# STUDIES RELATED TO WILDERNESS
# WILDERNESS AREAS

# SOUTH WARNER, CALIFORNIA

GEOLOGICAL SURVEY BULLETIN 1385-D

# Mineral Resources of the South Warner Wilderness, Modoc County, California

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*With a section on* AEROMAGNETIC DATA

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STUDIES RELATED TO WILDERNESS—WILDERNESS AREAS

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STUDIES RELATED TO WILDNERNESS

## WILDERNESS AREAS

Under the Wilderness Act (Public Law 88-577, Sept. 3, 1964) certain areas within the National Forests previously classified as "wilderness," "wild," or "canoe" were incorporated into the National Wilderness Preservation System as wilderness areas. The act provides that the Geological Survey and the Bureau of Mines survey these wilderness areas to determine the mineral values, if any, that may be present. The act also directs that results of such surveys are to be made available to the public and submitted to the President and Congress. This bulletin reports the results of a mineral survey of the South Warner Wilderness, California.

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# MINERAL RESOURCES OF THE SOUTH WARNER WILDERNESS, MODOC COUNTY, CALIFORNIA

By WENDELL A. DUFFIELD, U.S. Geological Survey, and
ROBERT D. WELDIN, U.S. Bureau of Mines

## SUMMARY

The South Warner Wilderness encompasses about 69,500 acres of rugged terrain in the Warner Mountains of northeast California. The crest of this north-trending range bisects the area and reaches a maximum elevation of nearly 10,000 feet. The Warner Mountains are a fault-bounded block of the Basin and Range province and have been uplifted between 5,000 and 12,000 feet along the fault zones. Bedrock of the area consists of 5,000 feet of coarse clastic sedimentary rocks of Oligocene age that are overlain by 5,000 feet of rhyolitic to basaltic volcanic rocks of Miocene age. Mafic sills are common in the Oligocene section, and abundant mafic dikes penetrate to the top of the range. The entire bedrock section is conformable and dips about 25° to the west. Quaternary glaciers carved out some of the present topography along the range crest and locally deposited small moraines.

This study evaluated the mineral resources of the wilderness by (1) a geochemical study of bedrock and stream sediment samples, (2) a reexamination of recorded mining claims, and (3) an analysis of an aeromagnetic map of the area. A geologic map was also made during the study to provide a framework for these three methods of mineral surveying. The 553 bedrock samples and the 315 stream sediment samples were analyzed for 30 chemical elements by semiquantitative spectrographic techniques. Because these analytical data show no anomalous concentrations of the analyzed elements, they indicate the presence of only ordinary crustal rocks in the area. The aeromagnetic map shows several anomalies, but all can be explained by contrasting magnetic properties of the surface rocks; thus it also indicates normal crustal material, both at and at some depth beneath the surface in the wilderness. The recorded mining claims were staked mostly on small calcite veins that were worked for optical grade calcite. It is unlikely that these veins will be commercially exploitable in the foreseeable future, largely because of their small size and the current availability of synthetic calcite crystals.

Except for the former calcite mining, the wilderness has not been an area of mineral production. Minor amounts of semiprecious stones, including hyaline opal, varieties of cryptocrystalline quartz, and petrified wood, occur in the area. Because such material is more abundant elsewhere, it is doubtful that the semiprecious stones would ever be worked commercially in the wilderness. Minor amounts of zeolite minerals are also present, but this material, too, is of no commercial value now or in the foreseeable future because of the existence of much richer deposits elsewhere and of the wide availability of synthetic zeolites.

Valuable deposits of gravel, used mainly for road metal, and potentially valuable concentrations of geothermal energy, indicated by hot springs, lie adjacent to the wilderness in Surprise Valley. The wilderness contains potential road metal in the form of volcanic cinder deposits and crushable lava flows, but these materials are equally abundant nearby outside the wilderness. The Miocene age of the youngest volcanic rocks in the wilderness suggests little or no potential for anomalous concentrations of geothermal energy there because most geothermal areas of the world are associated with Holocene or Pleistocene volcanism.

