TEC-7

AMAX EXPLORATION, INC.

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INTER-OFFICE MEMORANDUM

SUBJECT: Geology of the Gifford Peak area, Washington DATE: January 15, 1975

TO: H. J. Olson cc: W. M. Dolan

FROM: H. D. Pilkington

SUMMARY AND CONCLUSIONS

The Gifford Peak property contains a considerable volume of young Quaternary volcanic rocks; hence was considered to be an attractive geothermal prospect by the LVO Corporation. The area has been a center of volcanic activity, with only minor pauses, from late Pliocene to about 1,000 years ago. The Quaternary volcanism is characterized by olivine basalt flows, breccias, and cinder cones. The flow rocks vary from platy to massive and from dense to vesicular. The volcanoes were of the shield type and poured out pahoehoe and aa type flows at various times. Most of the volcanoes are now marked by cinder cones which rise from 200 to 800 feet above the lava aprons.

The only surface manifestation indicative of geothermal potential is the presence of young Quaternary volcanics. No signs of hydrothermal alteration were found within the lease area. A weakly to moderately argillized rhyolite dome is located about 5 miles southeast of the property. The only thermal springs in the immediate area are found on the north side of the Columbia River, about 18 miles south of the Gifford Peak area.

The well bedded volcanic conglomerates and sandstones of the Eagle Creek Formation of lower Miocene age and the older Tertiary volcanic flows, ash-flows, and volcaniclastics of the Council Bluff, Stevens Ridge, and Ohanapecosh Formation are potential geothermal reservoirs. They all have the lateral extent, thickness, and sufficient depth of burial in the project area to be of interest. In the case of the Eagle Creek Formation the composition of the rock is such that circulation of hot geothermal fluids would probably result in the formation of clay minerals which could effectively reduce, or even destroy the original permeability. The older rocks have already been subjected to zeolitic and argillic alteration which has made them impermeable. There fore, geothermal reservoirs in these rocks will be limited to areas of pervasive fracturing.

The basaltic volcanism of the type found in the project area was probably fed by small restricted conduits from great depths. Therefore, it seems extremely unlikely that heat source of sufficient size to generate a geothermal system exists at a depth that can be reached by a drill at this time.

RECOMMENDATIONS

The geologic study of the Gifford Peak area suggests the geothermal potential is not too great. Therefore, the property should be given a very low priority for additional exploration. The following steps are recommended:

1. The results of the ground noise survey should be reviewed and examined in light of the geologic study.
2. The results of the geochemical survey be evaluated and compared with the geologic data and the geophysical results.
3. The scheduled aerial magnetic survey should be completed as early as the contractor feels the weather will permit.
4. If the geochemical and geophysical surveys yield negative results then the property should be dropped before the anniversary date of the lease applications, that is at least thirty days before January 31, 1976.

H. D. Pilkington

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GEOLOGY OF THE GIFFORD PEAK AREA, WASHINGTON

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Portland, Oregon

January 1975

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INTRODUCTION

Location

The Gifford Peak property is located in the southern Cascade Range of Washington in the east-central part of Skamania County (Fig.1). The property lies within the Gifford Pinchot National Forest. The forest lies along the western flank of the Cascade Range and is characterized by rugged terrain and heavy forest cover. Two of the prominent stratocone volcanoes of the Southern Cascade Range fall within the boundaries of the National Forest; Mt. St. Helens, 9677 feet elevation and Mount Adams, 12326 feet elevation. The Gifford Peak property lies about 18 miles southeast of Mt. St. Helens and approximately 12 miles south-southwest of Mount Adams (Plate I).

Within Gifford Peak property the highest elevations are Gifford Peak at 5368 feet and Lemei Rock at 5927 feet. The area can be reached by well maintained Forest Service roads from White Salmon, Washington, or Willard, Washington (Plate I). Forest Service Road 123 crosses the northeastern part of the property. Access to the main part of the area is by the Pacific Crest National Scenic Trail and many Forest Service trails.

Previous Work

Reconnaisance geologic mapping by Hammond (1973 & 1974) at a scale of 1:250,000 covers the entire project area. The

