GEOLOGY OF THE MAZAMA AREA, METHOW VALLEY, WASHINGTON

by

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Approved by Julian D Barksdale

Department in which degree is granted Geology

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INTRODUCTION

Location

The area described in this thesis lies in the Methow River valley of Okanogan County, north central Washington. (Plate I) Geographic boundaries are north latitudes 48° 29' to 48° 39', and west longitudes 120° 16' to 120° 24'. The area covers approximately 70 square miles, and includes the townships T.35 N., R.20 E. and T.36 N., R.20 E. (Willamette meridian). The town of Mazama is just east of the Methow River on the west edge of the area. Approximately 5 miles east southeast of the area is Winthrop (population 394) at the confluence of Chewack Creek and the Methow.

Access by automobile is via U.S. 97 north from Wenatchee, then left on state route 16 at Pateros. Winthrop is 90 miles from Wenatchee and 240 miles from Seattle. The Canadian boundary is 25 miles due north of Mazama. South of Winthrop, route 16 is a hard-surface all-weather highway; beyond the town there are unpaved farm, Forest Service, and logging roads, as well as trails. There are no railroads in the Methow valley. A dirt airstrip is located midway between Winthrop and the town of Twisp to the south.

Details of the Investigation

The purpose of this investigation is to map the general geology of the area outlined, noting in particular lithologies and structure. The

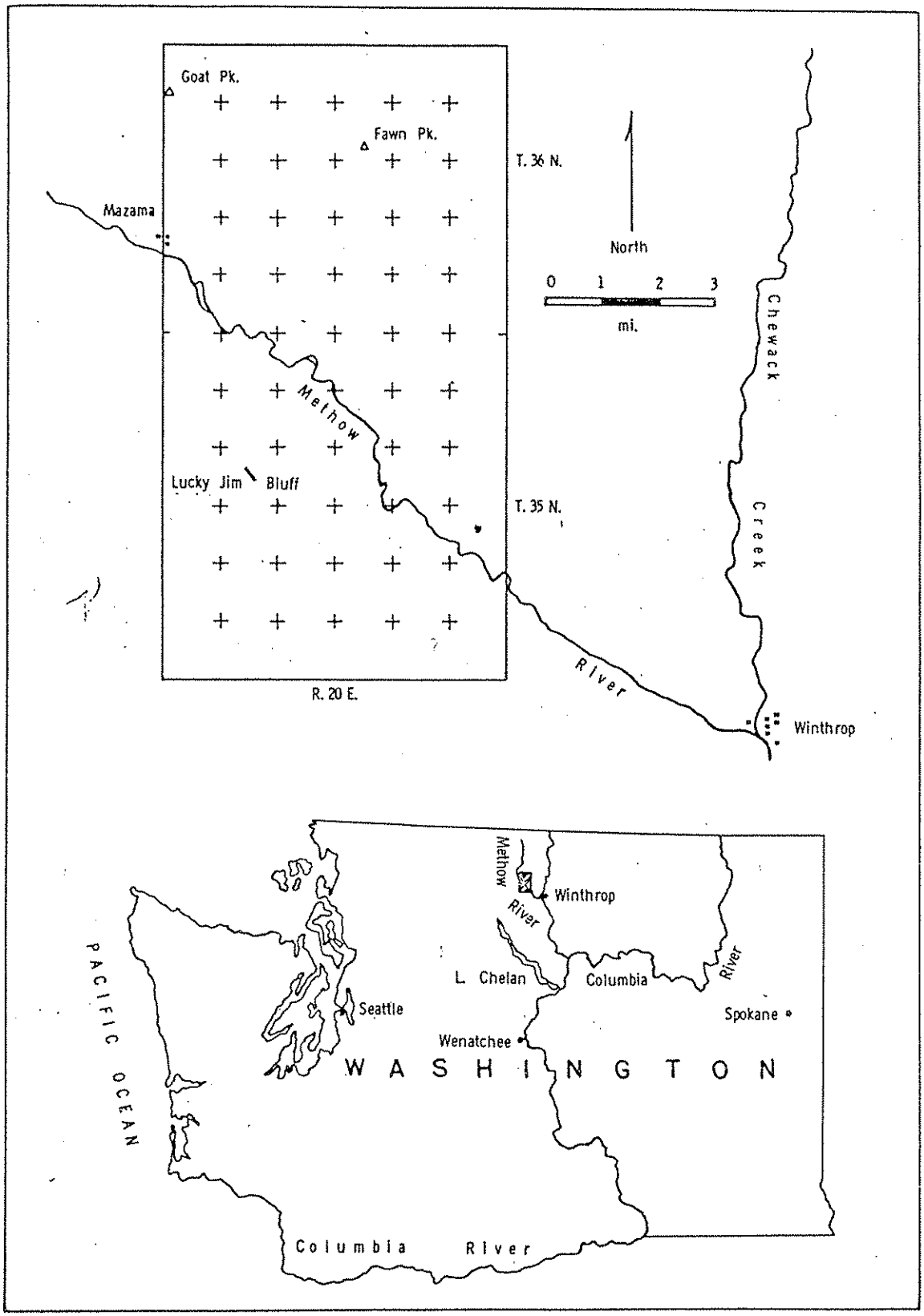


Plate 1. INDEX MAP OF THE MAZAMA AREA, METHOW VALLEY, WASHINGTON

area was selected with the assistance of Dr. Julian D. Barksdale, Professor of Geology at the University of Washington, because of the varied rock types, structures, and good exposures. The Geology Department faculty approved the selection for a Master of Science thesis in May, 1957.

The period of investigation included the months of September, 1957, and July, 1958, with a total of 28 days spent in the field. The U.S. Forest Service planimetric map of the 15 minute Mazama quadrangle, and an enlargement of the northern portion of the U.S. Geological Survey 30 minute Methow Quadrangle were used as base maps. Aerial photographs (1947) were used in the field for detailed work.

Acknowledgments

Dr. Barksdale visited the writer in the field several times and contributed greatly to the completeness and accuracy of this work by his comments and explanations of regional structure and general field relationships.

D. L. Maurer, a Washington graduate student, recently completed a thesis southeast of the writer's area. Mr. Maurer is to be thanked for the use of his biostratigraphic work in the Virginian Ridge formation and many helpful suggestions.

Professor Stewart Lowther of the College of Puget Sound was of assistance in determining generic names of flora collected in the Winthrop sandstone.

Thanks go to Mr. George Dibble, Winthrop banker, for his many kindnesses during the writer's stay in the Methow valley; and to geology students, Richard Alvord and Richard Allison, for assistance in the field.

Finally, the writer is indebted to Velma Hall for her time and effort spent in typing this thesis, and to Barbara Pitard, who at various times was a geology widow, chef, and chauffeur.

Previous Work

Russell (1898-99) made a reconnaissance trip down the Methow valley and formally named the Upper Cretaceous Winthrop sandstone and the "Jura-Trias(?) Ventura system."

Barksdale (1941) studied the glacial effects in the Methow valley and published on glaciation in the area.

Barksdale (1948), working in the Methow Quadrangle to the south, proposed the following formation names with the relationships as indicated.

"

Name	Age	Approx. Thickness (feet)
Pipestone Canyon fm.	Eocene(?)	2,300
Unconformity		
Midnight Peak fm.	Upper Cretaceous	8,000
Winthrop sandstone*	Upper Cretaceous	2,500
Virginian Ridge fm.	Lower & Mid. Cret.(?)	10,000-12,000
Unconformity		
Newby fm.	Triassic(?)	14,000
Fault contact		
Methow gneiss	Pre-Chelan batholith	
Leecher metamorphics	Pre-Chelan batholith	

*named by Russell (1898-99)"

The 1957 University of Washington summer field course was held in the Methow valley, and the four townships surrounding Winthrop were mapped. The west edge of these townships forms the east boundary of the thesis area. The writer was enrolled in the course and his unpublished report is used as a reference.

Rock and Fossil Collections

A representative suite of rock specimens with thin sections are in the Geology Department Petrography Collection at the University of Washington.

A small collection of fossil plants from the Winthrop sandstone is filed in the Museum of Paleontology of the University of Washington Geology Department as lot number 43. Locality numbers are UW A-2505, UW A-2506, and UW A-2507.

PHYSIOGRAPHY

Relief and Elevation

The area is one of moderate to high relief. The Methow River valley, at 1700 feet above sea level, is the lowest feature; while Goat Peak is the highest at 7019 feet. Ridges and valleys make up most of the topography, with approximate altitudes of 5000 and 3000 feet respectively.

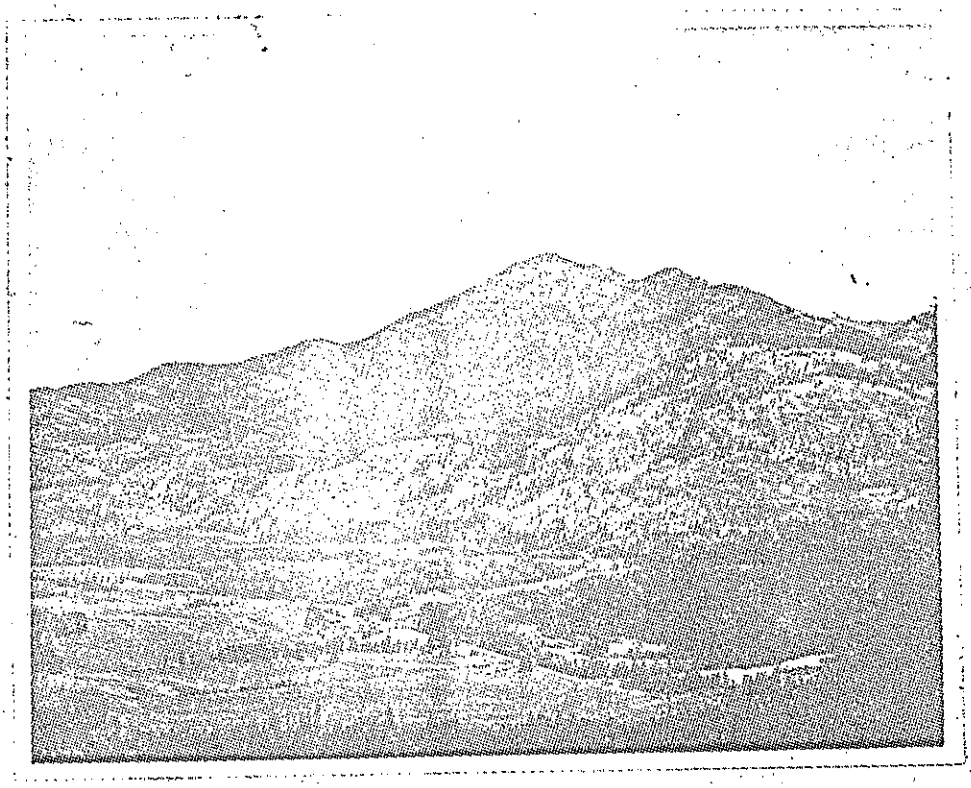
Topography

Topographically, the area is divisible into two parts; the ridge sections and the broad Methow River valley. An early mature stage of development can be applied to the ridges and smaller valleys that lie between them. The land is well-dissected and mostly hillside, with no level upland or valley surfaces present. The ridges are rugged and sharp-crested, and the valleys are narrow with little or no level floor areas. Southwest of the Methow, beds of resistant sediments form strike ridges paralleling the course of the river. The tributary streams dissect the dip slopes of a high red sandstone ridge, Lucky Jim Bluff, forming striking "flatirons".(Plate II-2) This topography contrasts strongly with that northeast of the river where the ridges do not conform to any pattern. Goat Peak, Grizzly Mountain and other features which border on the Methow valley are mainly composed of volcanic breccias and flows. Fawn Peak, 3 miles northeast of the river, is made up of a dioritic intrusion and steeply dipping sediments.

Plate II

1. Goat Peak (elev. 7019) View north across the Methow River valley.

2. Lucky Jim Bluff. Looking northwest at the steeply dipping dark red Ventura sediments which form the southwest limb of a major syncline. The white area near the crest of the bluff is a weathered feldspar porphyry sill.



