CARIBOU WILDERNESS AND TRAIL LAKE ROADLESS AREA, CALIFORNIA

By ALISON B. TILL,[1] U.S. GEOLOGICAL SURVEY, and

EDWARD L. MCHUGH, U.S. BUREAU OF MINES

SUMMARY

A mineral survey of the Caribou Wilderness and Trail Lake Roadless Area conducted in 1979 revealed no indications of a potential for mineral or fossil fuel resources in the areas. The wilderness is in the Cascade volcanic province, a setting locally favorable for geothermal resources, but no geothermal resource potential was identified in the wilderness or roadless area.

CHARACTER AND SETTING

The Caribou Wilderness and Trail Lake Roadless Area are part of Lassen National Forest, in northeast California. They are adjacent to the east boundary of Lassen Volcanic National Park and together are roughly 8.5 mi from north to south and 6 mi from east to west, a total of about 34 sq mi. Susanville, California, the nearest population center, is 25 mi to the east. Redding, California is 65 mi to the west.

Caribou Wilderness and Trail Lake Roadless Area lie within the southernmost part of the Cascade Range. The wilderness and roadless area are near the juncture of three major geologic provinces: the Cascade volcanic province, the Modoc plateau volcanic province, and the Sierra Nevada province of metamorphic and plutonic rocks. Geologic units within the area may be assigned to the High Cascade Volcanic series of Macdonald (1966), the post-Miocene rocks that form the crest of the Cascade Range. Oldest units of the High Cascade series are deeply eroded block-faulted lavas assigned a latest Pliocene age by Macdonald (1964). The lavas of the Caribou Wilderness and Trail Lake Roadless Area are less deeply eroded, less pervasively block faulted, and are probably Pleistocene to Holocene in age. The wilderness is a high plateau of Pleistocene basaltic andesite flows and basalt buttes. A thin veneer of glacial and lacustrine deposits occupies the central valley of the plateau. A Holocene basaltic cinder cone and flows that emanated from it sit on the north end of the plateau. The Trail Lake Roadless Area is on the east flank of the Caribou Wilderness. Rocks exposed there are the Pleistocene basaltic andesite which forms the high plateau of the Caribou Wilderness. Northwest of Silver Lake the wilderness and roadless area are physically separated by a vertical fault scarp as much as 150 ft high.

A light-medium-gray porphyritic basaltic andesite is the major unit in the wilderness and the only unit in the roadless area. It is a thick composite unit which includes flows and a subordinate volume of cinders erupted from numerous vents. The most prominent vents within the wilderness are North Caribou and South Caribou. Lavas erupted from Red Cinder overlie the basaltic andesite and are medium dark gray, sparsely porphyritic and glomeroporphyritic, and commonly platey and vesicular. Abundant red cinders cap the peak itself. The basaltic andesite and the basalt of Red Cinder have been glaciated. Both units are cut by near vertical faults trending roughly north south. A series of steep, talus-sided flat-topped buttes from 1/3- to 1/2-mi in diameter and as high as 300 ft are found in the central valley of the wilderness. They are composed of glassy olivine basalt, sit on the basaltic andesite, and were erupted along a roughly north-south trending line which is parallel to the vertical faults which cut the basaltic andesite. The general shape, limited lateral extent, glassy texture, and jointing perpendicular to the margins of the buttes are characteristics strongly suggestive of subglacial origin. The glacial deposits in the central valley of the wilderness consist of a thin veneer of ground moraine that is locally overlain by lacustrine deposits. The flows that emanate from Black Butte, a prominent cinder cone on the north boundary of the wilderness, are the youngest in the area. The flows are blocky, generally unvegetated, reddish gray, and 6 to 30 ft thick.

[1]With contributions from Clayton M. Rumsey, USBM.

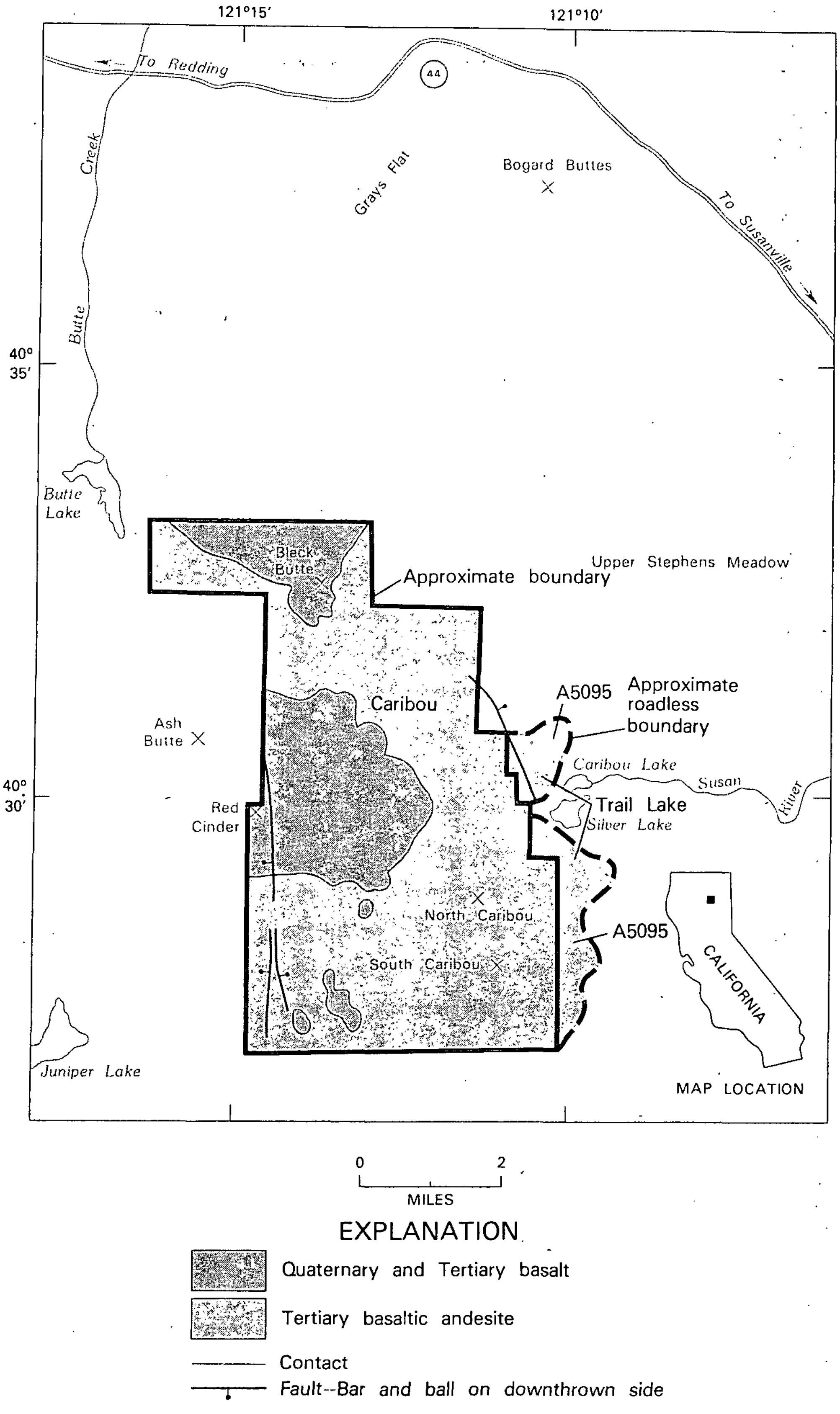


Figure 56.—Caribou Wilderness and Trail Lake Roadless Area, California.

MINERAL RESOURCES

Geologic mapping, geochemical sampling, and aeromagnetic surveys by the USGS and field assessment by the USBM have found little promise for the occurrence of metallic mineral or energy resources in the Caribou Wilderness and Trail Lake Roadless Area. Cinders, suitable for road metal, are locally abundant but difficult to access relative to more plentiful deposits outside of the wilderness. Hot springs, mineral sublimates from fumaroles, or other surface features indicating geothermal resource potential were not found. The wilderness is 1 mi northeast of the Morgan Springs Geothermal Resource Area (KGRA) that adjoins the south side of Lassen Volcanic National Park and more than 100 hot springs are known 7–15 mi west of the area (Waring, 1968, p. 20–21). Although known geothermal resources occur in the vicinity of Lassen Volcanic National Park, drilling is necessary to assess the geothermal resource potential of the Caribou Wilderness and Trail Lake Roadless Area.

No mining claims have been located, and no mines or prospects are known within the area studied. Mining for gold has occurred in Mesozoic granitic rocks in the Diamond Mountain gold district, 25 mi to the southeast, and in Mesozoic rhyolitic tuffs at Hayden Hill, 36 mi northeast of the wilderness and roadless area. Copper was mined 27 mi southeast of the area in the Plumas copper belt. Host rocks for these deposits are older than rocks of the Caribou Wilderness. In Lassen Volcanic National Park, the Supan Sulphur Works 15 mi west of the wilderness produced a small amount of sulfur before 1900 (Lydon, 1957, p. 616). The sulfur was deposited from hot gasses or water released at the Earth's surface. No sulfur was identified in the wilderness and roadless area.

Volcanic cinders have been mined from at least 14 sites within 10 mi of the wilderness. Most were used as road building material, railroad ballast, or as lightweight aggregate in concrete. Several million cubic yards of good quality cinders are available within the wilderness at Black Butte, Red Cinder, and other smaller cones, but abundant cinders are available at sources outside these areas.

Large volumes of basalt and andesite within the areas studied are potential sources of stone for construction uses. Quarries throughout the region have yielded undetermined quantities of stone, mostly used for road building and stone sources outside the wilderness, are sufficient to meet future needs.

SUGGESTION FOR FURTHER STUDIES

Further study of the wilderness and roadless area is not likely to identify mineral resources. The geologic setting is favorable for geothermal resources, but regional studies and drilling would be necessary to identify geothermal resource potential.

REFERENCES

Kane, Phillip, 1982, Pleistocene glaciation in Lassen Volcanic National Park: California Geology, v. 35, no. 5, p. 95–105.

Lydon, P. A., 1957, Sulfur and sulfuric acid, *in* Wright, L. A., editor, Mineral commodities of California: California Division Mines Bulletin 176, p. 613–622.

Macdonald, G. A., 1964, Geology of the Prospect Peak quadrangle, California: U.S. Geological Survey Geologic Quadrangle Map GQ-345, scale 1:62,500.

______1966, Geologic map of the Harvey Mountain quadrangle, Lassen County, California: U.S. Geological Survey Geologic Quadrangle Map GQ-443, scale 1:62,500.

Till, A. B., McHugh, E. L., and Rumsey, C. M., 1983, Mineral resource potential of the Caribou Wilderness and Trail Lake Roadless Area, Lassen and Plumas Counties, California: U.S. Geological Survey Open-File Report 83-481.

U.S. Geological Survey, 1978, Lands valuable for geothermal resources, northern California: Office of Area Geologist, Conservation Division, scale 1:500,000.

Waring, G. A., 1968, Thermal springs of the United States and other countries of the world—A summary: U.S. Geological Survey Professional Paper 492, 383 p.

Williams, Howel, 1932, Geology of the Lassen Volcanic National Park, California: University of California, Department of Geological Sciences Bulletin, v. 21, no. 8, p. 195–385.

LOST CREEK ROADLESS AREA, CALIFORNIA

By L. J. PATRICK MUFFLER, U.S. GEOLOGICAL SURVEY, and

HARRY W. CAMPBELL, U.S. BUREAU OF MINES

SUMMARY

Geologic and mineral-resource investigations in 1981–82 by the USGS and USBM identified no mineral-resource potential in the Lost Creek Roadless Area. Sand and gravel have been mined from alluvial flood-plain deposits less than 1 mi outside the roadless area; these deposits are likely to extend into the roadless area beneath a Holocene basalt flow that may be as much as 40 ft thick. An oil and gas lease application which includes the eastern portion of the roadless area is pending. Abundant basalt in the area can be crushed and used as aggregate, but similar deposits of volcanic cinders or sand and gravel in more favorable locations are available outside the roadless area closer to major markets. No indication of coal or geothermal energy resources was identified.

CHARACTER AND SETTING

The Lost Creek Roadless Area encompasses 13 sq mi of Lassen National Forest in Shasta County, north-central California, about 20 mi north of Lassen Peak. The nearest city is Redding, California, 50 mi to the southwest. Peripheral access is provided by State Highway 89 passing near the west boundary of the roadless area. The Pacific Crest Trail passes along the west margin of Hat Creek Rim adjacent to the east boundary of the roadless area. Most of the roadless area is a valley 3.5 mi wide, sloping from an altitude of 3800 ft at the south boundary to 3220 ft on the north. The Hat Creek Rim, along the east boundary of the roadless area, is a series of precipitous cliffs that rise to altitudes of nearly 4500 ft. Hat Creek flows from south to north not far from the west boundary of the roadless area. Lost Creek enters the valley from the southeast and disappears into the porous basalt and gravels near the Bidwell Ranch.

The Lost Creek Roadless Area lies just east of the crest of the Cascade Range in a major north-south-trending valley containing Hat Creek, the principal northerly drainage of the volcanic highlands 20 mi south near Lassen Peak. The valley is bounded on the east by the conspicuous young fault scarps of the Hat Creek Rim. Faults on the west side of the valley are inconspicuous; the valley can be considered to be an asymetric fault block tilted to the east and partly filled by alluvial material and volcanic rocks derived primarily from the south.

Rocks exposed in the hills to the west of the roadless area are a variety of locally derived andesite flows, faulted and partly eroded. No isotopic age determinations are available, but the degree of faulting and erosion is similar to andesite flows to the south, considered by Macdonald (1964) to be of Pliocene age. The andesite flows are stratigraphically beneath and significantly older than the dacite of Burney Mountain 10 mi to the west, dated at 240,000 years (G. B. Dalrymple, written commun.) by the potassium-argon method.

Rocks exposed on the fault scarps on the east side of the Hat Creek fault block comprise a series of low-potassium high-alumina olivine basalts correlative with those mapped by Macdonald (1964) as Burney Basalt south of the Lost Creek Roadless Area. Similar basalts are widespread over northeastern California east of the Cascade Range and probably range in age from Miocene to Quaternary. Although no isotopic ages are available for the Burney Basalt on the Hat Creek Rim and stratigraphic relationships are not clear, Macdonald's (1964) assignment of the Burney Basalt in the roadless area to the early Pleistocene is accepted.

Geologic units exposed in the Hat Creek fault block are all very young. A few miles north of the Lost Creek Roadless Area is Cinder Butte, a small shield volcano of mafic andesite showing very rugged topography unmodified by erosion but cut by one branch of the young fault system along the Hat Creek Rim. The vent

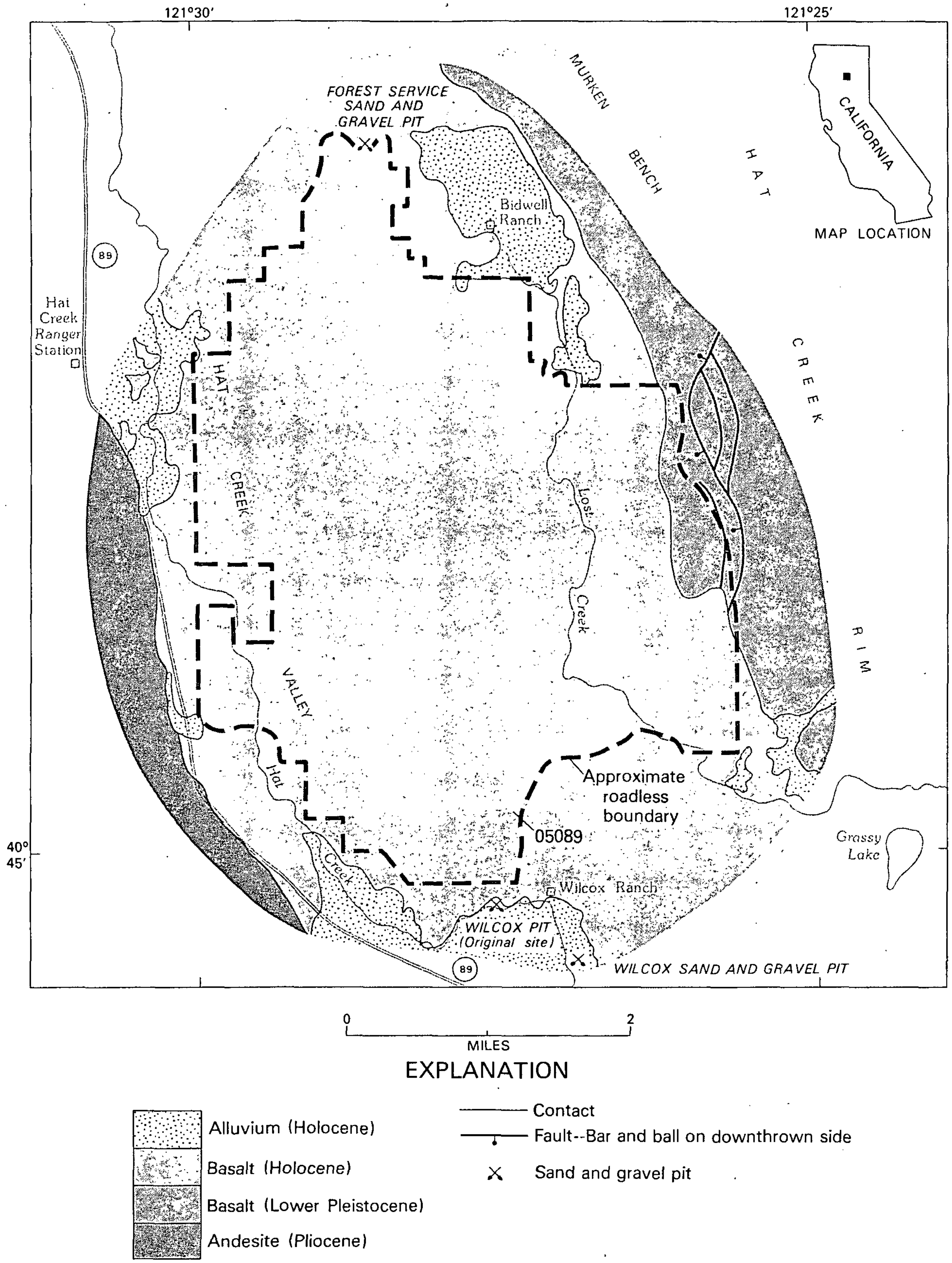


Figure 82.—Lost Creek Roadless Area, California.

areas of this shield volcano lie 2 to 3 mi north of the northernmost part of the Lost Creek Roadless Area. Coarse fluvial gravel and sand at least 30 ft thick are exposed in the Wilcox sand and gravel pit about 0:5 mi southeast of the Lost Creek Roadless Area.