We conclude that the South Warner Wilderness holds no potential for the commercial production of mineral resources either now or in the foreseeable future.

# INTRODUCTION

## LOCATION AND GENERAL CHARACTER

The South Warner Wilderness is in southeast Modoc County, Calif., about 6 miles east of Nevada and 40 miles south of Oregon (fig. 1). The area encompasses about 69,500 acres and forms a crude north-trending rectangle, averaging about 7 miles by 16 miles.

The topography is dominated by the crest of the Warner Mountains, which longitudinally bisects the area. Crest elevation generally ranges from 8,000 to 9,000 feet and reaches a maximum of about 9,900 feet at Eagle Peak. Several other slightly lower peaks also punctuate the ridge line. Maximum relief is about 5,000 feet from the floor of Surprise Valley on the east to the top of Eagle Peak. U.S. Geological Survey topographic maps at a scale of 1:24,000 are available for the entire area.

Several small lakes occur near the range crest within the wilderness, the largest and perhaps most beautiful of which is Patterson, situated in a glacial cirque beneath the northeast face of Warren Peak (fig. 2). The crest acts as a weather barrier that gives the east and west slopes of the range strongly contrasting vegetative covers. The west slope is relatively well watered and is characterized by forest with scattered open meadows (fig. 3). The east slope, however, lies in the lee of the mountain range and sustains relatively little vegetation. In fact, much of the lower east slope of the range in the wilderness has a badlands character (fig. 4).

The east and west slopes also differ topographically. The forested west slope is a relatively gentle dip surface on slightly tilted lava flows and is easily accessible on foot. The east slope, which cuts steeply across many lava flows and sedimentary rock strata, forms a rugged face where foot trails must be carefully located and constructed. Any significant amount of rainfall on this steep and barren east slope commonly results in flash flooding of all major streams and thus contributes greatly to the development of the rugged character of the area.

