UNITED STATES DEPARTMENT OF THE INTERIOR

GEOLOGICAL SURVEY

Geology and mineral resource potential map of the Windigo-Thielsen Roadless Area, Douglas and Klamath Counties, Oregon

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STUDIES RELATED TO WILDERNESS

Under the provisions of the Wilderness Act (Public Law 88-577, Sept. 3, 1964) and related acts, the U.S. Geological Survey and the U.S. Bureau of Mines have been conducting mineral surveys of wilderness and primitive areas. Areas officially designated as "wilderness," "wild," or "canoe" when the act was passed were incorporated into the National Wilderness Preservation System and some of them are presently being studied. The act provided that areas under consideration for wilderness designation should be studied for suitability for incorporation into the Wilderness System. The mineral surveys constitute one aspect of the suitability studies. The act directs that the results of such surveys are to be made available to the public and be submitted to the President and the Congress. This report discusses the results of a mineral survey of the Windigo-Thielsen Roadless Area (6132) in the Deschutes, Umpqua, and Winema National Forests, Douglas and Klamath Counties, Oregon. The Windigo-Thielsen Roadless Area was classified as a further planning area during the Second Roadless Area Review and Evaluation (RARE II) by the U.S. Forest Service, January, 1979; part of the area was administratively endorsed as wilderness in April 1979.

SUMMARY

The Windigo-Thielsen Roadless Area has no identified metallic mineral resources and there is no evidence of a potential for their occurrence. The area contains no mines or claims, and only five prospect pits were observed; samples from these pits contain no significant metal concentrations.

The roadless area contains more than 148 million cubic yards of

cinder in 16 cones. Development of these cinder deposits is unlikely because of their remote location and because of the abundance of other nearby sources. The area has a low potential for geothermal resources.

INTRODUCTION

The Windigo-Thielsen Roadless Area (fig. 1) occupies 105,345 acres (165 mi^2) in the Deschutes, Umpqua, and Winema National Forests, Douglas and Klamath counties, Oregon. Subsequently, 55,100 acres (86 mi^2) were recommended for wilderness status by presidential decree on April 16, 1979.

The roadless area straddles the crest of the Cascade Range and is transected by the Pacific Crest National Scenic Trail. Paved Oregon State Highway 138 parallels the south and west sides of the area and provides access to the area and to nearby Diamond Lake and Crater Lake National Park. Gravel roads provide access to the roadless area from the east and north.

The rugged spire of Mount Thielsen, 9,182 ft in elevation, is the most prominent landmark in the area; other peaks include Howlock Mountain, Tipsoo Peak, Tolo Mountain, and Windigo Butte. Streams are present only in glacially-carved U-shaped canyons, owing to a thick and extensive mantle of porous volcanic ash and pumice. Dense Hemlock and lodgepole pine forests grow on the lower slopes of the mountains; timberline is at approximately 8,000 ft elevation. Timber is being harvested near the northwestern, northeastern, and eastern boundaries of the area.

Extensive glaciation of Mount Thielsen is responsible for the spectacular view of the core of this basaltic andesite volcano, which has been the focal point of the only previous geologic studies of the area. Williams (1933) made the first detailed study of Mount Thielsen and later extended his reconnaissance mapping north beyond the limits of the roadless area (Williams, 1957). Subsequent workers have modified Williams' original map and supplied chemical analyses of some lavas and intrusive rocks (Purdom, 1963; Barnes, 1978). Gravity and aeromagnetic maps of the central Cascade Range (Couch and others, 1978; Pitts and Couch, 1978) include the Windigo-Thielsen Roadless Area; interpretations of lineaments observed on high altitude imagery of the region are given by Kienle and others (1981).

As part of this study a geologic map was made of the roadless area and analyses were made of rocks and stream-sediment samples to determine their content of base and precious metals.

GEOLOGY

The Windigo-Thielson Roadless Area is in the High Cascade physiographic province of Oregon, an area of late Cenozoic volcanic landforms. Rocks of the Windigo-Thielsen area are principally olivine basalt and basaltic andesite of late Pliocene and Pleistocene age; older rocks crop out only in the northern part of the area. West of the Windigo-Thielsen area the young volcanic rocks of the High Cascade Range lie depositionally above, and bank against, the deeply dissected Tertiary volcanic rocks of the Western Cascade province. South of Mount Thielsen is Crater Lake National Park which includes the caldera of Mount Mazama; climactic eruptions about 6,845 ^{14}C years ago (Williams, 1942; Bacon,

1983) spewed pumice and ash over the Windigo-Thielsen area.