The clasts in the gravel are well rounded and consist of a wide variety of volcanic rocks ranging in composition from basalt to dacite. These rocks are probably all derived from the highlands to the south in and adjacent to Lassen Volcanic National Park. At the deepest part of the gravel pit there are a few angular boulders of olivine basalt, interpreted as the top of a basalt flow underlying the gravel. This basalt has no natural exposures, and its extent and age are unknown.

Overlying the fluvial gravel and sand is the Hat Creek lava flow, a low-potassium high-alumina olivine basalt which flowed north from vents near Old Station, 8 mi south of the southern boundary of the Lost Creek Roadless Area (Anderson, 1940; Macdonald, 1964). The distal extremity of the lava flow is 6 mi north of the Lost Creek Roadless area. The Hat Creek lava flow has a rugged blocky surface with local relief of as much as 20 ft. The thickness of the flow is uncertain, but is unlikely to exceed 40 ft except where the basalt was ponded locally. Conspicuous on the east side of the flow are lava slump scarps, where the cooled crust of the lava slumped westward over the fault scarps of the Hat Creek Rim as underlying still-liquid lava drained to the northwest (Finch, 1933; Anderson, 1940).

The Hat Creek lava flow is almost certainly Holocene in age; preliminary analysis of paleomagnetic secular variation suggest an age of approximately 5000 years (Duane Champion, oral commun., 1982).

Overlying the Hat Creek lava flow and the fluvial gravel and sand are patches of Holocene alluvium, in part interlayered with silicic ash derived from the pyroclastic eruptions that accompanied the extrusion of the Chaos Crags domes in Lassen Volcanic National Park 1050 years ago. The ash commonly has been reworked and winnowed by wind action.

MINERAL RESOURCES

No potential for metallic mineral occurrences was identified in or adjacent to the Lost Creek Roadless Area. An oil and gas lease application is pending that includes the eastern part of the roadless area. No indication of coal or geothermal energy resources was found. The roadless area lies in an area of pronounced low heat-flow caused by regional movement of cold ground water north from the volcanic highlands near Lassen Peak (Mase and others, 1982, fig. 7). Although the Hat Creek basalt flow is indeed very young, its vent area is 8 mi south of the Lost Creek Roadless Area; any thermal energy in the flow itself has long since dissipated.

Significant sand and gravel deposits occur adjacent to the roadless area; the Wilcox sand and gravel pit about 0.5 mi to the southwest is an important source of construction aggregate for the region. This deposit is older than the Hat Creek lava flow and likely extends to the north for an unknown distance under the flow. Utilization of any gravels under the flow, however, would be subject to the necessity of removing the very resistant basalt cover. The basalt itself could be crushed and used as aggregate, but could not compete with volcanic cinders and sand and gravel that are readily available outside the roadless area. Similar considerations would apply to the possible use of the basalt for dimension stone.

SUGGESTIONS FOR FURTHER STUDIES

No further mineral-resource studies are suggested.

REFERENCES

Anderson, C. A., 1940, Hat Creek Lava Flow: American Journal of Science, v. 238, no. 7, p. 477–492.

Campbell, H. W., and Muffler, L. G. P., 1983, Mineral resource potential of Lost Creek Roadless Area, Shasta County, California: U.S. Geological Survey Open-File Report 83-508.

Finch, R. H., 1933, Slump scarps: Journal of Geology, v. 41, no. 6, p. 647–649.

Macdonald, G. A., 1964, Geology of the Prospect Peak Quadrangle, California: U.S. Geological Survey Geological Map, GQ-345.

Mase, C. W., Sass, J. H., Lachenbruch, A. H., and Munroe, R. J., 1982, Preliminary heat-flow investigations of the California Cascades: U.S. Geological Survey Open-File Report 82-150, 240 p.

MOUNT SHASTA WILDERNESS STUDY AREA, CALIFORNIA

By ROBERT L. CHRISTIANSEN[1], U.S. GEOLOGICAL SURVEY, and

ERNEST T. TUCHEK, U.S. BUREAU OF MINES

SUMMARY

The Mount Shasta Wilderness study area was surveyed in 1975. It lies wholly on the slopes and summit area of Mount Shasta and consists almost entirely of the products of geologically young volcanism. Small deposits of volcanic cinders and pumice are present. The volcanic system of Mount Shasta is judged to have probable resource potential for geothermal energy but that potential is least within the wilderness study area boundaries. Because any geothermal energy resource beneath the volcano would lie at considerable depths, exploration or development would be most likely at lower altitudes on the gentler slopes outside the study area.

CHARACTER AND SETTING

Mount Shasta is the largest high conical volcano of the Cascade Range. The volcano rises to 14,162 ft, far above its 3000-ft base and the generally 5000–8000-ft mountains of the region, making it the dominant natural feature of northern California. The communities of Weed, Mount Shasta, and McCloud lie at the base of the mountain, and Interstate Highway 5 and U.S. Highway 97 flank it on the west and north. Other state highways and unpaved roads provide access to the wilderness study area from all sides. The study area occupies mainly the upper slopes of the mountain near and above timberline, which is generally at about 9500 ft; on the northwest, the study area extends to near the level of the Southern Pacific Railroad at about 5000 ft.

The volcanic edifice of Mount Shasta grew by the successive eruptive emplacements of hundreds of lava flows and by associated mudflows and other fragmental deposits in at least four, and probably more, major cone-building episodes. Growth of the volcano has been geologically recent, having occurred within about the past 500,000 years; most of the present edifice has grown since about 250,000 years ago. The two youngest major cone-building episodes occurred within the past 10,000 years. During those last 10,000 years, significant eruptions have occurred on the average of at least once every 800 years; during the past 4500 years they have occurred about once every 600 yrs (Miller, 1980). The youngest known eruptions probably occurred during the latter half of the 18th century. Two areas of small sulfurous fumaroles (steam vents) occur near the summit of the volcano, and one of them includes a small acid hot spring.

Throughout its evolution, during times between the major cone-building episodes, Mount Shasta has erupted dacites, lavas whose compositions are commonly thought to reflect the residence of magmatic liquids at relatively high levels in the Earth's crust for considerable periods of time. Intermittent volcanic eruptions during the generally erosional periods between major cone-building episodes also produced several small cinder cones and moderately extensive deposits of pumice.

An aerial survey of the Earth's magnetic field in the area of Mount Shasta indicates a significant linear structural control for some eruptive vents of the volcano along a north-trending zone through the summit. Interpretation of the magnetic-field variations also indicates that a zone beneath the main summit area of the volcano induces a smaller field intensity than would be expected if the entire volcanic edifice were uniformly magnetized (Blakely and Christiansen, 1978).

MINERAL RESOURCES

Metallic mineral resources are commonly found to be associated with the formerly deeply buried parts of old volcanic systems that may once have been similar to

[1]With contributions from Frank J. Kleinhampl and Richard J. Blakely, USGS, and Fredrick L. Johnson and Martin D. Conyac, USBM.

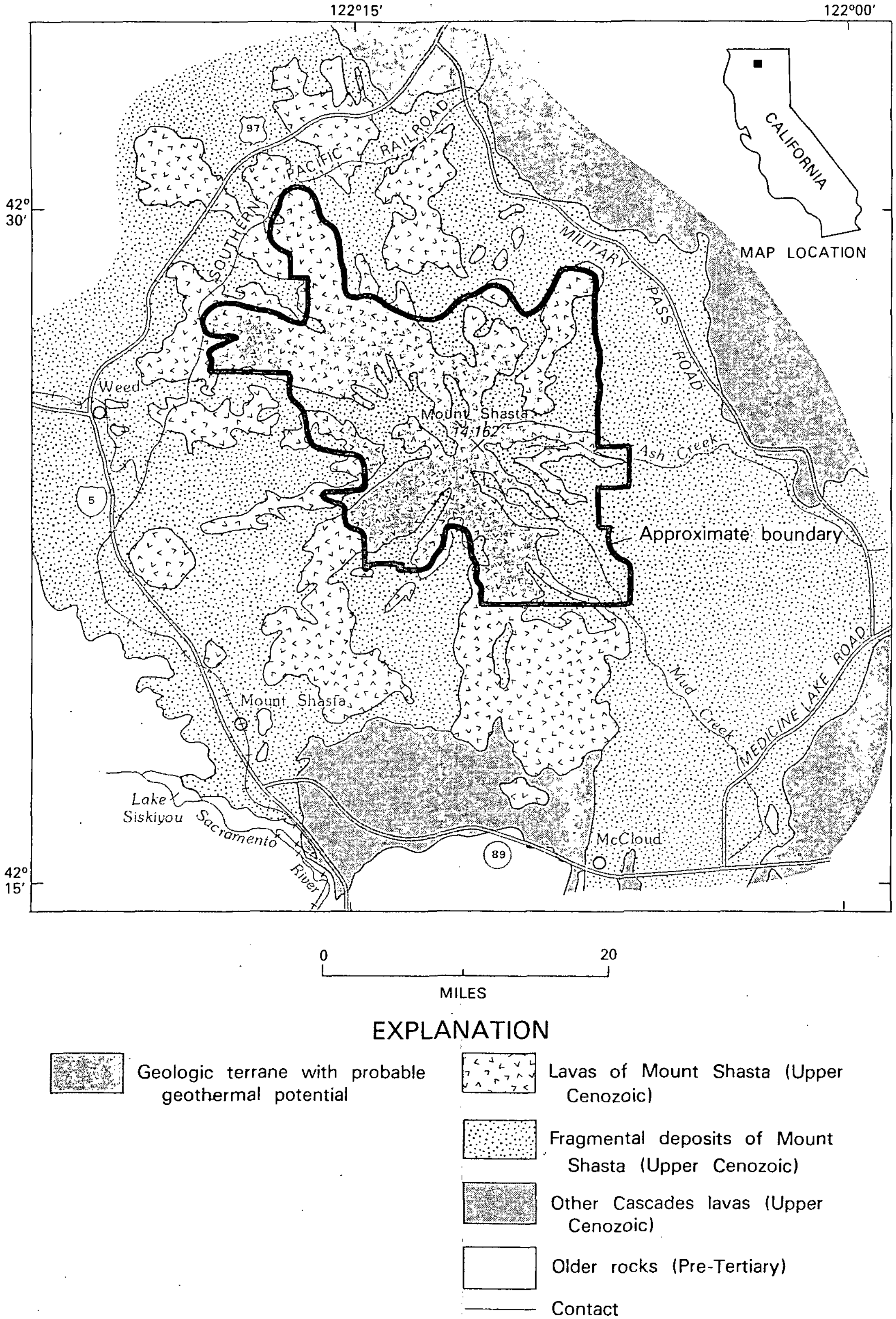


Figure 90.—Mount Shasta Wilderness study area, California.

Mount Shasta. Such metallic deposits, however, generally are accessible to development only after deep erosion has removed much or all of the surficial volcanic edifice, exposing rocks of types that would now lie many thousands of feet below the surface of Mount Shasta. Young volcanoes of this type, even where they have been altered by hydrothermal activity (the hot waters and volcanic gases that can transport metallic constituents in solution), are typically barren of significant mineral deposits. Small areas of intense but localized hydrothermal alteration have been recognized near the original central vents of the four recognized cone segments of Mount Shasta but virtually nowhere else. Metallic trace elements are nowhere found to be significantly above background values (Christiansen and others, 1977). Parts of the wilderness study area have been prospected previously for mineral deposits, and three unworked prospects were located in the area. No resources were found.

Although there are several cinder cones on the lower flanks of the volcano, very few of them occur within the wilderness study area. Minor deposits of cinders and moderately extensive pumice do occur, but they lie on steep slopes and are accessible only with difficulty while more extensive deposits are readily accessible nearby.

A probable resource potential is judged to exist within the study area for geothermal energy. The geologic elements necessary for commercial development of geothermal resources are a source of heat within the Earth, water to provide a medium for the transferral of heat from its source to a point of extraction, and an aquifer or some suitable structure to control the appropriate subsurface movement of this hydrothermal fluid. Several factors suggest that a suitable geothermal heat source exists beneath Mount Shasta: volcanic activity has been intermittent for about 500,000 years, the most recent activity has been within about the past 200 years, magma-filled chambers probably have formed repeatedly at high crustal levels beneath the volcano to produce its dacitic lavas, fumaroles remain active near the summit of the volcano, and the anomalously low magnetic intensity of the summit zone may reflect a high temperature at shallow depth beneath that part of the volcano (Blakely and Christiansen, 1978).

Despite the likely presence of a heat source, several factors are unfavorable for the occurrence of geothermal energy at Mount Shasta. The volcanic edifice itself consists mainly of highly fractured or porous materials that generally retain ground water only poorly, and meltwater from the extensive winter snowfields of the mountain percolate readily downward. Consequently, few permanent streams drain the slopes of the volcano, and only parts of two of them, Mud Creek and Ash Creek on the south and east flanks, maintain substantial year-round flows. Thus, the shallow parts of the volcanic system are readily flushed by downward-percolating cold waters. There are no hot springs other than the small one near the summit, and no other significant manifestations of hot water at shallow depths are known in or immediately around the volcano. Thus, if a hidden geothermal system exists, it would not likely be high within the volcanic edifice itself but rather within the Earth's crust beneath it. It could be investigated only by deep drilling, and such drilling would be difficult or impractical from the high altitudes or the steep and unstable slopes typical of the parts of the mountain where most of the wilderness study area lies.

SUGGESTIONS FOR FURTHER STUDIES

Further studies within the Mount Shasta Wilderness study area are unlikely to reveal significant new information on its mineral-resource potential. The only important potential judged to exist—for geothermal energy—probably is least within the wilderness study area. The potential for geothermal resources, both within the study area and in the larger area around the lower flanks of Mount Shasta, probably can best be evaluated by further work in the surrounding area. Ultimately, only drilling can test the geothermal resource potential definitively, but careful chemical and isotopic studies of surface and subsurface waters around the base of the volcano might shed additional light on the possibility that hydrothermal waters circulate actively beneath and around the volcano.

REFERENCES

Blakely, R. J., and Christiansen, R. L., 1978, The magnetization of Mount Shasta and implications for virtual geomagnetic dipoles determined from seamounts: Journal of Geophysical Research, v. 83, p. 5971–5978.

Christiansen, R. L., Kleinhampl, F. W., Blakely, R. J., Tuchek, E. T., Johnson, F. L., and Conyac, M. D., 1977, Resource appraisal of the Mount Shasta Wilderness study area, Siskiyou County, California: U.S. Geological Survey Open-File Report 77-250, 53 p.

Miller, C. D., 1980, Potential hazards from future eruptions in the vicinity of Mount Shasta volcano, northern California: U.S. Geological Survey Bulletin 1503, 43 p.