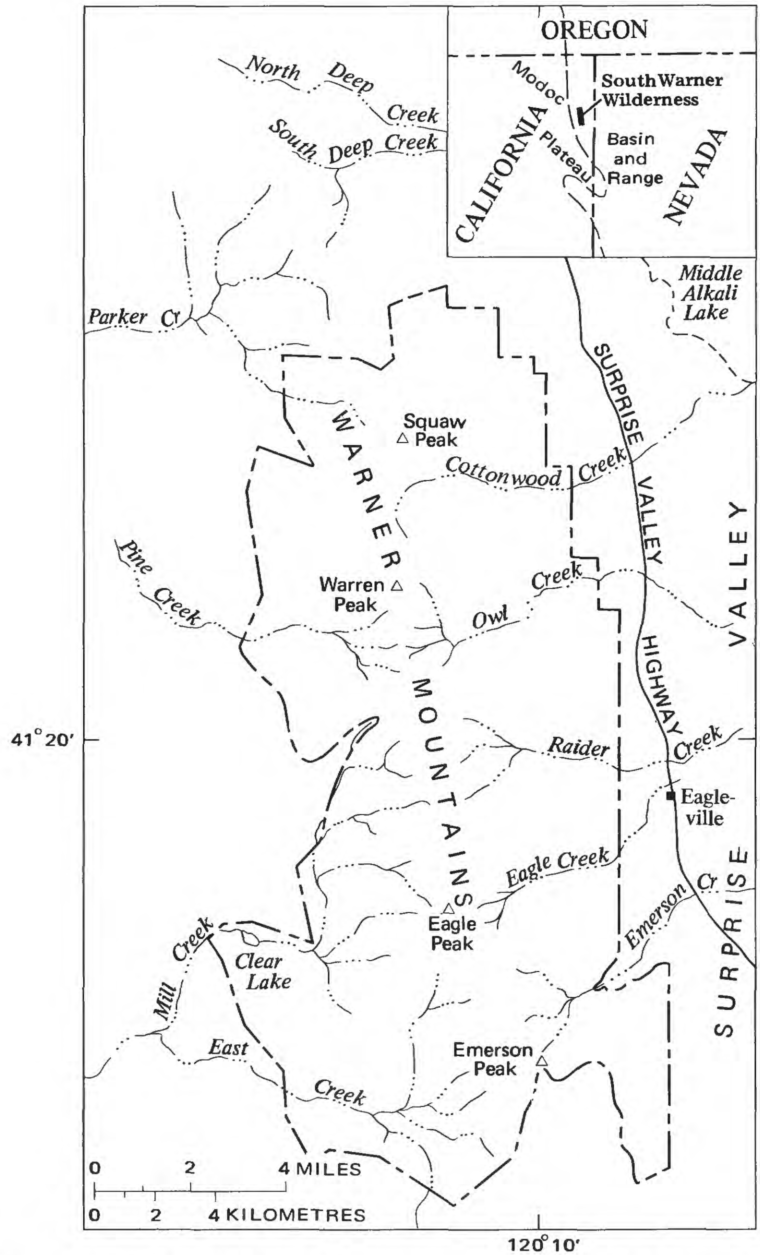


FIGURE 1.—The South Warner Wilderness and the principal streams and peaks within the area.

FIGURE 2.—Patterson Lake. View is to the south-southwest. The lake occupies a glacial cirque and is dammed by a moraine. The rocks directly behind the lake are a 250-foot-thick andesite flow overlain by seven 20-foot-thick basalt flows. The east point of the spur behind the lake is 9,710-foot Warren Peak; part of the Pine Creek Basin is visible directly behind this spur.

Access to the wilderness is good. Well-maintained hard-surfaced and graded roads nearly surround the area, and many spur roads lead to the wilderness boundary. A foot trail, which traverses the area from north to south, generally follows the summit ridge, and connecting side trails cross both the east and west slopes at several places.

## PREVIOUS STUDIES

The only published geologic study of the South Warner Wilderness was carried out by R. J. Russell in the 1920's (Russell, 1928). Russell's work was of a reconnaissance nature and included the entire Warner Mountain Range, well beyond the boundaries of the wilderness. Russell, who was interested principally in the structural geology, did not attempt a detailed subdivision of the various rocks into formational map units. Nonetheless, Russell's map (1928, attached map) still stands as the original source for geologic mapping of the wilderness and the Warner Mountains.

More recent work by Hulbe and Emerson (1969), including a study of the northernmost part of the wilderness, has resulted in revision of the original rock formational designations of Russell. These investigators have not published a map.

FIGURE 3.—A typical view of the west slope of the Warner Mountains in the South Warner Wilderness. The slope generally parallels the surface of gently tilted lava flows. Warren Peak is the high point on the horizon, and the Pine Creek Basin is adjacent to the right (south).

## PRESENT STUDY

The purpose of the present study is to evaluate the mineral potential of the South Warner Wilderness. This evaluation has been accomplished principally by extensive sample collection and analysis of surficial materials, supplemented by the interpretation of an aeromagnetic map. Except for a few small calcite mines that have been abandoned for many years, the area has not had a history of mineral production; nonetheless, the entire area was examined carefully.

The U.S. Geological Survey was responsible for collecting bedrock and sediment samples. During the course of sampling, a geologic map was made to provide a framework for discussion of the analytical data with respect to various rock types, their distribution, and their relations to one another (pl. 1). The locations of all samples are shown on plate 2. Wendell A. Duffield, with the help of Christopher Kenah and Roger Dockter, collected the samples and mapped the geology during the fall of 1972 and summer of 1973. All the samples were analyzed for 30 chemical elements by semiquantitative spectrographic techniques as described by Grimes and Marranzino (1968). Other more sensitive techniques were used to analyze for a few selected elements, and to obtain more accurate data. Mineral identification was by thin section and by X-ray diffraction methods.