The oldest rocks in the roadless area are silicic lava flows, pyroclastic rocks, and vent deposits of late Miocene or Pliocene age. They crop out in the northern part of the roadless area, where the terrain is more deeply eroded and not covered by Quaternary lava flows. Andesite and dacite are common; rhyodacite or rhyolite crops out at Clover Butte and Burn Butte. Vents on the east side of Tolo Mountain and the northwest flank of Cappy Mountain are indicated by coarse andesitic tuff breccia and andesitic intrusions. Basaltic andesite flows and mafic lapilli tuffs surround a satellite vent at Cappy Mountain.

The dominant rocks of the Windigo-Thielsen Roadless Area are lavas of late Pliocene and Pleistocene age. They are vesicular to massive olivine basalt and basaltic andesite and are 3 to more than 100 ft thick. Flow breccias are commonly associated with the lava flows.

The upper Pliocene and Pleistocene lavas were erupted from cinder cones and stratovolcanoes. Some of the cinder cones have youthful morphology, and possess central crater depressions. The older vents, however, have been extensively eroded by glaciation. Locally, glaciers have scoured away the pyroclastic material and left only a central conduit-filling plug, or neck, surrounded by a circular trough. This moat-and-island topography is a common feature of older glaciated mafic vents in the High Cascades.

Mount Thielsen and Howlock Mountain are eroded stratovolcanoes. Lavas from Mount Thielsen have yielded a 0.29±.05 m.y. K/Ar age (J. G. Smith, written commun., 1983). The vents grew by eruptions of mafic pyroclastic rocks and coeval lava flows. Most of the lava was erupted from dikes surrounding the central pyroclastic cone. Magma congealed in the central conduit to form a large central plug. The resulting structure is a pyroclastic edifice laced with dikes and sills and armored by flow aprons. The intrusive rock is usually as fine-grained as the lava but is distinguished from it by cross-cutting contacts. Plugs in excess of 1,500 ft in diameter are composed of medium grained and equigranular basalt or basaltic andesite.

Many of the High Cascade volcanoes have experienced multiple glaciations. U-shaped valleys and cirques heading on ridge crests attest to the extent of glacial erosion in the Windigo-Thielsen Roadless Area. Lateral and ground moraine landforms are apparent in the topography but the glacial drift is mostly buried beneath younger tephra. Exposures in outlying areas show the glacial deposits to be as thick as 75 ft.

Unconsolidated air-fall pumice deposits of Holocene age mantle most of the roadless area. They have been removed by erosion only along ridge crests and valley floors. The deposits are rudely stratified owing to size variations of pumice lapilli; lapilli are commonly 0.2 in. in diameter but some are as wide as 3 in. The deposit varies from 6 ft thick along the western margin to as much as 50 ft thick on the eastern flank of Mount Thielsen. These large volumes of dacitic pumice and ash--Mazama ash--were erupted about 6,845 ^{14}C years ago from a source now marked by the caldera at Crater Lake National Park, 16 mi south of Mount Thielsen (Williams, 1942; Bacon, 1983). The eruption of ash flows followed the air fall pyroclastic eruptions, leaving deposits of massive ash with pumice lapilli and blocks as large as 15 in. in diameter entrained in it. These unwelded ash-flow deposits form the surficial deposits around all but the northern margin of the roadless area and are preserved within the area in the drainages of Cottonwood and Thielsen Creeks.

No faults have been mapped within the Windigo-Thielsen Roadless Area because surficial deposits deeply bury any probable fault traces and because possible movement has been insufficient to juxtapose contrasting units. Possible structural features of the area, however are defined by topographic lineaments. The lineaments possess two distinct trends, approximately N-S and NW-SE. The trends reflect both local volcanism and regional tectonism. Very faint linear features trend N. 15° E. to N. 10° W. and probably are expressions of fractures developed during eruptions at vents. Mount Thielsen, Howlock Mountain, and Tipsoo Peak lie along a line trending N. 15° E., but the alignment may be fortuitous.

The upper drainage of the North Fork of the Umpqua River on the northwest side of the area has a well developed trend, N. 45° W., which is on line with Miller Creek and Miller Lake on the east side of the range; the crest of the range interrupts the lineament. The topographic lineament may be a product of erosion along faults. The amount of separation must be small, but neither the sense of separation nor time of faulting can be determined because of the extensive surficial deposits. This lineament may be part of the Eugene-Denio fault zone of Lawrence (1976).