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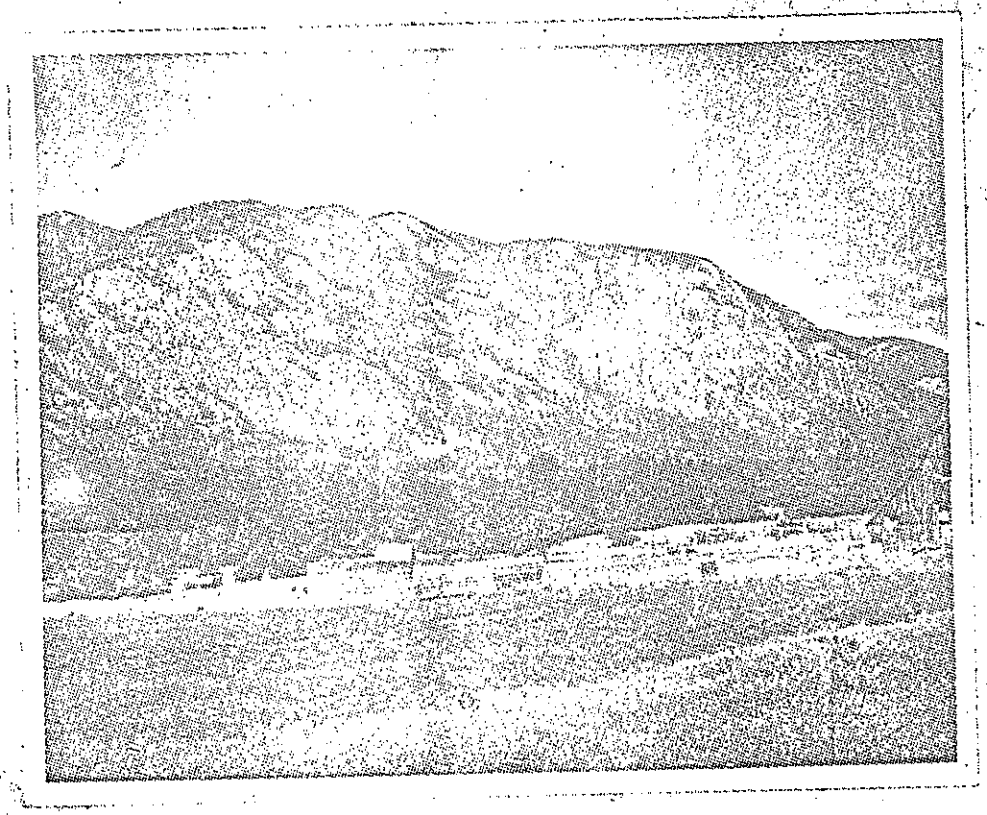


Plate II

2

Cutting a mile-wide swath diagonally across the area is the Methow River. It flows southeast in a U-shaped valley covered with glacial deposits and river alluvium. Glacial terraces line the northeast side of the valley, and glacial erratic boulders are frequently found far up the small valleys that open into the Methow.

Drainage

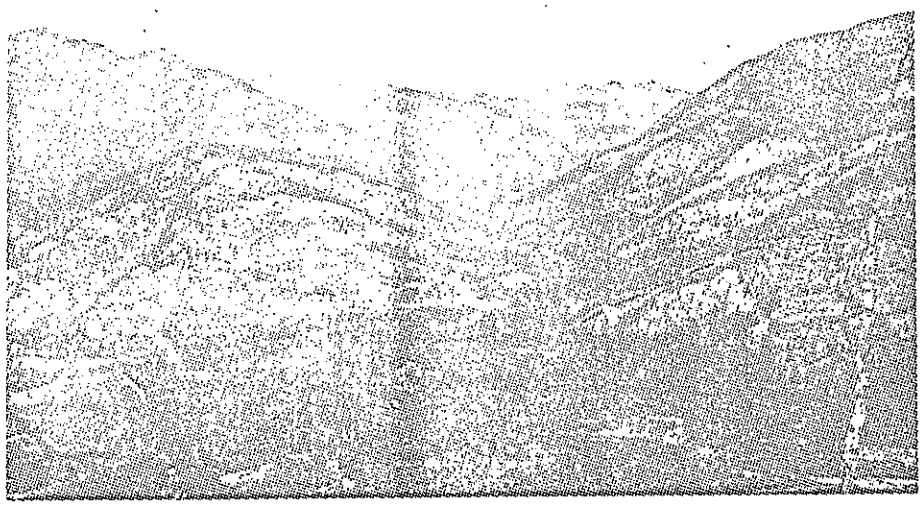
The trunk stream is the Methow River, the headwaters of which rise along the Cascade crest in the vicinity of Harts Pass and Washington Pass. The upper Methow flows southwestward until it joins its north fork, Chewack Creek, at Winthrop. Then the trunk stream flows southward 40 miles and joins the Columbia. One of the larger secondary streams, Wolf Creek, runs along the southern edge of the thesis area and empties into the Methow 3 miles northwest of Winthrop. Goat Creek (Plate III) drains the area north and east of Goat Peak, and joins the Methow 1 mile below Mazama. Much of the terrain east of Fawn Peak is drained by Cub Creek, which runs southeastward out of the thesis area and joins Chewack Creek. Fawn Creek flows parallel to Goat Creek and drains the area south of Fawn Peak. There are many smaller streams, several of them intermittent. Most of their courses are perpendicular to that of the Methow.

The pattern here resembles a trellis. Except for Goat Creek, the larger streams follow the northwest-southeast trend of the major structures. The course of Goat Creek is influenced by the presence of Goat Peak and Fawn Peak on either side of it.

Plate III

1. View north up Goat Creek. Goat Peak is on the left and Fawn Peak just off the photo to the right. In the lower right is a portion of an ice contact terrace (dashed line).

2. View farther up the Goat Creek drainage as seen from Fawn Peak. Logging roads are visible crossing the Winthrop Ss. Isabella Ridge is on the horizon.



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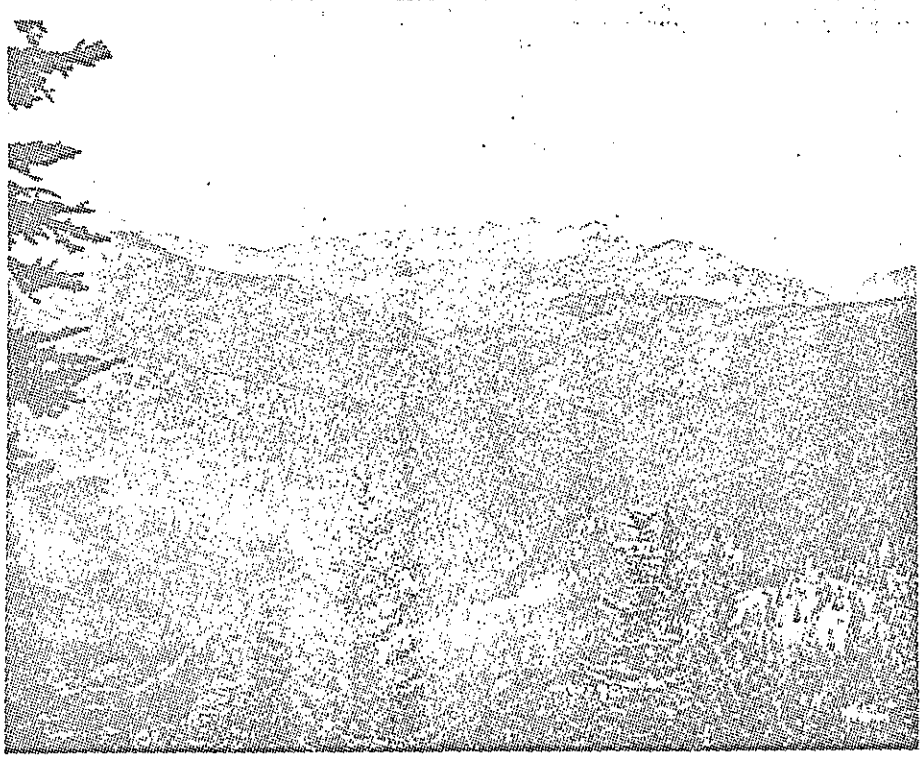

Plate III 2

The Methow River valley has reached a later mature stage of development than the surrounding area. It has a low gradient, and the mile-wide valley floor is several times the width of the meander swings. There are no lakes in the area, but a few marshy places are found in the flood plain.

Vegetation

With the exception of the Methow valley, the area is heavily forested. Logging operations are in progress in Goat Creek canyon. Other than some dense growth on the banks of the Methow, most of the valley is farmland.

Ponderosa pine (Pinus ponderosa) and lodgepole pine (Pinus contorta) are the predominant species in the higher areas. Some quaking aspen (Populus tremuloides) is found at lower elevations, and mullen, sagebrush, and grasses grow on open slopes and along the roads.

Climate

The climate of the area is semi-arid. The summers are hot and dry with occasional thunder showers which sometimes bring on flash floods. Summer nights are quite cool, lowering the average temperature considerably. The winters are cold and dry with most of the precipitation falling as snow. Local inhabitants claim the summers are getting dryer since increasing amounts of water for irrigation are being used. Below are some figures from 1956 and 1957 observations at the Winthrop weather station.

Temperatures are Fahrenheit.

	1956	1957
Annual average	43.0°	44.0°
Temperature high	99.0°(7/19)	96.0°(7/24)
Temperature low	-25.0°(1/31)	-29.0°(1/24)
High monthly average	69.3°(Jul)	65.7°(Jul)
Low monthly average	14.3°(Feb)	08.0°(Jan)
Annual precipitation	15.20"	13.18"
High month	2.79" (Jan)	2.94" (Dec)
Low month	0.40" (Jul)	0.03" (Sep)

Rock Exposures

Rock exposures in the area are good. The valley of the Methow River is covered with glacial deposits and alluvium, but the steep valley sides are generally well-exposed. Lucky Jim Bluff is a good example of this, as the steeply dipping red beds form one of the most striking features in the area. The crests of many of the ridges have bedrock exposed, but their slopes are covered with soil and vegetation. The smaller stream valleys sometimes have bedrock exposures where the creeks have cut through the glacial and stream detritus. Logging companies have recently built many new roads, particularly in the Goat Creek vicinity, exposing fresh bedrock in roadcuts. In the northeast portion of the area, outcrops are scarce due to thick soil cover and dense forest.

Glaciation

The portion of the Methow valley included in this thesis area was buried beneath several thousand feet of ice during the Pleistocene (Barksdale, 1941). The continental ice came from the north and granitic erratics of all sizes are present in the valleys and on hillsides. Evidence of glacial scouring is plentiful, particularly in bedrock that borders the main valley. Examples of roches moutonées are found between Goat Creek and Grizzly Mountain. There is some evidence of a phase of valley glaciation in the U-shaped Methow valley. Just southeast of the area, in section 18, T.35 N., R.21 E., is a hanging valley, the probable result of glacial deepening of the Methow. This was mapped by the writer's field party during the 1957 field course. Varved clays can be seen south of the entrance to Boesel Canyon.

The most striking glacial features in the area are the ice contact terraces that border the Methow valley on the northeast. They extend from the mouth of Goat Creek to Grizzly Mountain. Viewed from across the Methow, these terraces form a straight line almost two miles long, accentuated by vegetation differences on and behind them. There are no corresponding terraces on the southwest side of the valley, probably because the steep unbroken wall of sediments that form Lucky Jim Bluff were unable to prevent the ice from carrying its load farther southeast. For the same reason there are no terraces north of Goat Creek where andesite breccia makes the sheer Goat Wall, or at Grizzly Mountain whose steep face is in direct contact with the valley floor alluvium.