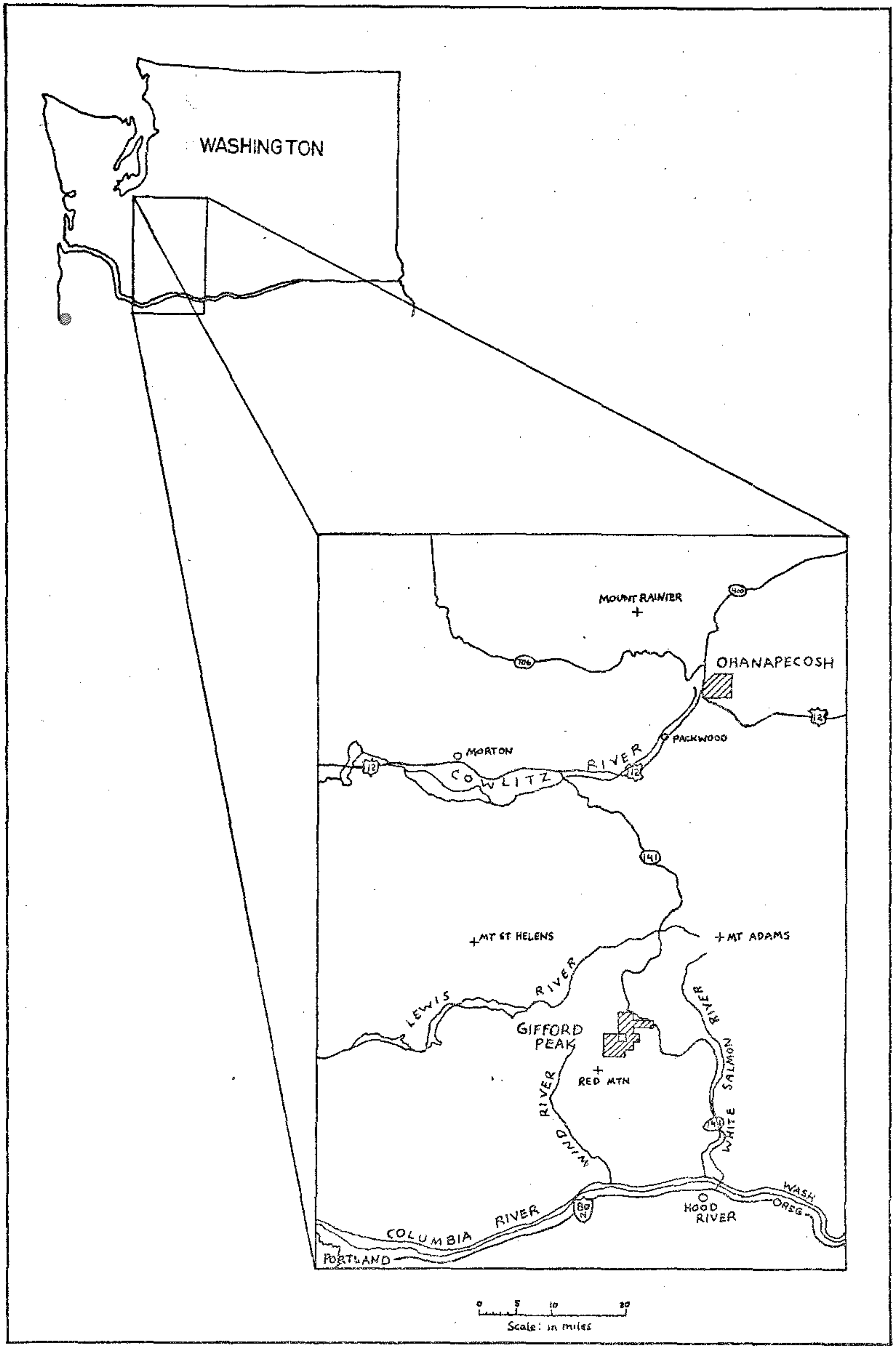

Figure 1. Index map of the Gifford Peak area, Washington.

southern part of the map area has been mapped at a scale of 1:62,500 by Wise (1970). Portions of the southeastern part of the map area are covered by 1:62,500 scale maps of the Husum quadrangle by Sheppard (1964). Pedersen (1973), a graduate student at Portland State University, is preparing a M.S. thesis on the Crazy Hills area.

REGIONAL GEOLOGY

The Cascade Mountains of Washington consist of a deeply dissected erosional surface upon which a series of large andesitic stratocones and basaltic cinder cones formed in Quaternary time. The northern part of the range is distinctly different from the Southern Cascades, both topographically and geologically. The Northern Cascades consist of a basement of pre-Tertiary granitic intrusives (Fig.2). The metamorphic complex has been folded into a series of N.40^{o}W. trending anticlines and synclines. The oldest rocks are pre-Devonian gneissic amphibolites and quartz diorite intrusives. Along the western flank of the Northern Cascades the pre-Devonian rocks are overlain by younger Paleozoic to Jurassic sandstones, quartzites, limestones, argillites, phyllites and greenstones. Jurassic to Cretaceous plutons of the Coast Range Batholith intrude the older rocks. Marine shales, sandstones and conglomerates of Cretaceous age rest unconformably upon the metamorphic basement in a large southeast trending graben on the east side of the Cascades (Fig.2). From Bellingham southeast to Wenatchee(Fig.2) the older rocks are overlain unconformably

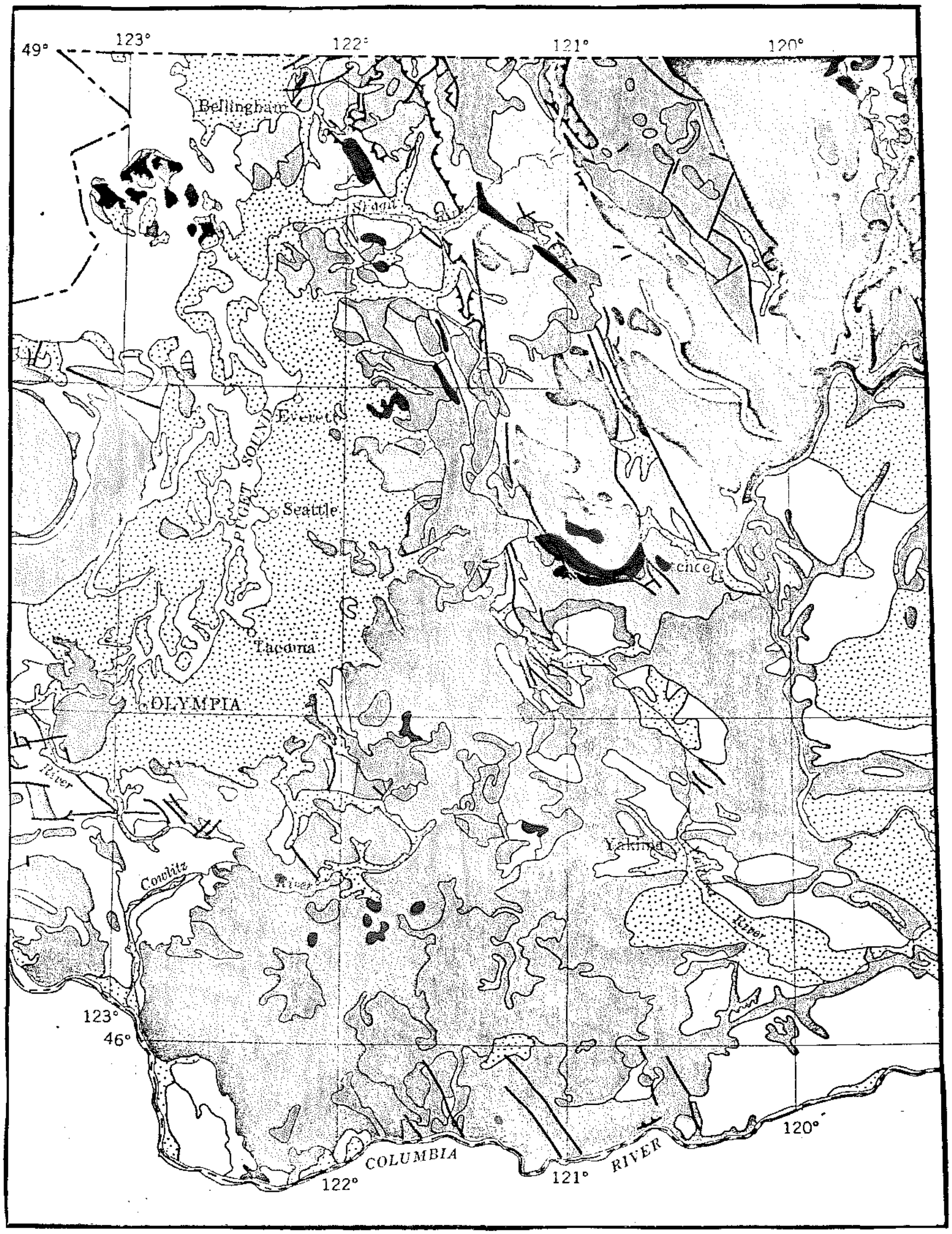

Figure 2. Generalized geologic map of western Washington, after Weissenborn, 1969.

by continental deposits of Cretaceous to Eocene age whith were folded and intruded by early Tertiary granitic plutons. Andesitic volcanics of Eocene to Miocene age burried the eroded surfaces of the older rocks, and were themselves deeply eroded before the Quaternary stratacones developed.

