0400 0036 BULL RUN



# GEOLOGY

## GENERAL REMARKS

The Bull Run area is a small basin composed of Tertiary sedimentary and volcanic rocks that rest on and are faulted against Paleozoic rocks that represent two distinct sequences (Decker, 1962; Fagan, 1962). The Bull Run Mountains are made up chiefly of a Cambrian to Devonian (?) 25,000-foot succession of miogeosynclinal rocks. They include a basal orthoquartzite, followed by carbonate and shale units, and also crop out on the east front of the Independence Range. The Independence Range is composed primarily of eugeosynclinal rocks, notably cherts, arenites, and minor amounts of conglomerate, limestone and volcanics that total 9,000 feet thick, and they occur locally in the Bull Run Mountains adjacent to Wilson Peak. These different sequences have been brought together by major thrusting from the west, as shown by structural evidence in the Bull Run area (Decker, 1962; Fagan, 1962) and also by regional relations (Roberts, et al., 1958). In both the Bull Run and Independence mountains rocks of the autochthonous miogeosynclinal suite

have been overthrust by the ~~allochthonous~~ exotic allochthonous cherts, quartzites, arenites and volcanics ~~of the Western Assemblage (Decker, 1962)~~.

Apart from the Paleozoic rocks that form the mountans and floor Bull Run basin, there is a small ~~stock of~~ quartz diorite stock of probable Cretaceous age at the north end of Bull Run basin that also forms part of the basement on which the older Tertiary rocks ~~were deposited~~ rest.

The Tertiary rocks were studied in only a general way by Decker (1962) because he was interested chiefly in the pre-Tertiary history of the region. As a result of my more detailed work, some of his conclusions with respect to the Tertiary stratigraphy have been modified. Whereas Decker referred all the sedimentary rocks in Bull Run basin to the Humboldt formation, they ~~are here considered to represent~~ are described here as 3 new formations. They not only differ in lithology from the Humboldt, they are separated from it by Miocene volcanics and two major unconformities. In addition, the sequential relations of the volcanics reported by Decker has been modified. As noted below, some of the rocks that he mapped as Pliocene volcanics are equivalent to his Miocene volcanics which are here considered to be of Miocene age. Although Decker did not ~~assign~~ assign formation names to any of the volcanic units, 4 of them are referred ~~here~~ to formations recognized by Coats (1964) in the bordering region to the northeast, and one other is described as new.

## CENOZOIC ROCKS

### Frost Creek volcanics

This volcanic sequence is exposed chiefly around the margins of the basin and in the bordering mountains, resting on Paleozoic rocks or locally on quartz diorite. The formation ~~has been~~ is named for its outcrops along the lower drainage of Frost Creek where it is well exposed, and where its interfingering relations with the oldest sedimentary rocks in the basin are clearly discernible. Rhyolite and latite pyroclastics are the most widespread rocks, and andesite and dacite are also present.

The rhyolites and latites chiefly represent welded ash flows. The biotite rhyolites are generally pink and are composed of crystals and crystal fragments of quartz, sanidine, plagioclase, and biotite in a matrix of devitrified glass shards, pumice fragments, and glassy ash. Biotite latite is represented by glassy ash flow tuffs composed of platelike and some bulbous shards, and fragmental crystals of plagioclase, oligoclase, and andesine-labradorite. Biotite and iron ore occur in a microcrystalline matrix that appears to be glassy. In some cases the welding is only slight since there is little flattening of the glass shards. Many of the ash flows have large 1-3 inch lapilli, generally flattened, and they impart a spotted appearance to the rock. Some of the dark gray brown latites are markedly porphyritic, with phenocrysts of plagioclase, biotite, and amphibole in a cryptocrystalline to microcrystalline groundmass. There has been some secondary replacement of the amphiboles and ~~biotite~~ by calcium carbonate, ~~though the biotite is usually fresh and unaltered.~~ Plagioclase ranges from andesine to bytownite in composition. The preferred orientation of the phenocrysts suggests flow banding, and their shattered nature

a pyroclastic origin. Another variety is represented by biotite-hornblende latite, composed of andesine-labradorite, fresh green hornblende, brown biotite, and a trace of fresh augite in a glassy to cryptocrystalline and ocassionally microcrystalline groundmass. The rock is commonly vitroclastic with a glassy groundmass filled with a felty aggregate of crystallites and small microlites. In places devitrification has progressed sufficiently so that glass shards and minute crystal fragments are fuzed. On the mountain front north of Mori Ranch there is a porphyritic diopside latite with phenocrysts of andesine-labradorite with a few grains as calcic as bytownite. Diopside and traces of biotite occur in a fine grained to microcrystalline groundmass.

Biotite dacite and rhyolite tuff overlie the andesite-latite on the south end of Lime Mountain. The dacite is light gray, is composed of oligoclase, andesine, quartz, and biotite in a microspherulitic groundmass containing microgranular quartz between the individual spherulites. The light greenish-white rhyolite welded tuff is composed of crystals and crystal fragments of oligoclase, andesine (?), sanadine, and quartz in a matrix of microcrystalline and cryptocrystalline material. Glass shards and pumice fragments are recognizable, and have undergone alteration by compression, devitrification, and recrystallization.

Apart from these pyroclastics that make up most of the area mapped as Frost Creek volcanics, there are also several rhyolite flows in the formation. These rocks cover a large area at the base of the scarp southeast of Wilson Peak (NW part sec. 30, T. , R. ), and smaller areas are ~~to be~~ found at the south end of Lime Mountain, ~~xxxx~~ along Deep Creek south of Mori Ranch (secs. 11, 12, T. , R. ), and on the summit saddle south of Wilson Peak. The rocks are generally white to cream in color, and usually poor in ferromagnesian minerals. A thin section shows phenocrysts of andesine, oligoclase, sanidine, quartz, and biotite (?) (completely altered to chlorite) in a microcrystalline granular groundmass consisting of quartz, feldspar, chlorite, and some cryptocrystalline material. The plagioclase has been moderately to highly altered to sericite. Semi-opaque grains of iron ore are scattered throughout the groundmass. The rock typically has a porphyritic texture and a microcrystalline-granular groundmass. The groundmass makes up fully 50 per cent of th rock, quartz about 17 per cent, andesite-oligoclase 15 per cent, sanidine 12 per cent, ~~with a trace of biotite and iron ore.~~

Andesites covers a large area ~~occur chiefly~~ in the Bull Run Mountains south of Wilson Peak, and local patches are at the north and northwest margins of Bull Run basin, and also on the east side near Mori Ranch. In these areas it is typically greenish gray to nearly black, with dull phenocrysts set in an aphanitic groundmass. The intrusive part of the section south of Wilson Peak is a porphyritic olivine andesite, with phenocrysts of twinned and highly altered labradorite-bytownite, olivine is completely altered to fibrous yellow-green crysolite or garnierite and magnetite, and fresh diopside is in a crystalline to microcrystalline groundmass composed of feldspar, pyroxene, specks of iron ore, and interstitial cryptofelsite.

~~To the south~~ At the south end of Lime Mountain, the rock is nearly transitional to latite in composition, and is overlain by and interbedded locally with light gray to white rhyolite and dacite welded tuffs. A thin section shows phenocrysts of zoned, twinned, and highly fractured, somewhat altered or resorbed ~~plagioclase,~~ andesine-labradorite, some oligoclase(?), completely altered mafic minerals--possibly olivine, amphibole, and magnetite in a felsitic groundmass containing feldspar, ~~altered mafic minerals~~ and iron ore dust. The texture is porphyritic, and the structure is vescicular on a very small scale. The vesicles are in part filled by chlorite, followed by carbonate or zeolite.

Andesites similar to those in the mountains south of Wilson Peak occur also in the northern part of Bull Run basin, usually underlying the rhyolite and latite tuffs. They have much the same general appearance--dark gray to greenish black, with prominent greenish feldspars. Thin sections show phenocrysts of pyroxene (often diopside) and plagioclase in a faintly pilotaxitic groundmass of micrucrystalline and cryptocrystalline material. The plagioclase is often highly altered, but some specimens clearly reveal bytownite, andesite-labradorite, and occasionally oligoclase.

A very distinctive hornblende andesite, not noted elsewhere in the area, crops out in the SW corner of Sec. 1, along Columbia Creek at the north end of Bull Run basin, where it is separated from rhyolite and latite pyroclastics by an east-west fault. It is a dark greenish to dark gray rock, with ~~large (1-2 inch)~~ hornblende crystals up to 1/4-1/2 inch long. The rock is a diopsidic augite-hornblende andesite with phenocrysts of bytownite (minor), andesine ?, labradorite, oxyhornblende--pleochroic from yellow brown to russet and fringed with granular magnetite in varying amounts-- and diopsidic augite in a fairly pliotaxitic (trachytoidal) groundmass composed of oligoclase-andesite (?) microlites, grains of iron ore and pyroxene, and interstitial cryptofelsite. Amygdules from 0.5 to 0.1 mm in size are scattered sparsely throughout the groundmass.

Rhyolite and latite attain greatest thickness on the northeast side of the basin where fully 500 feet is represented, and the section thickens to the northeast. Andesite is thickest in the hills south of Wilson Peak where it is about 600 feet thick at a maximum. Away from these areas the rocks gradually thin, and in some sites, as on the east side of the basin north of Mori Ranch (sec. ), they gradually taper out and disappear on the Paleozoic basement. The absence of a continuous volcanic cover on the Paleozoic basement below the sedimentary sequence probably is due in part to rapid stripping, and also to irregularities on the ancient terrain, with thicker sections accumulating in some areas than others. There was no hiatus between between the accumulation of the volcanics and the overlying sedimentary rocks because they interfinger in several areas, notably along Frost Creek, at Bull Run Reservoir, and in the hills directly north of it.