Alteration in upper Pliocene and Pleistocene rocks of the Windigo-Thielsen Roadless Area is minor and of the type expected in volcanic rocks: deuteric effects in flows, palagonitization and devitrification of once-glassy tephra, and development of minor amounts of clays associated with very small old fumaroles within some cinder deposits. Trace amounts of specular hematite occur along fractures of some flows and plugs, but no sulfide minerals have been found in the mafic lavas.

The older volcanic rocks, however, are extensively altered in some areas. Pervasive clay alteration occurs in a circular area 2 mi in diameter south and east of Tolo Mountain where upper Miocene or Pliocene rocks crop out. The rocks have a soft, white bleached appearance; locally they are light brown and orange brown where stained by limonite and reddish brown where stained by hematite. Fine-grained pyrite is visible in the less oxidized rocks, commonly occurring as "paint" on fracture surfaces. There is no evidence of potassic alteration.

Altered breccia crops out in a small area southeast of Tolo Mountain. This breccia is composed of close fitting, angular clay-altered clasts as much as 2 in. across, with little or no matrix. Pitch limonite fills the interstices between clasts. The clasts show no signs of rotation or other significant movement; slickensides were not observed. Alteration obscures most of the original texture of the rocks, but relict porphyritic textures similar to adjacent unaltered andesites and dacites persist. Pyrite occurs in slight amounts as disseminated grains less than 0.02 in. across. No other sulfide minerals and no supergene minerals after sulfide were observed.

The localization, geometry, and style of the alteration is consistent with leaching beneath an area of ancestral hot springs. The occurrence of pyrite is to be expected in such an environment. The absence of coarse-grained intrusive rocks at the present level of exposure, explosion breccias, sulfide minerals besides pyrite, and vein material supports this interpretation. The solfataric alteration could be the surface expression of an extinct hydrothermal system once driven by cooling intrusive magma.

Geophysical surveys that include the Windigo-Thielsen Roadless Area show anomalies that mostly correlate with mapped vents. Positive aeromagnetic anomalies, as large as 1000 gammas, and small gravity anomalies, mostly less than 6 milligals, are associated with larger vents, as at Mount Thielsen (Couch and others, 1978; Pitts and Couch, 1978). Areas where reversely polarized flows crop out show on the aeromagnetic maps as magnetic lows, mostly less than -500 gammas.

MINERAL RESOURCES

Metallic mineral resources are not known within the High Cascade physiographic province of Oregon, of which the Windigo-Thielsen Roadless Area is a part. No mining districts exist in or around the study area and the nearest mine is the Last Chance Sulfur Mine, 18 mi southwest of Diamond Lake, in older rocks of the Western Cascade province.

The only observed results of prospecting in the study area are small pits south and east of Tolo Mountain. The age and origin of these pits are not known, but no single excavation has removed more than a few cubic yards of rock. These pits are in slightly altered andesite and dacite with moderate limonite $\pm$ pyrite along fracture zones, and in white, clay-altered dacites(?) with the same limonite-pyrite association. Chemical analyses of these altered rocks show no anomalous amounts of gold, silver, copper, lead, zinc, mercury, or uranium.

As part of this mineral investigation, stream-sediment samples were collected from streams near the border of the roadless area and analyzed for their content of base metals and other elements. Sample locations are shown on Figure 1 and analytical data given in Table 1. Two samples of sand- and silt-size sediment were collected at each site, one of bulk sediment, the other a pan-concentrate of the heavy-mineral fraction of the sediment. In the laboratory each sample was dried, sieved to minus-80 mesh, and split. The heavy minerals in the pan-concentrate sample were further concentrated by settling in bromoform (specific gravity, 2.8) and separated into magnetic and nonmagnetic fractions. Stream sediment and nonmagnetic heavy-mineral concentrate samples were then pulverized before analysis by standard semiquantitative emission spectrography for 31 elements. The analyzed sediments from streams draining the Windigo-Thielsen Roadless Area show concentrations of metallic elements similar to those commonly found in volcanic rocks. No anomalous concentrations of any elements were found.

Cinder and rock are the only industrial resources in the Windigo-Thielsen Roadless Area (Benham, 1981). More than 148 million cubic yards of cinders are present in 16 cinder cones. Two large cones, Windigo Butte and Tenas Peak, contain 66.2 and 9.6 million cubic yards of cinders, respectively. Fourteen smaller cones make up the remaining 72.5 million cubic yards of cinder resources. Because other sources supply local needs, development of these resources is unlikely. The volume of rock material has not been estimated, but sufficient sources exist outside the roadless area to supply regional needs.