Plate IV

1. Looking southwest across the broad, alluvium covered Methow River valley.

2. Glacial drift from a quarry in an ice contact terrace near Goat Creek.

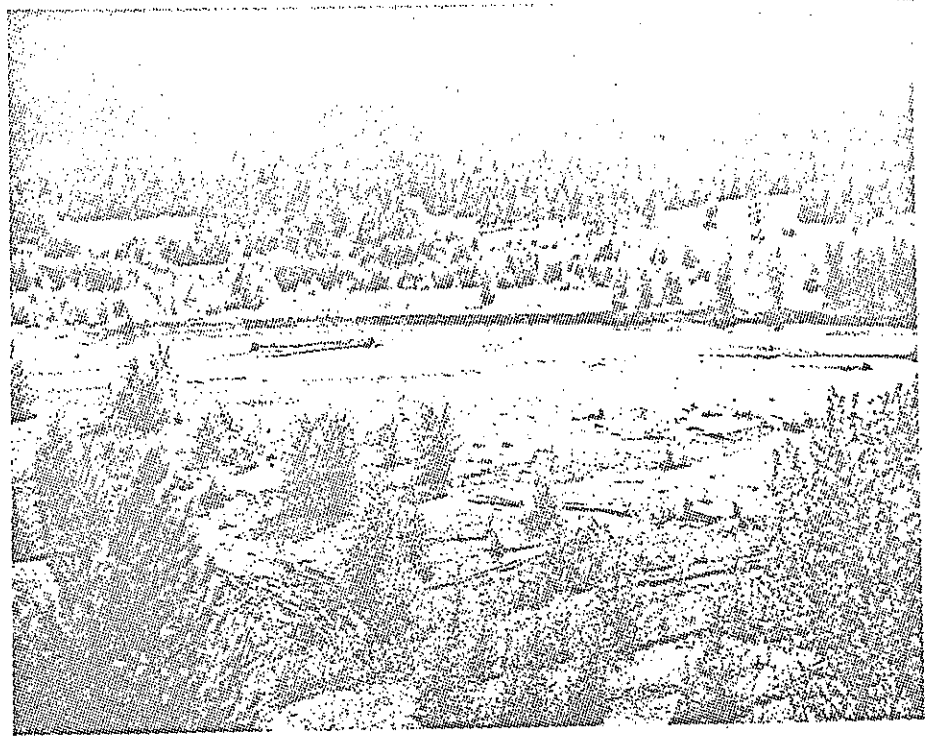

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Plate IV 2

STRATIGRAPHY

General

The sedimentary contacts in the portion of the Methow valley covered in this work parallel the northwest-southeast course of the river. The upper part of the Middle Cretaceous Virginian Ridge is the oldest unit mapped. It is a sequence of conglomerates, siltstones, shales, and graywackes. Beds of silica pebble conglomerate are characteristic of the top of the formation where it grades into the Winthrop sandstone. The Winthrop is predominantly a white arkose with a few scattered lenses of buff siltstone. Resting conformably on the Winthrop is the dark red Ventura formation consisting of sandstones, sedimentary breccias, siltstones, shales and conglomerates. This sequence was measured and is described in detail. Above the Ventura is the Midnight Peak formation, a thick series of andesitic flows and breccias. Goat Peak, highest point in the area, is composed of this material. Midway between Goat Peak and Grizzly Mountain is the large oval-shaped body of the Goat Creek diorite, which seems to cut out the sequence of Ventura beds northeast of the river. In addition, there are numerous sills and dikes cutting the Winthrop and Ventura sediments.

Sedimentary Rocks

Virginian Ridge Formation

The Middle Cretaceous Virginian Ridge formation is present in

COMPOSITE COLUMNAR SECTION OF MAZAMA AREA, METHOW VALLEY, WASHINGTON

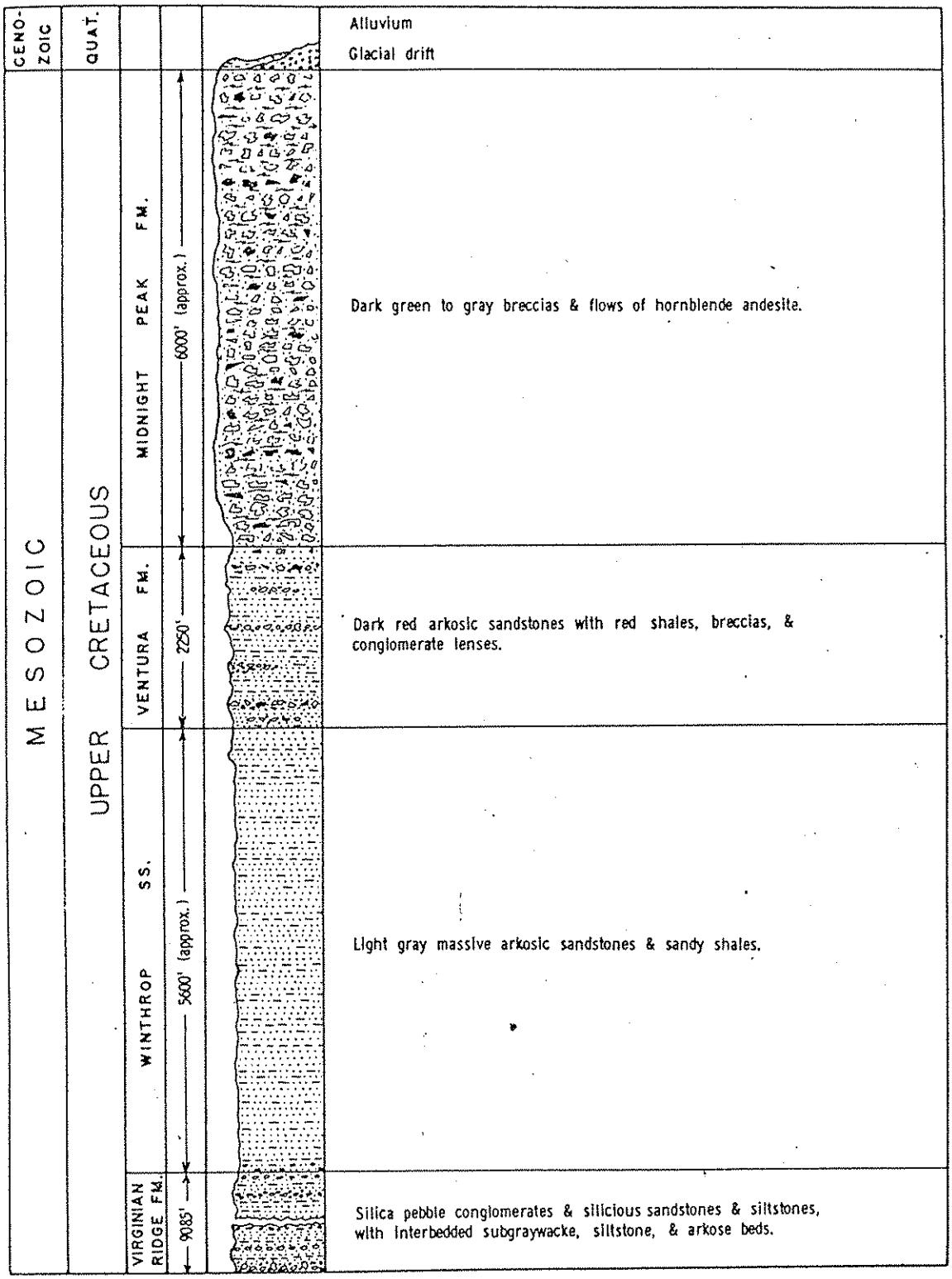

Plate V.

Scale: 1" = 2000'

the northeast, southeast, and southwest corners of the thesis area, where it is in conformable contact with the overlying Winthrop sandstone. The formation was named by Barksdale (1948), and was further defined and measured in 1957 by Hanson, Shideler, Van Noy, and Wallace in an unpublished field course report. Since only the upper part is present in the area, this discussion will be restricted to the Thompson Ridge member of the formation.

This sequence was measured as 7130 feet, which makes up about three-fourths of the Virginian Ridge section. Silica pebble conglomerate with gray silicious sandstone and siltstones occur repeatedly in what appears to have been cyclic deposition. Greenish subgraywackes, siltstones, and shales are found as thin interbeds. White arkose beds, up to 8 feet thick occur locally, particularly near the top of the section. The cycles, which progress from conglomerate to siltstones, average generally 75 to 100 feet.

In the southeast corner of the area, the Virginian Ridge strikes N.10°E., dips very steeply to the northwest, and is conformably overlain by the Winthrop sandstone. The contact can be recognized on both sides of the Methow valley. In sections 13 and 25, T.35 N., R.20 E., its upper limits are characterized by beds of silica pebble conglomerate with lenses of white sandstone. Upsection, the conglomerate beds become thinner and less frequent, grading into the arkose of the Winthrop. The Virginian Ridge-Winthrop contact here, as elsewhere in the area, is arbitrary because of its gradational nature. For mapping purposes, the boundary is placed where the silica pebble

conglomerate ceases to be continuous in the section and occurs as lenses in the white arkose.

In the southwest corner, the Virginian Ridge silica pebble conglomerate strikes N.40° W., dipping 60° to the northeast. Again the contact with the Winthrop is gradational. The pebbles in the Little Boulder Creek area have a maximum diameter of about 3/4 inch, while farther south near Wolf Creek they are as large as 1½ to 2 inches in diameter.

Northeast of Fawn Peak, beneath the Winthrop, are some buff siltstones and black shales with lenses of white sandstone, all striking N.35° W. and dipping very steeply to the southwest. Although this is the proper stratigraphic position for the Virginian Ridge, the characteristic silica pebble conglomerates are not found. This apparent lithologic variation may be due to a change in the source of the sediments in this sector. Another possibility is that the conglomerate is present in small lenses or beds, but was not observed because of the lack of good outcrop. The position of the contact is shown on the geologic map as questionable. A likely place for further study of this problem is Roundup Creek, a tributary of Goat Creek.

The Patterson Lake conglomerate member of the Virginian Ridge formation, which underlies the Thompson Ridge member, has been assigned a Middle Cretaceous (upper Albian) age by Maurer (1958) on the basis of Trigonia sp., Trigonia leana Gabb, Trigonia evansana Meek, and Beudanticeras haydeni (Gabb).

Winthrop Sandstone

The Winthrop sandstone, named by Russell (1898-99), is a white arkose found on both sides of the Methow River valley. The Winthrop is conformably above the Virginian Ridge formation, with a gradational contact which can be recognized on both sides of the broad glaciated Methow valley in the southeast corner of the area. The beds here strike N.10° E. and dip 70° to 80° west. The upper part of the formation is cut off by the Boesel Canyon fault. East of Boesel Canyon, numerous sills have caused contact metamorphism and "hornfelsing" of the sandstone.

In the vicinity of Lucky Jim Bluff, the Winthrop is very thick and forms the crest of the highest ridge in section 17, T.35 N., R.20 E. The sandstone grades into the stratigraphically younger dark red Ventura. Red siltstone lenses and beds occur within the light gray sandstone and become thicker and more numerous upsection. The Winthrop-Ventura contact is gradational and everywhere well-exposed. Attitudes range from N. 40° to N. 50° W with dips of 60° to 70° to the northeast.

The Winthrop also occurs between Banker Pass and Fawn Peak in the northeast part of the area. It strikes N.35° to N.40° W. with very steep southwest dips. It is in contact with the Goat Creek diorite in most places, but does grade into the Ventura north of Grizzly Mountain.

Barksdale (1948) measured the stratigraphic thickness as 2500 feet, and described the sandstone as it appears near the mouth of Boesel Canyon. However, the formation widens considerably to the north, as

Plate VI

1. Massive Winthrop arkose outcrop in Banker Pass roadcut. N. 40° W., dip 58° S.W.

2. White sandstone and black fossiliferous (plants) shale at the north end of Lucky Jim Bluff. This is in the uppermost part of the Winthrop section. The Ventura contact is just to right of photo.