THOUSAND LAKES WILDERNESS, CALIFORNIA

By ALISON B. TILL,[1] U.S. GEOLOGICAL SURVEY, and

EDWARD L. MCHUGH, U.S. BUREAU OF MINES

SUMMARY

A mineral survey conducted by the USGS and USBM in 1979 of the Thousand Lakes Wilderness in northern California indicated little promise for the occurrence of mineral resources. Volcanic stone and cinders occur, but similar materials are found in abundance outside the wilderness. The wilderness is in the Cascade Volcanic Province, a setting locally favorable for geothermal resource potential. No geothermal potential was identified in the wilderness; subsurface potential cannot be evaluated without regional studies and drilling.

CHARACTER AND SETTING

Thousand Lakes Wilderness, an area of about 25.5 sq mi, is located about 50 mi east of Redding and 12 mi south of Burney, in eastern Shasta County, California. The wilderness is part of Lassen National Forest, and is roughly 5 mi from north to south and 6 mi from east to west. The wilderness is on the crest of the Cascade Mountains and is dominated by a deeply eroded composite volcano. This volcano is the major volcanic edifice between Lassen Peak and Mount Shasta. Crater Peak, Magee Peak, and Fredonyer Peak are all on the volcano which will be called Crater-Magee volcano in this report. North and east of Crater-Magee volcano is the Thousand Lakes valley, which is at the center of the wilderness. Many small lakes are scattered in the valley between altitudes of 5600 and 8677 ft. Small Pleistocene shield volcanoes and Holocene flows and cinder cones are on the north and east sides of the wilderness. The Thousand Lakes valley is forested; peaks above the valley floor are generally free of vegetation.

Thousand Lakes Wilderness is in the southern part of the Cascade Volcanic Province (Macdonald, 1966), a belt of Tertiary to Quaternary volcanic centers that extends from southern British Columbia to northern California. The wilderness is 60 mi southeast of Mount Shasta and 18 mi northwest of Lassen Peak.

The bedrock in the wilderness is composed of volcanic rocks of Tertiary and Quaternary age. The oldest rocks exposed are pyroxene andesite of late Pliocene age (Macdonald, 1963). The pyroxene andesite is composed of a thick sequence of flows, is regionally extensive, and is considered the basement rock of the area. Younger (Pleistocene) shield and composite volcanoes overlie these flows. In the Thousand Lakes Wilderness, andesitic lavas of Crater Peak, Magee Peak, Fredonyer Peak, Freaner Peak, and Logan Mountain rest on the pyroxene andesite. Several faults in a north-northwest trending system of vertical to steeply dipping faults subsequently cut the flows in the northern and eastern part of the wilderness. During Holocene time, basalt and andesite flows emanated from cinder cones spaced along the fault system. These young flows occupy valleys along the east side of the wilderness. The youngest flow, the Devil's Rock Garden, extends across the south boundary of the wilderness.

MINERAL RESOURCES

No metallic mineral deposits are known in the Thousand Lakes Wilderness; nonmetallic deposits, consisting mainly of stone and cinders occur in the wilderness. A geochemical study revealed no significant anomalous values of metallic elements. An aeromagnetic survey showed no anomalies that suggest the existence of mineral deposits.

No mining claims or prospects exist within the wilderness. No nearby metallic mineral deposits occur in the type of rocks found within the wilderness. Gold and silver were produced before 1934 from altered Cenozoic rhyolitic tuff at Hayden Hill, 50 mi northeast of the wilderness. The more mafic Cenozoic rocks within

[1]With contributions from Clayton M. Rumsey, USBM.

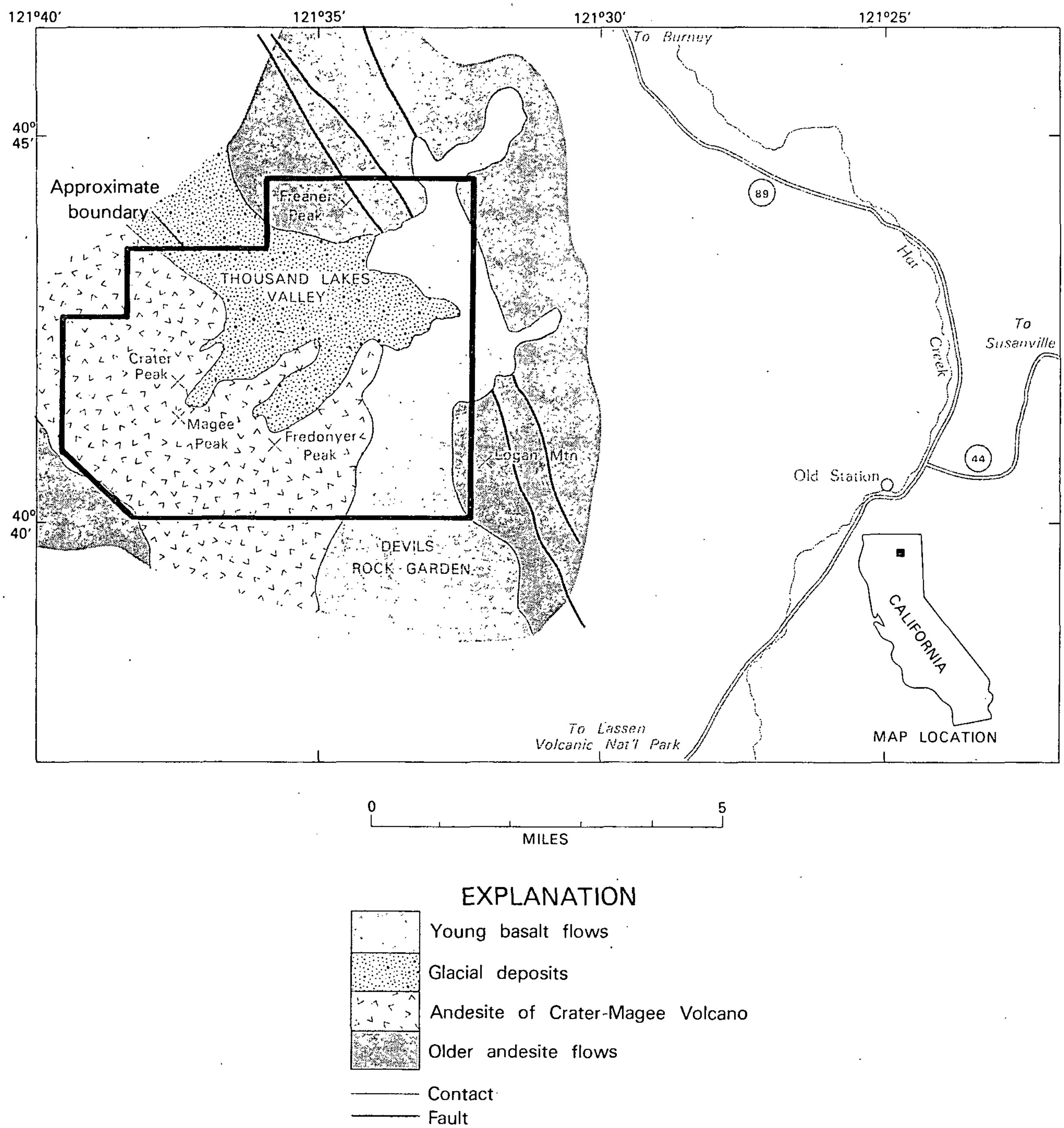


Figure 113.—Thousand Lakes Wilderness, California.

the wilderness contain no analogous alteration. Gold, silver, copper, lead, and zinc have been mined from Mesozoic metavolcanic and sedimentary rocks 15-20 mi to the west, but similar mineralized rocks do not occur within the wilderness. Coal, diatomite, and sulfur were also produced in the region but are not found in the wilderness.

The Thousand Lakes Wilderness is in a region recognized as having potential for geothermal resources (U.S. Geological Survey, 1978). Hot springs are known some 10 mi north along the Pit River, and south of the wilderness. To the south, geothermal activity occurs at several places within Lassen Volcanic National Park. The Morgan Springs Known Geothermal Resource Area (KGRA) along the south side of the park is 17 mi south of the wilderness. No geothermal resource potential was identified in the wilderness and further study and drilling would be required to fully identify any geothermal potential.

Mineral resources within the Thousand Lakes Wilderness are limited to volcanic stone and cinders. Large volumes of good quality basaltic cinders occur throughout the area and cinders from nearby sources have been used in road building, for railroad ballast, and as lightweight aggregate. The hard, dense, and partly vesicular dark-gray andesite at Freaner Peak, Logan Mountain, and Devil's Rock Garden could provide large volumes of stone for construction. Plentiful and more accessible deposits of both volcanic stone and cinders, however, are available at several developed sites within 20 mi of the wilderness closer to markets (Lydon and O'Brien, 1974, p. 144-147).

SUGGESTIONS FOR FURTHER STUDIES

Further study of the wilderness is not likely to identify metallic mineral or fossil fuel resource potential; the regional geologic setting, however, is favorable for geothermal resources. No surface indications of geothermal resources exist in the wilderness, so regional studies and drilling would be necessary to identify the potential.

REFERENCES

Lydon, P. A., and O'Brien, J. C., 1974, Mines and mineral resources of Shasta County, California: California Division of Mines and Geology, County Report 6, 154 p.

Macdonald, G. A., 1963, Geology of the Manzanita Lake quadrangle, California: U.S. Geological Survey GQ-248.

_____1966, Geology of the Cascade Range and Modoc Plateau, *in* Bailey, E. H., ed., Geology of northern California: California Division of Mines and Geology, Bulletin 190, p. 65-96.

Till, A. B., McHugh, E.L., and Rumsey, C. M., 1983, Mineral resource potential of the Thousand Lakes Wilderness: U.S. Geological Survey Open-File Report 83-408.

U.S. Geological Survey, 1978, Lands valuable for geothermal resources, northern California: Office of Area Geologist, Conservation Division, scale 1:500,000.

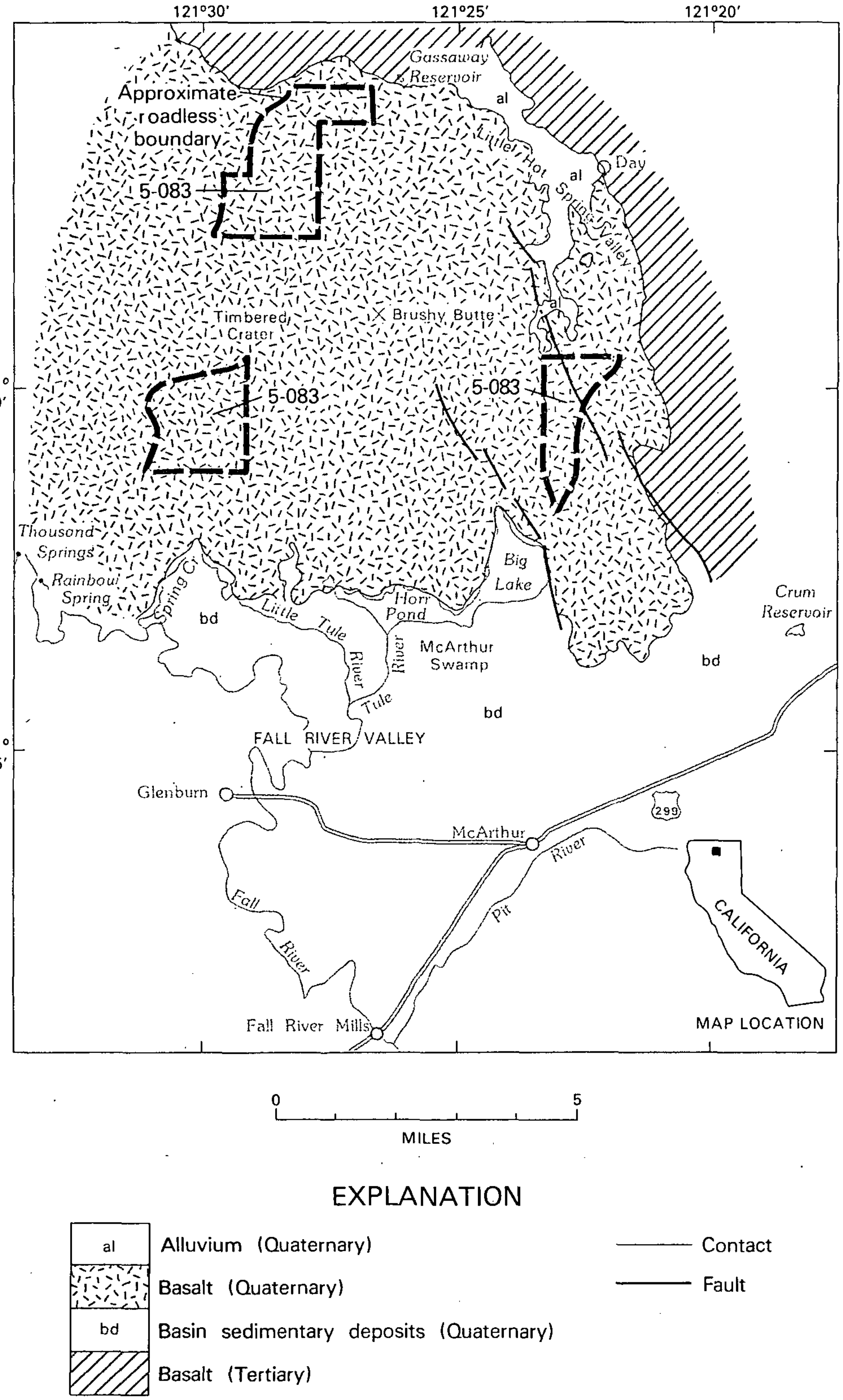


Figure 114.—Timbered Crater Roadless Area, California.

TIMBERED CRATER ROADLESS AREA, CALIFORNIA

By JOCELYN A. PETERSON,[1] U.S. GEOLOGICAL SURVEY, and

LEON E. ESPARZA, U.S. BUREAU OF MINES

SUMMARY

A mineral survey of the Timbered Crater Roadless Area conducted in 1979 indicated that the area has little or no promise for the occurrence of energy and mineral resources. Lava flows in the southern two segments of the roadless area contain large quantities of rubble that could be used in local construction projects. Further exploration in the area is unlikely due to the unfavorable geologic setting.

CHARACTER AND SETTING

The Timbered Crater Roadless Area occupies three small segments of land totaling about 7 sq mi in Siskiyou and Shasta Counties, 75 mi northeast of Redding, California. The area is about 20 mi south of the Medicine Lake Highland, the source for some of the lava flows found in the area. The towns of Fall River Mills and McArthur lie about 8 mi south of the roadless area along U.S. Highway 299. Altitudes in and near the area range from about 3300 ft to 3981 ft and the area is characterized by rough often barren lava flows.

The Fall River valley in which the Timbered Crater Roadless Area is located is a structural graben about 30 mi long and 15 mi wide in the vicinity of the study area (Peterson and Martin, 1980). The southern part of the graben is filled by lake sediments. Further north in the graben these sediments are covered by Quaternary basalt flows. Springs emanate from the southern toes of these basalts, 1–2 mi south of the roadless area.

The Quaternary basalts are divided into three groups based on age and source area, but they all have similar trace-element chemistry and petrography (Peterson, 1980; Peterson and Martin, 1980); these basalts have been combined into one unit for this report but are briefly described. The oldest group consists of possible Pleistocene basalt flows erupted from Timbered Crater which now are covered by a deep red soil and heavy vegetation. The second group of flows had its origin in the Medicine Lake Highland area sometime in the Holocene. The lava was apparently very fluid and able to flow down the pre-existing graben. The youngest basalt group consists of a small Holocene shield complex that erupted from several vents in the vicinity of Brushy Butte between the three segments of the roadless area.

MINERAL RESOURCES

Between the late 1940's and 1971, flat lava decorative stone was removed from the vicinity of the Timbered Crater Roadless Area but further removal was banned by the U.S. Bureau of Land Management and USFS to protect local archeological sites. Recorded production of flat lava in the vicinity was 1700 tons, but twice that amount may actually have been removed. Geochemical and geophysical data (Peterson, 1980; Griscom, 1981) do not indicate the presence of any metallic commodities. Warm springs northeast of the area may indicate some geothermal potential but recorded temperatures are inadequate for power production.

Based on the above discussion, it is concluded that the Timbered Crater Roadless Area has little promise for the discovery of energy and mineral resources. Some basalt rubble is present that could be used in the construction industry.

SUGGESTIONS FOR FURTHER STUDIES

It is unlikely that further studies in the area would discover any additional mineral resources.

[1]With contributions from Linda M. Martin, USGS, and Gary J. Cwick, USBM.