The northern volcano in the Cascades is Mount Baker, a 10,778-foot stratocone built upon pre-Tertiary metamorphic and igneous rocks. The bulk of the cone was formed during Pleistocene time; however, activity has been recorded in historic time. Considerable quantities of ash were flown from the summit crater in 1843, dense masses of smoke obscurred the summit in 1854, in 1859 eruptions occurred from two separate fissures, and in 1870 large volumes of smoke issued from the summit crater. Steam jets have been reported as recently as 1971. The second stratocone in the Northern Cascades is the 10,436-foot Glacier Peak. Glacier Peak is built upon the eroded surface of the pre-Tertiary metamorphic and granitic rocks. Detailed studies in the area indicate the last major eruption was 12,000 years ago. Several small basaltic cinder cones surrounding the peak may be as young as 2,000 years. There are no recorded volcanic activities within historic time; however, minor activity such as steam jets and fumerolic action could have occurred and gone unnoticed because of its remote location.

The Southern Cascades are characterized by a thick sequence of Tertiary volcanics with minor quantities of intercalated continental sediments which mask most of the pre-Tertiary rocks (Fig.3). Several small areas of pre-Tertiary metamorphic rocks are exposed on the east side of the Cascades between Mount Rainier and Yakima. The structural grain within the metamorphic complex trends about N.40^{o}W. as does that in the Northern Cascades. Lithologically the pre-Tertiary metamorphics in the Southern Cascades are similar to the metamorphic suite in the north. The Tertiary volcanic rocks consist of subaqueous accumulations of volcaniclastic debris in Eocene time followed by a thick accumulation of tuff, breccias, lava flows and epiclastic sediments of Oligocene age. Columbia River basalts overlie the older Tertiary volcanics throughout the Southern Cascades. The age of the Columbia River basalts is middle Miocene to lower Pliocene. The older rocks have been designated as the Picture Gorge Basalt and the younger rocks the Yakima Basalt. In the Southern Cascades of Washington the Yakima Basalt is the only representative of the Columbia River basalts. In Pliocene times a series of overlapping shield volcanoes built up of high-alumina olivine basalts and basaltic andesites formed (Fig.3). In the Mount Rainier area a large volcano-pluton was emplaced in Pliocene times. The Pleistocene stratocones of the high Cascades are built upon the above platform. Mount Ranier, elevation 14,410-feet, is the northern volcano of the Southern Cascades, and lies about 80 miles south of Glacier Peak. The stratocone was built upon Tertiary volcanic and intrusive rocks. Volcanic activity of one kind or another was reported in 1843, 1854, 1858, and 1870. Brown clouds issued from the crater in 1878 and again in 1888. Mud flows as recent as 1949 have come off the mountain and are thought by some geologists to have been initiated by local hot spots which melt the glaciers. Enough steam emerges from the

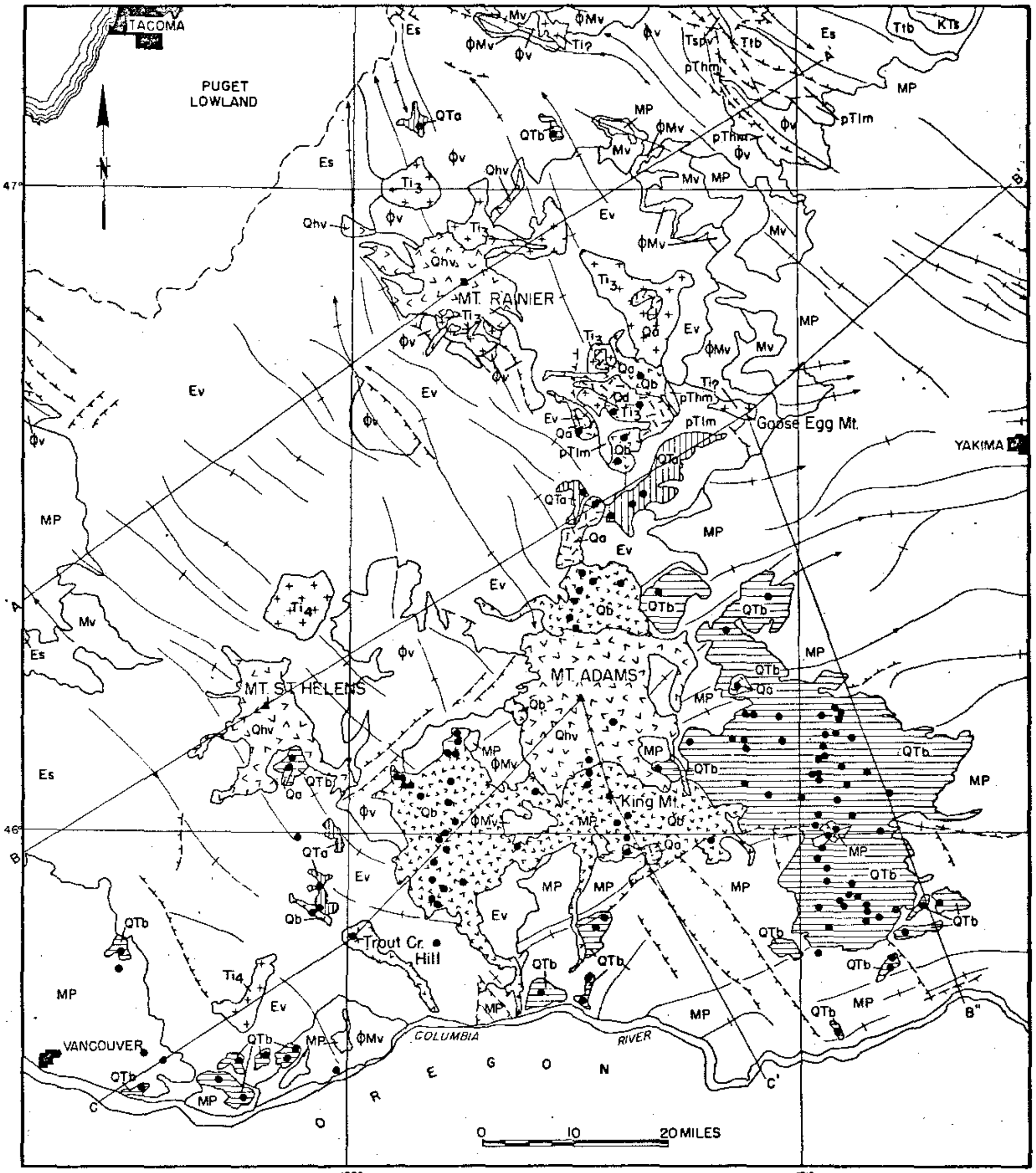

Figure 3. Generalized geologic map of Southern Cascades, Washington, after Hammond, 1973.