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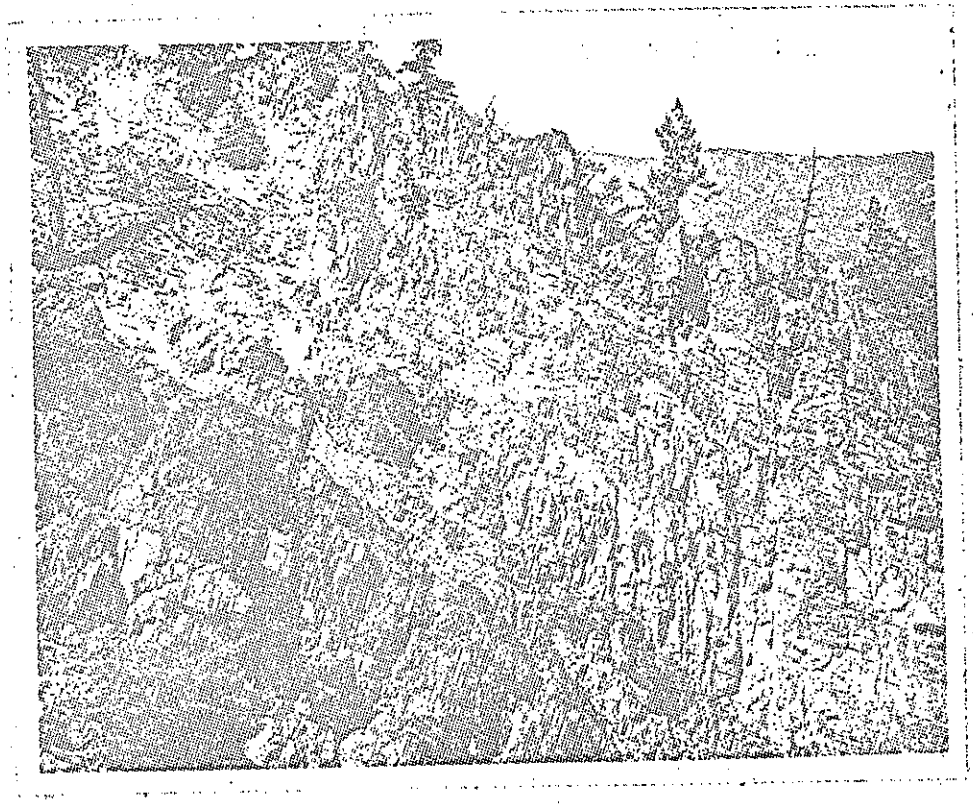


Plate VI 2

the writer estimates the thickness at 5600 feet in the Little Boulder Creek area. Excellent outcrops are also found on the ridges overlooking the Methow east of Boesel Canyon, and across the valley are more exposures of the sandstone which show up as white furrows on aerial photographs. The Winthrop is the lightest colored sediment in the area and is immediately identifiable in the field. Some confusion might stem from its highly feldspathic composition as in places it appears more igneous than sedimentary.

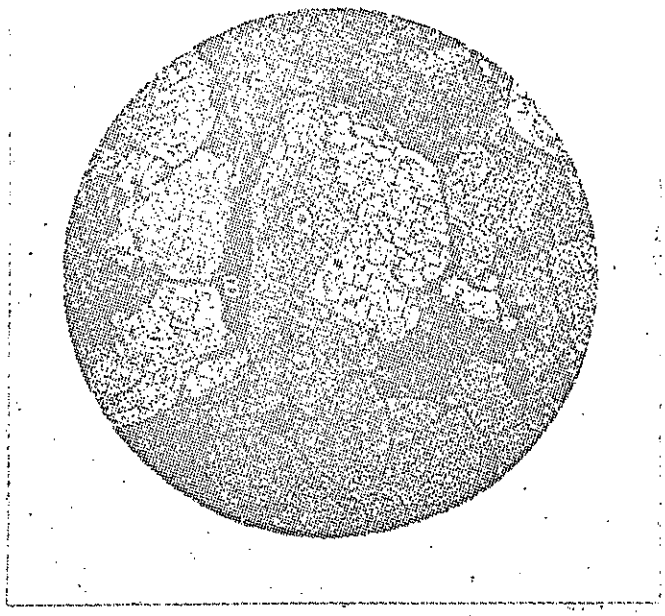
Some specimens of the Winthrop were taken from section 25, T.35 N., R.20 E. In hand specimen fresh pieces are light gray, but weather to white. Biotite flakes, feldspar, and quartz are conspicuous in the moderately indurated arenaceous rock. The grain size varies from fine sand to small pebbles, and the beds range from several inches to about 20 feet in thickness, with occasional lensing.

In thin section, sub-rounded quartz, orthoclase, and twinned plagioclase are predominant, with relative percentages as follows: plagioclase 47, quartz 36, biotite 12, and orthoclase 5. These figures were arrived at from point count analyses of several stained polished sections of the sandstone. The specimens were dipped in hydrofluoric acid, then immersed in potassium dichromate for 20 seconds to produce yellow staining of the potassium bearing minerals. The feldspar grains are generally 0.4mm long 0.2mm wide, but a few reach 0.8mm in length. The quartz is 0.3 to 0.4mm in diameter. Biotite and muscovite make up approximately 10-12% of the rock. The biotite, some of it chloritized, and muscovite flakes are 0.1 to 0.2mm long and 0.05 to 0.1mm wide. Calcite is present as a

Plate VII

1. Photomicrograph of Winthrop sandstone showing fractured subrounded quartz grains. Notice intergrown quartz (Q), with interstitial biotite (B) and altered feldspar (F). Plain light, x 40.

2. Photomicrograph of Winthrop sandstone. Crossed nicols, x 40.



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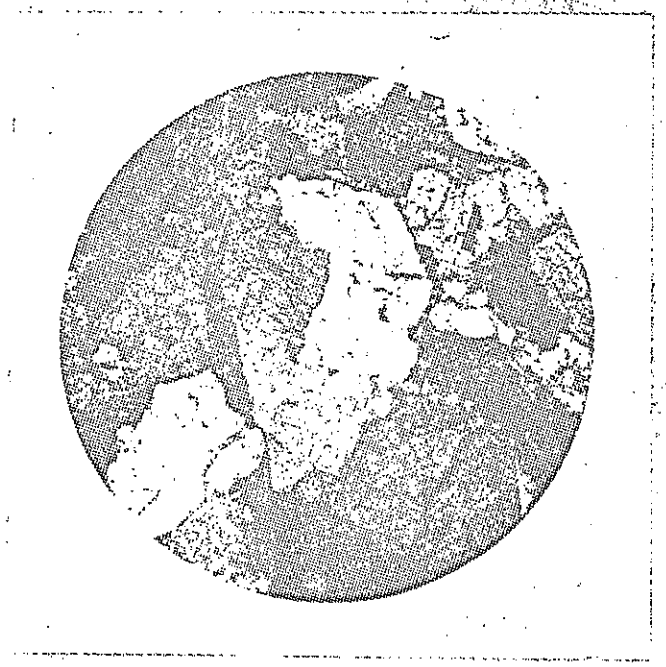


Plate VII 2

replacement product in plagioclase grains. Magnetite and zircon occur as accessory minerals.

Across the Methow and north along the strike from Russell's type area (in section 13), the Winthrop is more indurated due to its proximity to numerous small igneous bodies. Dark banding is common, and minerals are difficult to identify in hand specimen. Quartz and feldspar predominate in thin section, but the grains are smaller than in the samples discussed earlier. The quartz is subangular and frequently severely fractured. Much of it seems to have been recrystallized. From stained chips it is estimated that the feldspar is 35 to 40% potash bearing minerals and 60 to 65% plagioclase. The rock is too fine-grained to permit an accurate count of its constituents. The plagioclase has been partially altered to clayey material (?), but albite twinning is still noticeable. Clastic biotite is absent, but muscovite (sericite) and chlorite occur interstitially with the quartz and feldspar, and seems to have grown in place. The chlorite evidently is the result of biotite recrystallization. This rock is best described as a hornfelsed arkose.

Evidence of age of the Winthrop sandstone is a small collection of leaves and ferns found in Little Boulder Creek and listed below. Identifications were made by the writer from plates and descriptions in Bell (1956), with assistance from Prof. S. Lowther of College of Puget Sound. Most of the genera are listed in Bell under the Pasayten Group (Albian) as defined by Daly (1912) and revised by Rice (1947).

Cladophlebis cf. alberta (Dawson)

Cladophlebis sp.

Menispermites sp.

Onychiopsis sp.

Ventura Formation

The rocks of the Ventura were described briefly by Russell (1898-99) and called the "Ventura system." He placed the age tentatively as Jura-Trias (?) because of the red color of the outcrop. It was described as thick-bedded, red-brown sandstones, shales and course conglomerates, distinct from the Cretaceous terranes bordering it on the east and west. The name is taken from an old abandoned mining camp in the area. No fossils have been found in the Ventura, either by Russell or the writer, but its stratigraphic position above the Winthrop suggests an Upper Cretaceous age. Russell (1898-99) used "Ventura formation" in his text, and the writer has applied this name to the sequence at Lucky Jim Bluff.

The steeply dipping red sediments form the high cliff named Lucky Jim Bluff in sections 8, 16, 17, and 21 of T.35 N., R.20 E. The same sediments are also found in sections 7 and 8 of T.36 N., R.20 E., in a saddle northeast of Goat Peak. North of Grizzly Mountain the red beds outcrop in section 2 of T.35 N., R.20 E.

The Ventura conformably overlies the Winthrop sandstone. The lithology grades from the light gray arkose into red siltstone, and fine-grained red sandstone. The siltstone occurs as thin beds and lenses in the

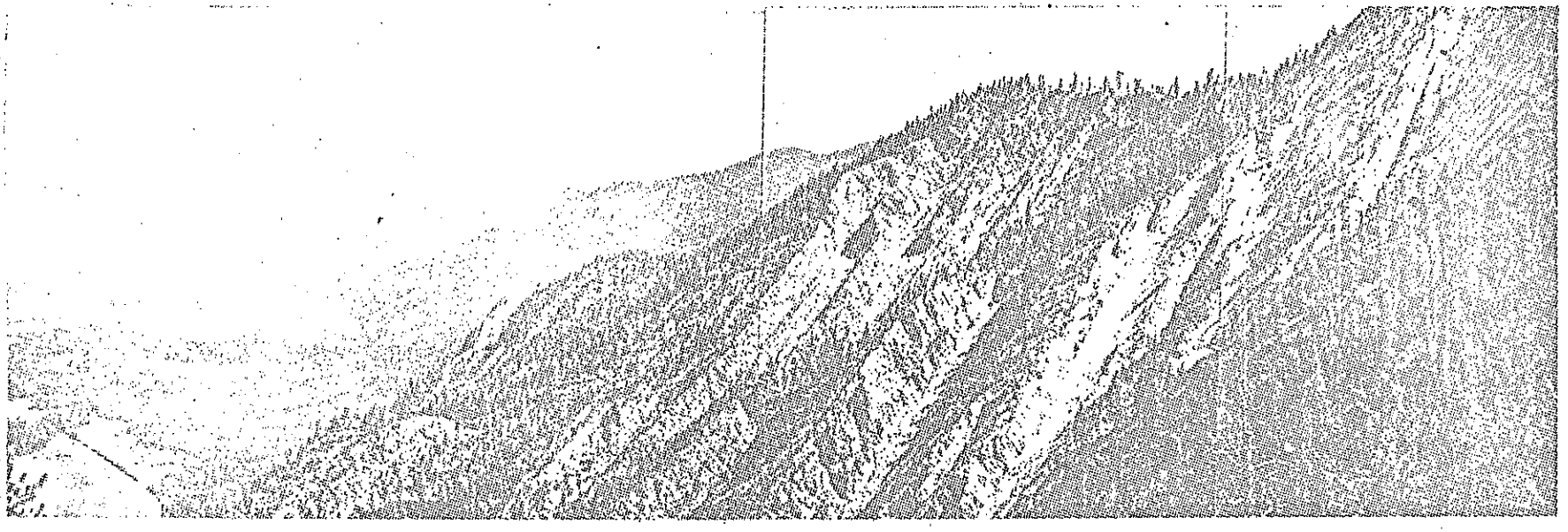


Plate VIII Looking southeast at red sediments of Ventura formation on Lucky Jim Bluff. Winthrop-Ventura contact is at right edge of photo. Mathow River valley is on the left.

upper Winthrop, increasing in thickness upsection until the gray arkose gives way entirely to the red beds. The contact is placed where the red beds and arkose are in the order of magnitude of 2 feet and 30 feet respectively.

Overlying the Ventura are the andesite breccias and flows of the Midnight Peak formation. The contact, observed in sections 2 and 9 of T.35 N., R.20 E., is sharp and apparently conformable.