FIGURE 4.—A typical view of the east face of the Warner Mountains in the South Warner Wilderness. Note the many exposed rock strata. The narrow persistent band of trees across the photograph about half way up the slope is just above a group of conglomerate and sandstone beds discussed in the section on "Sedimentary Rocks." Slightly higher, the light-colored rock is a 300- to 1,000-foot-thick rhyolitic welded ash-flow tuff. The high point on the horizon is Warren Peak, and the total relief from Surprise Valley in the foreground to this peak is about 4,800 feet.

The general philosophy behind extensive surface sampling and subsequent chemical analysis is that at least one or more samples will come from a mineralized area if such an area exists. Depending upon the density of sampling, such a technique might result in overlooking small mineralized areas if only samples of bedrock are collected, but if samples of stream sediments are collected they will provide composite samples of entire upstream drainage basins.

To complement the more general mineral survey technique of the U.S. Geological Survey, Robert D. Weldin of the U.S. Bureau of Mines examined all known mineral claims within the wilderness during the fall of 1972 and summer of 1973. Steven Schmauch and D'Arcy Banister helped with the fieldwork in 1972. Weldin also panned concentrates of heavy minerals from selected stream sediments and had the concentrates analyzed for valuable elements.

An aeromagnetic survey of the wilderness was made by the U.S. Geological Survey, and Willard E. Davis of the U.S. Geological Survey analyzed the aeromagnetic map for the possible presence of anomalously magnetic rocks.

Together, these various methods of study provide a reasonable exploration program for the discovery of mineral deposits at or near the ground surface that would be valuable now or in the foreseeable future.

## GEOLOGIC STRUCTURE AND HISTORY

The Warner Mountains have been carved from a west-dipping fault block at the west edge of the Basin and Range province. The principal zone of faulting, along which the mountains were uplifted, is buried by recent sediments in Surprise Valley at the east edge of the range. Uplift along this zone was at least 5,000 feet and possibly as much as 12,000 feet. Several subsidiary, transverse faults also formed during mountain building. These faults along or near Owl, Raider, Eagle, and Emerson Creeks (pl. 1), probably localized the present courses of these streams.

Range-bounding structures on the west side of the mountains are not well exposed. Much of the west side merges almost imperceptibly with an extensive lava sheet that is part of the Modoc Plateau, the next province to the west. Locally, however, exposures indicate that the range is at least partly fault-bounded on the west, although uplift there was less than along the east boundary.

The wilderness lies between the range-bounding fault zones and is underlain primarily by a conformable sequence of Tertiary sedimentary rocks and lava flows. In general, the lower half of the rock sequence is sedimentary, and the upper half volcanic. A few thin layers of volcanic tuff are intermixed with the sedimentary rocks, but the lower half of the rock sequence primarily represents a period of sediment deposition, whereas the upper half indicates a time of abundant lava and ash flows in the wilderness. Mafic sills of Tertiary age have intruded the sedimentary rocks locally, and slightly younger Tertiary mafic dikes cut all rocks of the sequence.

Initially the entire sequence of rocks accumulated in the horizontal position during Oligocene and Miocene time, and then it was tilted about 25° westward in late Miocene or younger time when the range was uplifted along fault zones. During uplift, large volumes of material were eroded from the range and were deposited in thicknesses of up to 7,000 feet in Surprise Valley, the major downfaulted block adjacent to the range on the east.

In Quaternary time, glaciers modified the landscape (see fig. 2) and, together with streams, formed local moraines and veneers of sand and gravel. These Quaternary deposits generally are small and are not shown on the geologic map (pl. 1).

With the melting of glaciers, Surprise Valley filled with water to a depth of at least 500 feet, partly submerging the eastern part of the wilderness. Several high-level, wave-cut beach lines and alluvial cones and stream delta deposits of gravel perched on the walls of the valley provide abundant graphic evidence of the former deep lake. Today, three shallow, ephemeral, alkaline lakes cover part of Surprise Valley.