crater to melt caverns beneath the edges of the ice. The next volcano southward is the 12,307-foot Mount Adams. It appears that Mount Adams originated as a shield volcano, and that the stratocone was built upon the older apron of flows. No eruptive activity has been reported in historic time. There are steam jets issuing within the crater with temperatures of 65°C. Sulfur deposits occur within the crater and Fowler (1935) reported that when the sulfur deposits were penetrated by a drill hole, fumarolic activity would start. Numerous small shield volcanoes and associated cinder cones and flows occur to the south and southwest of Mount Adams.

The fifth stratocone in the Washington Cascades is Mount St. Helens located about 30 miles west of Mount Adams (Fig.3). The 9,671-foot cone is built upon early Tertiary volcaniclastic rocks. Mount St. Helens is unique, as it is the only high Cascade volcano that does not fall on the regional trend but lies about 30 miles west of the line. Mount St. Helens is considered to be the youngest of the stratovolcanoes. Historic activity is recorded in 1831, 1842, 1844, 1845, 1847 and 1854. The 1842 activity spread ash and pumice as far as The Dalles, Oregon. In 1941 five steam vents errupted on the west slope of the mountain. Temperatures of the five vents were reported to be 81°C, 82°C, 88°C, 87°C and 61°C.

TERTIARY VOLCANIC STRATIGRAPHY

The Tertiary was a time of extensive volcanic activity in the Southern Cascades of Washington. Most of the older Tertiary rocks consist of volcaniclastics with intercalated volcanic flows. The middle Tertiary rocks are dominantly flows as are the late Tertiary rocks. The classification of Fisher (1960) has been used for volcaniclastic rocks. Epiclastic terms are used only for those sediments in which the clasts were derived from erosion of older indurated rocks.

Ohanapecosh Formation

The oldest rocks exposed in the Gifford Peak area are the volcaniclastic rocks of the Ohanapecosh Formation (Wise, 1970). The Ohanapecosh Formation, as defined by Waters, (1961), and described by Fiske, et al (1963) consists of about 10,000 feet of volcaniclastic and flow rocks exposed in the Mount Rainier area. Similar rocks in the Gifford Peak area are tentatively correlated with those of the Mount Rainier area. In the Gifford Peak area the lower two-thirds consists of volcaniclastic rocks while the upper one-third contains abundant flows, up to 50 percent epiclastic rocks, and associated volcaniclastic rocks. The total thickness of the Ohanapecosh Formation may be as much as 19,000 feet if there is no repetition by faulting(Wise, 1970). The top of the unit is characterized by a deeply weathered clay rich saprolite.

Flow Rocks

Basaltic and andesitic flows are intercalated with the volcaniclastic rocks throughout the Ohanapecosh Formation (Plate II). Single flows may be up to 45 feet thick, and cannot be traced for a very great distance. Most of the flows rest upon deeply weathered red clay zones from two to ten feet thick. The flows have been interpreted as being of subaerial origin.

The flow rocks of the Ohanapecosh Formation are hypocrystalline and many have porphyritic textures. Alteration has affected all flow rocks (Wise, 1970). Glass has been devitrified to celadonite, zeolites (mostly laumontite), and montmorillonite. The plagioclase phenocrysts have been extensively altered to mixtures of zeolite and albite. The mafic minerals show minor replacement by chlorite, calcite and montmorillonite.

Volcaniclastic Rocks

Tuff breccia - Tuff breccias are the most abundant rock type in the Ohanapecosh Formation (Plate II). The units are massive, show little stratification, and consist of angular fragments of andesite and pumice in a matrix of crystal fragments and volcanic ash. The tuff breccia units range in thickness from 5 to 75 feet, averaging about 40 feet.

The lower part, up to 10 feet, of each tuff breccia unit shows some evidence of welding. Pumice fragments in the lower 10 feet are flattened parallel to the base of the unit. The basal part of each unit contains charred wood fragments and the rocks are darker in color, very dense and hard.

The upper few feet of each tuff breccia unit appears to have been reworked to some degree. The clasts are relatively well sorted in the upper 3 to 6 feet of the unit. The composition of the clasts remains about the same as in the rest of the unit except that pumice is rare or absent. Wispy layers of ash and lapilli are interlayered with coarser poorly sorted debris.

The tuff breccia units have been affected by alteration similar to that found in the flow rocks. Pumice fragments and andesite fragments, three to six inches in diameter, have been altered to celadonite, calcite, and zeolites. The matrix of the rocks consists of devitrified glass, volcanic ash, and crystal fragments cemented with zeolites and celadonite.

Tuffs - Interbedded with the tuff breccia units are thin tuff beds. These tuff beds consist of reworked pyroclastic debris and probably represent deposition as crater laid ash, although lithic fragments of andesite and pumice as well as crystal fragments indicate some degree of reworking. The glass, pumice, rock fragments and crystal fragments have all altered to mixtures of celadonite, zeolite and clays.

Volcanic Sandstones - In the upper one-third of the Ohanapecosh Formation epiclastic rocks are interbedded with the volcaniclastic rocks and flow rocks. The presence of sedimentary structures such as channeling and cross-bedding, fossil leaf horizons, and association with conglomerate layers have been used to distinguish epiclastic beds from reworked tuffs.

Age

The Ohanapecosh Formation in the Mount Rainier area has been dated as Eocene based upon fossil leaves. A poorly preserved leaf collection from the upper part of the Ohanapecosh Formation at Nelson Creek, south of Gifford Peak area, has been dated as Oligocene (Wise, 1970). No rocks suitable for radiometric dating have been found in the Gifford Peak area as they are extensively zeolitized.