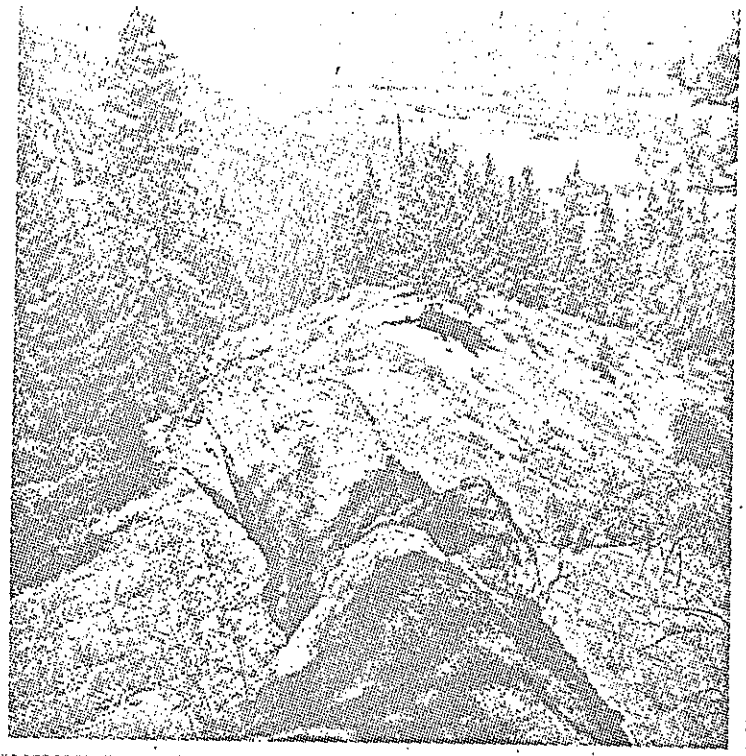
The beds south of the Methow strike N.40° to N.50° W. and dip 60° to the northeast. North of the river, the Ventura has the same strike but dips steeply to the southwest.

The lithology, described in detail in the columnar section, includes red conglomerates, sandstones, siltstones, and shales, cut by a few small dikes and sills. The entire Ventura section was measured by Dr. Barksdale and the writer and is 2253 feet thick (Plate X). The traverse was made in sections 8, 9 and 17 of T.35 N., R.20 E.

Plate IX

1. View north along a ridge of red silica pebble conglomerate on crest of Lucky Jim Bluff. N. 40° W., dip 60° NE.

2. Red sandstone and siltstone midway through the Ventura formation. The section was measured at this locality.



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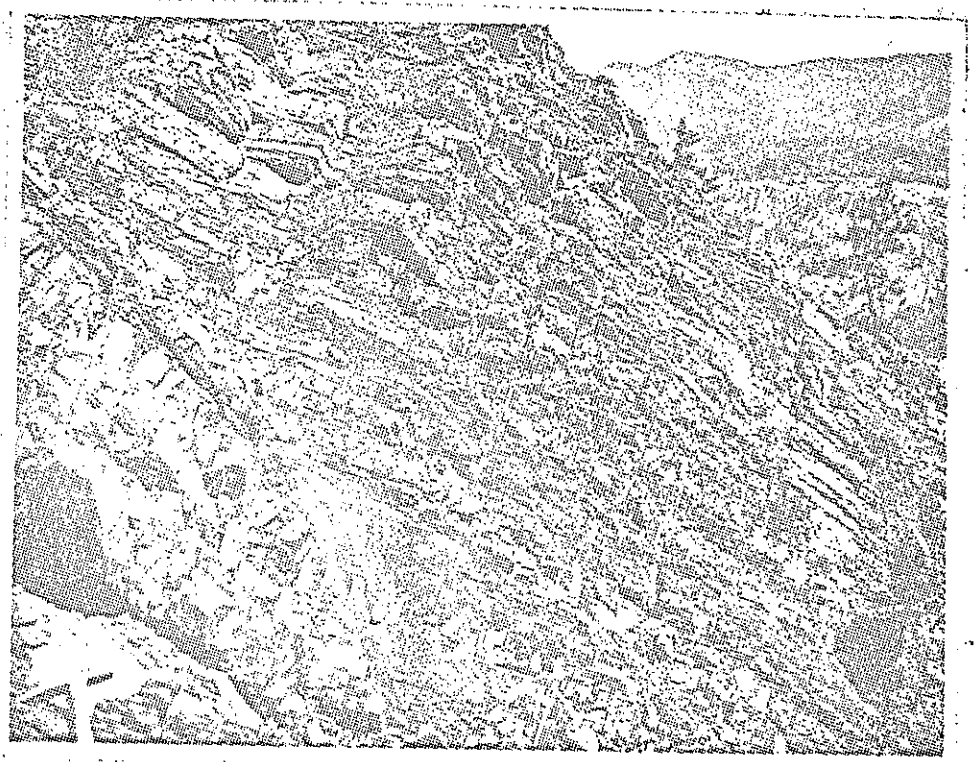


Plate IX 2

COLUMNAR SECTION OF THE VENTURA FORMATION

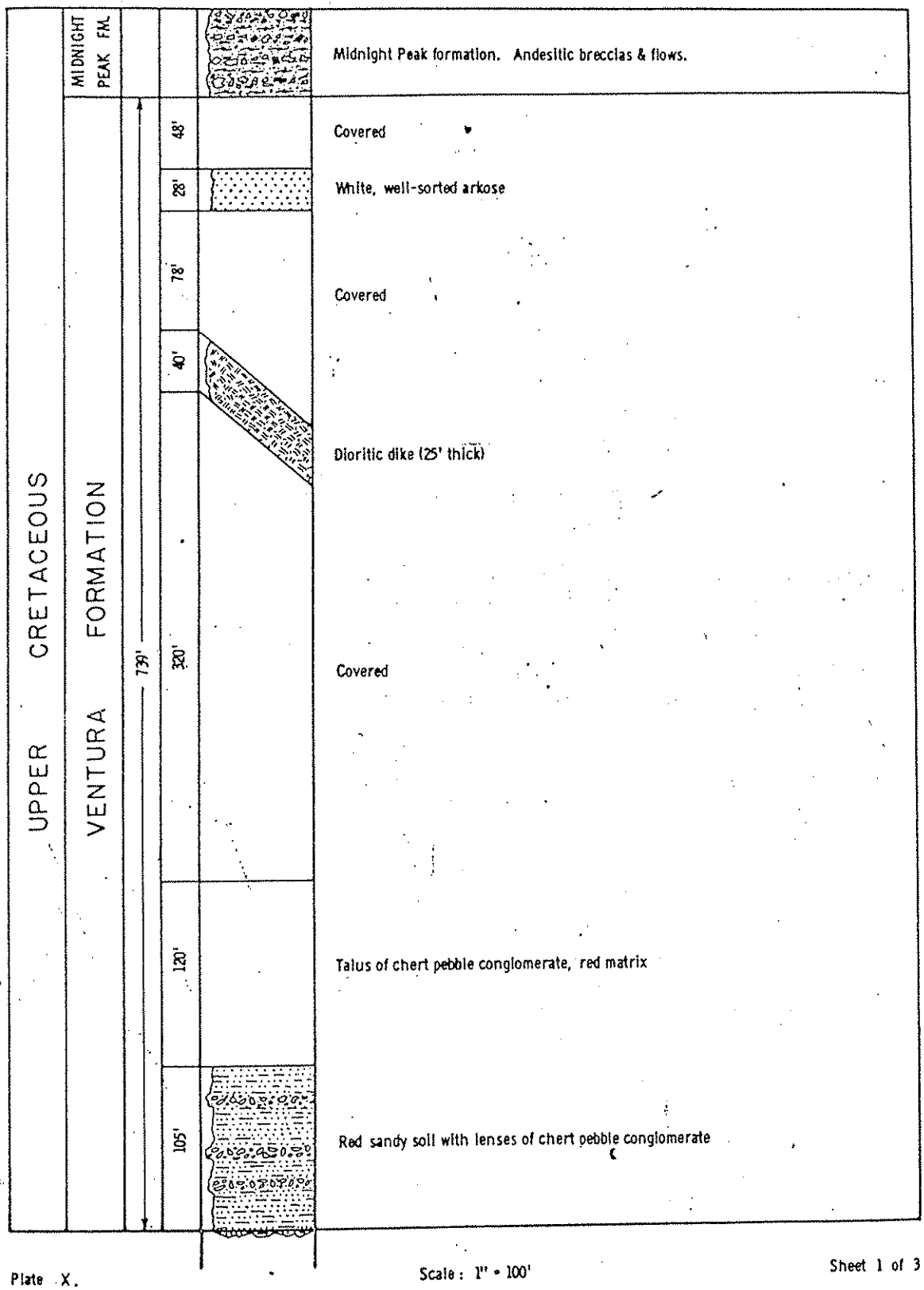


Plate X.

Scale: 1" = 100'

Sheet 1 of 3

COLUMNAR SECTION OF THE VENTURA FORMATION

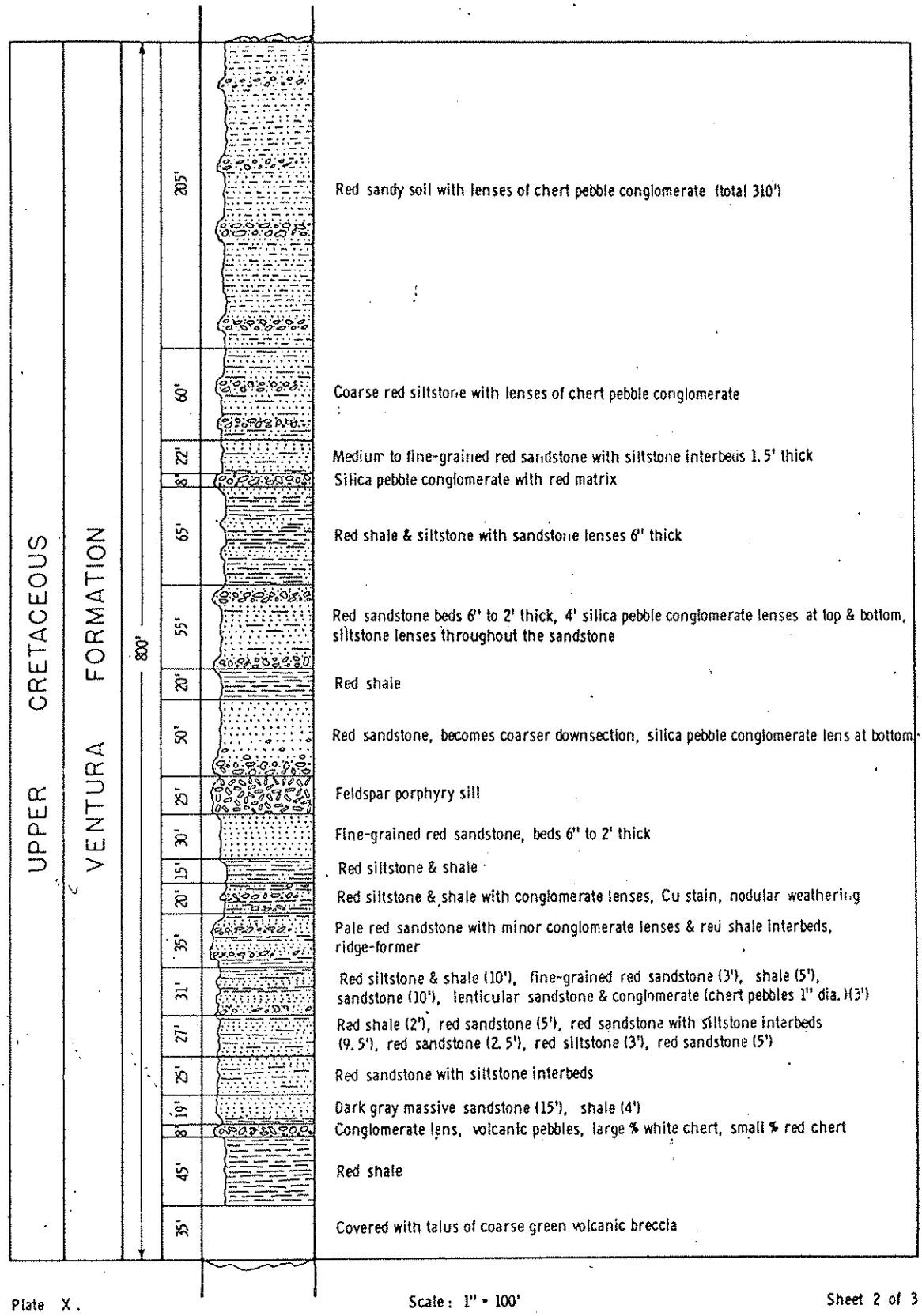


Plate X.