REFERENCES

Griscom, Andrew, 1981, Map showing aeromagnetic interpretation of the Baker-Cypress BLM Instant Study Area and Timbered Crater Forest Service Further Planning Areas, Modoc, Shasta, and Siskiyou Counties, California: U.S. Geological Survey Miscellaneous Field Studies Map MF-1214-C, scale 1:62,500

Peterson, J. A., 1980, Geochemical analyses and geochemical rock sample location map for the Baker-Cypress Area, California: U.S. Geological Survey Open-File Report 80-197, 4 p., scale 1:62,500.

Peterson, J. A., and Martin, L. M., 1980, Geologic map of the Baker-Cypress BLM Roadless Area and Timbered Crater Rare II Areas, Modoc, Shasta, and Siskiyou Counties, northeastern California: U.S. Geological Survey Miscellaneous Field Studies Map MF-1214-A, scale 1:62,500.

Peterson, J. A., Martin, L. M., Esparza, L. E., and Cwick, G. J., 1981, Mineral resource potential of the Baker-Cypress Instant Study Area and Timbered Crater Forest Service Further Planning (RARE II) Areas, Modoc, Shasta, and Siskiyou Counties, California: U.S. Geological Survey Miscellaneous Field Studies Map MF-1214-B, scale 1:62,500.

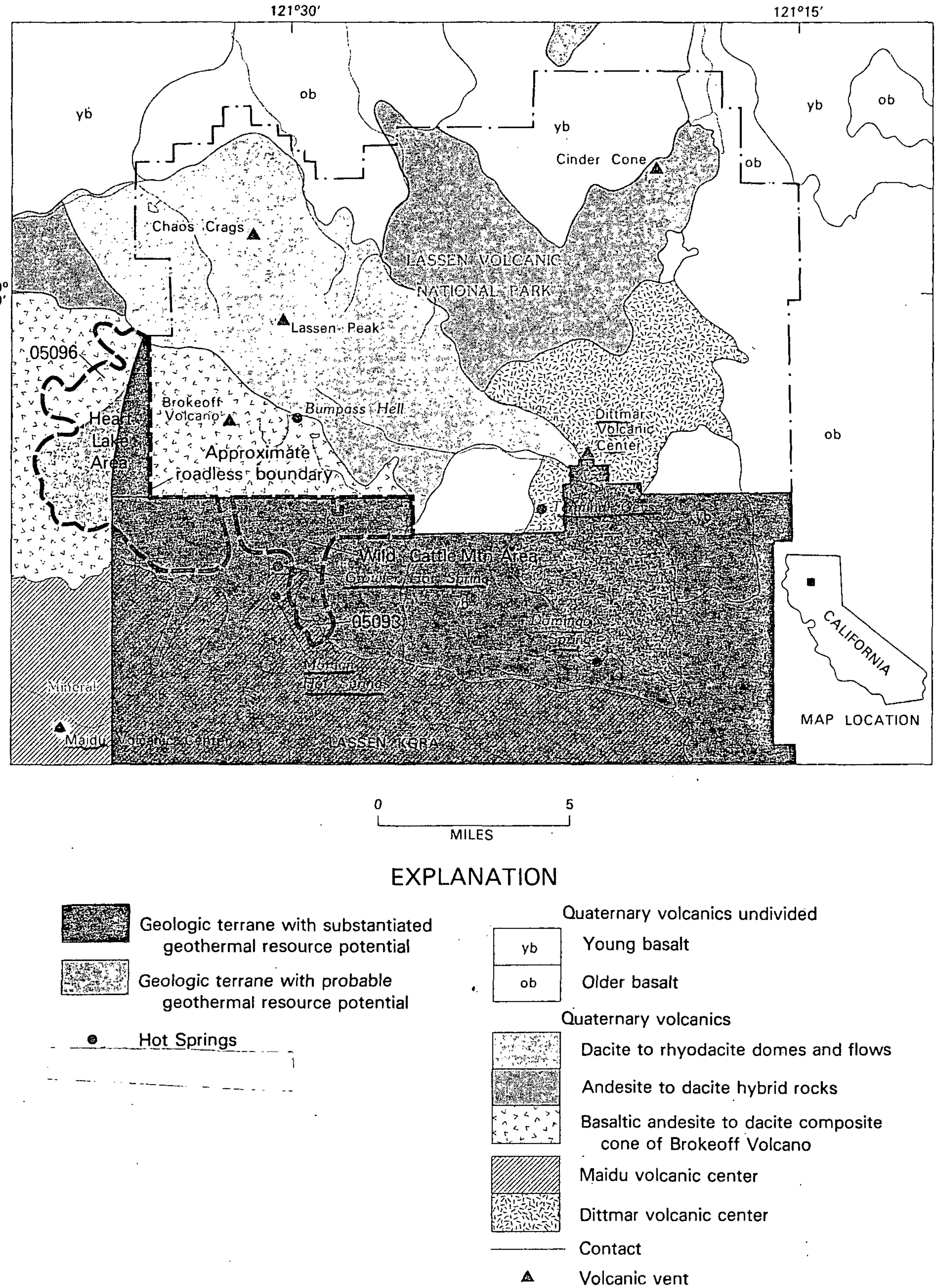


Figure —Wild Cattle Mountain and Heart Lake Roadless Areas, California.

WILD CATTLE MOUNTAIN AND HEART LAKE ROADLESS AREAS, CALIFORNIA

By L. J. PATRICK MUFFLER,[1] U.S. GEOLOGICAL SURVEY, and

DAVID K. DENTON, JR., U.S. BUREAU of MINES

1984

SUMMARY

The results of geologic, geochemical, and geophysical surveys in Wild Cattle Mountain and Heart Lake Roadless Areas in 1982 indicate little promise for the occurrence of metallic, nonmetallic, or fossil fuel resources. However, Wild Cattle Mountain Roadless Area and part of Heart Lake Roadless Area lie in Lassen Known Geothermal Resources Area, and noncompetitive geothermal lease applications have been filed on much of the rest of Heart Lake Roadless Area outside the KGRA. Both areas are adjacent to Lassen Volcanic National Park. Geochemical and geologic data indicate that the thermal manifestations in the Park and at Growler and Morgan Hot Springs just southwest of Wild Cattle Mountain Roadless Area are part of the same large geothermal system. Consequently, the entire Wild Cattle Mountain Roadless Area and part of the Heart Lake Roadless Area have a substantiated geothermal resource potential; the rest of the Heart Lake Roadless Area has a probable geothermal resource potential.

CHARACTER AND SETTING

Wild Cattle Mountain and Heart Lake Roadless Areas are in the southernmost part of the Cascade Range of northern California; the areas are about 45 mi east of Redding, and are in Lassen National Forest. The roadless areas, which were studied by Muffler, Clynne, and Cook (1982), and Denton and Graham (1983) are contiguous to the north and east with Lassen Volcanic National Park (LVNP) and lie partly within the Lassen Known Geothermal Resources Area (Lassen KGRA). Wild Cattle Mountain Roadless Area comprises 8.5 sq mi at altitudes between 4960 and 7680 ft, and Heart Lake Roadless Area comprises 14 sq mi at altitudes between 5600 and 7555 ft. Access to the areas is along a network of USFS gravel roads from California Highways 36 and 89.

Wild Cattle Mountain and Heart Lake Roadless Areas lie on the southeast and southwest flanks, respectively, of Brokeoff Volcano, an eroded andesitic composite volcano formed between 0.6 and 0.35 million years ago. Remnants of Brokeoff Volcano are overlain on the northeast by an extensive field of upper Pleistocene and Holocene dacites and andesites; historic volcanic eruptions occurred in 1915–1917 at the summit of Lassen Peak and in 1851 at Cinder Cone.

To the south, the Brokeoff Volcano overlaps older volcanic rocks of the Maidu Volcanic Center, formed 1.8 million years to 0.8 million years ago, which in turn overlaps the Pliocene Tuscan Formation, a sequence of andesitic breccias and flows that crops out extensively on the northeastern side of the Sacramento Valley. The nature of the basement under the central and northeastern parts of the Maidu Volcanic Center is uncertain; Cretaceous marine sedimentary rocks (the Chico Formation) and Mesozoic granitic and metamorphic rocks are exposed sporadically in canyons to the south, and Mesozoic granitic and metamorphic rocks crop out extensively in the northernmost Sierra Nevada 19 mi to the southeast (Lydon and others, 1960). These granitic and metamorphic rocks probably underlie the volcanic rocks of the region around LVNP to appear again to the northwest in the Klamath Mountains.

Regional geologic structure south and southeast of LVNP is dominated by northwest-trending high-angle faults, none of which are expressed in the young volcanic rocks of the Wild Cattle Mountain and Heart

[1]With contributions from Michael A. Clynne and Amy L. Cook, USGS.

Lake Roadless Areas. North of LVNP, faulting trends northerly; this direction is also expressed by a line of small basaltic cinder cones just east of the Wild Cattle Mountain Roadless Area.

All of Wild Cattle Mountain and Heart Lake Roadless Areas has been glaciated, and till of Tahoe and Tioga ages (Pleistocene) cover most of both roadless areas.

MINERAL RESOURCES

No metallic mineral or fossil fuel resources are known in either the Wild Cattle Mountain or Heart Lake Roadless Areas, and geochemical analyses of stream sediments revealed no anomalously high metal values.

The region around Lassen Volcanic National Park (LVNP) has long been recognized for its geothermal potential (Renner and others, 1975; Brook and others, 1979), and an area of 141 sq mi just south of LVNP is classified as a Known Geothermal Resources Area (KGRA) (Godwin and others, 1971). This classification was based on the extensive vapor-dominated thermal manifestations to the north in LVNP and on the boiling silica- and chloride-bearing thermal waters at Morgan and Growler Hot Springs.

Geologic observations, thermodynamic considerations, and extensive geochemical data on thermal waters and gases suggest that the fumarole areas within LVNP amd the hot springs at Morgan and Growler Hot Springs are parts of a single large geothermal system whose focus and major thermal upflow is under Bumpass Hell in LVNP (Muffler, Nehring, and others, 1982). Cold meteoric water percolates into Brokeoff Volcano in LVNP, flows underground, and is heated by a cooling igneous intrusion related to the silicic volcanic activity of the past 0.25 million years. Geothermal liquid at approximately 235°C at depth boils to form an overlying vapor-dominated reservoir, steam from which leaks upward to feed the fumaroles in LVNP. Part of the geothermal water flows laterally to the south to feed the Morgan and Growler Hot Springs and to the southeast where it is encountered in the Walker "O" No. 1 well at Terminal Geyser.

This model for the Lassen geothermal system is consonant with the data on mercury and other trace elements in the superficial deposits (soils, muds, and alteration halos) of LVNP and vicinity (Varekamp and Buseck, 1983). In particular, the mercury anomaly that extends southerly down Mill Creek appears to be due, at least in part, to the addition of mercury accompanying steam that boils off the hot thermal water moving to the south from the center of the geothermal system.

Nine shallow heat-flow holes have been drilled in Lassen KGRA (Mase and others, 1980). High gradients at depth in several holes suggest that thermal water may extend under much of the northern part of Lassen KGRA, which includes all of the Wild Cattle Mountain Roadless Area, and the southeastern one-third of the Heart Lake Roadless Area. This suggestion is supported by the detection of a minor thermal component in chemical analyses of cold waters from Domingo Spring (Thompson, 1982).

Several types of geophysical surveys have been conducted in Lassen KGRA (Christopherson, 1980; Christopherson and others, 1980; Christopherson and Pringle, 1981; Fraser, 1983). These surveys all display a complex pattern of resistivity reflecting primarily near-surface variations in lithology, porosity, and temperature. The known thermal areas in and adjacent to LVNP all show up as resistivity lows. Other conspicuous resistivity lows, however, may merely indicate near-surface porous aquifers in alluvium, glacial deposits, and young basalts.

In summary, geologic, geochemical, and geophysical evidence indicates a single geothermal system centered on the Bumpass Hell area of LVNP. The system consists of a vapor-dominated reservoir within LVNP and hot-water outflow to the south along Mill Creek and to the southeast to Terminal Geyser. The high thermal gradients at depths greater than 300 ft in several heat-flow holes suggest that this lateral flow of hot water may not be confined only to the valleys extending south and southeast from Brokeoff Volcano. Instead, the entire Wild Cattle Mountain Roadless Area could be underlain by thermal waters, and the area have a substantiated potential for geothermal resources.

The evidence for possible geothermal resources under Heart Lake Roadless Area is scanty, particularly pertinent geophysical and drill-hole data. The area is indeed adjacent to the southwest part of LVNP, and lateral flow of thermal water from the main upflow zone at Bumpass Hell is possible. Although there are no thermal manifestations in or immediately adjacent to the roadless area, a heat-flow hole just south of the area does show a high temperature gradient at depths greater than 518 ft. Accordingly, the southern part of Heart Lake Roadless Area has a substantiated potential for geothermal resources, and the rest of the roadless area has a probable geothermal resource potential.

SUGGESTIONS FOR FURTHER STUDIES

Hydrologic modeling, gas and water geochemistry, and repetitive gravity surveys are being performed by the USGS for the U.S. National Park Service in order to predict and evaluate possible effects on LVNP of geothermal development in the Lassen KGRA. Evaluation of geothermal resources probably will not be advanced by further surface surveys but will require deep exploratory drilling.

REFERENCES

Brook, C. A., Mariner, R. H., Mabey, D. R., Swanson, J. R., Guffanti, Marianne, and Muffler, L. J. P., 1979, Hydrothermal convection systems with reservoir temperatures ≥90°C, *in* Muffler, L.J.P., ed., Assessment of geothermal resources of the United States—1978: U.S. Geological Survey Circular 790, p. 18–85.

Christopherson, K. R., 1980, Geophysical studies of the Lassen KGRA, California: Geothermal Resources Council Transactions, v. 4, p. 25–28.

Christopherson, K. R., Hoover, D. B., Lewis, V., Radtke, B., and Senterfit, R. M., 1980, Lassen Known Geothermal Resource Area, California—Audio-magnetotelluric, telluric profiling, and self-potential studies: U.S. Geological Survey Open-File Report 80-313, 28 p.

Christopherson, K. R., and Pringle, Laurel, 1981, Additional audio-magnetotelluric soundings in the Lassen Known Geothermal Resource Area, Plumas and Tehama Counties, California: U.S. Geological Survey Open-File Report 81-959, 18 p.

Denton, D. K., Jr., and Graham, D. E., 1983, Mineral investigation of the Heart Lake (5096) and Wild Cattle Mountain (5043) RARE II Areas, Plumas, Shasta, and Tehama Counties, California: U.S. Bureau of Mines Open File Report MLA 30-83, 9 p.

Fraser, D. C., 1983, Airborne electromagnetic surveys of the Cascade Range, western USA: U.S. Geological Survey Open-File Report 83-92, 35 p.

Godwin, L. H., Haigler, L. B., Rioux, R. R., White, D. E., Muffler, L.J.P., and Wayland, R. G., 1971, Classification of public lands valuable for geothermal steam and associated geothermal resources: U.S. Geological Survey Circular 647, 18 p.

Lydon, P. A., Gay, T. E., Jr., and Jennings, C. W., 1960, Geologic map of California, Westwood sheet: California Division of Mines and Geology, scale 1:250,000.

Mase, C. W., Sass, J. H., and Lachenbruch, A. H., 1980, Near-surface hydrothermal regime of the Lassen "Known Geothermal Resources Area," California: U.S. Geological Survey Open-File Report 80-1230, 31 p.

Muffler, L. J. P., Clynne, M. A., and Cook, A. L., 1982, Mineral and geothermal resource potential of Wild Cattle Mountain and Heart Lake Roadless Areas, Plumas, Shasta, and Tehama Counties, California: U.S. Geological Survey Open-File Report 82-846, 25 p.

Muffler, L. J. P., Nehring, N. L., Truesdell, A. H., Janik, C. J., Clynne, M. A., and Thompson, J. M., 1982, The Lassen Geothermal System: Proceedings of Pacific Geothermal Conference, Auckland, New Zealand, November, 1982, p. 349–356 (also published as U.S. Geological Survey Open-File Report 82-926).

Renner, J. L., White, D. E., and Williams, D. L., 1975, Hydrothermal convection systems, *in* White, D. E., and Williams, D. L., eds., Assessment of geothermal resources of the United States—1975: U.S. Geological Survey Circular 726, p. 5–57.

Thompson, J. M., 1982, Preliminary chemical studies from Lassen Volcanic National Park and vicinity: Geothermal Resources Council Transactions, v. 6, p. 115–118.

Varekamp, J. C., and Buseck, P. R., 1983, Hg anomalies in soil—a geochemical exploration method for geothermal areas: Geothermics, v. 12, no. 1, p. 29–47.