STEVENS RIDGE FORMATION

The rocks of the Stevens Ridge Formation lie unconformably upon the gently folded and eroded rocks of the Ohanapecosh Formation (Plate II). The Stevens Ridge Formation ranges from 300 to 5,000 feet thick and is named for exposures in the Mount Rainier area (Fiske, et al, 1963). Hammond (1974) considers the Stevens Ridge Formation as an excellent marker in the Southern Cascades.

Ash-Flow Tuff

The most common rock type found in the Stevens Ridge Formation is light-colored rhyodacite ash-flow tuffs with intercalated pumice and lithic breccias.

The rocks are light-gray to white in color and contain abundant flattened fragments of dark gray pumice. The degree of welding varies from one flow unit to the next; however, nowhere are typical eutaxitic textures developed. The rocks are not altered to any extent except along contacts with the intrusives.

Volcaniclastic Rocks

Numerous thin layers of tuff breccias occur in the Stevens Ridge Formation. Compositionally the volcaniclastic rocks are similar to ash-flow tuffs. The lithic fragments include rhyodacite, andesites, and very minor basaltic debris. The volcaniclastic rocks constitute only about 10 percent of most sections.

Flow Rocks

Lava flows of basalt, andesite, or rhyodacite comprise a small portion of each section. The rocks are generally crystalline and porphyritic textures. Plagioclase is the most common phenocrysts. The flow rocks are unaltered or at most only weakly altered.

Age

The Stevens Ridge Formation in the Mount Rainier area was dated by Fiske, et al, (1963) as middle Oligocene to early Miocene. In the Gifford Peak area the rocks are probably all of middle Oligocene age based upon their stratigraphic position.

Council Bluff Formation

In the northern part of the Gifford Peak area the Stevens Ridge Formation is overlain by rocks of the Council Bluff Formation (Harle, 1974). The Council Bluff Formation consists of dark colored andesitic to basaltic flows, volcaniclastics, and laharic deposits. The rocks lie conformably upon the Stevens Ridge and crop out along the north side of the Lewis River (Plate II). It appears that the Council Bluff Formation overlapped onto the underlying Stevens Ridge Formation from the north. The dark colored flows and volcaniclastics are unconformably overlain by the lower Miocene Eagle Creek Formation; therefore, the age of the Council Bluff Formation is probably upper Oligocene.

Eagle Creek Formation

The Eagle Creek Formation was named by Chaney(1918) for exposures of sediments near the mouth of Eagle Creek on the Oregon side of the Columbia River. The rocks are light-colored volcanic conglomerates, sandstones, and tuffs with a few minor andesite and basalt flows. At the type locality the unit is 250 feet; however, north of the Columbia River the Eagle Creek Formation reaches a maximum thickness of 1300 feet. Along the Columbia River the base of the Eagle Creek Formation rests upon a saprolite developed upon the Ohanapecosh formation. North of the Gifford Peak area the Eagle Creek rests unconformably upon either the Council Bluff Formation or the Stevens Ridge Formation.

Volcanic Sediments

Typical sections of Eagle Creek Formation are characterized by conglomerate which constitute as much as 70 percent of the exposures. Two distinct types of conglomerates occur. The dominant type are paraconglomerates made up of poorly sorted angular to subrounded boulders and cobbles in a matrix of ash and pumice fragments. Single beds may be as much as 20 feet thick and have lateral extents of a mile or more. Such conglomerates are probably products of lahars.

Stream channel deposits of boulder and cobble conglomerates compose about 10 percent of the average section. The units fill channels cut into underlying rocks, contain numerous lenses of sand, and have well rounded clasts, are moderate to well sorted. Thickness of such units ranges up to 100 feet, and the lateral extent is quite limited.

Thin-bedded sandstones and pebble conglomerates occur interbedded with the conglomerates and comprise as much as 25 percent of typical exposures. The sands are medium to well sorted, show much evidence of channeling and cross-bedding and contain numerous fossil leaf horizons.

Tuffaceous sandstones make up about 5 percent of the section. The rocks are thin-bedded and consist of extensively altered glassy ash mixed with a small fraction of epiclastic debris. The tuffaceous sandstones have a great lateral extent and probably represent reworked air-fall tuffs.

The glassy components of the volcanic sediments in the Eagle Creek Formation have been extensively altered to montmorillonite. The degree of alteration is much less than that found in the Ohanapecosh Formation.

Volcanic Flows

Andesitic flows and basaltic flows constitute a very minor part of the sequence. The textures and composition of the flow rocks are similar to those of the clasts found in the conglomeratic rocks.

Age

The stratigraphic position of the Eagle Creek Formation would limit its age to post-Ohanapecosh and pre-Columbia River Basalt. The flow has been dated by Chaney as lower Miocene (Wise, 1970) based upon fossil collections from the type locality.

Columbia River Basalt

The Columbia River Basalts exposed in the Gifford Peak area belong to the Yakima Basalts according to Waters (1961). The total thickness exposed in the Wind River area is about 2,000 feet. The Columbia River Basalt rest disconformably or unconformably upon the Eagle Creek Formation or older rocks. The Columbia River Basalts are characterized by up to 12 flows of silica-rich tholeiitic basalt, pillow-palagonite breccia, with minor interbedded tuffaceous siltstones, sandstones, and diatomites. The Columbia River Basalts exposed in the central Cascades and western Columbia River Gorge may represent the older groups of flows. The age could extend from middle Miocene through lower Pliocene. Radiometric age dates range from 10 to 20 m.y.

Basic Intrusives

Several small intrusive masses of diabase, gabbro, and diorite occur as plugs and dikes in the Gifford Peak area (Plate II). The intrusives commonly intrude the Ohanapecosh Formation and at Table Mountain (Plate II) cut the Eagle Creek Formation. Similar intrusives in the Mount Rainier area have been dated as upper Miocene to middle Pliocene in age.

Soda Peak Andesite

A small area of light-gray to medium-brown andesite lava flows of the Soda Peak Andesite is found in the southwestern part of the map area. Small quantities of breccia and scoria were noted. The age of the rocks is in doubt. Hammond (1974) dates the rocks as Pliocene and Wise(1970) calls them Pleistocene.

QUATERNARY VOLCANIC STRATIGRAPHY

In the Gifford Peak area the Quaternary volcanic activity started early in the Pleistocene; however, most of the activity was post-glacial. The Big Lava bed was probably extruded within the last 1,000 years. The rocks are basaltic in composition.

Three main groups of rocks have been distinguished; the Older Cascade Basalts (greater than 690,000 years), the Younger Cascade Basalts (15,000 to over 50,000 years), and the Recent Basalts (less than 15,000 years).