Rhyolite and latite also erupted there, though their chief centers appear to have been to the north in the upper drainage of Trail Creek just north of Maggie Summit.

Decker (1962) noted that Wilson plug includes both intrusive and extrusive phases, the latter occurring higher stratigraphically. The plug appears to have been the principal center for extrusion of andesite. ~~and also the latite~~. Decker was puzzled about the age relations of Wilson plug and concluded that it probably was Pliocene and younger than the sedimentary rocks (his Humboldt), though he noted the possibility that the vent may have contributed to the older volcanic sequence (i.e. Frost Creek volcanics). The volcanics at Wilson plug and in the bordering area are part of the oldest Tertiary rocks in the area because the andesite rests on the Paleozoic sequence on the upthrown sides of the basin and must therefore underlie it at depth in the graben for the volcanics have been truncated and downdropped by the marginal faults. Support for this interpretation is provided by the thin lense of conglomerate and breccia that rests on Paleozoic rocks and underlies and interfingers with andesite and rhyolite on the east side of the saddle (alt. 7,860 ft.) half a mile south of Wilson Peak. The clasts are of local derivation, and the 20-60 foot section represents part of he Mori Ranch formation, the oldest sedimentary unit in the basin. Furthermore, at Bull Run Reservoir the small

outcrops of andesite are separated from the Paleozoic rocks by a thin (3-5 ft.) conglomerate. In addition, at the south end of Lime Mountain the andesite ~~and latite are~~ is overlapped by Tertiary sedimentary rocks that represent the middle upper part (I L formation) of that sequence. ~~It is also critical that~~ andesite At the north end of Bull Run basin clearly underlies the ~~rhy~~rhyolite and latite tuffs that dip south under the sedimentary sequence, and andesite also underlies rhyolite on Frost Creek where the ~~section~~ volcanics ~~grades up into~~ interfinger with the sedimentary section. These relations indicate that the andesite is part of the Frost Creek volcanic sequence, the oldest Tertiary rocks in the basin.

Decker has pointed out that the presence of Frost Creek volcanics (his Miocene volcanics) on the upthrown east side of the basin implies that they should underlie the Humboldt (=Mori Ranch formation) in Bull Run basin. Thus he was puzzled as to why volcanics were not encountered in the petroleum test well drilled in the middle of the basin that penetrated 2,300 feet of sedimentary rocks and down into the Paleozoics for 200 feet. This led him to suggest that the volcanics may be equivalent to the upper volcanic member of the "Humboldt" (=Chicken Creek formation), and "overlapped large areas which were too elevated to receive sediments of the Humboldt" (Decker, 1962, p. ). This interpretation is not consistent with the relations of the two formations where they are juxtaposed along the Jack Creek fault in the area directly north of Boyd Creek (NE part sec. 35, T. 42 N R 52 E). Here they display no evidence of interfingering such as might be expected if they were equivalents, and the volcanics in the two units are quite different.

There is no doubt that Frost Creek volcanics interfinger with the lower part of the Mori Ranch formation ("Humboldt") along Frost Creek, and also at Bull Run reservoir. In addition, at higher stratigraphic levels throughout the basin the original Mori Ranch formation includes beds of rhyolitic ~~ash and lapilli tuff, as well as~~ latite and ~~rhyolite tuff~~. Furthermore, the sandstones and conglomerates are ~~composed principally~~ contain much of debris derived from Frost Creek volcanism. It seems highly probable that the rocks recovered from the drill cores that were identified (Decker, 1962, p. ) as arkosic conglomerate, arkosic sandstone, and ashstone are largely composed of the products of Frost Creek volcanism, as are most of the sandstones and conglomerates that are exposed along the axis of the anticline directly above the test hole. My observations indicate that arkoses are not exposed anywhere in the Bull Run basin, a relation consistent with the fact that granitic rocks is confined to the small area of Columbia Basin at the north end of the region, and it was covered by Frost Creek rhyolitic ~~and~~ latite during accumulation of the Mori Ranch formation. The absence of a thick volcanic section in the test well ~~hole in the middle of the basin~~ seems best explained by the field relations which indicate that the volcanics interfinger with and are largely replaced by sedimentary volcanogenic rocks ~~xxxx~~ in the central part of the basin.

Since the Frost Creek volcanics are rich in biotite, and interfinger with the oldest part of the sedimentary sequence that grades up into the plant bearing beds, it seemed desirable to determine their age by radiometric means. A sample of ~~the~~ biotite latite welded tuff interbedded with the lower part of the section on Frost Creek was submitted to Geochron Laboratories, Inc. for K/Ar dating. Their report (No. B0439, October 30, 1964) indicates an age of 42.5 ± 2.1 million years. In terms of North American land mammal ages it is late Uintan, and later Eocene.

## Mori ~~Ranch~~ Road Formation

This formation is named for its readily accessible continuous exposures along the road to Mori Ranch, extending from Deep Creek crossing up Deep Creek to just east of its junction with Bailey Creek. Another good section is in the low cliffs bordering Bull Run ~~River~~ Creek just east of the county road,[1] and the basal part of the unit is well exposed between Bull Run Reservoir and the mountain front a mile to the west. The formation makes up the central part of the anticline that occupies the middle of the basin, and ~~for the most part is~~ of it is situated east of the county road. ~~north to Ibex summit.~~

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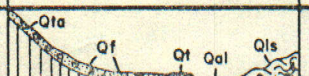
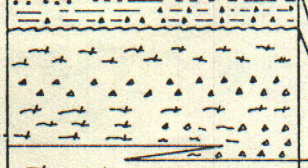
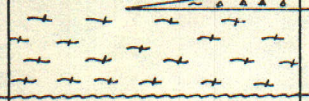
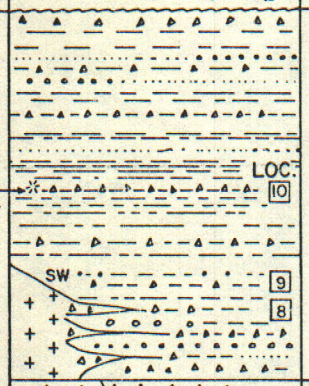
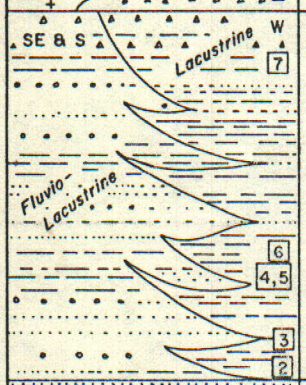
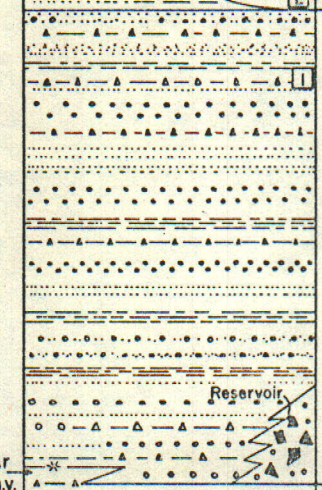
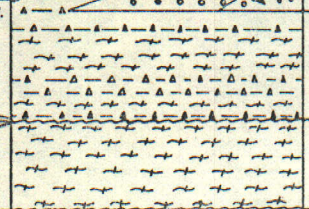
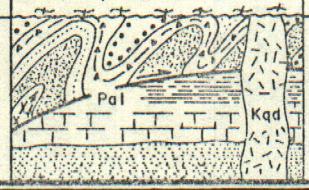
1 It would have been preferable to name the formation for its occurrence along Bull Run ~~River~~ Creek where it intergingers ~~with and~~ with and overlies ~~the~~ the Frost Creek volcanics. Unfortunately, the name Bull Run is preoccupied.

The Mori ~~Ranch~~ Road is typically dark colored, and composed of sedimentary and interbedded volcanic rocks. The sedimentary rocks are well stratified, olive gray to dark brown coarse sandstone, grit, and pebble to cobble conglomerate, the larger clasts being derived chiefly from the Paleozoic cherts and quartzites in the bordering ranges. These sedimentary rocks regularly carry a large fraction of volcanic detritus, including grains of biotite and feldspar as well as rock fragments derived from ~~the underlying and interfingering~~ Frost Creek volcanics. The sandstones and conglomerates are well indurated and form conspicuous cuestas and low cliffs. The beds are from 5 to 20 feet thick, and the sandstones frequently display current-bedding. Alternating with these coarser clastics are well bedded, dark gray to brown and black mudstones and shale, the latter ranging from 5 to 15 feet thick, or somewhat more. There also are a few thin coaly beds locally in the formation, and many of the sandstones and shales are highly carbonaceous.