GLACIER PEAK ROADLESS AREA, WASHINGTON

START OF VOLUME 2

By S. E. CHURCH,[1] U.S. GEOLOGICAL SURVEY, and

F. L. JOHNSON, U.S. BUREAU OF MINES

SUMMARY

A mineral survey by the USGS and the USBM from 1978 to 1982 outlined areas of mineral-resource potential in the Glacier Peak Roadless Area, Washington. Substantiated resource potential for base and precious metals has been identified in four mining districts included in whole or in part within the boundary of the roadless area. Several million tons of demonstrated base-and precious-metal resources occur in numerous mines in these districts. Probable resource potential for precious metals exists along a belt of fractured and locally mineralized rock extending northeast from Monte Cristo to the northeast edge of the roadless area.

CHARACTER AND SETTING

The Glacier Peak Roadless Area is a glaciated rugged mountainous terrain located in the Northern Cascade Mountains. It covers an area of about 90 sq mi in the Mount Baker-Snoqualmie National Forest, Snohomish County, Washington. The area is bounded on the south by the North Fork of the Skykomish River; the Eagle Rock Roadless Area lies just to the south. The Sauk River and the Glacier Peak Wilderness study area bound the area on the north and east. The relief is great; altitudes range from about 1500 ft near the North and South Forks of the Sauk River to about 7800 ft at Sloan Peak. Glacier-clad peaks rise 4000 to 4500 ft above the site of the old mining town of Monte Cristo.

Access to the roadless area from the north is by gravel logging roads. Roads to Monte Cristo come east over Barlow Pass from Granite Falls and south from Darrington along the Sauk River. The access to the area from the south is along paved and gravel county roads from U.S. Highway 2.

The Glacier Peak Roadless Area is divided roughly into two geologic terranes by the Straight Creek fault, a major somewhat discontinuous north-south structure with probable major pre-Tertiary strike-slip movement (Vance and Miller, 1981). On the north, the fault separates low-grade melange terrane (Misch, 1966) on the west from higher-grade metamorphic rocks of the North Cascades crystalline core. The metamorphic rocks east of the Straight Creek fault consist of Chiwaukum Schist, banded garnet-biotite gneiss derived from it, and gneissic Upper Cretaceous Sloan Creek plutons (Tabor and others, 1982a, b).

Within the Glacier Peak Roadless Area, the Straight Creek fault has been intruded by the Miocene Grotto batholith, the associated Monte Cristo stock, and the Oligocene Goblin Creek stock (Tabor and others, 1982b). Upper Eocene volcanic rocks of Barlow Pass were intruded by the plutons and contain many of the mineralized zones. Miocene breccias of Kyes Peak unconformably overlie the folded Barlow Pass volcanic rocks and appear to be roughly equivalent to the Grotto batholith in age and composition. These volcanic breccias may represent a catastrophic filling of a caldera. Mineralization is mostly associated with the Grotto batholith and late Miocene tonalite stocks exposed in Silver Creek (Tabor and others, 1982a).

Analytical results from geochemical sampling of stream sediments, bedrock, and hydrothermally altered areas (Church and others, 1982), and a detailed interpretation of the geochemical data showed the presence of anomalous metal concentrations in stream sediments. These include gold, arsenic, mercury, cobalt, copper, molybdenum, tungsten, zinc, lead, silver, and in places, some antimony, manganese, bismuth, and tin. Effects of hydrothermal alteration are widespread.

Aeromagnetic data were analysed as a part of the study of the Glacier Peak Wilderness study area. No particular magnetic signature can be associated with mineralization except that a magnetic low appears to persist along the axis of mineralization.

[1]With contributions from R. W. Tabor, USGS, and D. K. Denton, S. R. Iverson, R. B. McCulloch, S. A. Stebbins, and R. B. Stotelmeyer, USBM.

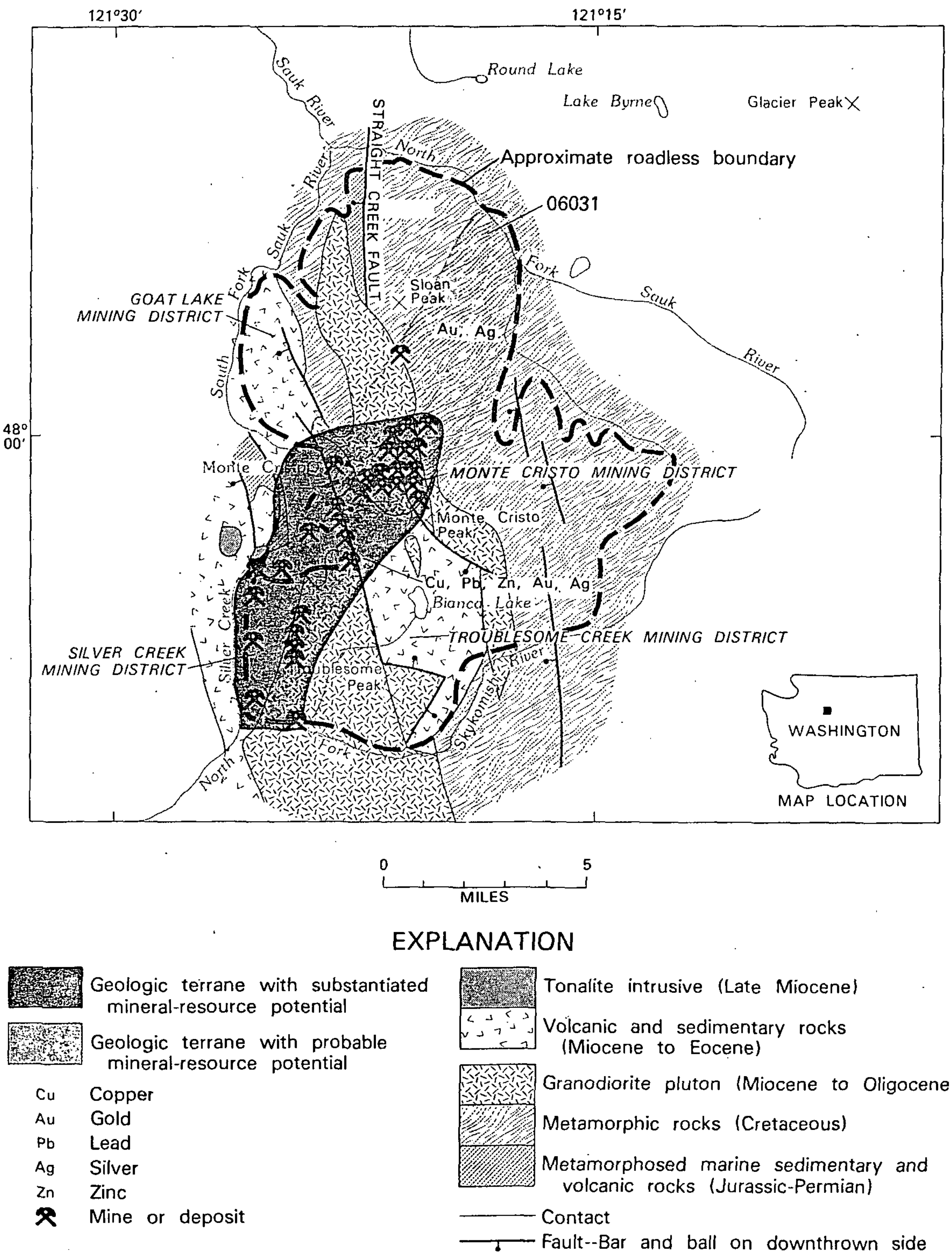


Figure 299.—Glacier Peak Roadless Area, Washington.

MINERAL RESOURCES

Early mining activity in the Monte Cristo mining district began in 1874 and many claims were filed along Silver Creek, a tributary of the North Fork of the Skykomish River. The ore contained gold, silver, lead, and arsenic, with lesser amounts of zinc and molybdenum. Most of the mining activity in the district was in the Glacier Creek drainage, a tributary of the South Fork of the Sauk River. Spurr (1901) made a classic study of the mineralization in the Monte Cristo mining district; he concluded that the ores were formed by downward percolating ground waters. He also argued that the precious metals did not persist at depth. His study, along with labor, transportation, and capital problems encountered shortly thereafter, caused the collapse of mining activity in the Monte Cristo district about 1903 (Woodhouse, 1979, p. 169-198).

More than 4000 mining claims had been located in the roadless area by the summer of 1979, and 196 patented claims are in or within 1 mi of the area. About 160 underground and 40 surface workings were identified. The workings are so numerous in the four districts, particularly in the Monte Cristo and Silver Creek districts, that only the mine workings with resources are shown (see Johnson and others, 1983 for detailed descriptions). More than 50,000 ft of underground workings were mapped and sampled. Twenty-eight properties in the roadless area and five near it contain several million tons of demonstrated resources. The most significant deposit in the roadless area is developed by the Justice, Golden Cord, Mystery, Pride of the Woods, New Discovery, and Pride of the Mountains mines. Gold-and-silver-rich quartz veins and lenses containing varying amounts of pyrite, pyrrhotite, arsenopyrite (arsenic), sphalerite (zinc), galena (lead), chalcopyrite (copper), and stibnite (antimony) occur in a northeast-trending shear zone over an exposed strike length of 5800 ft. In addition, a large low-grade copper-molybdenum porphyry deposit may underlie part of the roadless area in the Silver Creek district. Production from the roadless area is estimated to have been in excess of 230,000 tons of ore, all from the above mines.

The Silver Creek, Troublesome Creek, Goat Lake, and Monte Cristo mining districts (Johnson and others, 1983) contain mines having demonstrated resources for both base and precious metals. Most of the resources occur in steeply dipping, northeast-trending shear zones. Gold, silver, copper, lead, zinc, arsenic, and antimony occur in many of the mineralized zones that roof the Grotto batholith and in zones that appear to be closely related to the Miocene Monte Cristo stock. Mineralization is controlled by a pre-existing transverse fracture system (Spurr, 1901; Grant, 1969) that includes two mineralized breccia-pipe structures (Tabor and others, 1982a).

On the basis of the combined studies, the bulk of the roadless area that is included in the four mining districts, principally the Silver Creek and Monte Cristo, has substantiated resource potential for additional mineral resources for base and precious metals.

Studies of adits and prospect pits along the transverse structure east of Monte Cristo revealed only low-grade demonstrated resources. However, gold, silver, and mercury anomalies indicate a potential for precious-metal veins in the Sloan Peak area. This zone is shown on the map as having probable mineral resource potential.

SUGGESTIONS FOR FURTHER STUDIES

Several geologic, geochemical, and geophysical trends intersect at the loci of major mineralization in the Monte Cristo and Silver Creek mining districts. A subtle change in character of the geochemical suite from the Silver Creek to the Monte Cristo districts may reflect these structural controls, but alternative hypotheses are also viable. For example, the mineralization at Monte Cristo may be the result of several episodes of mineralization, or the differences may simply reflect a temperature gradient. Further examination of these trends is essential to document the nature of the control of mineralization.

REFERENCES

Church, S. E., Mosier, E. L., Frisken, J. G., Arbogast, B. F., and McDougal, C. M., 1982, Analytical results from stream sediments and panned concentrates from stream sediments collected from the Monte Cristo and Eagle Rock study areas, Washington: U.S. Geological Survey Open-File Report 82-303, 83 p.

Church, S. E., Tabor, R. W., and Johnson, F. L., in press, Mineral resource potential map of the Glacier Peak Roadless Area, Snokomish County, Washington: U.S. Geological Survey Miscellaneous Field Studies Map MF-1380-C, scale 1:50,000.

Grant, A. R., 1969, Chemical and physical controls for base-metal deposition in the Cascade Range of Washington: Washington Division of Mines and Geology Bulletin 58, 107 p.

Johnson, F. L., Denton, D. K., McCulloch, R. B., Stebbins, S. A., Iverson, S. K., and Stotelmeyer, R. B., 1983, Mineral investigation of the Glacier Peak RARE II Area (no. 6031), Snokomish County, Washington: U.S. Bureau of Mines Open-File Report MLA 75-83, 27 p.

Misch, Peter, 1966, Tectonic evolution of the Northern Cascades of Washington State—a west-cordilleran case history, *in* A symposium on the tectonic history and mineral deposits of the western Cordillera in British Columbia and in neighboring parts of the U.S.A.: Canadian Institute of Mining and Metallurgy Special Volume, v. 8, p. 101-148.

Spurr, J. E., 1901, The ore deposits of Monte Cristo, Washington: U.S. Geological Survey Annual Report 22, pt. 2, p. 777-865.

* Tabor, R. W., Frizzell, V. A., Jr., Yeats, R. S., and Whetten, J. T., 1982a, Geologic map of the Eagle Rock and Glacier Peak Roadless Areas, Snohomish and King Counties, Washington: U.S. Geological Survey Miscellaneous Field Studies Map MF-1380-A, scale 1:100,000.

Tabor, R. W., Zartman, R. E., and Frizzell, V. A., 1982b, Possible accreted terranes in the North Cascades Crystalline Core, Washington [abs.]: Geological Society of America Abstracts with Programs, v. 14, no. 4, p. 239.

Vance, J. A., and Miller, R. B., 1981, The movement history of the Straight Creek Fault in Washington State: The last 100 million years (mid-Cretaceous to Holocene) of geology and mineral deposits in the Canadian Cordillera: Cordillerean Section Geological Association of Canada, Programs with Abstracts, v. 6, p. 39-41.

Woodhouse, P. R., 1979, Monte Cristo: The Mountaineers, Seattle, 307 p.

GLACIER PEAK WILDERNESS STUDY AREA, WASHINGTON

By S. E. CHURCH,[1] U.S. GEOLOGICAL SURVEY, and

R. B. STOTELMEYER, U.S. BUREAU OF MINES

SUMMARY

Geologic, geochemical, gravity, aeromagnetic, and mine and prospect surveys were conducted in 1976–82 to evaluate the mineral-resource potential of the Glacier Peak Wilderness study area and proposed additions. In the study area, six areas containing several base and precious metals have been identified that have substantiated mineral-resource potential, two of which are in areas recommended for wilderness addition. An additional 10 areas have probable mineral-resource potential. The most important demonstrated resource identified is the porphyry copper-molybdenum deposit at Glacier Peak mine near the center of the wilderness study area, where a deposit totaling 1.9 billion tons of mineralized rock has been delineated by drilling. A possible geothermal potential exists on the east side of the Glacier Peak volcano, and a possible 24-million-cu-yd cinder resource is identified at the White Chuck Cinder Cone in the wilderness study area, but both are remote and no resources were identified. No other energy resource potential was identified in this study.

CHARACTER AND SETTING

The Glacier Peak Wilderness study area encompasses 726 sq mi of the Mt. Baker-Snoqualmie and Wenatchee National Forests, Chelan, Skagit, and Snohomish Counties, north-central Washington. Adjoining recommended additions totaling 141 sq mi are included in this study. The study area extends south about 40 mi from the North Cascades National Park, along the crest of the northern Cascade Range. It consists of rugged highly varied alpine terrain cut by many deep river valleys. Dense Douglas fir dominate the western slopes and contrast with the more open larch and pine forests on the east side of the Cascade crest. Glaciers and permanent snow fields cover extensive areas west of the crest. The terrain is dominated by the volcanic cone of Glacier Peak, which has an altitude of 10,541 ft and rises 3000–4000 ft above most of the nearby summits.