Older Cascade Basalts

Three remnants of volcanoes which errupted the olivine basalts, breccias, scoria and minor palagonite breccia occur south of the Gifford Peak property (Plate II). The flows are of both the pahoehoe or aa types. The rocks all have reversed magnetism which indicates they are older than 690,000 years. Several areas of Older Cascade Basalts have been mapped along the Columbia River Gorge south of the map area (Hammond, 1974).

Younger Cascade Basalts

Most of the Quaternary volcanoes within the map area are younger than 690,000 years (Hammond, 1974). Two volcanic centers in the east-central part of the map area (Plate II) could not be correlated with other units and were simply mapped as younger Cascade Basalts by Hammond.

Skull Creek Point Basalt

The oldest volcanic rocks of the Younger Cascade Volcanics are those of the Skull Creek Point Formation (Hammond, 1974). The source of these rocks appears to have been in the Bird Mountain area. The rocks are light gray, fine-grained, dense, slightly porphyritic andesitic basalts. The flows generally are platy and may be somewhat vesicular. Scattered phenocrysts of olivine are found in most of the rocks. Several scoriaceous flows and minor reddish black cinder layers are exposed on the northeast slope of Bird Mountain (Plate II). The flows of the Skull Creek Point Basalt exposed along Forest Service Road 123 are dark colored massive flows of olivine basalt with some well developed columnar joints.

Mosquito Lake Basalt

A series of light to medium-gray, slightly porphyritic olivine basalts mapped as the Mosquito Lake Basalt (Hammond, 1974) errupted from the vent at Sawtooth Mountain. The olivine occurs as scattered phenocrysts. The flows range from massive to platy. The volcanism occurred during the Salmon Springs glaciation.

Trout Creek Hill Basalts

Dark gray to black olivine basalt flows from the small shield volcano at Trout Creek Hill flowed southeastward down Wind River and dammed the Columbia River. Waters(1973) dates the flows as about 35,000 - 50,000 years or concomittant with Salmon Springs glaciation. The flows are of the intracanyon type and filled the Wind River Valley to a depth of at least 325 feet. Two small cinder cones, aligned East-West, are found atop the shield volcano.

Dry Creek Basalts

Light to medium-gray, platy olivine basalt flows mapped as Dry Creek Basalts (Hammond, 1974) originated from East Crater. The largest flow extends southeastward as far as Black Creek Swamp and filled the Fall Creek drainage (Plate II). Lava tubes, mostly collapsed, are common in the Dry Creek Basalts. Exposures are not too good because of the topography and usually consist of platy basalt rubble piles (Wise, 1970).

Rush Creek Basalt

Medium-gray to black, vesicular, slightly porphyritic olivine basalts of the Rush Creek Formation crop out in several places within the map area (Plate II). Hammond (1974) postulates that the source of these flows was Lemei Rock. The flows must have been fairly fluid at the time of erruption. Lava tubes, mostly collapsed, are common.

Outlaw Creek Basalt

The youngest flows to erupt from East Crater are those of the Outlaw Creek Formation (Plate II). The rocks are medium-gray, vesicular, porphyritic olivine basalts. Plates of plagioclase up to 15mm in length are common in most of the flow units. The cinder cone of East Crater stands about 400 feet above the adjacent lavas. The crater is about 150 feet deep. The flows of the Outlaw Creek Formation are typically pahoehoe. Flow breccia and scoria are found along margins of the flow units.

Papoose Mountain Basalt

Papoose Mountain (Plate II) is a small cinder cone and associated flows located southeast of Red Mountain. The Papoose Mountain Basalts are dark-gray to black, slightly vesicular, slightly porphyritic olivine basalts. A low, somewhat asymmetrical cinder cone stands almost 200 feet above the lava flows.

Black Creek Basalts

Flows of the Black Creek Formation (Plate II) originated from the Red Mountain Shield Volcano. The flows underlie an area of about 18 square miles. The flows consist of medium to dark-gray, slightly porphyritic, olivine basalts. Some flow units are massive with irregular blocky jointing and others are more platy. Tops of flow are usually vesicular and may be scoriaceous. The more scoriaceous zones along flow tops tend to have abundant plates of plagioclase. Similar flows errupted from at least six centers along the West Fissure Zone (Plate II) from Gifford Peak south to the Wart. The topographic highs all represent cinder cones. At Red Mountain the main cone is made up of cinders and lava spatter and the north cone is loose cinders and bombs. Three small cinder cones are located on the southeast slope of Berry Mountain.

Forlorn Lakes Basalt

Light-gray to medium-gray, slightly porphyritic, platy olivine basalt flows cover about 5 square miles in the Forlorn Lakes area. The flows errupted from a small center southeast of Gifford Peak (Plate II). No cinder cones are associated with the Forlorn Lakes Basalts.

Falls Creek Basalts

The Falls Creek Basalts crop out in an area of about 4 square miles west of Falls Creek (Plate II). The rocks are medium-gray, slightly porphyritic olivine basalts. Hammond (1974) mapped three volcanic centers along a north-south line which apparently served as vents for the flows.

Ice Cave Basalts and Swampy Meadows Basalts

The youngest of the interglacial volcanic flows are those of the Ice Cave Basalts in the east central part of the map area (Plate II) and those of the Swampy Meadow Formation in the northeastern corner of the map. The source of the Ice Cave flows was from the crater east of Lemei Rock while the Swampy Meadow flow originated beneath Mt.Adams (Hammond,1974). The rocks are medium-gray, vesicular, porphyritic olivine basalts. Plagioclase lathes up to 1cm are common and olivine occurs as scattered phenocrysts.

Burnt Peak Basalts

The youngest Pleistocene volcanics in the Gifford Peak area are those of the Burnt Peak Formation (Pedersen, 1973), dated as being older than 15,000, but younger than 20,000 years. The Crazy Hills area (Plate II) in the west-central portion of the map area was a center of explosive activity. Lone Butte is a large cinder cone of the same general age. On the southwest side of Lone Butte large areas of pillow-palagonite breccias occur which are postulated to be the result of lavas erupting beneath the glaciers of Fraser age.

High Cascade Volcanics

The youngest volcanics in the area are the Quaternary andesites of Mount Adams which fill canyons cut into the older lavas. The High Cascades andesites are confined to the northeastern part of the map area. The rocks are light to medium-gray, fine-grained, dense, olivine pyroxene andesite flows, breccias and pyroclastics.

Recent Cascade Basalts

Post glacial Quaternary volcanism of a limited extent has occurred in the Gifford Peak area. In general the rocks have restricted outcrop areas, but show widespread distribution. The rocks are younger than 12,000 years.