Scale: 1" = 100'

Sheet 2 of 3

COLUMNAR SECTION OF THE VENTURA FORMATION

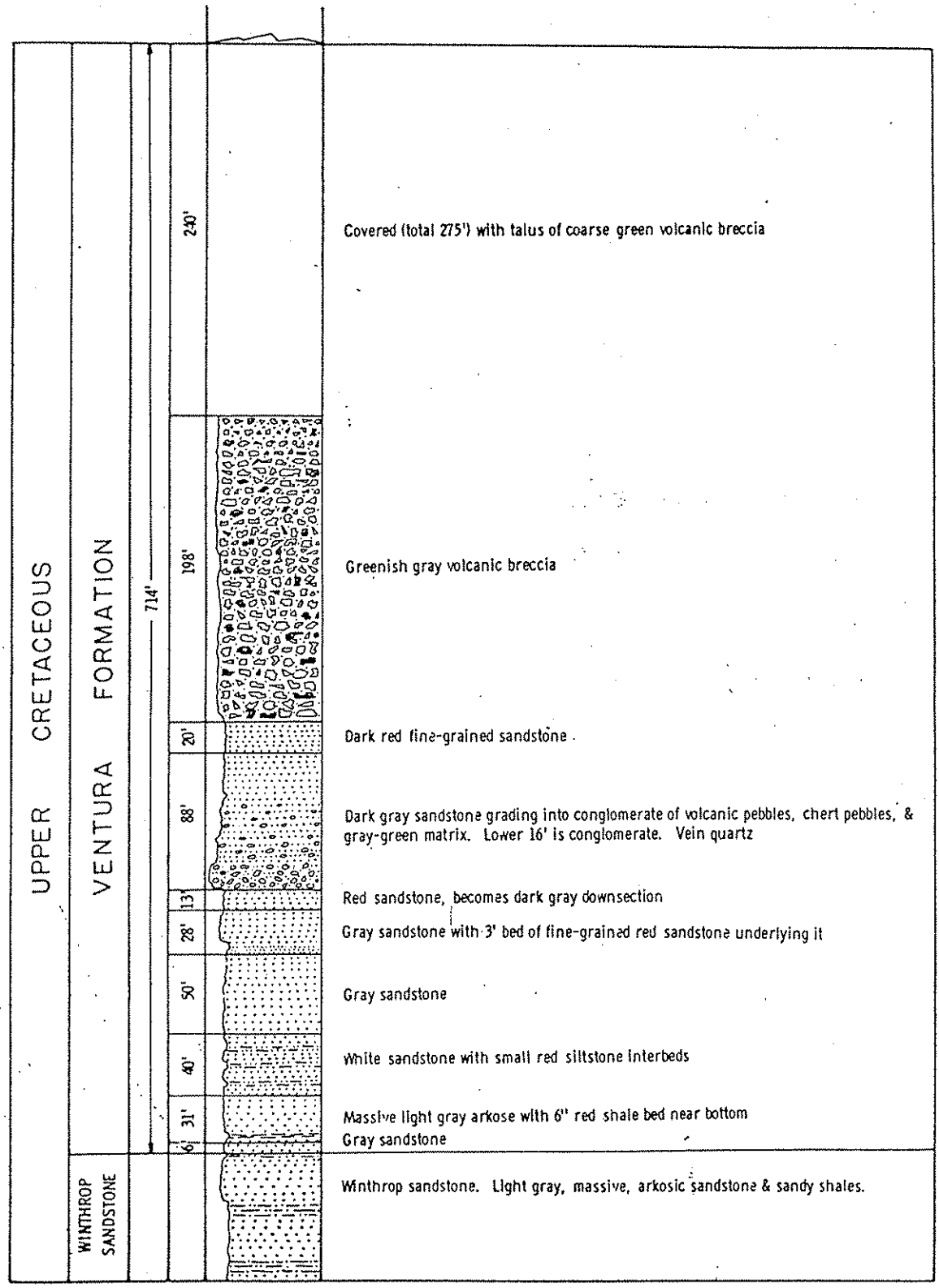


Plate X.

Scale: 1" = 100'

Sheet 3 of 3

Midnight Peak Formation

Barksdale (1958) proposed the name Midnight Peak formation for a thick (8000 feet) series of tuffs, breccias, and flows found in the vicinity of Midnight Peak, 5 miles southwest of this thesis area. Stratigraphically below the volcanics are a 500 feet sequence of red sediments, and beneath them the Upper Cretaceous Winthrop sandstone. Rocks of similar lithology, and in the same relative stratigraphic position, are found north of the Methow River at Grizzly Mountain, Goat Peak, and the Goat Wall. Although these cannot be traced directly to the beds at Midnight Peak, the writer feels that the similarities are strong enough to warrant using the same formational name.

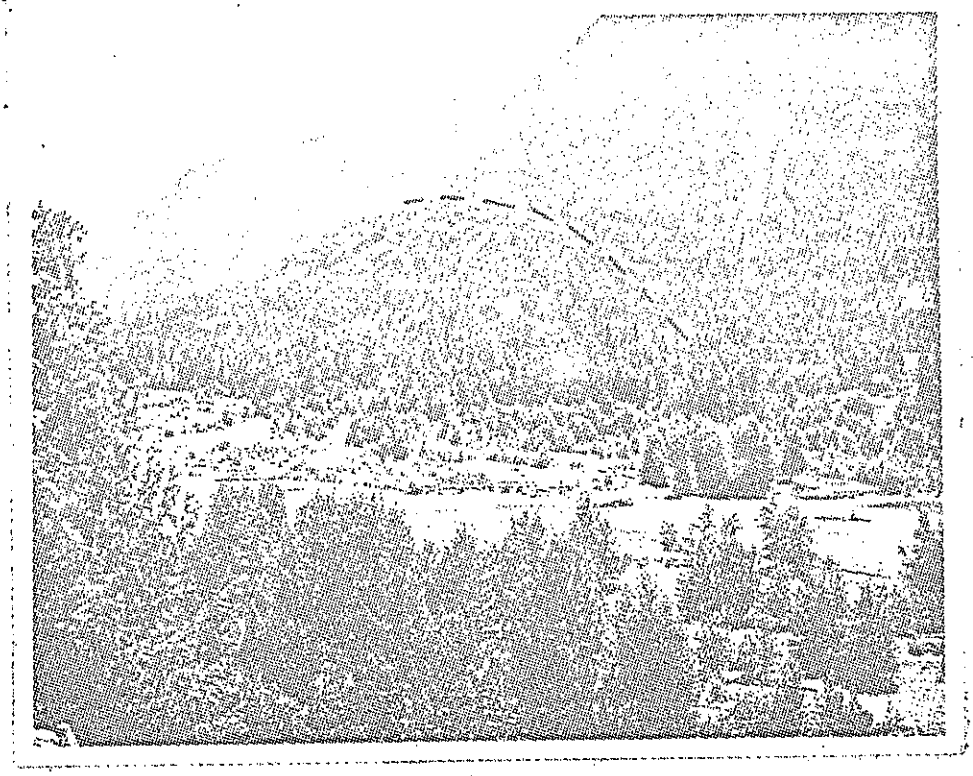
Except for a small knob in section 9, T.35 N., R.20 E. (Plate XI-1), the Midnight Peak formation is found north of the Methow River. From Goat Peak and the Goat Wall, the andesite breccias extend southeastward, paralleling the valley, and end at the Boesel Canyon fault. Northeast of Goat Peak, Grizzly Mountain, and Lucky Jim Bluff, the Midnight Peak is in contact with the Ventura formation. Elsewhere, the breccia has been intruded by the Goat Creek diorite, or is bounded by the alluvium and glacial deposits of the Methow valley.

The rock is a dark gray-green andesite breccia. Only feldspar phenocrysts and a few amphibole and pyroxene crystals can be seen in hand specimen, as the remainder of the rock is fine-grained. Epidote veinlets are common, and on weathered surfaces, concentrations of epidote minerals are easily discernible.

Plate XI

1. Knob of Midnight Peak breccia at base of Lucky Jim Bluff on south side of Methow River (dashed line).

2. Looking north at the bold outcrops of andesitic Midnight Peak breccia on Grizzly Mtn. Methow River is to left of photograph.



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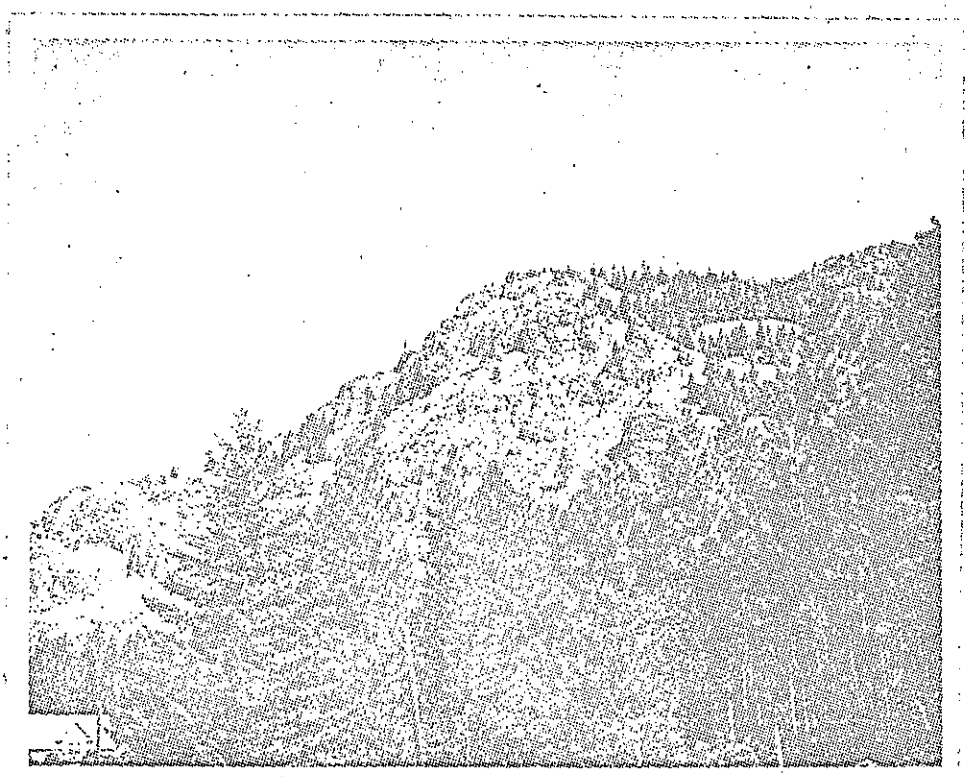


Plate XI

2

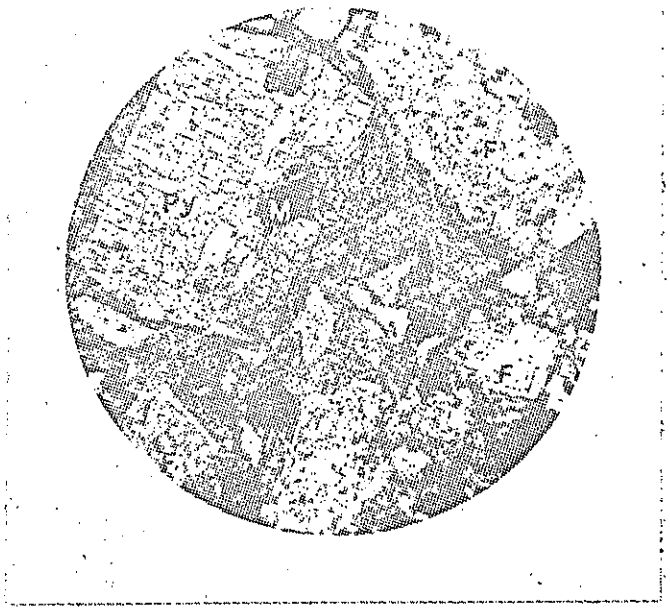
Under the microscope, the feldspars are badly altered, but albite twinning, zoning, and crystal outlines are distinguishable. Suitable orientations for determinations are rare, but two phenocrysts were run down as oligoclase (approx. Ab 75). However, this is not reliable. Many of the larger plagioclases coalesce. Unidentifiable clay minerals obscure most of the feldspar. Slightly altered pyroxene with magnetite and chlorite inclusions and iron-rich rims are abundant. Much of the pyroxene is being replaced by epidote. Amphibole, altered in the same manner, is also present. The feldspar laths average 1mm in length and 0.5mm wide. Most of the mafics are smaller, but outlines of a few large pyroxenes (1 x 1mm) were seen (Plate XII-1). Minor amounts of calcite and quartz were identified. The groundmass is mostly saussuritized plagioclase. An estimate of mineral percentages in the rock is as follows: plagioclase 65, pyroxene 15, amphibole 10, chlorite 5, and epidote, magnetite, calcite, and quartz 5.