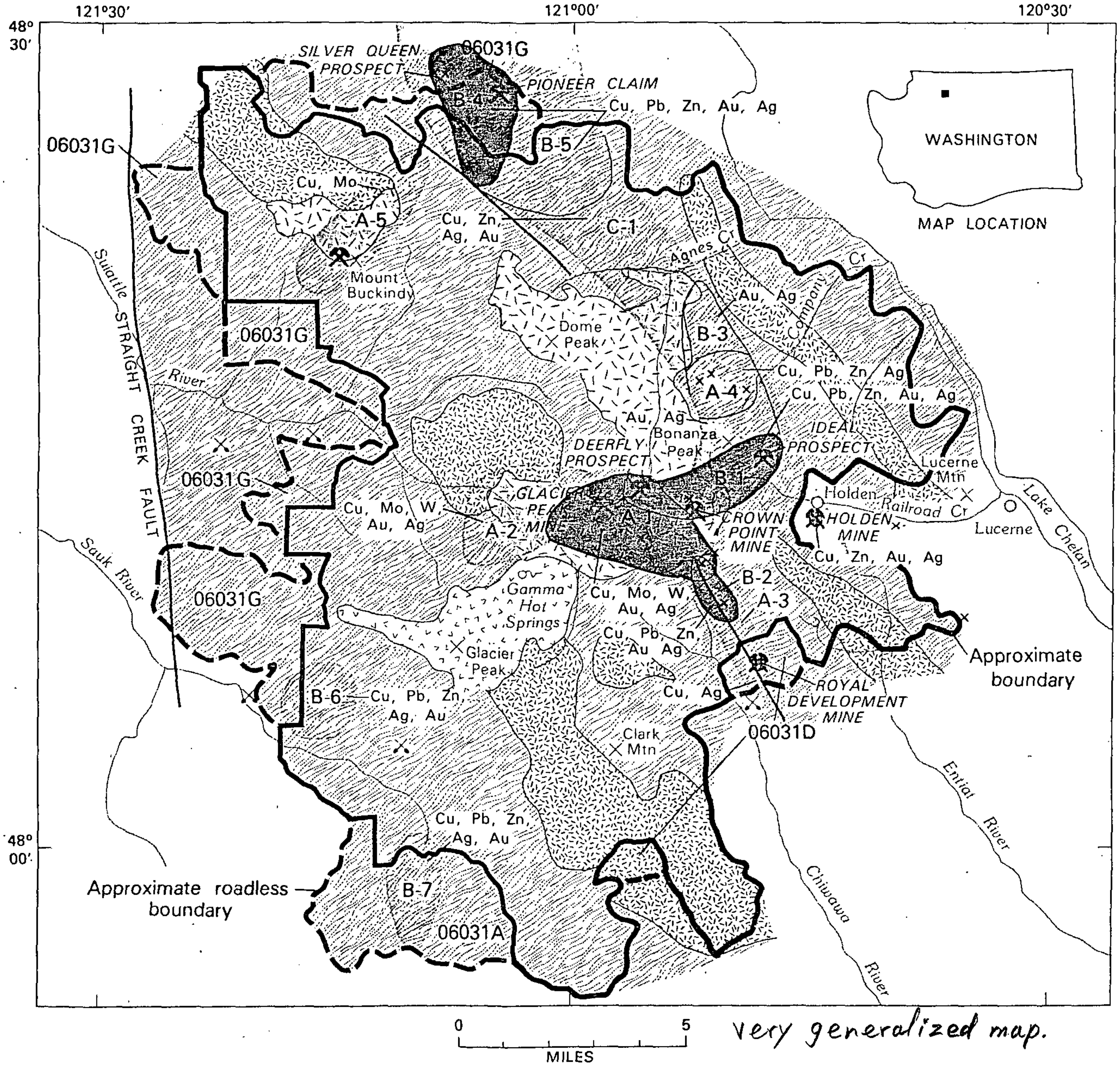
Access to the study area is by generally well maintained and graded trails or gravel logging roads leading up major valleys from Darrington, Marblemount, Stehekin, Holden, Trinity, and Lake Wenatchee. Major trail routes in the study area cross the mountain passes, and many minor trails exist in the study area but are generally rough and infrequently maintained.

The North Cascades crystalline core complex is composed of pre-Tertiary gneiss, schist, and foliated igneous rocks. The regional framework and evolution of the crystalline core complex and its complicated structural and metamorphic history have been described by Misch (1966). Many large intrusions of pre-Tertiary age were altered by metamorphism and accompanying intense deformation. Following metamorphism, a large fault trough, the Chiwaukum graben, developed in the early Tertiary just south of the study area and was filled with locally derived sediments. The Straight Creek fault, a major structural feature of the area, separates low-grade metamorphic rocks to the west from the more metamorphosed crystalline core complex. Plutonic bodies of Cretaceous to Miocene age have intruded this complex. Mineralization appears to be associated primarily with igneous intrusions of Miocene age, and many of the mineralized areas are located along transverse zones of structural weakness (Grant, 1969). The Cascades were uplifted and deeply dissected by erosion prior to the building of andesitic volcanos, such as Glacier Peak, in Quaternary time.

MINERAL RESOURCES

To obtain data for the mineral-resource assessment of

[1]With contributions from A. B. Ford and V. J. Flanigan, USGS, and F. L. Johnson, E. L. McHugh, F. E. Federspiel, D. K. Denton, and S. A. Stebbins, USBM.



Very generalized map.

EXPLANATION

Geologic terrane with substantiated mineral-resource potential

Geologic terrane with probable mineral-resource potential

Mine or deposit

× Mineral occurrence

Mine

Quarry

Cu	Copper
Au	Gold
Pb	Lead
Mo	Molybdenum
Ag	Silver
W	Tungsten
Zn	Zinc

Volcanic and volcaniclastic rock (Quaternary)

Granitic rock and porphyry (Miocene)

Granitic rock and granitic gneiss (Tertiary and Cretaceous)

Foliated diorite and gabbro, schist and gneiss (Pre-Tertiary)

Contact

Fault

B-2 Area discussed in text

Figure 300.—Glacier Peak Wilderness study area, Washington.

the study area, stream-sediment geochemistry surveys (Church and others, 1982), geochemical studies of the bedrock, gravity (V. J. Flanigan, unpub. data), aeromagnetic studies, and geologic mapping were conducted. Significant results of the many prior geologic investigations (Ford, 1983) and mineral-exploration studies (Grant, 1982) have been reviewed in a summary report (Church and others, in press). Mineral occurrence investigations of previously mined and prospected areas were conducted by Stotelmeyer and others (1982).

The principal mineral deposits in the Glacier Peak Wilderness study area are associated with porphyry-copper-molybdenum-type systems; the resources and reserves defined by subsurface drilling at the Glacier Peak mine are examples. The major area of substantiated resource potential (A-1, on map) is around Glacier Peak mine site, which has 1.9 billion tons of demonstrated resources containing 0.334 percent copper, with molybdenum, tungsten, gold, and silver as possible byproducts; the area contains 17 patented claims. The deposit is a late phase of the Cloudy Pass pluton that has disseminations and veinlets of sulfide minerals. The axis of the deposit trends east-west and is marked by a linear regional aeromagnetic low within the Cloudy Pass aeromagnetic anomaly. Nearby areas of probable mineral-resource potential A-2, A-3, and A-4 show similar geologic characteristics and geochemical suites of elements, but either do not contain demonstrated resources, or have less favorable indications of mineral potential. The Royal Development mine, located in the recommended addition area to the south, is in a small area of substantiated resource potential in a breccia pipe containing inferred resources of 8.5 million tons of 0.4 percent copper and 0.9 oz silver/ton. Similar breccia pipe structures are present at the north end of area A-3. Area A-4 also contains a relatively unexplored tactite zone having high-grade occurrences of silver, lead, and zinc associated with copper.

The area A-5, in the vicinity of Mt. Buckindy, has a probable resource potential for copper and molybdenum in porphyry-type deposits. Widespread geochemical anomalies and localized alteration are present; two breccia pipes are exposed on Mt. Buckindy. Five exploration holes in an area near Mt. Buckindy indicate demonstrated resources having 0.34 percent copper and 1.3 percent molybdenum content.

Peripheral to the major porphyry-copper systems are several areas having resource potential for silver and gold along with base metals. Area B-1 has substantiated mineral-resource potential and contains three known deposits with demonstrated resources. The Deerfly prospect, a finely dispersed vein deposit probably associated with the Glacier Peak mineralizing system, has demonstrated resources of 174,000 tons containing 0.75 oz silver/ton, with some gold and copper. The Crown Point mine has demonstrated resources of 1300 tons that contains 2.9 oz silver/ton along shear zones in the Cloudy Pass pluton; other contained metals include copper (2.6 percent), lead (0.39 percent), and zinc (0.72 percent). The Ideal prospect is on a fissure vein containing demonstrated resources of 34,000 tons with 1.42 oz silver/ton. Area B-2 also has a substantiated resource potential for base and precious metals. Area B-3 to the north of area B-1 has a probable potential for precious metals, based on geochemical anomalies as well as on examination of the prospect pits in this area.

Area B-4 has substantiated base and precious metal resource potential, in large part located in the recommended wilderness addition to the north, which contains a major sulfide vein at the Pioneer patented claims. Demonstrated and inferred resources are 734,000 tons of silver-lead-zinc ore at 6.46 oz silver/ton, 6.4 percent lead, and 6.5 percent zinc. Copper (0.52 percent) and gold (0.015 oz/ton) are also present. This deposit lies adjacent to the Triplets, a very large breccia pipe. The Silver Queen prospect just outside the wilderness addition boundary, also located in this same zone, is on a sulfide vein in the Cascade River Schist of Misch (1966); an estimated 69 tons of material are in high-grade pods that contain silver (4.8 oz silver/ton), lead (5.0 percent), zinc (2.0 percent), and associated copper, gold, and cadmium. An adjacent area, B-5, has similar geochemical, geophysical, and geologic features and is designated as a zone having probable mineral-resource potential.

Area B-6, near Red Mountain, is located in a regional transverse shear zone (Grant, 1969) and is associated with a granitic plug; it also has several base- and precious-metal geochemical anomalies, and has a probable mineral-resource potential.

Area B-7, located mainly in a recommended addition south of the wilderness is based largely on geochemical anomalies associated with volcanic plugs. Company assay records from an adit in area B-7 indicate a silver vein having 13.85 oz silver/ton and 8.3 percent copper, but there are no indications that this is anything other than a localized high-grade occurrence. This area has probable resource potential for base and precious metals.

Area C-1, delineated by the outcrop pattern of the pre-Tertiary schist belt, is marked by high geochemical anomalies of acid-soluble zinc, and has a probable mineral-resource potential. The Holden mine, which is about 1 mi east of the study area and is in a small area of substantiated mineral-resource potential, lies in this unit. Ores from the mine are not typical of a porphyry-copper system, and ages obtained from alteration zones in the mine indicate that these ores formed earlier than those associated with the Cloudy Pass pluton. From 1938 to 1957, 10 million tons of copper-zinc-gold-silver ore were produced from the Holden, which was the largest copper mine in the State. Demonstrated resources of 3 million tons remain in the Holden mine; ores contain 1.1 percent copper, 0.3 percent zinc, 0.2 oz silver/ton and 0.06 oz gold/ton. The tailings pile at the Holden mine also contains resources of gold, silver, and zinc.

Several nonmetallic deposits occur in the study area; they include cinder at the White Chuck Cinder Cone, limestone, marble, pumice, and garnet. The occurrences are in remote areas, however, and substitute materials closer to markets are available elsewhere.

Investigations of the three hot springs in or near the study area indicate a reservoir temperature at Gamma Hot Springs between 350° and 410° F, but studies by Brook and others (1979) indicated a reservoir of limited size. Consistent with geologic information, gravity data suggest a thick pile of volcanic rock in the area (Tabor and Crowder, 1969), but the area is in rugged terrain, is remote, and no geothermal resources are identified.

SUGGESTIONS FOR FURTHER STUDIES

Additional, more detailed studies of the schist and gneiss belt (area C-1), and further work on the Holden mine are warranted to define the deposit type and outline areas for potential exploration. Detailed mapping, geochemical, isotopic, and geophysical studies, and exploration drilling are needed to establish the exact mineral-resource potential, particularly in areas A-1, A-3, A-5, B-1, B-2, and B-4. Further investigation of the geothermal potential may also be warranted.

REFERENCES

Brook, C. A., Mariner, R. H., Mabey, D. R., Swanson, J. R., Guffanti, Marianne, and Muffler, L.J.P., 1979, Hydrothermal convection systems with reservoir temperatures >90° C, *in* Muffler, L.J.P. ed., Assessment of geothermal resources of the United States—1978: U.S. Geological Survey Circular 790, p. 18-85.

Church, S. E., Mosier, E. L., Frisken, J. G., Arbogast, B. F., McDougal, C. M., and Evans, J. G., 1982, Analytical results for stream sediments and panned concentrates from stream sediments collected from the Glacier Peak Wilderness and adjacent areas: U.S. Geological Survey Open-File Report 82-780, 227 p.

Church, S. E., Ford, A. B., Flanigan, V. J., and Stotelmeyer, R. B., *in* press, Mineral resource potential map of the Glacier Peak Wilderness and adjacent areas, Chelan, Skagit, and Snohomish Counties, Washington: U.S. Geological Survey Miscellaneous Field Studies Map MF-1652-A.

Ford, A. B., 1983, Annotated guide to geologic reports and maps of the Glacier Peak Wilderness and adjacent areas, Northern Cascades, Washington: U.S. Geological Survey Open-File Report 83-97, 27 p.

Grant, A. R., 1969, Chemical and physical controls for base-metal deposition in the Cascade Range of Washington: Washington Division of Mines and Geology Bulletin 58, 107 p.

Grant, A. R., 1982, Summary of economic geology data for the Glacier Peak Wilderness, Chelan, Snohomish, and Skagit Counties, Washington: U.S. Geological Survey Open-File Report 82-408, 37 p.

Misch, Peter, 1966, Tectonic evolution of the Northern Cascades of Washington State—a west-cordilleran case history, *in* Symposium on the tectonic history and mineral deposits of the western Cordillera in British Columbia and in neighboring parts of the USA: Canadian Institute of Mining and Metallurgy Special Volume 8, p. 101-148.

Stotelmeyer, R. B., Johnson, F. L., McHugh, E. L. Federspiel, F. E., Denton, D. K., Jr., and Stebbins, S. A., 1982, Mineral investigation of the Glacier Peak Wilderness and adjacent areas, Chelan, Skagit, and Snohomish Counties, Washington: U.S. Bureau of Mines Open-File Report MLA 89-82, 36 p.

Tabor, R. W., and Crowder, D. F., 1969, On batholiths and volcanoes—intrusion and eruption of Late Cenozoic magmas in the Glacier Peak area, North Cascades, Washington: U.S. Geological Survey Professional Paper 604, 67 p.

GLACIER VIEW ROADLESS AREA, WASHINGTON

By RUSSELL C. EVARTS, U.S. GEOLOGICAL SURVEY, and

DONALD J. BARNES, U.S. BUREAU OF MINES

SUMMARY

Surveys conducted in 1980 and 1982 indicate little promise for the occurrence of metallic mineral resources in the Glacier View Roadless Area, Washington. Small, thin lenses of coal may be present at depth near the western edge of the area, but larger coal deposits occur at or near the surface outside the roadless area. Oil and gas may be in the subsurface, but the evaluation of the potential requires additional information obtainable only by drilling.

CHARACTER AND SETTING

The Glacier View Roadless Area is within the Snoqualmie National Forest on the heavily forested western slope of the Cascade Range about 40 mi southeast of Tacoma, Washington. It is a north-south-elongated area bounded on the east by Mount Rainier National Park. The roadless area comprises 4.7 sq mi at altitudes between 3300 and 5500 ft, and offers spectacular vistas of the western flank of Mount Rainier and its glacial carapace. The roadless area is accessible by a USFS road network originating at Washington State Highway 706, 3 mi east of Ashford.

The geology of the roadless area is dominated by a sequence of sedimentary rocks dipping steeply to the east, forming the eastern limb of a major anticline (Hammond, 1980). Most of the sedimentary rocks are Tertiary sandstone, conglomerate, and breccia derived from erosion of a volcanic source terrane. Volcanic rocks such as lava flows and ash-flow tuff are widespread but not abundant. Rocks similar to these make up much of Mount Rainier National Park to the east, and are described by Fiske and others (1963). Along the western margin of the roadless area, the volcanic sedimentary rocks overlie Eocene arkosic sandstone and siltstone which locally contain beds of impure bituminous coal. These lower beds evidently represent deposits in part of a Mississippi-type deltaic system that extended westward from a broad granitic highland during Eocene time (Buckovic, 1979). The overlying volcanic and sedimentary rocks represent the initial products of volcanic activity in the Cascade Range.

Many small dikes and sills of mafic composition occur throughout the sedimentary sequence. In addition, a larger body of granitic rock intrudes volcanic and sedimentary rocks in the northern part of the Glacier View Roadless Area. The granitic intrusion is similar to parts of the Tertiary Tatoosh pluton in Mount Rainier National Park (Fiske and others, 1963) and was probably emplaced during the same igneous episode.

All rocks in the roadless area have been affected by low-grade zeolite-facies metamorphism, and rocks immediately adjacent to the granitic intrusive body have been moderately altered to hornfels. However, there are no areas of extensive hydrothermal alteration, and sulfide minerals are uncommon.

Geologic mapping and geochemical sampling of stream sediments and altered bedrock were accomplished in 1980. Records of mining activity were searched in 1982. The detailed results of these studies were published by Evarts and others (1983).