Outside the Windigo-Thielsen Roadless Area, but near the boundary, are three quarries. Two contain cinders and the other rip-rap material. A large cinder quarry at Kelsay Point (Fig. 1) contains in excess of 24 million cubic yards of cinders that range from 1/8 to 2 in. in diameter. The U.S. Forest Service manages this source of cinders for local Forest

Service and county road construction. This source should supply local needs for the foreseeable future. The other cinder quarry, at Cinnamon Butte, supplied cinders for nearby logging roads, but is now overgrown by pine trees and not in use; cinder reserves are estimated to be 41.7 million cubic yards. A rock quarry at Summit Rock, south of the roadless area, was used in 1972 as a source of rip-rap for construction of State Highway 230. Local residents use the remaining rock for small building projects.

Hydrocarbon deposits (oil, natural gas, coal) are not known to occur in the region and are highly unlikely in Windigo-Thielsen Roadless Area, which is underlain by a very thick sequence of volcanic rocks.

The High Cascade physiographic province, formed of young volcanic rocks, may locally contain high temperature geothermal energy resources, although the Windigo-Thielsen area is not among the most geologically favorable areas. Low temperature resources, which can be utilized for heating and other direct uses of hot water, are likely to be more abundant throughout the High Cascade province.

Hot springs occur marginal to the province, mostly near the contact between the Western Cascades and High Cascades. They occur near valley bottoms, locally along faults, and are interpreted to represent lateral flow of hot water from sources beneath the High Cascades (Blackwell and others, 1978). No thermal springs occur in or near the Windigo-Thielsen Roadless Area (Waring, 1965; Riccio, 1978; Bowen and Peterson, 1970; Bowen and others, 1978; Brown and others, 1980).

Temperature gradients in drill holes at scattered locations near the boundary between the Western Cascades and High Cascades suggest that heat flow increases significantly under the High Cascades (Blackwell and others, 1978). Shallow heat-flow holes drilled in older rocks of the Western Cascades 10 to 15 mi west and northwest of the Windigo-Thielsen Roadless Area had only moderate temperature gradients (Priest and Vogt, 1982, appendix D). No deep holes have been drilled in the High Cascades near the roadless area and consequently the depth-temperature relationship is not known.

On the basis of local geology, there is no reason to suspect that geothermal resources are more likely in the Windigo-Thielsen area than in other nearby parts of the High Cascades. If geothermal resources are present, they likely occur at substantial depth. The volcanic rocks at these depths may have very low porosity and permeability and fluids may not be present in sufficient quantity for geothermal power production. Exploitation of low-temperature geothermal resources that may occur beneath the area is probably not viable because of the distance to the nearest points of use. In summary, available evidence does not substantiate the presence of geothermal resources, and if they do occur they are likely deep.

MINERAL RESOURCE POTENTIAL

The Windigo-Thielsen Roadless Area has no identified metallic mineral resources and there is no evidence of a potential for their occurrence. Cinder cones within the study area contain an estimated total of 148 million cubic yards of volcanic cinders suitable for road construction, but voluminous alternative sources are present outside the roadless area. The area has an undefined, but low, potential for geothermal energy.