The volcanics that occur in the Mori ~~Creek~~ Road include latite, rhyolite, and andesite, ~~and most of them are~~ pyroclastics. They can not be distinguished from the Frost Creek volcanics, and in places the two units interfinger, as on the east side of the basin along Frost Creek. ~~To the west,~~ Numerous 3 to 10-foot beds of rhyolite and latite tuff ~~and ash~~ are exposed in the basal part of the formation, which is here exposed by faulting. near Bull Run Reservoir. ~~They~~ Volcanics also make up a prominent part of the ~~prominent~~ cliff-forming section north of the reservoir in the ~~SE~~ SW corner of Sec. 4. The Mori ~~Ranch~~ Road volcanics include flesh-colored and gray-purple biotite latite tuff, with crystals and crystal ~~fragments~~ fr of oligoclase, biotite, and magnetite in a matrix of microcrystalline and cryptocrystalline material. Accessory minerals are diverse, including apatite, magnetite, hematite, rutile and sphene. Pumice fragments occur locally in some specimens, and the texture is pyroclastic. Greenish-gray biotite hornblende latite is also present, with crystal and crystal fragments of andesite-labradorite (predominant), brown biotite, green hornblende largely replaced by a mafic mineral, and magnetite grains. The glassy and devitrified groundmass indicates that it is a pyroclastic.

Biotite rhyolite ash flows having a vitroclastic texture are also exposed at Bull Run Reservoir. The rock is composed of angular euhedral grains of quartz, sanidine, andesine, and biotite, with a few highly altered pyroxene grains in a fine grained and devitrified glassy matrix. Small (1-3 mm) foreign rock fragments are present, and some of them are vitrophyric, and Devitrified pumice fragments are common. On the cliff section north of the reservoir there are biotite andesite tuffs in the fanglomerate, as well as rhyolite. The andesite tuff is composed of crystals of altered and resorbed plagioclase, biotite, and amphibole largely replaced, and anhedral grains of hematite and magnetite scattered through the groundmass. The groundmass consists of crystalline to microcrystalline grains of feldspar, epidote, augite, and devitrified greenish-brown glass in a complex mixture. The texture is porphyritic, but the structure indicates a pyroclastic origin as does the devitrified glass in the groundmass.

The samples recovered from drilling operations show that the Mori ~~Ranch~~ Road formation does not change in composition at depth in the middle of the basin (Decker, 1962, p. ). This is consistent with the nature of the basal part of the formation exposed at Bull Run Reservoir; the ~~thin~~ flows and welded tuffs in that section evidently thin out basinward except for some of the fine ash beds. Well-log data show that the formation is 2,300 feet thick in the middle of the basin. If we add to this another 500 feet for the overlying part of the formation that was not penetrated by drilling on the anticlinal axis, the Mori Ranch Road has a total maximum thickness of approximately 2,800 feet, thinning toward the basin margins.

| AGE | FORMATION | THICKNESS (Approx.) | SALIENT LITHOLOGIC FEATURES |
|---|---|---|---|
| Quaternary |   | 0-500 | *Quaternary deposits (Q).* Recent stream deposits (Qal) and low terraces; high stream terraces (Qt), alluvial fans (Qf) and talus deposits (Qfa), and landslides (Qls). |
| M. Pliocene |  | 100 | *Banbury basalt (Tb).* Black olivine basalt flows. |
| U. Miocene |  | 40-50 | *Cougar Point welded tuff (Tcp).* Gray to brown welded acidic tuffs; thicken to N. |
| | | 50-300 | *Jenny Cr. fm. (Tj).* Black vitroclastic rhyolite tuff at base, grading up to white, cream ash beds, waterlaid; some sandstone and conglomerate locally. |
| | | 0-500+ | *Long Hollow volcanics (Tlh).* Rhyolite, latite, dacite flows, ashfall tuffs, and black vitroclastic latites. Thickens to W. |
| M. Miocene |  | 0-600+ | *Jarbidge rhyolite (Tjb).* Red rhyolite flows, characterized by large quartz and sanidine crystals. Interfingers with and is replaced by Long Hollow volcanics to west. |
| U. Eocene |   | 300-2200 | *Chicken Creek formation (Tc).* Cream to white and tan ashy shale, ashy sandstone, conglomerate, ostracodal shale, welded rhyolite and latite tuff. Lower part interbedded with rhyolite and latite at S edge of area. |
| |   | 40-2100 | *IL formation (Til).* Well bedded fluvio-lacustrine sandstone, shale, conglomerate, generally dark brown, in the S and SW parts of area, grading to light colored shales in the W, becoming ashy in upper part. |
| |   | 0-2600 | *Mori Road formation (Tmo).* Coarse sandstone, conglomerate, shale and coaly beds, with interbedded rhyolite, latite, and dacite welded tuffs chiefly in lower part. Sedimentary breccia (fanglomerate) butressed against Bull Run fault in western part |
| |  | 0-600+ | *Frost Creek volcanics (Tfc).* Rhyolite, latite, and dacite welded tuffs, and andesite and rhyolite flows. Grades up into Mori Road formation along Frost Creek. |
| |  | 0-600 | *Wilson andesite (Tw).* Andesite flows chiefly, locally grading to latite. Intrusive phase S of Wilson Peak. |
| pre-Tertiary |   | 34,000 | *Pre-Tertiary Rocks (Kqd) (Pal).* Autochthonous quartzite, limestone, shale of Cambrian to Devonian (?) age, overthrust by an allochthonous series of cherts, quartzites, volcanics and conglomerates of Mississippian age. Locally intruded by quartz diorite stocks of Cretaceous (?) age. |

Locally on the east side of the basin north and south of Mori Ranch, which is in the east part of sec. 2, T 42N, R 52E, small patches of the formation are preserved at the base of the scarp, dipping 20°-40° basinward off the Paleozoic basement. Since these rocks are sandstone and pebble- to small-cobble conglomerate much like those in the central part of the basin, they do not provide evidence for either high relief along the east margin of the basin, or for an active scarp there during deposition. It also seems clear the marginal sedimentary breccias derived from an active scarp do not lie at depth at the base of the Independence Range, having been overlapped by younger rocks. The map shows that south of Mori Ranch (boundary between secs. 11 & 12) the formation thins to about 40 feet where it rests on the Paleozoic basement. In this area the sedimentary rocks are normal sandstones and conglomerates, and marginal breccias are absent. These relations suggest (1) that the east margin of the basin was ~~relatively~~ low during Mori Road deposition, (2) that the sediments derived from it were being transported northwestward into the basin where a subsiding delta was being constructed, and (3) that the Jack Creek fault on the east margin of the basin was initiated after deposition of the Mori Road and the overlying formations.

By contrast, along the front of the Bull Run Mountains near Bull Run Reservoir, and in the hills immediately to the north and south, there is a conspicuous fanglomerate member with associated volcanics in the lower Morrison Road formation. It is composed chiefly of basement debris derived from the adjacent Paleozoic section in the hills immediately to the west. The larger angular and subangular blocks are 4 to 8 feet long, set in a well-cemented grit filled with angular rock chips and blocks. Since the fanglomerate is buttressed against Paleozoic rocks on the high angle Bull Run fault, it is evident that in this area the fault was active during deposition, ~~its~~ the scarp shedding debris into the basin.

The Mori ~~Ranch~~ Road formation is also exposed on the summit divide south of Wilson Peak, ~~cropping out on the eastern scarp~~ where it lies on the Paleozoic rocks ~~(Western Assemblage)~~ and is interbedded with the overlying volcanics. The 150-160 foot section includes a basal conglomerate-breccia associated with rhyolite, latite tuff and andesite breccia. Some beds are ~~made up of~~ sedimentary breccias composed of fully 90 per cent of clasts from the ~~Western Assemblage~~ Paleozoic rocks, with blocks up to 3 feet long though most range from 3 to 12 inches. Other beds ~~include debris from the Western Assemblage~~ represent Paleozoic debris together with reworked volcanics. These breccia-conglomerate beds representing the basal part of the Mori ~~Ranch~~ Road formation provide evidence for the altitude of the hills behind the scarp during deposition. The ~~evidence~~ data suggest that the basin was not bordered by high mountains ~~for~~ because there is only 500-600 feet of relief on the Paleozoic basement above the lense. Even if two or three times this amount of basement was removed by erosion since the range was elevated, high mountains would not have towered above the western rim of the basin. The highest part of the ancestral Bullfrog Mountains probably was situated 3 miles farther north, near its present summit section adjacent to Porter Peak. Since it stands about 1,500 feet above the lense on the scarp south of Wilson Peak, this figure may approximate the maximum altitude of the western hills that

bordered the basin during deposition. It probably was somewhat lower, however, because the faulting that accounts for the present range uplifted it more in the north than the south, as shown by the formations (I L, Chicken Creek) above the Mori ~~Ranch~~ Road that lap across the range at the south end of Lime Mountain.

Fossil plants have been recovered only at one site in the Mori Ranch formation. The locality was brought to my attention by Dr. Robert Decker who found it during his reconnaissance of the Tertiary geology of the area.

Mori road locality (Loc. P571-1). From the county road, proceed up Deep Creek 0.4 miles at which point the creek is directly below the road. Fossil plants are in gray brown shales exposed in the bank on the north side of the road. The site is 3,200 feet W and 2150 feet S of the NE corner of sec. 4, T 42 N, R 52 E, Bull run quadrangle, U. S. Geol. Surv. scale 1:62,500, edit. 1956. The following section is exposed here:

Section at Mori ~~Creek~~ locality

Top.