Twin Buttes Basalts

The Twin Buttes volcanoes lie about 5 miles north of the Gifford Peak property (Plates I and II). The rocks are gray, slightly vesicular olivine basalts. Some scoria and cinders are associated with the cone development.

West Crater

Small olivine basalt flows erupted from West Crater, in the southwestern part of the map area, and flowed down existing valleys. The pahoehoe flows are of small areal extent. The age of the rocks is greater than 6600 years and less than 8300 years, (Hammond, 1974).

Big Lava Bed

Big Lava Bed, in the southern part of the map area (Plate II), is a striking example of the pahoehoe flows in the Cascade region. The medium-gray, slightly vesicular, slightly porphyritic olivine basalts issued from a low shield volcano, now marked by an 800-foot high cinder cone. The flows are quite young as only limited soil and tree cover have developed on them. Hammond (1974) dates the Big Lava Bed as older than the 450 year old "W" ash and younger than the 2,000 year old Cave Basalts.

STRUCTURE

Folds

Folding of the Tertiary rocks in the Gifford Peak area began after the deposition of the Ohanapecosh Formation. The folds were broad, open, northwest trending structures (Fig.2). Deformation in the mid-Pliocene followed the older northwest trends, and was responsible for most of the structures shown on the western half of Figure 2. On the east side of the Cascades the structural grain developed by the mid-Pliocene tectonism has an east-northeast trend (Fig.2). Within the map area such structures are confined to the area east of the Wind River (Plate II). Interference along the structural boundary between the two tectonic styles results in deflection of the east-northeast structure to the northwest trend. A broad north-south arch formed in the Cascades during late Pliocene to Pleistocene time, about 2-4 m.y. ago.

Faults

In general the early Tertiary and mid-Pliocene tectonism developed a series of steep normal faults parallel with the fold structures (Fig.2). Within the map area such structures are seen east of Wind River and also in the northeastern corner of the map (Plate II).

Two parallel north-northeast trending fissure zones controlled the Quaternary volcanism. The West Fissure Zone

(Plate II) lies along the probably northward extension of the western boundary fault of the Cascade Graben of Oregon. The line of volcanic centers through the center of the map area follow the West Fissure Zone. Immediately east of the map area Hammond (1974) maps a parallel trend called the East Fissure Zone which appears to be the northward extension of the eastern boundary fault of the Cascade Graben.

GEOTHERMAL POTENTIAL

Geothermal Manifestations

The surface manifestations of geothermal activity are an abundance of young volcanic rocks throughout the property and the presence of hot springs a few miles to the south. No evidence of hydrothermal alteration was found within the lease area; although the rhyolite done at Mann Butte exhibits weak to moderate argillization. The abundance of young Quaternary volcanic rocks is really the only favorable geothermal manifestation found on the property or in the immediate area. The basaltic flows common to the area are, unfortunately, not especially favorable indicators of geothermal potential.

Reservoir

Several units are considered as potential geothermal reservoirs. The descriptions will be given of the units as they would be encountered in a drill hole.

The Columbia River Basalts are good aquifers. Water wells which penetrate the rubble of interflow zones produce moderate to large amounts of water. The discontinuous nature of the rubble zones and flows suggest multiple and discontinuous reservoirs. Within the map area it is extremely unlikely that the Columbia River Basalts are buried to sufficient depth to be good potential geothermal reservoirs even though the appropriate reservoir characteristics are present.

The well bedded volcanic conglomerates and sandstones of the Eagle Creek Formation could provide potential geothermal reservoirs. The rocks have a moderate degree of permeability. However, circulation of hot fluids through such rock would undoubtedly result in the development of clay minerals from the volcanic debris and thus effectively reduce the permeability.

The other Tertiary volcanic flows, ash-flows, and volcaniclastic rocks of the Council Bluff Formation, Stevens Ridge Formation, and Ohanapecosh Formation represent potential geothermal reservoirs. They all have the lateral extent and a sufficient thickness and depth of burial in the project area to be of interest. Much of the original porosity and permeability of these rocks has been lost as a result of alteration of volcanic glass to zeolites and clay minerals. Therefore, suitable geothermal reservoirs in these rocks will be limited to areas of pervasive fracturing. Theoretically, the boundary between the tectonic styles on the east and west sides of the Cascades should be a zone of pervasive fracturing. Therefore, the early Tertiary rocks represent the most attractive reservoir rock in the area.

Heat Source

The heat source for the Gifford Peak area is probably the magma chamber related to the Quaternary volcanics. The extent and volume of basaltic volcanic flows is quite large indicating considerable magmatic activity. The probability of having a magmatic heat source close enough to the surface to be reached with a drill depends upon the model one chooses for Cascade volcanoes. If they represent channels or conduits projecting above a large magma chamber then perhaps a sufficient heat source is available for commercial geothermal operations. However, the most widely accepted model is one in which the volcanic conduits extend as small channels from great depths, perhaps from a magma chamber at the mantle-crust boundary. Thus geologic sections such as those on Figure 3 indicate that the magma chamber, and hence heat source, is too deep to be a potential geothermal heat source.