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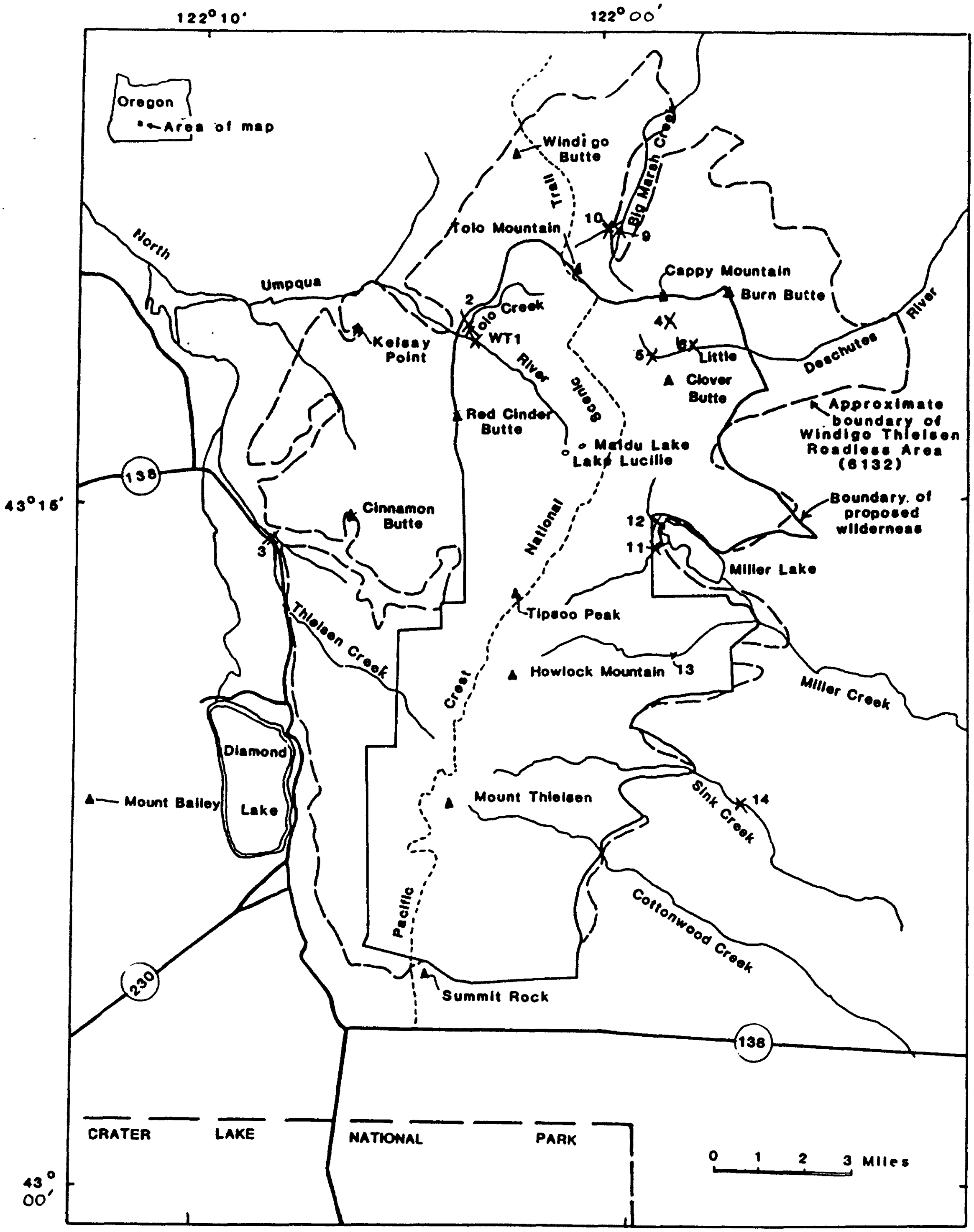

Figure 1.--Map showing location of the Windigo-Thielsen Roadless Area (6132), High Cascades, Douglas and Klamath Counties, Oregon. Sample localities (X) and numbers are referred to in Table 1.

