontal compressive forces folding the sediments and leaving the mass a highly folded positive area. This positive area apparently existed throughout the interval from the close of the lower Triassic period until upper Cretaceous time as
12,000 feet of mid-Mesozoic marine sediments are exposed some 30 miles south of the area near Suplee (13). The truncated folds of the old highland subsided during upper-Cretaceous time and an arm or embayment of the Pacific Ocean occupied the area. Sediments deposited in the new seaway indicate near shore conditions prevailed during this time. The Mesozoic era was terminated by regional uplift and folding which forced the retreat of the last invasion of the sea into central Oregon. With the marine sediments now occupying a positive position, erosion was dominant.

The rhyolite porphyry was intruded contemporaneously with the folding that closed the Cretaceous history. Consequently the sequence of events in the Birch Creek area closely resemble those of the Laramie Revolution as recorded in the Rocky Mountain region (19-p.350,351). Eastern Oregon could have been affected by a western extension of this orogeny.

The acidic intrusion initiated the igneous cycle of a dominantly volcanic Tertiary period. The next succeeding stage in this cycle is shown by the more basic andesite flows and volcanic breccias of the Clarno formation. Crustal deformation probably coincided with the close of Eocene. A break in depositional history lasted until upper Oligocene time when pyroclastic showers of ash
accumulated on an erosional surface. Erosion of the John Day ash exceeded deposition in some localities where local variations in relief existed in the topography. The intermittent pyroclastic showers continued until middle Miocene time when fissure eruptions of basalt, representing the basic end-member of the Tertiary volcanic cycle, covered the existing topography to a maximum depth of approximately 3500 feet. Single flows probably were local but the areal distribution of this formation in the Pacific Northwest indicates widespread volcanic activity during middle Miocene time. Relatively quiet times between successive eruptions are indicated by soil zones that exist between some flows. Carbonaceous material present in some of these "fossil soils" suggest that sufficient soil accumulated to support plant life.

A basin was formed by a slight structural sag in the basalt, the depression foreshadowing the major folding occurred at the close of Miocene. This slight sag provided a site of accumulation for the ash that fell on the new plateau surface in Mascall time. The Mascall sediments, composed of ash and detritus eroded from the basalt, collected to a depth of about 1500 feet.

Compressional forces of probably regional magnitude then folded the Columbia River basalt and Mascall
formation into the John Day syncline. Faulting that was contemporaneous with the folding further disrupted the plateau surface at the close of Miocene.

The source area for the Rattlesnake formation was thus provided by the broken disrupted basalt standing in marked relief. Vigorous erosion accomplished by the run-off from heavy rainfall dumped gravels into the synclinal basin. At one stage in this process a volcanic eruption of the "nuées ardentes" type spread the ignimbrite member of the Rattlesnake formation over the gravel. This hot gaseous flow was of short duration. Thereafter streams built coalescing alluvial fans out upon the new ignimbrite surface from the south side of the syncline. Structural adjustment continued in late Pliocene time when faulting in the syncline disrupted the ignimbrite rim.

The history from the close of the Pliocene epoch to the present has been dominantly erosional. Since the John Day River began cutting its channel through Picture Gorge, probably at the beginning of Pleistocene, the streams of the area have been incised and erosional features are prominent.
Fig. 29  Secondary fault of Dayville fault zone. West side of Clarno basin.

Fig. 30  Post-ignimbrite step fault, lower Cottonwood creek.
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