## DESCRIPTIONS OF THE ROCKS

### SEDIMENTARY ROCKS

The sedimentary rocks, based on unpublished K/Ar data (E. H. McKee, oral commun., 1973), are Oligocene in age. They consist of about 5,000 feet of consolidated clastic debris that forms both well-bedded strata and massive structureless units. The bedded rocks include thin layers of siltstone and sandstone, but mostly they are rounded cobble conglomerate. Individual layers rarely can be traced far laterally, but distinctive groups of strata extend for several miles. For example, a sequence of conglomerate and sandstone beds 100–300 feet thick is traceable from the north boundary of the wilderness to Hornback Creek, about 8 miles south. Over most of this distance, the sequence forms a conspicuous cliff, above which small trees and brush grow on a 100- to 200-foot-wide slope (fig. 4).

The massive sedimentary rocks form thick accumulations of chaotically mixed angular clastic debris ranging in size from silt particles to blocks 15 feet in diameter. Scattered fragments of petrified wood are abundant locally; with some logs measuring as much as 8 feet long and 2.5 feet in diameter.

The stratified sedimentary rocks probably accumulated through vigorous stream erosion, transportation, and deposition. The unstratified deposits apparently resulted from catastrophic water-saturated debris flows that uprooted and transported large trees. Both rock types imply the presence of a steep, rugged source terrain nearby.

Almost all of the sedimentary debris was derived from andesitic lavas, suggesting that this rugged terrain may have been the slopes of volcanoes that probably were active, at least intermittently, during Oligocene time. A few cobbles and boulders of granitic rock occur near the base of the section, but most clasts are porphyritic andesite with plagioclase, pyroxene, olivine, and amphibole phenocrysts.

### VOLCANIC ROCKS

The volcanic sequence is Miocene in age (based on unpublished K/Ar data of E. H. McKee, oral commun., 1973). It consists of about 5,000 feet of rhyolitic, welded ash-flow tuff, andesite flows, rhyolitic to andesitic air-fall pyroclastic deposits, basalt flows, and small, local rhyolite flows. Not all of the mappable volcanic units have been delineated separately on the geologic map (pl. 1), but a complete composite section through the volcanic pile as exposed in the east face of the wilderness is shown in table 1. The following descriptions are of this section from bottom to top.

TABLE 1.—*A composite section of all volcanic rocks exposed in the east face of the South Warner Wilderness*

| Rock | Map symbol | Approximate range in thickness (ft) |
|---|---|---|
| Rhyolitic flows and plugs | Tvr | ?– 150 |
| Mafic lava flows | Tvm | ?–1,600 |
| Tephra | Tvt | 100– 400 |
| Basalt flows | Tvb | 900–1,300 |
| Composite volcanic unit: | | |
| Upper Rhyolitic welded ash-flow tuff | Tvc | 100– 200 |
| Andesite flows | do | 400–1,200 |
| Lower rhyolitic welded ash-flow tuff | do | 300–1,000 |

The lower rhyolitic welded ash-flow tuff commonly crops out as light-colored, steep slopes (fig. 4) or bold cliffs studded with nearly vertical joint-bounded columns as much as 12 feet in diameter. The rock is composed of pumice, dark lithic fragments, and scattered crystals of quartz, biotite, feldspar, and rarely hornblende; all are set in a matrix of glass shards. A few distinctive thin layers composed almost entirely of black glass are scattered through the unit. A gently westward dipping planar structure is apparent at most outcrops, especially where compaction through flattening of particles is pronounced.

Andesite flows that overlie this tuff are as much as 400 feet thick and commonly crop out as steep cliffs. The flows range from massive to pervasively jointed and locally contain irregular zones of breccia that probably formed in solidified, brittle parts of a flow in response to continued movement of still molten parts. Most of the flows exhibit a porphyritic texture; they contain phenocrysts of plagioclase, pyroxene, amphibole, and rarely biotite.