(Quaternary terrace, talus)

| | Ft. | In |
|---|---|---|
| Shale. Platy, olive-tan, ~~mixx~~ to dark gray, well bedded, somewhat limey. With fossil leaves, seeds. ..... | 4 | 8+ |
| Sandstone. Gritty, gray, weathering tan, massive cliff-former, rhyolitic ash in matrix with much biotite, ~~and crystals~~ of quartz, and sanidine . . . . . | 3 | 4 |
| Ashstone. White to light gray, cross-bedded with occasional reworked shale balls (chips) and clasts of volcanic rocks and chert. Occasional lenses of shale 2"-3" thick | 3 | 6 |
| Shale, Ashstone. Alternating light gray shale and very fine white ash beds. Well bedded, grading ~~xxxx~~ up to ..... | 1 | 2 |
| Ashstone. White, poorly bedded, rhyolitic ..... | 1 | 0 |
| Shale. Hard, limy, massive, slate gray, breaking into blocks ..... | 0 | 4 |
| Sandstone. Tuffaceous, with small pumice chards, occasional clasts of chert, quartzite, hornfels; gray-green, massive | 3 | 0 |
| (Creek bed) Thickness: | 17' | 0" |

Fossil plants are not very abundant at this locality. The following species make up the Mori Road florule:

Conifers

| | |
|---|---|
| Abies rigida | Picea magna |
| Abies sonomensis | Picea sonomensis |
| Picea lahontense | Pinus crossii |
| Chamaecyparis linguaefolia | Pinus harneyana |
| Fokienia praedecurrens | Pinus wheeleri |
| Larix nevadensis | Thuja dimorpha |
| Picea lahontense | Tsuga sonomensis |

Angiosperms

| | |
|---|---|
| Arbutus idahoensis | Pterocarya ——— |
| Berberis elkoana | Quercus morii |
| Betula thor | Populus payettensis |
| Acer glabroides | Robinia orbiculata |
| Acer nevadensis | Vaccinium sonomensis |
| Acer scottiae | Viburnum bathyrivus |
| Mahonia cuprovallis | |
| Nyssa copeana | |

I L Formation

The dark colored, coarse sedimentary rocks and associated volcanics that comprise the Mori ~~Ranch~~ Road rapidly grade up into the I L formation. It is of lacustrine origin chiefly, but also includes ~~lenses of~~ sandstone and conglomerate of fluvatile derivation. The name of the formation is taken from I L Summit because one of the most accessible and best exposed parts of the formation lies in the area immediately west of it, extending to the front of the Bull Run Mountains.

The I L formation is generally lighter colored than the Mori ~~Ranch~~ Road. Owing to the preponderance of shale in it, areas composed of ~~the~~ I L rocks weather to gently rounded slopes which contrast with the low sandstone-conglomerate cuestas that characterize most most areas of the Mori Road. In its typical lacustrine phase, as exposed west of I L Summit, the shales are laminated to well bedded, with the latter from 1/8 to 1/4 inch thick for the most part. The shales vary in composition from marl to opaline platy shale, ranging in color from light olive to tan, and commonly weathering to shales of yellow, yellow-orange, and white. Some of the shale units are up to 100 feet thick, and are relatively persistent laterally. From I L Summit north to the Bull Run River and south into the drainage of L Creek, the formation is predominantly shale: only a few thin (1-3 feet) sandstones occur in it there. Farther south (sec. 32) and continuing southward, sandstones become more frequent in the

section, as do pebbly sandstones and conglomerates.

Regularly scattered through this fluvio-lacustrine facies are thin coaly seams that appear to represent swamps or ponds that were rapidly buried at times of flood. The associated siltstone and mudstone units weather to deep, dark, soil-covered slopes and the mudstone areas are frequently blanketed by dense colonies of balsam-root (Balsamorhiza).

The I L formation rarely contains coarse clastics in the western part of the basin along the front of the Bull Run Mountains. This is particularly true of the lacustrine unit which only locally has thin sandstone and pebble conglomerate beds near the scarp. The ~~relation~~ is suggests that movement on the Bull Run fault may have ceased during I L deposition, with the I L probably being deposited against the scarp where fine clastics accumulated, and from which little coarse detritus was shed into the basin. This is consistent with relations just south of Lime Mountain (sec. ), where both the I L and overlying Chicken Creek have overlapped the Mori Ranch Road formation and rest on andesite of the Frost Creek volcanics. In this area the I L is scarcely 40 feet thick as compared with fully ~~1500~~ 2000 feet near the middle of the basin.

Like the underlying Mori ~~Ranch~~ Road, the I L formation also rapidly thins toward the southeast margin of the basin. It is scarcely 100 feet thick close to the mountain front where it overlies the Mori ~~Ranch~~ Road (sec. 11, T , R ). In this area, where outcrops are well exposed, there is no evidence for an active marginal scarp shedding debris into the basin during deposition, a relation also displayed by the underlying Mori ~~Ranch~~ Road formation.

Fossil plants have been recovered at 6 localities in the I L formation, distributed from near the base to near the top of the ~~formation~~ unit. These localities are ~~listed~~ noted here, together with a description of the rocks exposed at the sites ~~and thexplants~~ and a list of the plants recovered.

Summit locality (loc. P571-2). From I L Summit proceed 200 yards west up the swale that drains east and thence north to Bull Run River. Fossil plants are preserved in dark olive brown to gray black shales that dip 8° W, and are exposed in the bed and adjacent low banks of the drainageway that were opened up by tractor. The site is 1,600 feet S and 1,500 feet E of the NW corner of sec. 28, T. 43 N., R. 53 E., at an altitude of 6,100 feet. The following section is exposed:

| Top | Thickness feet | inches |
|---|---|---|
| (shale section continues to west, poorly exposed for most part) | | |
| Shale. Yellow brown, limonite stained on joints, ¼ - ½ inch thick, conchoidally fractured . . . . . | 2 | 0 |
| Shale. Olive gray, well bedded, 1/8 to ¼ inch thick, weathers out to plates. Fossil plants ... | 1 | 3 |
| Shale. Well laminated, brown to black, filled with organic debris, weathers to muddy soil . . . . . | 0 | 6 |
| Mudstone. Chocolate gray, conchoidally fractured, breaks into small chips, grades up into . . . . | 1 | 6 |
| Shale. Yellow brown to light brown, limy, well bedded, weathering into small chips 1/8 to ¼ inch thick, poorly exposed . . . . . | | |

Pau 70

Shale. Gray, black, weathering white, semi-conchoidal fracture, massive, silicified and locally cherty .... 12

Shale. Black to brown, coaly and fissle, well laminated, weathering to earthy soil, alternating with thin yellow brown pocker-chip shale . . . . . 33

Shale. Black, siliceous shale, semi-conchoidal fracture weathers white, with few siliceous ash beds 1-2 ft. thick, alternating with yellow brown shale 59

Shale-sandstone. Soft, dark silty shale, weathering to deep soil, alternating with coaly beds and gritty sandstones up to 1-2 ft. thick. Yellow brown fine sandstone, brown pebbly sandstone 2-4 ft. thick. ~~Silty shale soft and fissile.~~ 200

(Road , gradational contact with Mori Road formation).

The Summit florule is composed of the following plants:

Conifers:

Abies

Picea lahontense

Chamaecyparis linguaefolia

Picea magna

Picea sonomensis

Pinus harneyensis

Pinus crossii

Pinus wheeleri

Tsuga sonomensis

Thuja dimorpha

Sequoiadendron chaneyi

Angiosperms

Alnus jarbidgana

Alnus

Acer bendirei

Acer glabroides

Acer minor

Acer columbianum

Acer nevadensis

Acer scottiae

Arbutus idahoensis

Populus votyana

Populus sotremuloides

Pterocarya

Quercus soprinus

Quercus tarus

Quercus morii

Sorbus ovalis

Ulmus paucidentata

Zelkova nevadensis

Gulch locality (Loc. P 571-3). From Deep Creek bridge proceed 0.8 miles west along State Highway 11. This point corresponds to a small gulch on the north side of the road and is at the west base of the low hill directly west of the figure 5 that marks sec. 5 on the topographic map. Fossil plants are in shales on the lower, west-facing slope of the gulch, at an altitude of 5,720 to 5,750 feet, and were opened up by a tractor. The site is 1,600 feet east and 2,700 feet south of the NW corner of Sec. 5, T. 42 N., R. 52 E. The shale section exposed here is as follows:

## Gulch Locality

(concealed)

| | Thickness feet | inches |
|---|---|---|
| Shale. Buff, red brown and ashy, well bedded, with occasional fossil plants. . . . . | 12 | 6 |
| Shale. red brown, ashy, with fossil plants, well bedded | 8 | 6 |
| Shale. Yellow brown, platy, barren of plants, well laminated | 12 | 6 |
| Shale. Reddish brown, platy, ashy, well indurated with fossil plants | 4 | 8 |
| Shale. Gray brown, well bedded, platy . . . . . | 5 | 2 |
| Shale. Reddish brown, irregularly bedded, hackly fracture, ashy, very well indurated . . . . . | 6 | 6 |
| Shale. Gray brown, very well indurated, with fossil plants . . . | 4 | 3 |
| Total thickness: | | |

(covered on slope)

In terms of numbers of species, the Gulch florulem is the largest of the 10 assemblages that have been collected. The following plants are represented in it:

Conifers

| | |
|---|---|
| Abies alvordensis | Picea sonomensis |
| Abies klamathensis | Pinus crossii |
| Chamaecyparis linguaefolia | Pinus harneyana |
| Larix lyalloides | Pinus wheeleri |
| Picea magna | Tsuga mertensioides |
| Picea lahontense | Thuja dimorpha |
| Pseudotsuga sonomensis | |