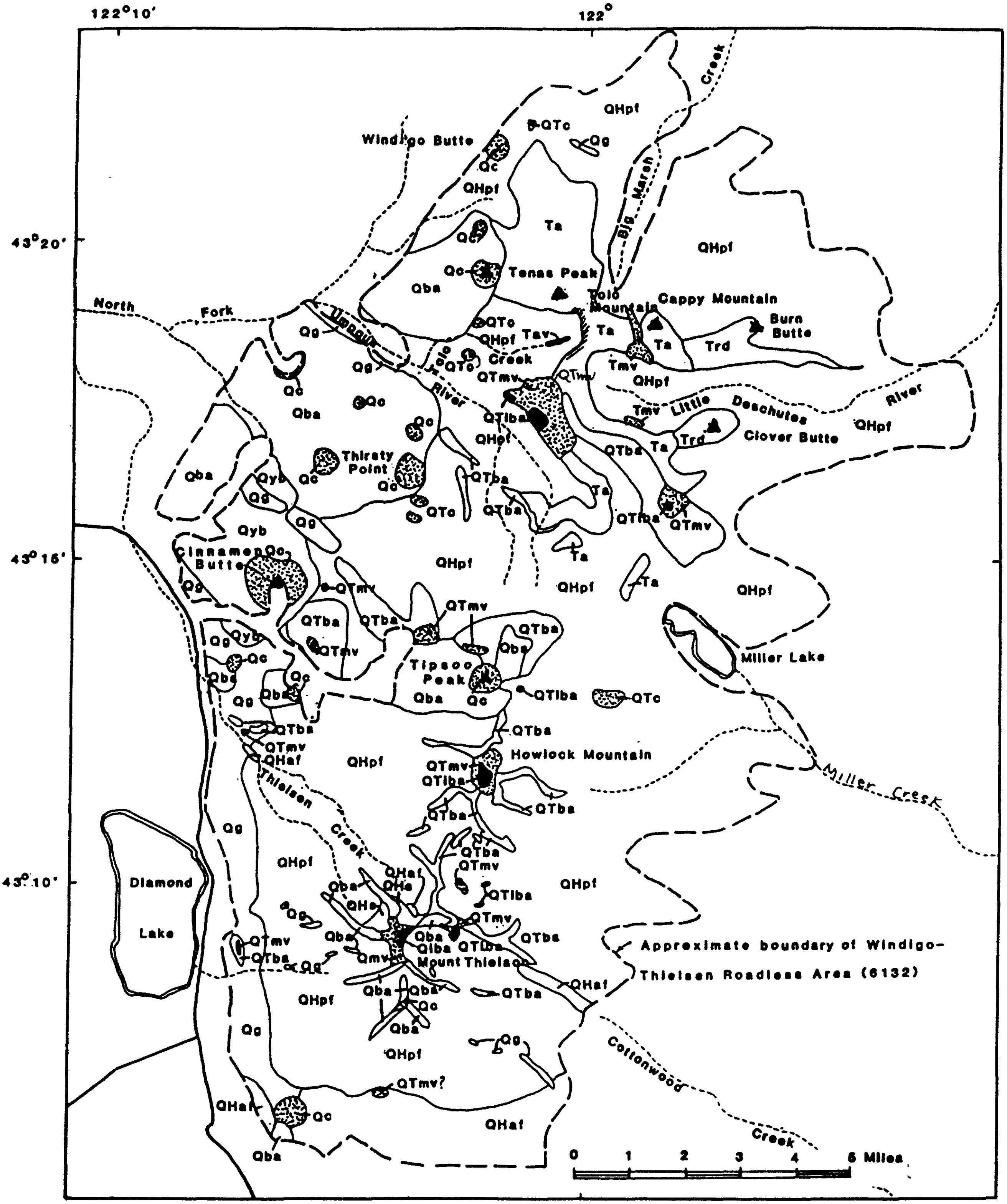

Figure 2.--Generalized geologic map of the Windigo-Thielsen Roadless Area, Oregon. Geology by David R. Sherrod, 1981, 1982.

EXPLANATION

(Geologic map unit symbols may not necessarily conform to U.S. Geological Survey standards)

QHs SURFICIAL DEPOSITS (HOLOCENE)--Coarse to fine, poorly sorted, angular unconsolidated rubble that forms talus cones around Mount Thielsen. Includes neoglacial protalus cone in the north cirque of Mount Thielsen. Principally younger than the Mazama ash

QHaf ASH FLOW DEPOSITS (HOLOCENE)-Poorly sorted pumiceous ash, minor lapilli, and blocks as much as 15 in in diameter, and crystals of plagioclase, pyroxene, and hornblende. Oxidized to grayish pink in the upper 3 to 6 ft of deposit and pale gray in lower unoxidized parts. Thickness ranges from 6 to 60 ft. Restricted to topographic lows, such as valley floors and canyons mostly beyond margin of area. Isolated remanents crop out along Cottonwood Creek and Thielsen Creek at elevations as high as the cirque floors of Mount Thielsen (7,000 ft). Erupted from caldera at Crater Lake National Park approximately 6,845 ^{14}C years ago (Williams, 1942; Bacon, 1983)

QHpf MAZAMA ASH (HOLOCENE)--Air-fall deposit of slightly porphyritic, pale gray glassy dacite pumice lapilli and ash. Lapilli range from 0.1 to 3 in; most commonly 0.2 in. Thickness varies from 5 ft at Diamond Lake to more than 58 ft on eastern flank of Mount Thielsen. Mantles all volcanic rocks in area except unit QHaf; underlies unit QHaf but essentially the same age and from same source (Williams, 1942; Bacon, 1983)