The upper rhyolitic ash-flow is similar to the lower one, but it has a higher porportion of crystals, less pronounced flattening of particles, and no black vitric zones. Because this unit is only 200 feet thick or less, it generally does not form conspicuous outcrops, but it is well exposed near the junction of Cole and Emerson Creeks, in the southern part of the wilderness (see pl. 1).

The next higher unit exposed in the east face of the wilderness is a distinctive succession of about 40 to 70 basalt flows that average 20 feet thick. Locally, some flows were ponded to as much as 150 feet thick, and these commonly display columnar jointing. Plagioclase, olivine, and pyroxene, the common phenocrysts, generally increase in size to a few millimetres in diameter toward the center of a flow. Some flows are slightly vesicular throughout, others have dense massive cores, and most are capped by a zone of red, oxidized scoria several inches thick. Commonly, vesicles are partly or completely filled with secondary minerals, mostly zeolites.

These basalt flows are overlain by well-bedded deposits of poorly consolidated, rhyolitic to andesitic, air-fall pyroclastic debris (tephra). Individual beds vary in thickness from a few inches to several feet and are composed of different proportions of intermediate to mafic lithic fragments, pumice, scoria, feldspar, and rarely hornblende in an ash matrix. Graded bedding and crossbedding are common locally, suggesting some working of the deposits by streams.

The range crest in the wilderness generally is capped by interlayered basalt and andesite flows. The basalt flows are similar to those described lower in the section, although diktytaxitic texture is common and secondary zeolites are uncommon in flows along the range crest. Similarly, the upper andesite flows resemble the lower ones, although porphyritic texture is less pronounced and pervasive, platy jointing is better developed in the crest flows.

A small remnant of a rhyolite flow overlies the crestal basalt-andesite unit on Cole Peak (pl. 1). Elsewhere, in the southeast and southwest parts of the area (pl. 1), rhyolite flows overlie deposits of tephra that correlate stratigraphically with the previously described tephra that is exposed almost continuously across the eastern part of the wilderness. All of the rhyolite flows are generally dense, light-colored, flow-banded rocks that contain scattered biotite grains in an aphanitic groundmass. Lithophysae and spherulites form distinctive textures locally.

## INTRUSIVE ROCKS

Mafic sills are common in the lower part of the sedimentary section, especially in the northern third of the wilderness. Most of these sills are several feet thick, but locally they are as much as 75 feet thick. The thickest sills have slightly metamorphosed adjacent rocks in a zone up to a few feet wide. The sills, which are generally massive and coarsely porphyritic, contain abundant pyroxene phenocrysts several millimetres in diameter. Only the largest sills are shown on the geologic map (pl. 1).

Mafic dikes intrude into both the sedimentary and volcanic sections. Most are from 1 to 4 feet thick, dip vertically or nearly so, and trend between north and west. Textures range from fine- to medium-grained holocrystalline. Crosscutting relations indicate that at least some dikes are younger than the sills and that at least two generations of dikes are present. The dikes are probably Tertiary in age, though no younger than late Miocene.

A few rhyolite plugs associated with rhyolite flows crop out in the southern part of the area. The plugs almost certainly served as feeders for the flows. The plug rocks generally are light colored and dense, with well-developed steeply dipping, concentric flow banding. Much of the rock is aphanitic, but locally biotite and feldspar crystals are apparent.

## EVIDENCE OF TERTIARY VOLCANOES

The remnants of three volcanoes have been tentatively identified in the South Warner Wilderness (see pl. 1). Two of the volcanoes were mafic composite cones that are now eroded as much as 1,000 feet below their former summits. One of these is indicated by the presence of a vent of brecciated and hydrothermally altered rocks, and both are indicated by a surrounding blanket of pyroclastic material and interlayered flows with quaquaversal dips. The third volcano probably was a basaltic shield; its existence is suggested by central areas of ponded(?), zeolitized flows surrounded by relatively fresh flows, and by coarsening of some surrounding pyroclastic debris toward these central areas. Rhyolitic plugs and flows are associated with all three of the mafic volcanoes.