Angiosperms

| | |
|---|---|
| Alnus relatus | Mahonia bathyrivus |
| Alnus rugosoides | Rhysocarpus |
| Betula thor | Populus |
| Betula lenta | Potamogeton |
| Berberis bathyrivus | Prunus chaneyi |
| Amelanchier | Ribes |
| Acer glabroides | Rosa |
| Acer columbianum | Rhamnus splendida |
| Acer bendirei | Salix |
| Acer minor | Tilia aspera |
| Crataegus cuneiformis | Ulmus |
| Crataegus wilderi | Zelkova nevadensis |
| Gaultheria | Quercus morii |
| Halesia columbiana | |

Bluff locality (Loc. P 571-4). From Deep Creek crossing, proceed 1.0 mile west on the county road. Here a double meander of Deep Creek is close to the road, which is at the south base of a steep bluff. Fossil plants occur throughout the section of olive brown shale exposed on the bluff above the road. The richest horizon is about 25 feet stratigraphically above the third pebbly sandstone, at an altitude of 5,800 feet, on the boundary between secs. 5 and 6, T. 42 N., R. 52 E. The following section is exposed in the bluff:

~~Section at Deep Creek~~ Locality

| | Thickness Feet | Thickness Inches |
|---|---|---|
| Hilton. | | |
| Shale. Well bedded, ¼ to ½ in. thick, laminated locally. Dark brown to yellow brown below grading up into ashy lenses that weather white. Fossil plants abundant in dark shale about 20 ft. above sandstone. . . . . | 90 | 0 |
| Sandstone. Massive, medium to coarse grained, yellow brown, locally with pebbly lenses, biotite flakes common. Well indurated . . . . . | 3 | 6 |
| Shale. Well bedded, weathering yellow brown, tan on fresh surface, well laminated. . . . . | 1 | 6 |
| Sandstone. Pebbly, with angular rock chips. Yellow brown, with tuffaceous matrix including small lapilli and biotite flakes; massive, poorly bedded . . . . . | 3 | 2 |
| Sandstone. Fine grained, tuffaceous, with local shale lenses, yellow brown, moderately indurated, grading down to . . . . | 4 | 10 |
| Conglomerate. Massive, filled with basement chips ¼ inch long chiefly, composed of quartzite, chert, set in a fine to medium grained volcanic sandy matrix. . . . . | 4 | 6 |
| Shale. Light yellow brown to chocolate colored, well bedded .... | 4 | 6 |
| Sandstone. Massive, light brown to yellow brown, with rhyolitic ash and biotite..... . . . . | 1 | 3 |

Sandstone and shale. Alternating 1 ft. ashy shanstone, cross bedded, rhuolitic, with well bedded dark gray shale . . . . . 8 0

(road level). Total thickness:

The Bluff florule is represented by ~~numerous~~ over 1000 specimens, (~~=7000~~), but relatively few species have been recovered; hence

Conifers:

Abies bathyrivus

Abies

Abies

Larix lyalloides

Picea lahontense

Picea magna

Picea sonomensis

Pinus crossii

Pinus harneyana

Pinus wheeleri

Pseudotsuga sonomensis

Taiwania nevadensis

Thuja dimprorha

Tsuga mertensioides

Angiosperms

Populus voyana

Mahonia bathyrivus

Mahonia cuprovallis

Ribes

Prunus harneyensis

Pachystima nevadensis

Streambank locality (Loc. P571-5). From Deep Creek crossing proceed west on county road 0.3 miles, then follow the old dirt road that leads northwest up the principal valley in sec. 5 for half a mile. The plant-bearing shales are exposed on the south side of the valley, on the south bank of the flowing creek, at a site 1,200 feet E and 1,200 feet S of the NW corner of sec. 5, T 42 N, R 52 E. The following section is exposed at this ~~site~~ locality:

| | Feet | Inches |
|---|---|---|
| (Top) (Concealed) | | |
| Shale. Light gray, highly indurated, breaking into irregular plates, dense and heavy, with occasional fossil plants. . . . . | 15 | 4 |
| Shale. Light brown to tan, well bedded, fissile, breaking into large plates, with fossil plants . . . | 6 | 0 |
| Shale. Dark gray to brown, thickly bedded, hackly, becoming a pencil shale on breaking . . . . . | 4 | 0 |
| Shale. Light gray, well bedded, in beds 1/8 - ½ inch thick, fissile, with fossil plants . . . . . | 6 | 6 |
| Shale. Light yellow-tan to gray, well bedded to nearly laminated, in beds 1/16 to 1/8 inch thick, very fissle, few fossil plants . . . . . | 14 | 6 |
| (Bottom. Stream bed). | | |

The Stream bank florule is also represented by numerous specimens (+3000), but is relatively poor in species:

Conifers

| | |
|---|---|
| Abies bathyrivus | Pseudotsuga sonomensis |
| Abies alvordensis | Tsuga mertensioides |
| Larix lyalloides | Thuja dimorpha |
| Picea sonomensis | |
| Picea amagna | |
| Pinus harneyana | |
| Pinus crossii | |
| Pinus wheeleri | |

Angisperms

| | |
|---|---|
| Mahonia bathyrivus | Ribes |
| Potamogeton | Vaccinium |

Hilltop locality florule (Loc. P571-6). From I L Summit proceed north of county road about 100 yards, then follow the old county road, which is west of the present one, for 0.4 miles. Here, in the southwest part of Sec. 21, a track leads west ~~on the south side of the valley and continues west~~ over the low divide that straddles the boundary between secs. 20 and 29. The fossil locality is close to the top of the hill directly north-northeast of the saddle that the track crosses, ~~and~~ in the southeast corner of sec. 20 at an altitude of 6,280-6,300 feet. Plant bearing shales crop out along the strike for fully 150 yards on the east slope just below the hilltop, ~~crest of the hill~~, scattered through 15-20 feet of section. The central part of the area is 900 feet west and 600 feet north of the SE corner of sec. 20, T. 3 N., R. 52 E. The rocks exposed here are as follows:

~~Hilton Florida~~

(Top of hill)

| | Thickness feet | inches |
|---|---|---|
| Shale. Yellow to tan, locally with ashy lenses white, with fossil plants. Shales 1/8 - ¼ inch thick, locally with lenses of platy shale 1 to 2 inches thick, ashy. | 30 | 0 |
| Shale. Olive to tan, well indurated, 1/8 to ¼ inch thick, fossils, with fossil plants . . . . . | 26 | 0 |
| Shale. Tan to white, ashy, well bedded, weathering to chips and plates 1/8 to 1 inch thick, occasional fossil plants in upper part . . . . . | 45 | 0 |
| (base of hill) Total thickness | 101 | 0 |

The following plants make up the Hilltop florule, which is represented by only a moderate number (600) of specimens:

Conifers

| | |
|---|---|
| Abies | Pinus wheeleri |
| Abies | Pseudotsuga sonomensis |
| Picea magna | Taiwania nevadensis |
| Picea sonomensis | Thuja dimorpha |
| Larix nevadensis | Tsuga sonomensis |
| Pinus harneyana | |
| Pinus crossii | |

Angiosperms

| | |
|---|---|
| Crataegus wilderi | Salix |
| Mahonia bathyrivus | Vaccinium |
| Mahonia cuprovallis | Potamogeton |

Benchmark locality (Loc. P571-7). From Deep Creek bridge proceed west on the county road 1.7 miles. Fossil plants are in the shales about 75 yards north of the road, on the eastern 1 for Highway 11, as shown on the topographic map. The site is 2,400 feet E and 600 feet N of the SE corner of sec. 6, T. 42 N., R. 52 E., and directly NNE of BM 5,630. The section exposed on the slope is as follows:

~~Section at~~ Benchmark ~~Floralo~~ locality.

(Top, ridge crest).

| | Thickness feet | inches |
|---|---|---|
| Sandstone, conglomeratic sandstone. Light gray to light brown, poorly sorted, volcanic sandstone with biotite, quartz, small basement chips. Conglomeratic sandstone with small gravel pockets, clasts of black & green chert, quartzite. In beds 6" to 2' thick, well indurated ..... | 13 | 6 |
| Ashy shale. Tan to light chocolate, weathering light ~~pelldex~~ to white. Well bedded ..... | 16 | 0 |
| Ashy mudstone. Dark brown to brown gray, well bedded, with fossil plants ..... | 8 | 6 |
| Ashy shale. Tan to yellow, breaking into small chips, well bedded and hard, with occasional biotite flakes, and very small pumice shards. (poorly exposed) | 18 | 0 |
| Sandstone. Tuffaceous, rhyolitic, fine grained, with biotite, quartz, and small basement clasts. Light gray to white, locally pebbly. | 1 | 0 |
| ~~(concealed)~~ | | |
| Road level. Total thickness: | ft. | in. |

The following plants comprise the Benchmark florule, which is the highest stratigraphically of the 6 florules that have been ~~collected~~ recovered from the I L formations

Conifers

| | |
|---|---|
| Abies | Pinus harneyana |
| Abies klamathensis | Pinus crossii |
| Chamaecyparis linguaefolia | Pinus wheeleri |
| Larix nevadensis | Pseudotsuga sonomensis |
| Picea lahontense | Sequoiadendron affinis chaneyi |
| Picea magna | Thuja dimorpha |
| Picea sonmensis | Tsuga mertensioides |

Angiosperms

| | |
|---|---|
| Alnus jarbidgana | Prunus chaneyi |
| Betula ashleyi | Populus voyana |
| Betula thor | Ribes |
| Acer bendirei | Rhododendron giannellana |
| Acer glabroides | Salix payettensis |
| Acer minor | Zelkova nevadensis |
| Mahonia bathyrilus | |

## Chicken Creek Formation

The upper part of the I L formation graddally becomes ashy, and grading up into the light-colored Chicken Creek formation in the southern and southwestern parts of the area. The formation is named for its exposures in the upper drainage of Chicken Creek, which is traversed by State Highway 11 north of Jack Creek.