The texture of the Midnight Peak is not uniform. Volcanic fragments are very common (Plate XII-2), and many small sediment derived chert pebbles are present. The feldspars at the bottom of the sequence are generally larger and more euhedral than those near the top. The rock is not highly metamorphosed.

Plate XII

1. Photomicrograph of Midnight Peak andesitic breccia showing euhedral pyroxene (Py), plagioclase (F), and magnetite inclusions (M). Plain light, x 20.

2. Photomicrograph of Midnight Peak breccia showing outline of lithic (volcanic) fragment, made up of plagioclase and altered pyroxene. Plain light, x 20.



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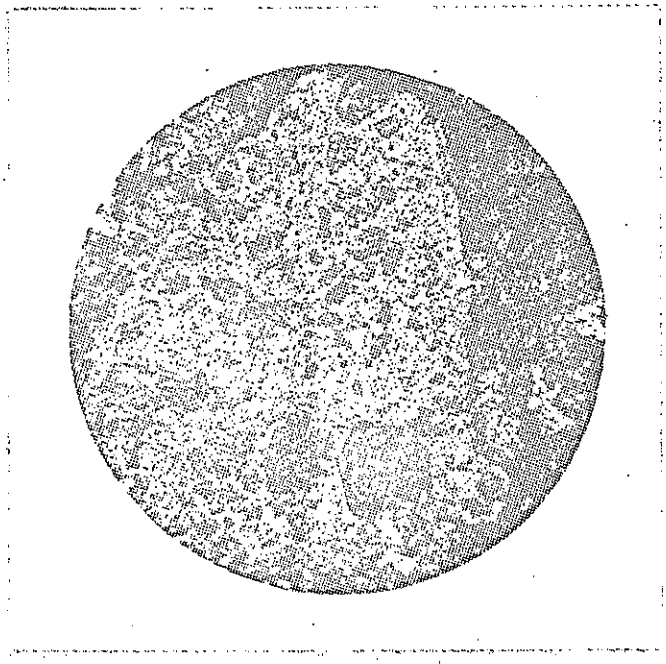


Plate XII 2

Intrusive Rocks

Goat Creek Diorite

The largest intrusion in the area is a dioritic body approximately 4 miles long and 2½ miles wide. It is located north of the Methow River between Goat Peak, Fawn Peak and Grizzly Mountain, and intrudes the Winthrop, Ventura, and Midnight Peak formations. The writer has tentatively assigned the name Goat Creek diorite to the intrusion.

The composition does not vary to a great extent throughout the intrusion, but the texture and degree of alteration do. In sections 19, 20, and 28 of T.36 N., R.20 E., the diorite is dark gray and very coarse-grained. Large fresh feldspar laths are readily visible in hand specimen. Analysis under the microscope (Plate XIII-1) shows the feldspar to be andesine (Ab 58) plagioclase, as maximum extinction angles of -23° were measured on MP sections. The crystals are strongly twinned, and most of them measure 1 x 4mm, with a few as long as 7mm. Plagioclase makes up 75% of the rock. A faint element of lineation is exhibited by the arrangement of feldspar laths.

About 25% of the rock is composed of biotite, amphibole, and their alteration products. Pseudomorphs of amphibole contain chlorite and epidote, and tremolite and actinolite are common. The amphiboles total about 12% of the rock. The biotite (8%) is relatively unaltered except in a few isolated cases where it has gone to chlorite. Pyroxene is present (2-3%), and shows polysynthetic twinning. Some uralitization has occurred as hornblende pseudomorphs of pyroxene were observed.

Plate XIII

1. Photomicrograph of twinned plagioclase in coarse phase of Goat Creek diorite. Mafic minerals are biotite (B), tremolite-actinolite (A), and uralitized pyroxene (P). Apatite (a) is present as an accessory. Crossed nicols, x 15.

2. Photomicrograph of finer-grained phase of Goat Creek diorite. Crossed nicols, x 15.

1

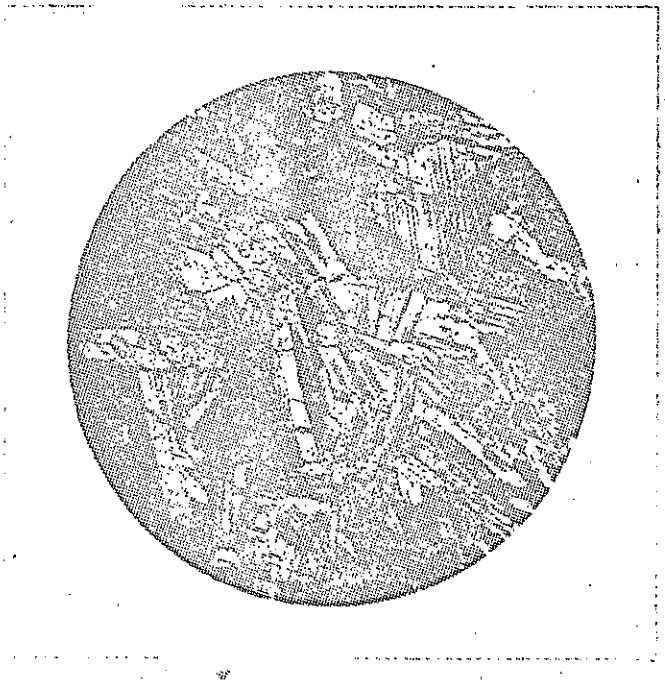


Plate XIII 2

Magnetite, both as an alteration product and as authigenic crystals, is present as an accessory. Prisms of apatite 1.3 x 0.2mm also are a common accessory. Traces of interstitial quartz and sericite are in the rock.

Running northwest-southeast through the center of the body is a medium-grained phase which contains 5 to 10% more mafic minerals than the coarse diorite (Plate XIII-2). The feldspars are on the order of magnitude of 2mm long, and are not as fresh as those described above. There is less unaltered biotite and more secondary magnetite in this phase than in the coarser rock. Otherwise the composition and mineralogy is similar.

Along the northern edge of the intrusion there is a fine-grained phase which has undergone considerable alteration. The feldspars have been destroyed to the point where they appear to be groundmass for the altered pyroxenes and amphiboles. Chlorite is present, and the outlines of a few badly altered plagioclases are visible.

Minor Intrusions
(North of the Methow River)

A number of small sills were mapped in and around section 13, T.35 N., R.20 E., at the gradational contact between the Virginian Ridge formation and the Winthrop sandstone. Considerable compositional variety was noticed here.

In section 13, T.35N., R.20 E., a large coarse-grained sill of hornblende

diorite makes a prominent outcrop within the beds of the Virginian Ridge formation. The body is approximately 40 feet wide and extends from just above the alluvium of the river valley for nearly a mile until it disappears beneath soil cover.

Fresh-appearing feldspar and hornblende were identified megascopically, the mafics making up about 20% of the rock. Some feldspars are completely surrounded by hornblende, indicating the earlier crystallization of the former. The rock weathers to a reddish light brown.

Microscopically, the main constituents are plagioclase feldspar and hornblende (Plate XIV-1). The plagioclase is badly altered, but some albite twinning is visible. The composition is estimated as sodic andesine (Ab 70) since maximum extinction angles of -18° were measured on MP sections. Retrogressive alteration is shown by the albitic rims and the crystal interiors which have gone to clay mineral and clinozoisite. The plagioclase crystals average 2mm long and 1mm wide. In general, the lath-like shape of the original feldspar has been well-preserved, and it comprises 60 to 65% of the rock.

The hornblende is zoned, with darker shades of green appearing at the rims. Much of the hornblende is altered to chlorite and magnetite. The pleochroic formula of the amphibole is Z = Y>X, with Z and Y = light olive green, and X = very pale greenish tan. Many of the hornblende crystals terminate abruptly against feldspars, and, as was mentioned in the megascopic description, several smaller feldspar crystals are included within large amphiboles. The hornblende is present in

amounts of 20 to 25%, and the crystals are approximately 0.8 to 1mm long and 0.5mm wide. The minor constituent chlorite makes up 3 to 5% of the rock, and the magnetite is less than 1%.

Quartz occurs interstitially, and is evidently a late-comer as it is unaltered. Its crystal habit is completely controlled by the faces of the earlier minerals. The quartz is not common enough to be included in the rock name as it constitutes only about 5% of the diorite.

Approximately 100 yards northwest of the diorite is another sill similar in composition, but more severely altered. In hand specimen, none of the constituents appear fresh. In thin section, the feldspars are even more altered than before, yet they still retain their crystal outline. Lithic fragments give the rock the textural appearance of a breccia. Albite twinning made possible several determinations, all of which fall in the andesine range. The phenocrysts are about 1.5mm long and 0.07 to 1mm wide. The hornblende is slightly smaller, and also has crystal faces well-preserved in spite of alteration to chlorite and magnetite.

Still farther to the northwest are more sills. These are smaller and considerably more leucocratic than the dioritic bodies just discussed. The bodies are medium-grained with feldspar and quartz identifiable in hand specimen. Mafics are minor except for what appear to be scattered hornblende(?) phenocrysts. The groundmass is light gray.

Under the microscope, the feldspars show little evidence of alteration. Euhedral quartz and Carlsbad-twinned plagioclase phenocrysts are

contained in a groundmass of fine-grained quartz and feldspar. Calcite, magnetite, and chlorite occur in severely folded aggregates, evidently alteration products of (?) amphibole. These three minerals also are found as anhedral phenocrysts. The original mafic minerals are entirely gone, and there are no psuedomorphs which might give a clue as to what they were.

Just east of Boesel Canyon, another sill was mapped in the Winthrop sandstone. It is not unlike the dioritic bodies described above. In hand specimen, it is feldspathic with acicular hornblende crystals 1 to 2mm long. In thin section, extreme alteration has taken place. The plagioclase is altered to epidote and albite, and 1mm long ghosts of Carlsbad twins were visible. The hornblende has been altered to chlorite and magnetite.

Minor Intrusions
(South of the Methow River)

South of the Methow, between Wolf and Little Boulder Creeks, numerous feldspar porphyry dikes were mapped. They were observed as far south as section 35 of T.35 N, R.20 E. in the Winthrop sandstone near the Virginian Ridge formation contact. In the vicinity of Lucky Jim Bluff many dikes and sills of the same material are present. They are conspicuous from the highway, appearing as white streaks against the dark red Ventura sediments.

The most striking features in hand specimen are the large feldspar phenocrysts. In the southern outcrops, they are as long as 4 to 5mm and as

wide as 1 to 2mm. Farther north, the size decreases gradually. Some collected at the northwest end of the Bluff are only 2 to 3mm long by .5 to 1mm wide. Intermediate sizes were noted at localities between these two outcrops. The feldspar phenocrysts comprise approximately 40% of the rock. Next in abundance in all samples taken is hornblende. Usually it occurs as acicular phenocrysts that average 1 to 2mm in length. At one place on Lucky Jim, the phenocrysts are very well developed and euhedral, reaching a length of 3mm and a width of 1mm. The groundmass is greenish-gray and aphanitic.

Microscopically, the feldspar was identifiable in several thin sections as andesine plagioclase. The phenocrysts are generally subhedral. In many cases, the plagioclase was apparently deuterically altered to epidote, small amounts of calcite and albite. Often the crystal outline of plagioclase has been perfectly preserved, while the original mineral has undergone complete alteration. Twinning and zoning is common, and coalescent plagioclases are present throughout the rock (Plate XIV-2). Sodic plagioclase rims surround epidote centers in many of the phenocrysts, and unidentifiable clay minerals within many of the feldspars make determinations impossible. In all, the plagioclase in phenocrysts makes up approximately 60% of the rock.