Qyb BASALT OF CINNAMON BUTTE (LOWER HOLOCENE OR UPPER PLEISTOCENE)--Dark gray lava with microphenocrysts of plagioclase and olivine in intersertal to hyalopilitic groundmass. Characterized by rugged, unglaciated(?) flow surfaces. Overlain by units QHaf and QHpf; underlain by glacial drift (Qg)

Qg GLACIAL DRIFT (UPPER PLEISTOCENE)--Unsorted, unstratified deposits of sub-angular to sub-rounded cobbles and boulders in a matrix of poorly indurated to well-indurated rock flour. Clasts have negligible weathering rinds. Thickness variable; may be in excess of 80 ft. Probably formed during the Cabot Creek glaciation of Scott (1977)

Qba YOUNGER BASALTIC ANDESITE, ANDESITE, AND BASALT (UPPER PLEISTOCENE)--Medium gray to dark gray, vesicular to massive, slightly porphyritic lava and grayish-red flow breccia. Single flows vary from 3 ft to more than 100 ft thick; aggregate thickness in excess of 500 ft. Flows interbedded with and overlying the pyroclastic deposits of Mount Thielsen are arbitrarily assigned to Qba to distinguish them from underlying lavas. This contact is mappable only above timberline and in the vicinity of Mount Thielsen. Possible distal correlative rocks are included in unit QTba. Age less than approximately 700,000 years on basis of normal magnetic polarity, and association with slightly or moderately eroded vents; older than 10,000 years, on basis of glaciation. Flows from Mount Thielsen have yielded a K/Ar age of 0.29 $\pm$ .05 m.y. (J. G. Smith, written commun., 1983). Correlates in part with unit QTba of Williams (1957)

Qc CINDER DEPOSITS (HOLOCENE? AND UPPER PLEISTOCENE)--Cones of cinder lapilli and lapilli tuff. Only slightly or moderately eroded with preservation of all or some of the following features: central crater depression; abundant unconsolidated cinder rubble; cinder agglutinate around and above vent-filling plug. Map unit Qc marks some of the sources of unit Qba and is similar in age. Cones at Thirsty Point and Cinnamon Butte have very youthful morphology and may be Holocene in age

Qmv MAFIC VENT DEPOSITS OF MOUNT THIELSEN (PLEISTOCENE)--Olive gray to yellow gray, palagonitic lapilli tuffs, cinder breccia, and cinder lapilli tuffs. Rocks have normal remanent magnetization. K/Ar age of 0.29 $\pm$ .05 m.y. determined on associated flows (J. G. Smith, written commun., 1983)

Qiba YOUNGER MAFIC INTRUSIONS (PLEISTOCENE)--Dikes, sills, and plugs of fine-grained basalt and basaltic andesite that intrude units Qc and Qmv. Petrographically similar to unit Qba

QTba OLDER BASALTIC ANDESITE, BASALT, AND ANDESITE (PLEISTOCENE AND UPPER PLIOCENE?)--Lava flows similar to unit Qba but generally more eroded. Some flow units have normal magnetic polarity, others are reversed. Derived from deeply eroded vents or not assignable to particular vents. May be partly as young as unit Qba; older flows may be 2 m.y. or older in age

QTmv OLDER MAFIC VENTS (PLEISTOCENE AND UPPER PLIOCENE?)--Indurated cinders and palagonitic lapilli tuff of uncertain age. Occur as deeply eroded landforms. Includes vents that erupted lava flows included in unit QTba

QTiba — OLDER MAFIC INTRUSIONS (PLEISTOCENE AND UPPER PLIOCENE?)--Dikes, sills, and plugs of basalt and basaltic andesite

Trd — RHYODACITE (PLIOCENE)--Black to pink, vitrophyric to lithoidal, flow-banded flows and domes. SiO_2 69%. K-Ar age on flow at Burn Butte is 2.5 $\pm$1.0 (Fiebelkorn and others, 1982)

Ta — ANDESITE (PLIOCENE OR UPPER MIOCENE)--Porphyritic two-pyroxene andesite and minor olivine andesite. Includes hornblende-bearing andesite and dacite on the east slope of Tolo Mountain and dacite or rhyodacite near Miller Lake. Relationship to unit Trd uncertain, but at least older in part

Tba — BASALTIC ANDESITE (PLIOCENE OR UPPER MIOCENE)--Slightly porphyritic flows on southern flank of Cappy Mountain. Includes mafic lapilli tuff that forms a vent for the flows. Age similar to unit Ta