The entire formation is light tan to white and cream colored and is readily recognized on this basis alone. The formation is composed of well bedded ashy sandstone and shale, thin water-laid ash beds, and ostracodal limy shale, and welded tuff. Conglomerate is present locally, chiefly near the margins of the basin. A prominent bed of opalized ash about 50 feet thick crops out on the ridge in the east part of sec. 30, T 42 N, R. 52 E. In the unnamed drainage east of Chicken Creek Summit (sec. 23), the formation contains lenses of sedimentary breccia that evidently were derived from Paleozoic rocks in hills to the east, across the present Jack Creek fault. They probably were not shed from an active scarp otherwise they would be expected to have a greater lateral extent. They breccias disappear a short distance to the north where fine ashy sediments lie against the fault. It seems probable that these coarse clastics represent debris

transported into the basin at times of flood. The angularity of the clasts is understandable for they are chiefly quartzite and hornfels and are similar to the angular weathered rock fragments that form today in the hills of Paleozoic rocks east of the Jack Creek fault.

White biotite rhyolite and latite ash beds are common in most of the Chicken Creek formation, and they increase in abundance and thickness to the south west. Near the southern west edge of the quadrangle ~~in the southwest corner~~ (secs. 25, 36) the Chicken Creek has numerous interbedded tuffs and their source rocks are ~~center of eruption~~ appear ~~to lie~~ on the south edge of the quadrangle. In this area (sec. 36) the interbedded volcanics ~~increase~~ become more abundant lower in the section, and give way to a completely volcanic ~~area~~ terrain composed of rhyolite and latite. The interbedded Chicken Creek directly north of these volcanics is composed of coarse sandstone and conglomerate, as well as lake beds and coaly seams. ¶ The biotite rhyolite welded tuff is composed of crystals of oligoclase, andesine-labradorite, sanidine, quartz, and biotite in a tuff matrix. Quartz is very abundant and biotite is common in many samples. The light gray to tan rock has a matrix consisting of devitrified glass, the glass shards are distorted due to plasticity during welding, and glass bubbles ranging from round to flattened are present.

The light cream colored biotite latite is composed of an extremely heterogenous mixture of (a) crystal fragments of andesine-labradorite, oligoclase (?), biotite, and altered pyroxene(?) and/or hornblende (?), and (b) rock fragments predominantly volcanic in nature and a few glass shards, all enclosed in a matrix of microcrystalline to cryptocrystalline material. The texture is vitroclastic, with highly fragmented crystals.

Since these volcanic rocks that interfinger with the Chicken Creek formation make up only a small area on the south edge of the quadrangle, and increase in thickness and in areal distribution to the south, it has seemed best not to name them formally, but to include them provisionally as an unnamed volcanic member of the Chicken Creek formation. Future geologic mapping in the area to the south probably will show that they deserve formational status.

At a maximum, the Chicken Creek is approximately 1,500 feet thick in its type area, and it appears to exceed 2,000 feet in the hills south of Lime Mountain. Exact measurements can not be made because many small faults cut the section, good marker beds are not present, and due to slumping and weathering outcrops are poor in much of the area underlain by the formation. The formation appears to thin to the north of Lime Mountain, with only about 100 feet represented in the headwaters of L Creek. Some of this thinning is no doubt due to erosion of higher Chicken Creek beds following folding and uplift of the section.

An upper age limit for the formation is indicated by stratigraphic evidence. Since the Chicken Creek formation is folded and overlain unconformably by Jarbidge rhyolite which is middle Miocene (early Barstovian), (at a minimum) the Chicken Creek is probably no younger than early Miocene. On the basis of a K/Ar date of 35.2 ± 1 million years (Geochron Laboratories, Sample No. B0124, Feb. 1962), yielded by biotite from an ash bed ~~high up in the formation at a~~ 30 feet north of the junction of State Highway 11 and locality at the road junction to Cornucopia, ~~west of Lime Mountain~~, the formation is considered to be late Eocene, with its highest parts probably basal Oligocene in age.

Although fossil plants have been recovered at 3 localities in the formation, but they are not abundant at any of the sites.

Swale locality ~~Section of Shale Florule~~ (Loc. P571-8). This florule ~~is~~ was recovered ~~situated~~ at a site one mile east ~~sou~~ of the summit of Lime Mountain, at the head of the small south-trending swale ~~midway~~ in the NW part of Sec. 6, at an altitude of 6,110 feet. It is readily reached from the county road in Deep Creek, by taking the turnoff ~~the turnoff being~~ at BM 5630. The section is chiefly composed of shale in this area, as follows:

| Tbp. | | Thickness feet | inches |
|---|---|---|---|
| 12. | Sandstone. Pebble, coarse, massive, poorly bedded, ashy and ostracodal, with rounded granules and small pebbles of Paleozoic rocks and pumice shards ..... | 2 | 8 |
| 11. | Ash. Rhyolitic, white, poorly bedded below, grading up to well bedded ash above | 8 | 6 |
| 10 | Shale. Well bedded, platy, limy, in beds 1/16-1/8 inch thick, laminated, white to light tan | 9 | 10 |
| 9. | Shale. Limy, yellow brown, irregular surface on splitting, well bedded, from 1/8-1 inch | 14 | 8 |
| 8. | Ash. Rhyolitic, white, well bedded, ¼-1 inch thick. | 0 | 8 |
| 9. | Shale. Limy, ostracodal, irregular surface , white, to light gray and tan. | 15 | 3 |
| 6. | Shale. Finely laminated, brown-gray brown and wi bluish cast, weathering to large plates, os~~ceta~~tracodal-rich, occasional plants (Loc. P571-8) | 1 | 10 |

| | | | |
|---|---|---|---|
| 5. | Shale. Limy, yellow brown, in beds 1/8-2 inches thick, splitting with irregular surface | 4 | 6 |
| 4. | Rhyolite ash. White, biotite rich, conchoidal fracture, poorly bedded | 3 | 5 |
| 3. | Shale. Yellow-white, ostracodal, limy, well bedded, ¼ - ½ inch thick, irregular surface, weathering to small plates | 18 | 3 |
| 2 | Rhyolite ash. Poorly bedded, conchoidal fracture, white, few biotite flakes | 7 | 3 |
| 1 | Shale. Ostracodal, limy, tan, platy, thinly bedded (1/8-1/16 inch), occasional insect larvae .... | +4 | |

(bottom of section)

Only a few plants have been recovered at this locality, where the following species are rppresented:

Conifers

Abies rigida

Larix nevadensis

Picea lahontense

Picea sonomensis

Picea magna

Pinus crossii

Pinus wheeleri

Pinus harneyana

Tsuga mertensioides

Chamaecyparis linguaefolia

Angiosperms

Salix

Ribes

Holodiscus idahoensis

Bahia

Rhododendron

Willow Spring locality (loc. P571-9). This site is exposed on the south-facing bank of the flowing stream in the southwest corner of sec. 31, T. 43 N., R. 52 E. The locality is about 75 yards NW of a prominent spring on the south bank of the stream which is marked by a prominent clump of willows, and a long, tall aspen. It is most readily reached by proceeding up the canyon that drains into Deep Creek 0.4 miles west of the bridge at Deep Creek crossing. The section is poorly exposed because it is in a stream bank which is largely capped by a small terrace deposit, and is concealed by dense brush. The following section is exposed here:

| | Thickness feet | Thickness inches |
|---|---|---|
| Top. | | |
| (Concealed) | | |
| 4. Shale. Yellow brown, well bedded, ½-1 inch thick, limy, with numerous ostracods ..... | 6 | 0 |
| 3. Shale. Ligh gray brown to tan, platy, limy, well laminated, filled with ostracods. Splits into large plates, with slightly undulating, irregular surface . . . . . | 8 | 6 |
| 2. Shale. Light gray brown, limy, platy, laminated, splitting into large plates scarcely 1/16 in. thick, filled with insect impressions, occasional plants . . . . . | 1 | 0 |
| 1. Shale. Dark gray brown, finely laminated, limy, iron-stained on fractured surfaces, breaks into small blocks . . . . . | 5 | 5 |
| (Base, bottom, Concealed, about 10 ft. above creek bed). | | |
| Total thickness: | 20 ft. | 11 in. |

The small willow spring florule is composed of the following plants:

Conifers

| | |
|---|---|
| Abies rigida | Pinus crossii |
| Abies klamathensis | Pinus wheeleri |
| Picea lahontense | Pseudolarix parviseminis |
| Picea magna | |
| Larix nevadensis | |

Angiosperms

| | |
|---|---|
| Mahonia marginata | Chamaebatia praefoliolosa |
| Ribes | Holodiscus idahoensis |
| Ribes | Vaccinium sonomensis |