MINERAL RESOURCES

The Glacier View Roadless Area offers little promise for the occurrence of metallic mineral deposits. No significant indications of hydrothermal alteration or concentrations of sulfide or other metallic minerals were encountered during the mapping. Analyses of stream-sediment and bedrock samples revealed no geochemical anomalies attributable to mineralization. Although six coal claims were located in the roadless area between 1905 and 1907, no coal was found at the described locations or anywhere else in the roadless area. Coal beds are exposed immediately to the west, and the geologic structure indicates coal is probably present beneath the surface in the roadless area. However, the coal beds are

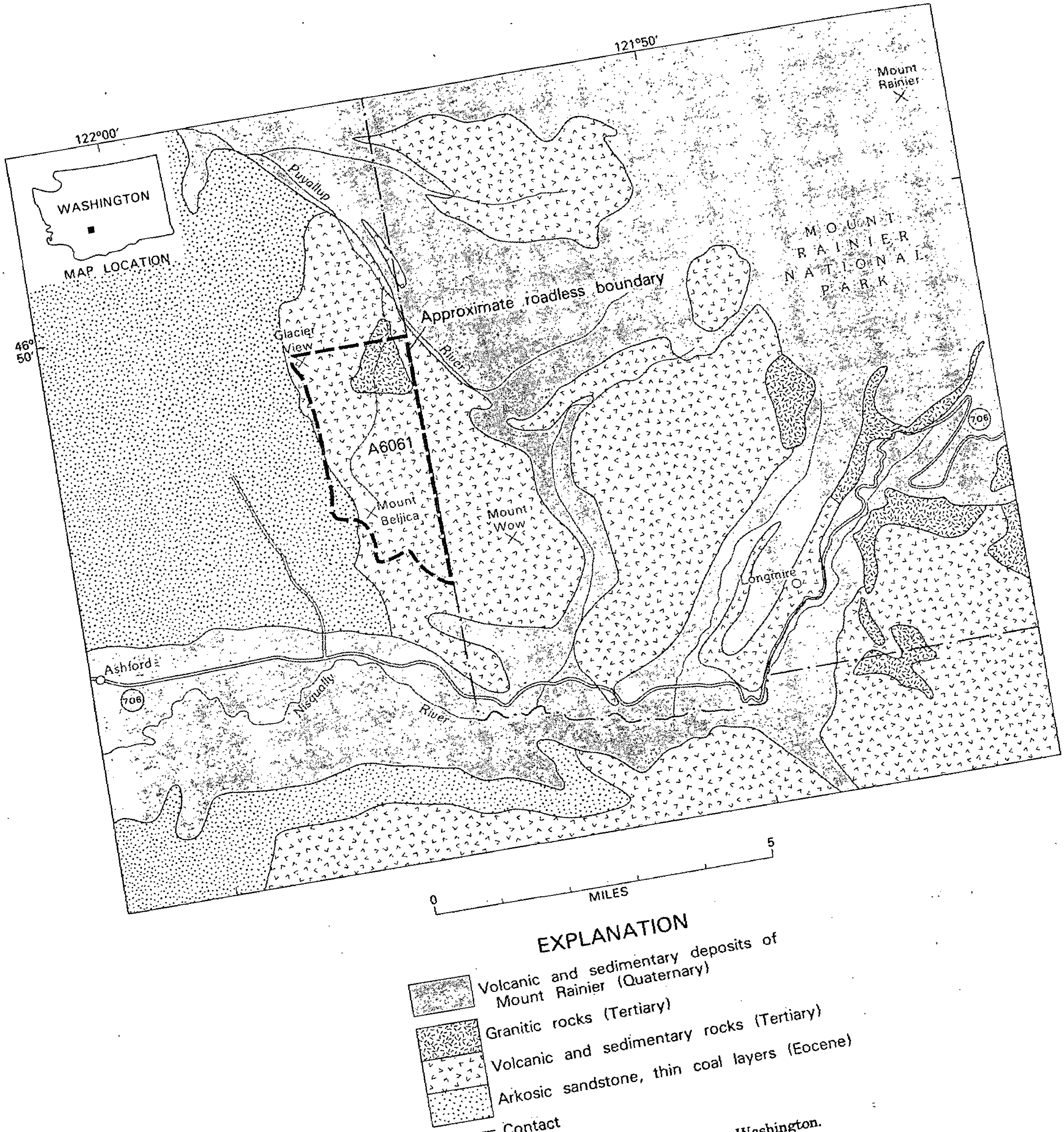


Figure 301.—Glacier View Roadless Area, Washington.

relatively thin and of limited extent, and analyses of samples from the exposed beds show the coal to be an impure bituminous variety with a low heat value. Furthermore, recovery by conventional coal-mining techniques would be difficult because of intensive minor faulting. About half of the roadless area is covered by recent oil and gas leases; the geology is permissive for the occurrence of these commodities, but without additional supporting geophysical or drilling information, the resource potential cannot be adequately evaluated.

SUGGESTIONS FOR FURTHER STUDIES

Available data indicate little promise for the occurrence of mineral resources in the Glacier View Roadless Area. If further study and exploration for mineral deposits is contemplated, they should be concentrated in and adjacent to the granitic pluton in the northern part of the area, because most mineral deposits in the Cascades are associated with such rocks (Grant, 1969). Drilling might reveal coal deposits at depth, but is probably unjustified because larger and higher-grade coal deposits occur at or near the surface in the region to the west (Beikman and others, 1961). Geophysical studies and exploratory drilling are necessary, however, to determine the likelihood of oil and gas resources.

REFERENCES

Barnes, D. J., 1983, Mineral investigation of the Glacier View RARE II Area (No. A6061), Pierce County, Washington: U.S. Bureau of Mines Open-File Report MLA 16-83.

Beikman, H. M., Gower, H. D., and Dana, T. A. M., 1961, Coal reserves of Washington: Washington Divison of Mines and Geology Bulletin 47, 115 p.

Buckovic, W. A., 1979, The Eocene deltaic system of west-central Washington, *in* Armentrout, J. M., Cole, M. R., and Terbest, Harry, Jr., eds., Cenozoic paleogeography of the Western United States: Society of Economic Paleontologists and Mineralogists, Pacific Section, Pacific Coast Paleogeography Symposium 3, p. 147-163.

Evarts, R. C., Mosier, E. L., Church, S. E., and Barnes, D. J., 1983, Mineral resource potential of the Glacier View Roadless Area, Pierce County, Washington: U.S. Geological Survey Open-File Report 83-501, 16 p.

Fiske, R. S., Hopson, C. A., and Waters, A. C., 1963, Geology of Mount Rainier National Park, Washington: U.S. Geological Survey Professional Paper 444, 93 p.

Grant, A. R., 1969, Chemical and physical controls for base-metal deposition in the Cascade Range of Washington: Washington Division of Mines and Geology Bulletin 58, 107 p.

Hammond, P. E., 1980, Reconnaissance geologic map and cross sections of southern Washington Cascade Range: Portland, Oregon, Portland State University, Department of Earth Sciences, 31 p.

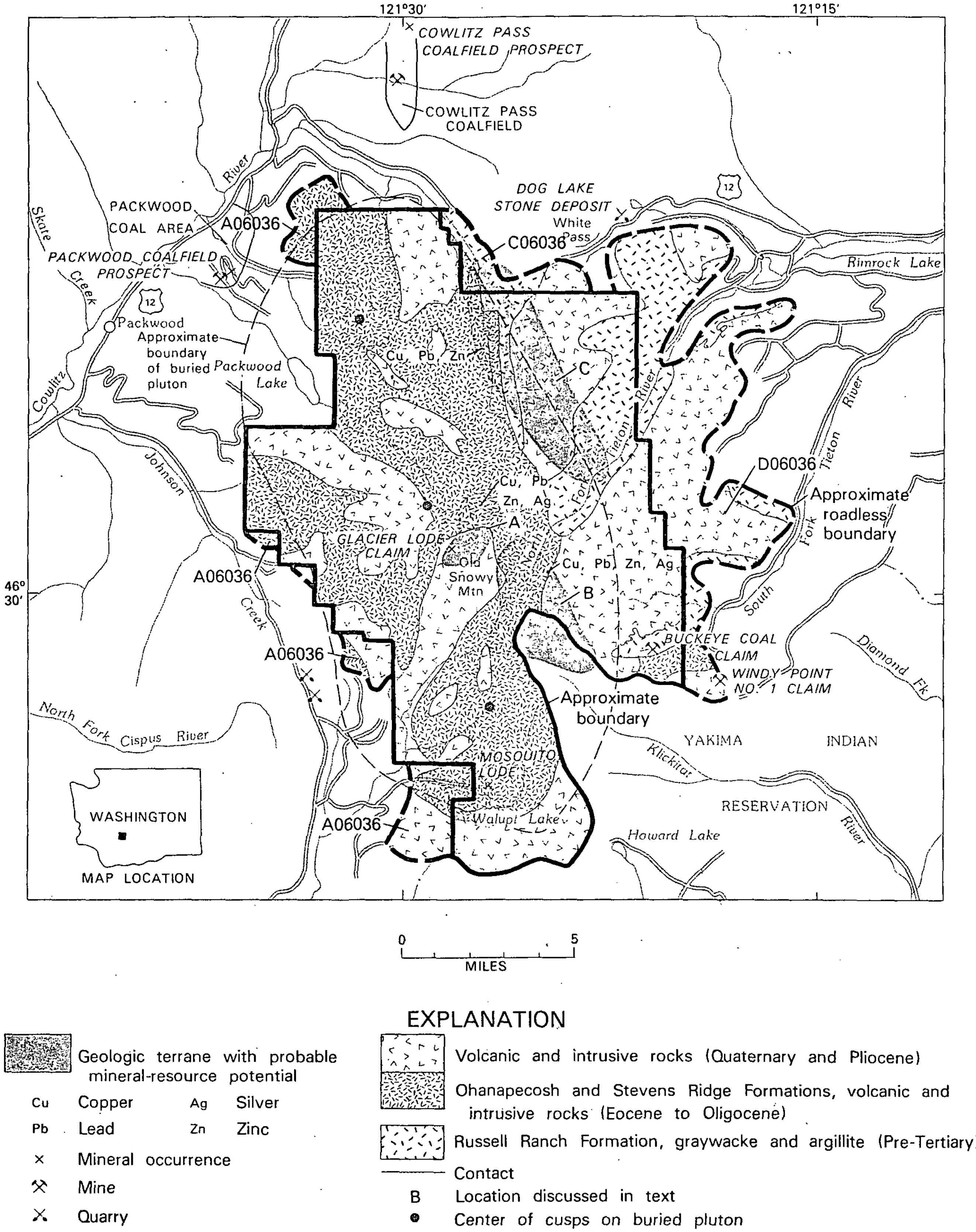


Figure 302.—Goat Rocks Wilderness and adjacent roadless areas, Washington.

GOAT ROCKS WILDERNESS AND ADJACENT ROADLESS AREAS, WASHINGTON

By S. E. CHURCH,[1] U.S. GEOLOGICAL SURVEY, and

T. J. CLOSE, U.S. BUREAU OF MINES

SUMMARY

The Goat Rocks Wilderness and adjacent roadless areas are a rugged, highly forested, scenic area located on the crest of the Cascade Range in south-central Washington. Several mineral claims have been staked in the area. Mineral surveys were conducted in 1981. Geochemical, geophysical, and geologic investigations indicate that three areas have probable mineral-resource potential for base metals in porphyry-type deposits. Available data are not adequate to permit definition of the potential for oil and gas. There is little likelihood for the occurrence of other kinds of energy resources in the area.

CHARACTER AND SETTING

The Goat Rocks Wilderness and adjacent roadless areas, here referred to as study area, cover about 170 sq mi in the Gifford Pinchot and Wenatchee National Forests, Lewis and Yakima Counties, Washington. The deeply eroded Goat Rocks volcano, located in the central part of the wilderness, is a part of the Cascades Range volcanic province. Mount Rainier is about 15 mi to the north, and Mount Adams is about 15 mi to the south. Access to the study area is provided by good unpaved roads from U.S. Highway 12. Travel within the study area is aided by the Pacific Crest National Scenic Trail and connecting USFS trails.

The wilderness and adjacent roadless areas are underlain by the pre-Tertiary marine graywacke and argillite of the Russell Ranch Formation, that comprise the southernmost known exposures of pre-Tertiary rocks in the Cascade Range of Washington and Oregon. The Russell Ranch is overlain by a thick sequence of Eocene to Oligocene volcanic rocks. The thickest and most extensive formation is the Eocene Ohanapecosh Formation, which consists of volcaniclastic rocks and lava flows dominantly of andesitic composition. The Ohanapecosh is overlain by silicic ash-flow tuff of the Oligocene Stevens Ridge Formation. A major erosional unconformity separates these early Tertiary rocks from a sequence of Pliocene and Quaternary volcanic rocks. The oldest unit occurs in the eastern part of the study area and consists of upper Pliocene silicic tuff and flows. A thick sequence of pyroxene andesite erupted in the late Pliocene and Pleistocene from the Goat Rocks volcano, centered in the core of the wilderness, and satellitic vents fed andesite and basalt flows. The youngest volcanism, of late Pleistocene age, produced hornblende andesite from vents in the central and northern part of the study area and olivine basalt from small volcanoes in the northern and southern part.

Intrusive bodies, particularly of intermediate composition are common. They range from narrow dikes to shallow plutonic bodies several miles in diameter. Ages are poorly constrained; it is likely that they were intruded throughout much of the Cenozoic. Many of the bodies and adjacent country rocks underwent quartz-sericite-pyrite and propylitic alteration.

The Russell Ranch Formation is cut by major north-trending faults, but the Ohanapecosh and Stevens Ridge Formations are only broadly folded along north-northwest trends and are not demonstrably deformed.

Geologic mapping, geochemical and geophysical studies, and detailed studies of hydrothermally altered areas within the study area were undertaken by the USGS; detailed chip sampling of the altered zones was done by the USBM.

A reconnaissance geochemical survey of the study area was undertaken during 1981. Stream-sediment samples, panned concentrate samples from stream sediments, and water samples were taken and analyzed using several analytical methods (Church and others, in press).

[1]With contributions from D. A. Swanson, D. L. Williams, and G. A. Clayton, USGS, and T. J. Peters, USBM.

Both gravity and aeromagnetic surveys were conducted. The gravity data are interpreted to show a buried pluton, trending approximately N. 10° W., bounded on the east and west sides of the study area by thick piles of Russell Ranch and Ohanapecosh rocks. The aeromagnetic data primarily reflect the topographic relief, but one of the hydrothermally altered areas is underlain by a pronounced negative magnetic anomaly interpreted to represent a large mass of hydrothermally altered rock at depth.

A search of county claims, and U.S. Bureau of Land Management and USBM records, shows that only five claims have been filed in the study area; field examination of these areas failed to produce any evidence of mining.

MINERAL RESOURCES

Within the study area, three areas having probable mineral-resource potential have been identified. Areas A and B are very similar in their major characteristics. They are areas of pyritic-sericitic alteration, surrounded by argillic and propylitic alteration zones. These zones have geochemical anomalies for copper, molybdenum, cobalt, nickel, lead, and zinc with smaller and somewhat more random anomalies in other metals. Both areas show sporadic high values for silver; no significant gold values were found. Pyrite is ubiquitous. Area A coincides with a magnetic low covering about 1 sq mi. Both areas include, or are adjacent to old volcanic vents, and are inferred to lie above cusps on a larger pluton below. Both areas fit the environment in which porphyry-copper deposits form. Area B extends into the Yakima Indian Reservation, which is closed to public access; the boundary of the altered zone on the reservation has been inferred from color anomalies and mapped alteration zones in the study area. A hydrothermally altered system with ore-grade rock does not crop out in either area, but both areas have probable mineral-resource potential for base metals and silver in a buried system.

Area C is defined by a large geochemical anomaly located along the inferred contact between the Goat Rocks pluton and the older volcanics and sediments in the east. Anomalous amounts of copper, cobalt, manganese, and barium, with smaller amounts of lead, zinc, nickel, and molybdenum were found in the stream-sediment samples. In the panned concentrates made from these samples, pyrite was ubiquitous, and cinnabar and barite were each identified from four sites. Boron, tin, and mercury were found in anomalous amounts in the panned concentrate samples. Altered rocks collected in this region contained high values of zinc, manganese, lead, molybdenum, and arsenic. Water samples contain high concentrations of chlorine, fluorine, molybdenum, and copper. This area is regarded as having probable mineral-resource potential for base metals in buried deposits.

Outside the study area, coal resources have been identified in the Packwood and Cowlitz Pass coal fields (Beikman and others, 1961). The coal-bearing unit, the Eocene Spiketon Formation, does not crop out inside the study area; there seems to be little promise for the occurrence of coal resources in the study area.

Quantities of building stone and gravel are currently being quarried from deposits located north and west of the study area. Similar deposits of stone and gravel probably occur within the study area, however, current market needs can be met from existing quarries or from deposits found closer to existing markets.

The potential for oil and gas in the area cannot be defined from current data. Recent drilling 5 mi north of Yakima (30 mi east of the study area), has shown the presence of sedimentary rocks beneath the lavas of the Columbia River Basalt Group. If the gravity model is correct, as much as 10,000 to 25,000 ft of sedimentary rocks may be present on the east and west sides of the Goat Rocks pluton. Marine strata, if present and particularly if they represent an accreted terrain, could supply both the source beds as well as the structural and stratigraphic traps necessary for the accumulation of oil and gas (W. D. Stanley, written commun., 1983). Because we do not have the resources at hand for subsurface seismic reflection work in the study area, the potential for oil and gas resources cannot be assessed, but should not be dismissed without additional data.