Tmv — ANDESITIC VENT DEPOSITS (PLIOCENE OR UPPER MIOCENE)--Andesitic tuff breccia and associated intrusive rock. Crops out near Cappy Mountain. Age similar to unit Ta

CONTACT - Approximately located

VENT AREAS - Pyroclastic rocks, dotted pattern;
Intrusions, solid pattern

AREA OF CLAY ALTERATION

APPROXIMATE BOUNDARY OF WINDIGO-THIELSEN ROADLESS AREA

Table 1. Analytical data for stream-sediment samples from Windigo-Thielsen Roadless Area, Oregon. Analyses were performed by G. W. Day at the U.S. Geological Survey, Denver, Colorado. Locations of samples are shown on Figure 1. (Fe, Mg, Ca, and Ti in percent; all other elements in parts per million (ppm); N, not detected; L, detected, but below limit of determination; * identifies non-magnetic heavy-mineral fraction of pan-concentrate sample)

Field No.	Map No. (fig. 1)	Fe	Mg	Ca	Ti	Mn	B	Ba	Co	Cr	Cu	La	Ni	Pb	Sc	Sr	V	Y	Zr
WT 1A*	1	1	.5	10	.2	300	70	500	N	N	10	N	10	20	N	2000	20	N	200
WT 1B	1	7	5	5	1	3000	70	500	30	70	100	N	50	50	20	700	300	20	100
WT 2A*	2	2	.5	10	1.5	200	70	1000	10	N	30	70	20	150	15	2000	150	20	200
WT 2B	2	7	7	15	.7	3000	50	700	30	70	100	N	50	50	20	1000	200	30	100
WT 3A*	3	2	1	30	3	700	L	1000	N	150	L	150	20	50	20	5000	300	100	3000
WT 3B	3	10	10	15	1+	5000	70	700	30	100	100	N	50	50	30	700	300	30	100
WT 4B	4	10	5	5	1+	2000	100	700	30	100	100	N	50	70	20	700	200	20	150
WT 5A*	5	2	1	10	1	500	1000	700	10	50	15	N	20	100	10	2000	200	20	1000
WT 5B	5	15	10	10	1+	5000	100	500	30	100	100	N	70	50	30	500	200	30	100
WT 6A*	6	2	.7	10	.5	500	70	1000	10	N	20	N	15	150	L	2000	70	20	500
WT 6B	6	10	5	10	.7	2000	50	700	30	70	70	N	50	50	15	700	200	20	100
WT 9A*	9	2	1	15	.5	1000	50	1000	10	20	20	50	15	150	L	2000	100	50	1000
WT 9B	9	10	7	10	1+	2000	50	500	30	100	70	N	50	50	20	700	200	20	100
WT10A*	10	10	7	10	1+	3000	100	500	30	70	70	N	50	30	20	500	300	20	70
WT10B	10	1.5	.7	10	.7	500	20	700	10	N	20	50	10	50	10	2000	50	20	2000
WT11A*	11	2	.7	20	.7	500	L	1000	10	N	15	200	15	150	L	5000	100	30	500
WT11B	11	10	5	10	1+	2000	70	700	20	70	70	N	50	70	20	700	200	20	150
WT12A*	12	1	.5	20	.5	300	L	700	N	N	10	N	15	30	N	2000	50	N	100
WT12B	12	20	10+	20	1+	5000+	150	700	70	300	100	N	70	30	30	700	700	20	50
WT13A*	13	1.5	.5	7	.7	300	L	500	N	N	15	N	15	70	30	1500	70	N	100
WT13B	13	10	10	10	1+	3000	70	700	30	700	100	N	50	70	20	700	300	20	100
WT14A*	14	1.5	.5	10	.3	500	L	1000	N	N	10	N	10	70	L	2000	50	N	700
WT14B	14	7	7	5	1	2000	50	500	30	70	70	N	70	50	20	700	200	20	200
Lower limit of detection:		.05	.02	.05	.002	10	10	20	5	10	5	20	5	10	5	100	10	10	10

In addition to the elements listed above the following samples contained tin (WT6A, 30 ppm; WT9A, 50 ppm; WT11A, 30 ppm; WT13A, 30ppm), silver (WT5A, 2 ppm), zinc (WT9B, 200 ppm).

Looked for but below limit of detection (indicated in ppm in parentheses), except as noted above: gold (0.1), silver (0.5), arsenic (200), beryllium (1), bismuth (10), cadium (20), molybdenum (5), antimony (100), tin (10), thorium (100, and tungsten (1).