Cornucopia Junction locality (Loc. P571-10). Fossil plants occur in well bedded limy shale on the low spur 40 yards north of the turnoff to Cornucopia from State Highway 11. The site is in the NE corner of sec. 11, T. 42 N, R. 51 E., one mile SW of the north summit of Lime Mountain. The following section is exposed here:

| | Thickness feet | inches |
|---|---|---|
| Top. (Road bank). | | |
| 8. Shale. Shale--Light gray and tan, limy, ostracodal locally, well bedded to laminated, irregular surface on parting plane | 14 + | |
| 7. Ash. Biotite rhyolite ash. massive, white. (K/Ar age = 35.1 my)..... | 4 | 3 |
| 6. Shale. Gray, limy, laminated, with few biotite flakes | 2 | 2 |
| 5. Ash. Rhyolite biotite ash. White, poorly bedded | 2 | 8 |
| 4. Shale. Gray to tan, well bedded, limy, with occasional fine sand smears on surfaces, somewhat ashy, with fossil plants, and some insects near top (Loc. P571-10) .....18.0 | 0 | |
| 3. Shale. Soft, silty, gray brown, weathering to dark soil | 5 | 8 |
| 2. Biotite rhyolite ash. Poorly bedded, gray to white, iron stained. | 0 | 6 |
| 1. Shale. Ostracodal, limy, well bedded to laminated, white to light gray, platy .... | +25 | 0 |
| Total thickness | ft. | in. |

The florule recovered at the Cornucopia Junction locality is a small one, including the following species:

~~Ahimxxxxxxxxxx~~

Conifers

Abies rigida

Chamaecypris linguaefolia

Larix nevadensis

Pinus crossii

Pinus harneyana

Pinus wheeleri

Pinus crossii

Picea magna

Picea sonomensis

Pseudotsuga sonomensis

Thuja dimorpha

Angiosperms

Crataegus wilderi

## Jarbidge Rhyolite

This distinctive formation, which has its type area near Jarbidge 45 miles northeast (Coats, 1964), is well exposed in the southern part of the Bull Run quadrangle where it rests unconformably on the Chicken Creek formation. State Highway 11 ~~traverses it~~ where Harrington Creek cuts through a prominent cuesta of Jarbidge rhyolite a mile north of Jack Creek. The formation also caps the higher hills east and west of Chicken Creek Summit, and small patches occur just east and west of Line Mountain.

Jarbidge rhyolite is ~~typically~~ characteristically brownish to reddish brown in color, and characterized by large quartz and sanidine crystals.

The formation is about 400 feet thick on the high unnamed hill northeast of Chicken Creek Summit, and is about 500 feet thick in the hills south of Lime Mountain (sec. 24) where there appears to have been an eruptive center. Elsewhere in the area it varies from 0-200 feet thick, as compared with fully 2,000 feet in the Owyhee River Canyon 20 miles northeast. The formation gradually thins to the west, and interfingers with the overlying Long Valley volcanics which replace it.

The contact between Jarbidge rhyolite and the underlying Chicken Creek is poorly exposed in most of the area ~~owing to~~ because talus of Jarbidge rhyolite covering it, ~~and to slumping in the Chicken Creek.~~ Where they are in contact on the south nose of the anticline, dips are low (±5°) in both units so if angular discordance is present it is not apparent. The presence of an unconformity is suggested by the distinctive mappable beds (conglomerate, tuff, sandstone, etc) that occur in the Chicken Creek close to the Jarbidge contact in the southeast of the quadrangle, ~~and which~~ vary from exposure to exposure, far more so than might be expected of normal lithologic variation in nonmarine rocks. The most conclusive evidence for an unconformity ~~is found~~ may be seen on the hill just east of Lime Mountain where the Chicken Creek is folded into a north-trending tight syncline with dips of 20° - 40° on the flanks, and with Jarbidge rhyolite lying across it, dipping gently south.

Jarbidge rhyolite is Miocene since a K/Ar age on sanddine gives an age of 16.8 ± 0.5 million years (Geochron Laboratories Inc., Sample F0 204, Sept. 1962), and the formation is overlain in the region to the southeast (Pie Creek) by the Humboldt formation which yields Barstovian mammals. Furthermore, Dr. Robert Coats reports (personal communication, 1964) that a small mammalian fauna from ash beds just below the Jarbidge rhyolite near Rizzi Ranch, a few miles south of Mountain City, is Miocene in age-- probably ~~late Hemingfordian~~. Arikareean

## Long Hollow Volcanics

In the southwestern part of the area the ~~upper part of the~~ Jarbidge rhyolite gradually thins and interfingers with the Long Hollow volcanics which replaces it in the area just to the west. The formation, composed of welded tuffs and flows that vary in composition from rhyolite to latite and dacite, is named for its good exposures in the low hills west of Long Hollow in the southwest part corner of the quadrangle. The formation is also well developed in the drainage of Hot Creek, though ~~that area is not as accessible.~~ ~~The formation~~ and it covers an extensive area in the drainage of Deep Creek west of the quadrangle, along the road to Cornucopia.

The rocks are generally dark colored, reddish to brown and black, though locally there are light gray and pink rocks ~~in the formation.~~ The Most latites have phenocrysts of oligoclase-andesine and labradorite (predominant) in a microgranular groundmass consisting of quartz and feldspar that is sprinkled with anhedral magnetite grains. Some of the pyroclastics are rich in diopside, in a glassy devitrified groundmass composed of feldspar and mafic microlites. One specimen represents a diopside latite, composed of phenocrysts of plagioclase and diopside with a trace of quartz in a glassy devitrified groundmass containing feldspar (19 per cent plagioclase) and diopside (16 percent) with a sprinkling of hematite and magnetite. Some of the latites are

black and nearly vitrophyric. They usually occur in form the basal part of the formation, resting on and interfingering with Jarbidge rhyolite, and also are occur scattered through the middle and higher parts of the formation.

In thin section the dacite tuffs display crystals and crystal fragments of andesine-labradorite, oligoclase (minor), quartz, and pyroxene (?) in a cryptocrystalline groundmass containing some interstitial devitrified and partially devitrified glass. Magnetite and some hematite grains up to 0.25 mm are scattered throughout the groundmass in which there are a few tuff fragments partially resorbed.

Quartz latite tuff is also represented in the formation. It is a pinkish rock, with phenocrysts of oligoclase, andesine-labradorite, sanidine, and quartz in a granular microfelsitic groundmass. Plagioclase represents about 35 percent, quartz 9, and sanidine 5 per cent. of the rock, the remainder groundmass.

The formation is over 500 feet thick in the hills west of Long Hollow, and evidently thickens to the west, outside the quadrangle. In the drainage of Hot Creek it is at least 300 feet thick. In view of its interfingering relations with the Jarbidge rhyolite, the Long Hollow volcanics are judged to be early late Miocene (Barstovian) in age.

Jenny Creek Formation

The type area of this formation is in the Jarbidge quadrangle, 35 miles northeast of the Bull Run area (Coats, 1964), where it rests unconformably on Jarbidge rhyolite and grades up into the Cougar Point welded tuff. Since ~~there are~~ the rocks in the Bull Run area that have a similar composition and stratigraphic position, they are identified as Jenny Creek. Although Coats named the unit Jenny Creek tuff, in the Jarbidge quadrangle the formation also includes diatomite and other sedimentary rocks. Since the formation in the Bull Run area is not composed wholly of tuff, it seems more appropriate to use the name Jenny Creek formation.

This unit is composed of welded rhyolite tuff, vitric ash, ashy shale, and subordinate sandstone and conglomerate. It rests unconformably on Jarbidge rhyolite and Long Hollow volcanics in the southwestern part of the area. The formation is best exposed in the drainage of Long Hollow, where it overlies Long Hollow volcanics. ~~It is also exposed in small patches in the drainage of Hot Creek to the east of Long Hollow,~~ and also occur along the road west of Lime Mountain where ~~it lies~~ they rest on Jarbidge rhyolite.

The basal part of this unit in the drainage of Long Hollow ~~and in the hills to the southeast~~ is typically a dark gray to black vitroclastic welded rhyolite tuff. It ranges from 30-50 feet thick, and apparently thins out to the north for it is not exposed in the area west of Lime Mountain. ~~though possibly it is concealed there by the alluvial fans.~~ Thin sections of the tuff show crystals and crystal fragments of quartz, sanidine, oligoclase, and some highly corroded andesine-labradorite, and completely resorbed biotite in a matrix of highly compressed glass shards, collapsed pumice grains, and vitroclastic rock fragments. The glass shard structure is readily recognizable even though welding and strong compression have occurred. The collapsed glass shards are welded together in subparallel orientation. The rocks have a vitroclastic texture and a groundmass of glass with the crystals from 0.5 to 1.5 mm in size. Groundmass composes some 75-85 per cent of the rock and shows very little devitrification. Of the identifiable minerals there is 3-5 per cent quartz, which is bipyramidal and corroded; 7 per cent plagioclase; 3 percent sanidine; and some microcline.

These blackish vitrophyric beds are thickest and most widespread at the base of the formation. They also occur at higher stratigraphic levels but are represented there by thinner units, usually from 1-4 feet thick. The welded tuffs are associated with buff to tan vitric tuff, usually poorly indurated. Small glassy fragments and ash fragments are present, and a few small (0.05-0.1 mm) crystal fragments. Specimens of the buff vitric tuff were examined by Dr. Robert Coats who reports (written communication, Dec. 1961):

> Megascopically the specimens look not unlike the coarser reworked parts of the Jenny Creek tuff in the Jarbidge quadrangle. Microscopically, they show brown and clear glass in fresh shards, plus a great amount of nontrachonitic material. The primary minerals seem to be quartz, plagioclase, sanidine, and pyroxene, with rare biotite and muscovite. This corresponds very well with the Jenny Creek.