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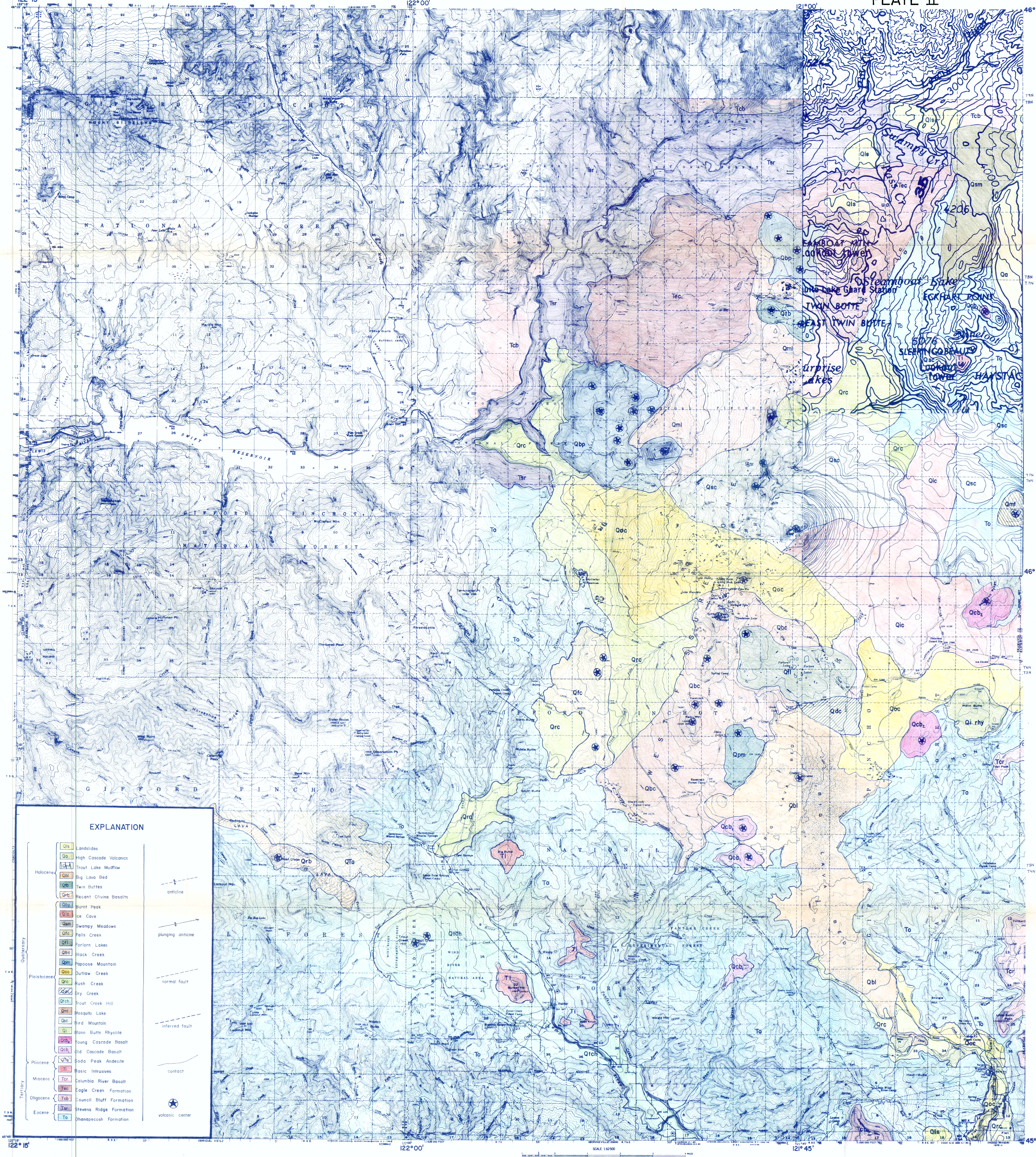
PLATE II



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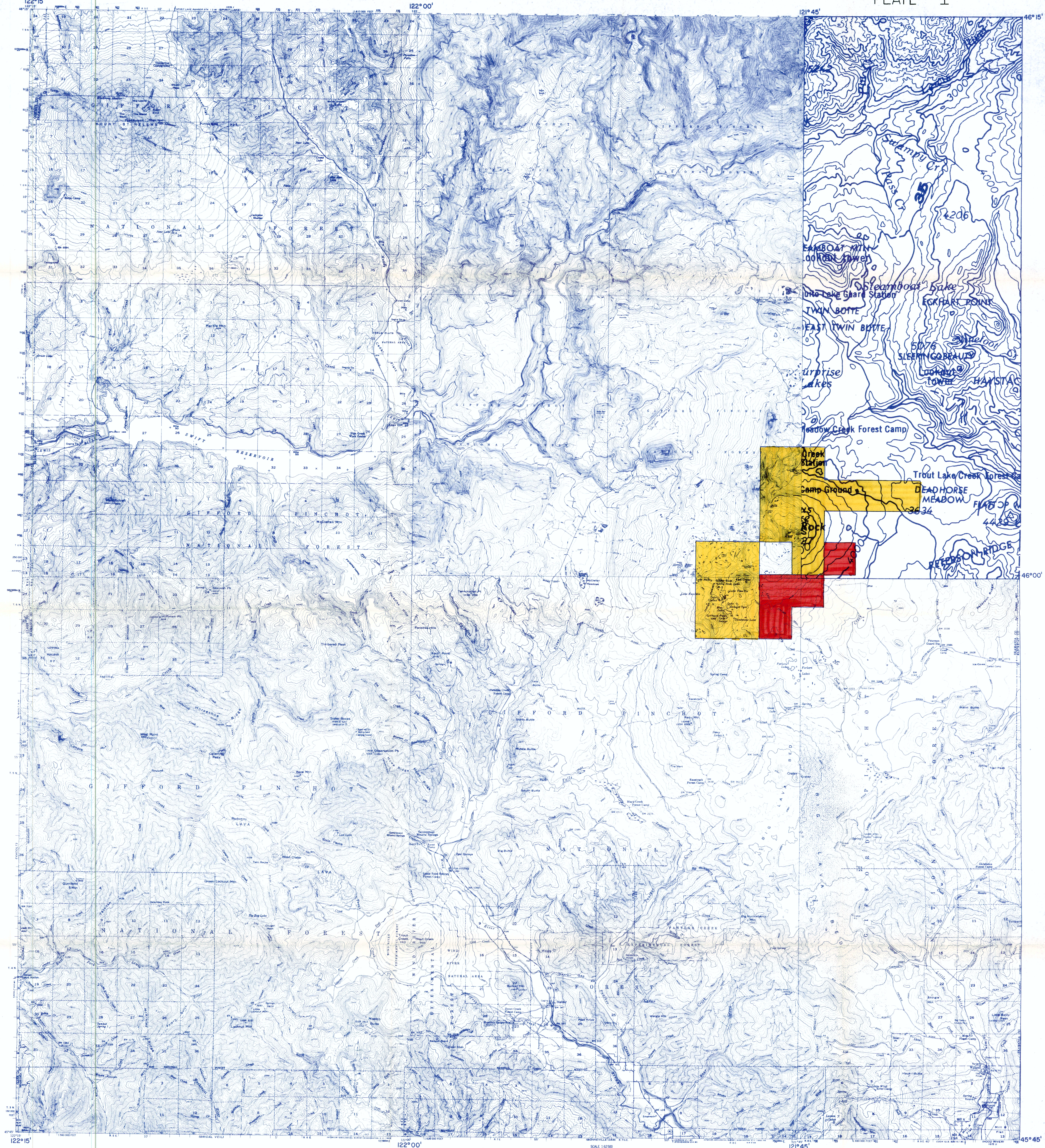
GIFFORD PEAK
WASHINGTON
GEOLOGIC MAP

PLATE I



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GIFFORD PEAK
WASHINGTON
PROPERTY MAP