Hornblende is common, and with its alteration products, comprises 20 to 25% of the rock. Basal sections where the characteristic 124°-56° cleavages are seen are common. The principle alteration product is chlorite. Often, the original crystal form of the hornblende remains, but chlorite has completely replaced the primary mineral. The hornblende

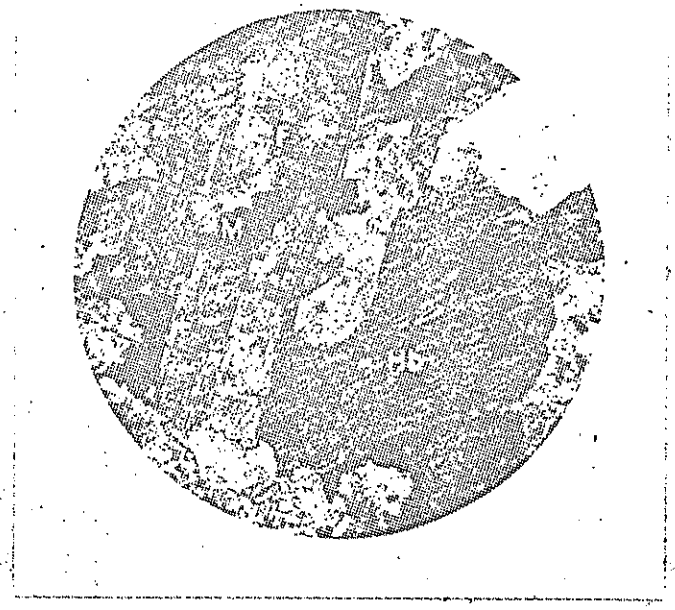
has a 2V of 80°, is optically negative, an extinction angle of 16° and a pleochroic formula as follows: Y = pale greenish-brown, Z = greenish-brown, and X = medium brown, with X = Z>Y. Magnetite, also from the amphibole, is present in amounts of 1 to 2%.

No unaltered pyroxene was observed, but mafic alteration products were found bounded by the octohedral faces that are characteristic of pyroxene basal sections. Minor amounts of muscovite and quartz are present. Apatite occurs as an accessory, some of it with cores altered to calcite. As near as could be determined, the groundmass is composed of feldspar, quartz, epidote, hornblende, and magnetite.

Plate XIV

1. Photomicrograph of diorite sill north of Methow River showing intergrowth of plagioclase (F) and hornblende (Hb). Feldspars are clouded with clayey material, but have sharp euhedral form, indicating deuteric alteration. Magnetite (M) occurs as an accessory. Crossed nicols, x 40.

2. Photomicrograph of feldspar porphyry sill occurring in the Ventura fm. south of the Methow River. Note the coalescent plagioclase and sharp zoning. Crossed nicols, x 20.



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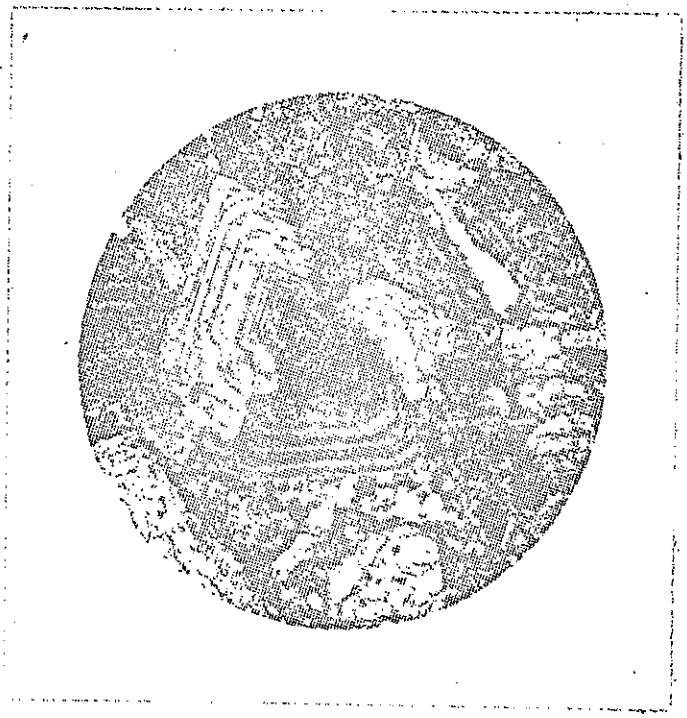

Plate XIV 2

GEOLOGIC STRUCTURE

Regional Structure

This semi-arid area of moderate relief offers many advantages to the study of geologic structure. Outcrops are plentiful and deformation has obviously played an important part in controlling topographic expression.

The Methow River valley contains a thick sequence of Upper Mesozoic sediments, bordered by the Cascade Range on the west and the Okanogan Highlands on the east. This depositional basin has been folded, faulted, and subjected to various minor igneous intrusions. The major fold axes trend northwest-southeast.

A brief outline of Cascades history (Misch, 1952) and mention of the Okanogan Range will assist in establishing the overall geologic picture in the Methow.

The ancient Cascade geosynclinal clastic sediments and volcanics were strongly metamorphosed in early Mesozoic times. Although the deformation destroyed nearly all evidence of age, a few late Paleozoic fossils have been found. Deposition of a thick sequence of Jura-Cretaceous shallow water marine sediments followed this folding and shearing. The easternmost of these sediments extend to the Pasayten valley in the north, and the Methow in the south (fig. 1, Misch 1952). Overlying these marine beds are the fresh water continental sediments mapped by Dr. Barksdale and the writer in the Methow valley.

To the east, the gneissose and directionless granitic rocks of the Okanogan Range extend north and northwest to the Canadian boundary (Goldsmith, 1952). Allison, Kremer, Lindquist and Pitard (U.W. Field Course, 1957) found these to be in fault contact with the Methow sediments. East of the Okanogan Mountains is a thick geosynclinal Paleozoic series of metamorphosed sediments, presumably altered in the Jurassic (Misch, 1949). These metamorphic rocks extend westward to the Tiffany Range, mapped by Goldsmith, which forms the divide between the Methow and Okanogan valleys.

Local Structure

The most prominent structural feature in the mapped area is a large northwest trending syncline, whose axis is parallel to the north margin of the Methow valley (see geologic map). Lucky Jim Bluff and the high ridges on both sides of the river are on the limbs of this structure. The andesitic breccias and flows of the Midnight Peak formation are the upper beds of this syncline and evidently underlie the alluvium and drift of the Methow valley. This interpretation is shown in structure section B-B' (Plate XV). The only outcrop of this breccia south of the river is a knob in section 9, T.35 N., R.20 E.

Beneath the Midnight Peak are the dark red sediments of the Ventura formation, which make up Lucky Jim Bluff. These beds strike N.40° to 60° W. and dip 45-60° to the northeast. Across the river, outcrops of the Ventura are found north of Whiteface Creek and northeast of Grizzly Mountain. The strikes are N.35-45° W. and dip is 60° to

the southwest.

In the vicinity of Goat and Fawn Creeks there is an igneous intrusion which the writer calls the Goat Creek diorite. This stock cuts out parts of the Midnight Peak, Winthrop, and Ventura formations, with relationships as shown in structure section A-A' (Plate XV). Attitudes taken in the rocks surrounding the intrusion show no warping or distortion of the adjacent beds, although contact metamorphism is apparent in the Winthrop sandstone and Midnight Peak breccias.

The arkosic Winthrop is conformably below the Ventura, and outcrops are numerous on both limbs of the syncline. Strikes are N. 40-50°W., and south of the Methow the dips are 55-60° northeast. North of the river, the Winthrop dips very steeply to the southwest.

Conformably underlying the Winthrop is the Virginian Ridge formation. In the southwest part of the mapped area, the top of this unit is characterized by the silica pebble conglomerate. Since no silica pebble conglomerate was found in the northeast, the Winthrop-Virginian Ridge contact is inferred. This problem has been discussed in the section on stratigraphy.

The major syncline is truncated south of Lucky Jim Bluff and in Boesel Canyon by a fault normal to the fold axis. South of the fault is the Winthrop sandstone which strikes N.10° E. and dips very steeply to the west and northwest. The sandstone is continuous across the Methow valley. No determination of direction or amount of displacement of the fault could be made. The writer feels that to understand the mechanics of

Plate XV is in pocket.

this faulting would involve study on a more regional scale than has been undertaken in this work. The stratigraphic relationships of the Winthrop and the Virginian Ridge are similar on both sides of Boesel Canyon, and the straight course of the fault seems to indicate that this is a high angle to vertical fault. No evidence was found to explain what had happened to the section above the Winthrop south of the fault.

In the southeast corner of the map is a portion of the Upper Jurassic(?) Newby formation, mapped by Allison et al. in 1957, and was named and described by Barksdale (1948). A small syncline and an anticline of steeply dipping breccias and shales are shown on the map.

The relationship between the Newby and the Virginian Ridge is unconformable at an angle of almost 90°. In section 8, T.35 N., R.21 E., the Newby is in fault (?) contact with a sequence of sediments that are post-Newby yet underlie the Virginian Ridge. These beds were tentatively called the Cross Mountain formation by Allison et al., but their relationships to adjacent units are not understood. The Cross Mountain is absent south of the thesis area where the Newby and Virginian Ridge are in direct unconformable contact. The fact that the Virginian Ridge is contiguous with two older formations is further evidence for the unconformity mentioned above.

GEOLOGIC HISTORY

A history of the area covered in this thesis includes periods of sedimentation from the Upper Mesozoic to Recent times, interrupted by episodes of structural deformation.

It is known that an Upper Triassic-Lower Jurassic orogeny took place in the Cascades (Misch, 1952), which was prior to the deposition of the Newby formation. The Newby-Virginian Ridge angular unconformity points to at least one major post-Newby time break; and possibly two, depending on the actual time of deposition of the Cross Mountain sequence. Following the Newby sedimentation, there was folding, tilting, and minor igneous activity.

Lower Cretaceous marine deposits were laid down on the eastern flanks of the Cascades northwest of the mapped area (Misch, 1952). Their approximate equivalents are represented in the Methow valley by the Newby formation. Marine sedimentation continued with the Virginian Ridge formation, but the environment at the time of the Winthrop sandstone deposition must have been shallow water marine or continental as numerous plant fossils occur about midway through this section. There was continuous deposition during the Upper Cretaceous, climaxed by the outpourings of andesite which comprise the Midnight Peak breccias. After this, the fresh water sea retreated.

The main period of disturbance associated with this area occurred following the Midnight Peak flows, presumably during the Tertiary

Period. Severe folding and faulting took place, with the fold axes trending northwest-southeast. The breccias and underlying sediments were folded into a large syncline with steep limbs. The sediments to the south were also strongly tilted, but are separated from the northern structures by the Boesel Canyon fault. Little is known of the structural relationships between the rocks north and south of the fault, however it is post-folding.

After this episode of deformation, the Tertiary (?) Goat Creek diorite and numerous minor dikes and sills were intruded.

Following a period of Tertiary erosion, Pleistocene continental glaciers came from the north. They scoured the bedrock and scattered erratics throughout the area. The continental glaciers retreated, and a valley glacial phase left its imprint on the Methow valley. Ice contact terraces near Goat Creek, glacial boulders and cobbles, and the general U-shape of the valley support this later phase of valley glaciation.

Finally, Recent alluvium, from the meandering Methow River and its tributaries, is found on the valley floors and in stream beds.

CONCLUSIONS

The rocks in the Mazama area of the Methow River valley are predominantly sedimentary, deposited in a basin under shallow water continental conditions. The lithologies, totaling approximately 23,000 feet, are conglomerates, siltstones, sandstones, shales, and breccias. Formational names beginning with the oldest are Virginian Ridge, Winthrop, Ventura, and Midnight Peak. The interformational contacts are all conformable. Source areas of the Upper Cretaceous sediments were mostly granitic and volcanic.

The major episode of deformation occurred after the Midnight Peak breccias were extruded. Sediments and flows were strongly folded and faulted. Subsequently there was a period of igneous activity, resulting in numerous small intrusions.

During the Pleistocene, two types of glacial activity took place. Continental ice covered the entire area, scoured many bedrock surfaces, and deposited numerous erratics on the highest peaks of the map area. The second type was a valley phase which formed the U-shaped Methow valley.

The Tertiary (?) deformation resulted in a general northwest-southeast structural trend. The major fault in the area is normal to the axes of the folds.

Pleistocene drift, ice contact terraces, and Recent alluvium are in evidence in the stream valleys.

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