Most of the formation in Long Hollow is composed of light colored ashy beds that have been redeposited by streams, probably in a small lake. Associated rocks in this section include well bedded, scarcely indurated vitric ash ranging in color from cream to pearly white and tan. Locally in Long Hollow there are a few pebbly sandstones in the formation, composed chiefly of detritus from the bordering volcanic uplands. A prominent conglomerate is in the formation west of Lime Mountain, with the clasts representing Jarbidge rhyolite chiefly. In general, the formation is poorly indurated and good outcrops are not common except locally in badland areas along streamways or near faults where ~~the rocks have been displaced~~ and steep gullied slopes are present. At a maximum, the formation is about 300 feet thick in Long Hollow. The small patches along the road west of Lime Mountain are scarcely 40-50 feet thick, and where the formation appears to have been near the edge of the depositional basin.

Regional relations of the Jenny Creek formation indicate that it probably is a correlative of the "middle Humboldt" formation, and of late Miocene age (for discussion, see Axelrod, 1964, p. ).

## Cougar Point Welded Tuff

This distinctive formation, composed of highly welded acidic tuffs, crops out on the Owyhee Desert along the west front of the Bull Run Mountains. These nearly flat-lying ~~xxxxx~~ to slightly warped rocks have been traced northward around the range to beyond Owyhee, and thence eastward into the type area of the formation in the Jarbidge quadrangle (Coats, 1964). Along the county road west of Lime Mountain, Cougar Point welded tuff grades down into the Jenny Creek formation which rests unconformably on Jarbidge rhyolite. The rocks are yellowish brown and brownish gray, and include several ash flows whose thickness totals 40-50 feet. A thin section shows that the rock is a vitric crystal tuff, consisting of a heterogenous mixture of glass shards, with ash and crystal fragments ranging from 0.01 to 0.2 mm in size. It appears to be rhyolitic in composition.

On the basis of its regional stratigraphic relations the formation is ~~apparently~~ of late Miocene age (see Axelrod, 1964, p. ).

Banbury Basalt

Basalt forms a low, slightly warped mesa directly west of the junction of Long Hollow and Deep Creek, one mile west of Lime Mountain. It overlaps Cougar Point welded tuff and Jarbidge rhyolite, and is separated from the Chicken Creek formation by a northeasterly trending fault. Owing to talus and rubble covered slopes, its total thickness is not readily determinable, but it is approximately 100 feet thick. The rock is a dense black basalt and locally rather vesicular. A thin section shows that it is densely aphanitic, with phenocrysts of labradorite, bytownite, and some olivine. The groundmass ~~showing~~ has a subophitic texture. ~~The groundmass of feldspar laths of random orientation with interstitial pyroxene that is sometimes enclosing them poikilitically.~~

Banbury basalt is exposed discontinuously to the north, where it regularly overlies Cougar Point welded tuff unconformably. It has a similar stratigraphic position in the Jarbidge quadrangle. To the north in Idaho, Banbury basalt is associated with sedimentary rocks that yield fossils of middle Pliocene age (Malde & Powers, 1962, p.1204).

## Quaternary Rocks

Unconsolidated Quaternary rocks of diverse origins blanket a good part of the region, but they were not studied in detail. Apart from the recent alluvium and low stream terrace deposits in the valleys, there are large alluvial fans in the area, notably along the east and west front of the Bull Run Mountains. They grade ~~laterally~~ laterally into high stream terrace deposits that occupy generally low to moderate altitudes ~~in the basin~~, and have been so dissected that they are now reduced to remnants. Important landslide areas are south of Mori Ranch (sec. , T. , R. ) and in the upper drainage of L Creek (sec. , T. , R. ). The former ~~has~~ developed on the Chicken Creek formation, the latter on poorly consolidated shales of the upper I L formation. Both units are ashy and instability appears related in part to the water-retention properties of the shale, as well as to ~~active~~ faulting. Talus aprons locally cover the Tertiary rocks, as at the base of the cliffs of Banbury basalt along Deep Creek west of Lime Mountain, and also on the mountain front west of Wilson Peak. In addition, the upper part of the alluvial fans ~~on the Mountain front~~ north of Bull Run Reservoir grade up into talus slopes.

## STRUCTURE

The Tertiary rocks of Bull Run basin form a broad southwesterly plunging syncline (~~Fig. 6~~ map, pl. 1), the axis of which lies near the middle of the basin east of the county road. The limbs of the fold have gentle dips, increasing to somewhat higher attitudes where they are disturbed by faults. The west flank of the anticline passes into a syncline that affects the I L and Chicken Creek formations near the front of the Bull Run Mountains east of Lime Mountain. The syncline appears to be a drag fold that developed in response to early (pre-Jarbidge rhyolite) folding, possibly in Oligocene time.

The moderately deformed Tertiary section is flanked on the east and west by high angle basin-range faults on which the present Bull Run and Independence ranges were elevated. As noted earlier, the Bull Run fault at the east base of the central Bull Run Mountains was active during deposition of the Mori Ranch formation, following which it appears to have been quiescent. Rejuvenation of the fault, and initiation of the Owyhee fault system on the west front of the Bull Run Range and the Jack fault on the east side of the basin occurred in the later Cenozoic, probably after extravasation of the Banbury basalt which is middle Pliocene. It seems probable that all the faulting commenced during the early Quaternary, at which time the ranges were elevated to nearly their present heights.

That normal faulting has continued into later Quaternary time is apparent from the faulted fans and terraces deposits at a number of localities. Furthermore, it is evident to note that the major basin-range faults have been displaced by a younger northeast-trending set (map). One of the more conspicuous faults of this set cuts across Bull Run Reservoir and brings Paleozoic rocks to the surface well out in front of the range. This raises the problem of the depth of the basement along the west margin of the basin, and also the elevation amount of vertifal displacement on the Bull Run fault.

Drilling on the anticlinal crest northeast of I L Summit shows that the Paleozoic rocks are at a depth of 2,300 feet there (Decker, 1962, p. ). Several lines of evidence indicate that the basin shallows toward the mountain fronts. (1). As shown on the map, a patch of Frost Creek volcanics occurs in the basin a short distance north east of Bull Run Reservoir, close to the county road (sec. 10 ), indicating that the Paleozoic basement is not more than 200-300 feet deep there. (2). ~~As discussed earlier,~~ Both the Mori Ranch and I L formations thin to the southeast, ~~showing~~ showing that the basin shallows in that direction ~~basement is near the surface there~~. (3). On the south flank of Lime Mountain the Mori Ranch formation is not present, and the I L is only about 40 feet thick, also indicating a shallowing in that direction. (4). Structure sections (fig 3) indicate that the basin is not a simple graben, but is composed of a series of treads and risers with the basement contact deepening toward the center of basin from both sides of the trough.

## Summary

The preceding brief description of the Tertiary geology of the Bull Run basin can be summarized in terms of the evidence it provides with respect to the physical setting and stratigraphic occurrence of the Bull Run flora. The salient features are shown in fig. 3 which depicts schematically the stratigraphic-structural relations at the close of Chicken Creek sedimentation in late Miocene time. As shown there, the 10 florules composing the Bull Run flora are distributed from the upper Mori Ranch to near the top of the Chicken Creek formation, and through a stratigraphic thickness of about 4,500 feet.

The basin of deposition, bounded by low hills of Paleozoic rocks at the sites of the present Independence Range and Bull Run Mountains, apparently came into existence with initiation of the Bull Run fault and was accompanied by volcanism that produced the Frost Creek volcanics. The volcanics interfinger with the overlying Mori Ranch formation of fluviolacustrine origin. These sediments were derived chiefly from low terrain at the site of the Independence Range, and from which a delta was being constructed that thickened toward the center of the trough. At the same time, sediments were pouring into the basin from an active scarp fault on the central

east front of the ancient Bull Run Mountains where a thick fanglomerate accumulated with associated volcanics. The Bull Run hills behind the scarp were probably not more than 1,000 feet above the basin at its north end, and decreased southward to basin level at the south end of the Mountains.

¶ The overlying I L formation includes two facies, fluviolacustrine to the south and southeast, and lacustrine in the west. Since the I L thins to the southwest and rests on the Frost Creek volcanics, it evidently overlapped the Bull Run fault which was quiescent during I L deposition, a relation consistent with the presence of lacustrine shales close to the central scarp area where coarse detritus is absent. Like the underlying Morri Ranch, the I L formation also thins to the southeast toward the head of the delta that was building out into the basin. Deposition of the overlying Chicken Creek formation of ashy sediments, limy shale, and some coarse clastics and pyroclastics, brought to a close the period of Eocene sedimentation.

The abundance of coaly seams and highly organic shale, generally of limited areal extent, indicates swamps and ponds were widely scattered over the lowlands.

Fig. 3. Schematic representation distratigraphic-structural relations in Bull Run basin during deposition of Eocene formations.

Chicken Creek fm.

I L fm.

Mori Ranch fm

Frost Creek volcanics

Paleozoic Rocks

Fossil florules, 1 to 10

1-5 = Lower Bull Run Flora

6-10 = Upper Bull Run Flora