There is no evidence to indicate the occurrence of geothermal resources in the study area. There are no hot springs in the study area, there is no recent silicic volcanism, and most of the andesitic volcanism occurred in the Pliocene and early Pleistocene. The most recent volcanism in the area is basaltic and occurred about 14,000 years ago. Even though the study area lies along the crest of the Cascade Range, an active volcanic chain, there is little promise for the occurrence of geothermal resources.

SUGGESTIONS FOR FURTHER STUDIES

Evaluation of resource potential in the three areas identified as having probable mineral-resource potential could be improved by more detailed geochemical studies and geologic mapping. Study of the southern part of the hydrothermal aureole on the Yakima Indian Reservation might significantly improve understanding of the mineral potential of area B. Detailed geologic mapping would help to resolve details of the structure of the host rocks and the associated hydrothermal alteration zones.

East-west seismic-reflection profiles crossing the center of the Goat Rocks pluton would be useful in deciphering the structure of the area and would assist interpretation of the gravity survey and magnetotelluric data (W. D. Stanley, written commun., 1983). Confirmation of an accreted, pre-Tertiary marine terrane in this area would add significantly to the understanding of tectonic models for the region and would help define the potential for oil and gas in the buried sedimentary rocks.

REFERENCES

Beikman, H. M., Gower, H. D., and Dana, T. A. M., 1961, Coal reserves of Washington: Washington Division of Mines and Geology Bulletin 47, 115 p.

Church, S. E., Swanson, D. A., Williams, D. L., Clayton, G. A., Close, T. J., and Peters, T. J., in press, Mineral resource potential map of the Goat Rocks Wilderness and adjacent roadless areas, Lewis and Yakima Counties, Washington: U.S. Geological Survey Miscellaneous Field Studies Map MF-1653-A, scale 1:48,000.

Fiske, R. S., Hopson, C. A., and Waters, A. C., 1963, Geology of Mount Rainier National Park, Washington: U.S. Geological Survey Professional Paper 444, 93 p.

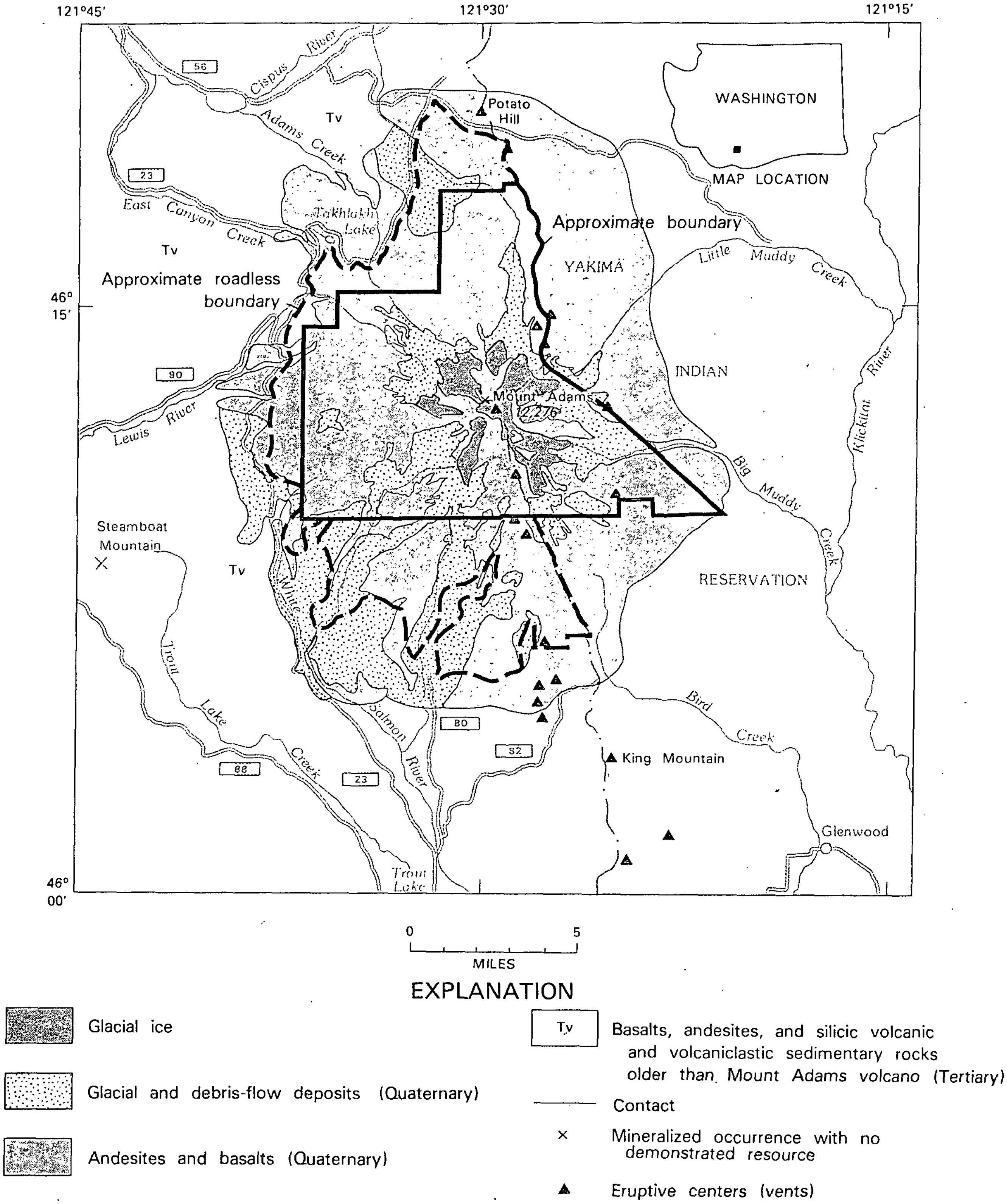


Figure 305.—Mount Adams and contiguous roadless areas, Washington.

MOUNT ADAMS WILDERNESS AND CONTIGUOUS ROADLESS AREAS, WASHINGTON

WES HILDRETH,[1] U.S. GEOLOGICAL SURVEY, and

M. MILLER, U.S. BUREAU OF MINES

SUMMARY

There is little likelihood for the occurrence of metallic mineral or energy resources based on a mineral survey in 1981-82 in the Mount Adams Wilderness and contiguous roadless areas. No mining claims exist in the study area, which is almost entirely a young andesitic stratovolcano. There is no indication of a shallow magma reservoir capable of supporting a convective geothermal system.

CHARACTER AND SETTING

Mount Adams is one of the dominant natural features of the Pacific Northwest, rising nearly 2 mi above its surroundings to an altitude of 12,276 ft. An ice-capped stratovolcano, the mountain consists largely of andesitic lava and ejecta that total about 135 cu mi in volume, ranking it behind Mount Shasta as the second most voluminous volcano in the High Cascades. There have been no historical eruptions of Mount Adams and probably only one in the past 3500 years, but evidence for several eruptions during Holocene time and persistent sulfurous fumaroles on the summit indicate that the volcano remains potentially active.

The andesitic stratocone covers approximately 250 sq mi, its upper portion being the Mount Adams Wilderness, which consists of 50.6 sq mi of glaciers, rugged ridges, barren moraines, alpine meadows, huckleberry thickets, and, below the 6000-ft level, a densely forested periphery. The contiguous roadless area, an additional 44.1 sq mi under consideration for inclusion in the wilderness, would extend this forested peripheral zone outward to the existing system of USFS logging roads.

Mount Adams stands upon the Cascade crest and is drained radially by many tributaries of the Klickitat, Cispus, Lewis, and White Salmon Rivers. On USFS lands, easy access to the mountain is provided by several generally unpaved logging roads. The Yakima Indian Reservation on the east, however, is closed to all but enrolled members of the Yakima Nation and permittees approved by the Yakima Tribal Council. The southeasterly tract of the Mount Adams Wilderness, administered by the tribe since 1972, remains open to the public and is accessible by graded dirt roads from Trout Lake and Glenwood during the summer months. Several foot trails penetrate the wilderness, which is itself roadless.

The main cone of Mount Adams consists of porphyritic pyroxene andesite and subordinate amounts of olivine andesite and basalt. A few dacitic lava flows erupted early in the evolution of the volcano but crop out only outside the wilderness. Potassium-argon dating suggests that the bulk of the main stratocone is younger than about 220,000 years, but two distal flows have been dated at 400,000 and 470,000 years (Hildreth and Fierstein, 1983).

Late Pleistocene glaciers covered more than 90 percent of the volcano's surface, compared to only 2.5 percent today. Seven or more eruptions of Mount Adams, however, have taken place during latest Pleistocene and Holocene time, roughly the 12,000 years since disappearance of the last extensive ice sheets. None of these eruptions issued from a vent near the summit, but all did come from flank vents higher in altitude than 6500 ft, that is, well up on the stratocone.

The central part of the main cone is underlain largely by andesitic scoriae and breccias, which are extensively exposed on the headwalls of glaciers and high on several cleavers. Owing to their permeability and their focal position in a zone of persistent solfataric emission, these pyroclastic deposits have in most places undergone pervasive acid-sulfate leaching and precipitation of kaolinite, silica, alunite, gypsum, sulfur, iron-oxides, and iron-hydroxides. This altered pyroclastic core

[1]With contributions by Judy Fierstein and E. L. Mosier, USGS.

grades radially into stacks of thin and very rubbly lava flows that mostly dip outward at 15°–35°.

Two groups of Tertiary rocks, the Columbia River Basalt Group on the east and mafic to silicic lavas and pyroclastic rocks typical of the western Cascades on the west, are presumed to extend well beneath Mount Adams, but within the wilderness they crop out only along the western fringe. All rocks exposed within the wilderness and contiguous roadless areas are therefore of igneous origin or consist of equivalent material that was reworked by avalanches, glacial ice, or running water. Moreover, all are of Quaternary age, apparently younger than 0.5 million years, except for about 1 sq mi of Oligocene and (or) Miocene lavas, breccias, tuffs, and associated volcaniclastic sedimentary rocks at the western edge of the wilderness.

The volcanic deposits erupted from Mount Adams and its contemporaneous peripheral centers are essentially undeformed. Compared to the other nearby stratovolcanoes (Mounts Hood, St. Helens, and Rainier), few fragmental deposits have been noted at Mount Adams outside of its highly brecciated and scoria-rich summit zone. No widespread ash layers are known to have erupted from Mount Adams. The only major debris flow documented from Mount Adams originated in the headwall of the White Salmon Glacier cirque about 5070 years ago and devastated the White Salmon River valley for at least 25 mi downstream (Hopkins, 1976).

MINERAL RESOURCES

The mineral survey did not identify any metallic mineral or energy resource potential, nor is there any likelihood for the occurrence of resources in the wilderness or the contiguous roadless areas. There have been no major producers of base or precious metals in southwestern Washington (Moen, 1977), and not a single mine is now in production in the St. Helens and Washougal mining districts, west of Mount Adams. The only mining operations near the volcano have been quarries for rock, sand and gravel, or cinders.

A solfatarically altered summit region is the only mineralized zone that has been recognized at Mount Adams. Deposition of sulfur has taken place near fumarolic orifices immediately beneath the insulating cover of the summit icecap, but the deposits are not a significant resource.

Sulfur claims were filed on the summit of Mount Adams in 1929 and in 1931, under the name "Glacier Mining Company." Several pits were excavated into solfatarically altered rocks adjacent to the summit icefield. In 1934, as much as 305 ft of ice and as much as 38 ft of altered rocks were penetrated with 16 drill holes. Although no coring was done, sulfates and sulfur were prominent in sludge from the holes that successfully penetrated through the ice. Fowler (1935) analyzed about 33 samples from outcrops, crevasses, and pits, obtaining values ranging between 11 and 79 percent sulfur. In remarking on the possible difficulties of mining sulfur on the summit of the second highest peak in the Northwest, an unpublished report recommended, perhaps tongue-in-cheek, that the operation should be conducted underground (beneath the protective icecap) and in the winter, when uninterrupted freezing might reduce caving of the soft altered rocks and stronger atmospheric convection might help to cool the hot ground and ventilate the noxious gases.

In 1981 and 1982, the late-summer meltdown on the summit of Mount Adams was inadequate to permit a thorough re-evaluation of the sulfur and sulfate content of the altered rocks there. We collected a variety of texturally and mineralogically different kinds of altered rocks peripheral to the summit icecap and from debris that had avalanched from precipitous outcrops. More than 60 (Hildreth and Fierstein, 1983) of these were X-rayed and contain assemblages dominated by alunite, kaolinite, and silica minerals; in a few samples gypsum is also important. Elemental sulfur is present in surprisingly few samples, mostly as yellow crusts and vesicle fillings in altered scoriae but also as fragments of white, massive, fine-grained material in which it is mixed with silica and alunite. Rare pyrite was the only sulfide mineral identified.

Nearly pure sulfur is largely restricted to irregular veins and vug fillings, whereas most of the elemental sulfur present appears to be mixed with alunite, silica, and altered andesite. Spectrographic analyses indicated trace amounts of Hg in some of the fumarolically altered summit rocks. Excavation beneath the summit icecap for sulfur, sulfates, or kaolinite would involve formidable risks of life, limb, and capital.

Lower on the volcano, the exposed Quaternary lavas are generally unaltered and certainly unmineralized. Some of the Tertiary lavas and pyroclastic rocks exposed along the western fringe of the wilderness are weakly propylitized and cut in a few places by veinlets—typically fracture fillings of silica and iron oxides in breccias—but none appear to contain sulfides or unusual concentrations of metals.

Mount Adams also appears to be a poor target for geothermal-resource exploration. The only silicic lavas known to have been derived from Mount Adams erupted early in the evolution of the volcano. The many subsequent eruptions that have built the present cone appear to have been exclusively andesitic or basaltic, irrespective of whether their vents were on the flanks or at the summit. This virtually precludes the possibility of a silicic magma reservoir beneath Mount Adams during most of its history. Geophysical data for Mount Adams are sparse, but neither the aeromagnetic pattern (U.S. Geological Survey, 1975) nor the gravity map (Schuster and others, 1978) provide any indication of a magma body beneath the volcano. The high precipitation on the stratocone, estimated by Cline (1976) to be about 140 in., makes Mount Adams an important site of ground water recharge. The high permeability of its rubbly lava flows suggests that much of this ground water moves rapidly downward and outward from the stratocone, failing to remain in the warmer central region of the volcano long enough to develop a hydrothermal convection pattern but, instead, dispersing and dissipating whatever heat is supplied from depth to the fumarolically altered core. The weak and diffuse fumarolic emissions on the summit are the only manifestations of possible hydrothermal activity anywhere on the stratocone. There are ample exposures of permeable pyroclastic rocks on the steep cliffs all around the summit plateau, such that any significant hydrothermal system in the cone itself would be readily identifiable. The warmest spring that we have found anywhere in the contiguous roadless areas measured only 37°F on a summer day.

Because no faults of significance cut the gently dipping apron of Quaternary lavas around the central cone of Mount Adams, no structures have been identified that might control upward convection of ground water heated at great depth.

SUGGESTIONS FOR FURTHER STUDY

Further study of the wilderness offers little promise for identification of hidden mineral deposits. Drilling in the lowland periphery of the volcano might be technically difficult, but 150°-200°F waters suitable for space heating would not be unexpected at depths of 5000-6000 ft.

REFERENCES

Cline, D. R., 1976, Reconnaissance of the water resources of the upper Klickitat River basin, Yakima Indian Reservation, Washington: U.S. Geological Survey Open-File Report 75-518, 54 p.

Fowler, C. S., 1935, The origin of the sulfur deposits of Mount Adams: M.S. thesis, State College of Washington, Pullman, 22 p.

Hildreth, W., and Fierstein, J., 1983, Mineral and geothermal resource potential of the Mount Adams Wilderness and contiguous roadless areas, Skamania and Yakima Counties, Washington: U.S. Geological Survey Open-File Report 83-474.

Hopkins, K. D., 1976, Geology of the south and east slopes of Mount Adams volcano, Cascade Range, Washington: Seattle, University of Washington, unpublished Ph.D. thesis, 143 p.

Moen, W. S., 1977, St. Helens and Washougal mining districts of the southern Cascades of Washington: Washington Division of Geology and Earth Resources, Information Circular 60, 71 p.

Schuster, J. E., Blackwell, D. D., Hammond, P. E., and Huntting, M. T., 1978, Heat flow studies in the Steamboat Mountain-Lemei Rock area, Skamania County, Washington: Washington Division of Geology and Earth Resources, Information Circular 62, 56 p.

U.S. Geological Survey, 1975, Aeromagnetic map for part of southwestern Washington: 4 sheets; scale 1:62,500: U.S. Geological Survey Open-File Report 75-648.