## HYDROTHERMAL ALTERATION

The entire Tertiary section has been mildly hydrothermally altered. Field evidence of this alteration consists of a widespread secondary green color that pervades many outcrops, especially those of the sedimentary rocks and the rhyolitic and andesitic rocks, and the presence of secondary minerals along many joint surfaces and in cavities, especially in vesicles of basalt flows. Laboratory study indicates that the green color is caused by the mineral celadonite and that the minerals in cavities are mainly zeolites and carbonates. Some cavities and joint surfaces, especially in andesite and basalt flows, are partly veneered with hyaline opal and crystalline or cryptocrystalline varieties of $Si0_2$. Original sedimentary and volcanic structures and textures are virtually unaffected by the alteration.

## INTERPRETATION OF AEROMAGNETIC DATA

By WILLARD E. DAVIS

In September 1970, the U.S. Geological Survey made an airborne magnetometer survey of the region between lat 41°10′ N. and 41°30′ N. and long 120°06′ W. and 120°20′ W.; this region includes the South Warner Wilderness. Total-intensity magnetic data were obtained with a continuously recording fluxgate magnetometer installed in a Convair 240 aircraft. North-south traverses about 1 mile apart were flown at an average barometric elevation of 10,000 feet above sea level. The magnetic data were compiled relative to an arbitrary datum at a scale of 1:48,000 and were contoured at intervals of 20 and 100 gammas (pl. 1).

Several rock samples were collected in areas that underlie some of the magnetic anomalies indicated on plate 1 and were examined with a vertical component magnetometer. A few of these samples were oriented, and their magnetic properties were studied with an induction bridge and a spinner magnetometer. The magnetic response of all studied samples indicates that andesite and basalt flows generally possess strong remanent magnetization intensities, whereas tuffaceous and rhyolitic rocks and sedimentary rocks have much lower intensities. Some of the volcanic rocks are inversely polarized; this polarization indicates that they were formed when the polarity of the earth's magnetic field was reversed.

The magnetic pattern of the area consists of: (1) narrow northwest-trending zones of high magnetic intensity, generally along the range crest; (2) a dominant high-gradient negative anomaly centered about 1 mile west of Emerson Peak, on the west slope of the range; (3) a northwest-trending elongate positive anomaly centered over lower East Creek; (4) magnetic lows of generally small amplitude in the central and north parts of the west slope of the range; and (5) general low magnetic relief in the eastern part of the area. Most of the anomalies seem to be caused by contrasts in magnetic properties of rocks that are exposed or lie near the ground surface, principally the contrast between basaltic to andesitic flows and the more silicic volcanic rocks and sedimentary rocks. All the magnetic features are superimposed on the earth's regional magnetic field, whose intensity decreases to the southwest at a rate of about 9.1 gammas per mile in this region.

A 1-mile-wide, somewhat irregular zone of high magnetic intensity follows the mountain crest nearly across the entire wilderness. The general position of this zone correlates with the distribution of the uppermost basaltic and andesitic flows along the crest, and discontinuities correlate with topography and the northern three transverse faults. For example, in the northern part of the area the magnetic zone sweeps around the south and west sides of Pine Creek Basin and then turns abruptly to the northeast along the north edge of the basin, roughly following the outcrop pattern of the mafic flows there. Discontinuities caused by topographic effects are indicated where a low saddle in the anomalous zone correlates with a pronounced topographic saddle at the head of Raider Creek, and where topographic highs such as Warren Peak and Eagle Peak underlie local magnetic highs. Fault-related discontinuities occur where the magnetic zone is offset or sharply bent along the Owl Creek, Raider Creek, and Eagle Creek faults. Thus, this magnetic anomaly zone almost certainly results from the relatively strong magnetic effect of the mafic lava flows and is pronounced along the crest of the range by the relative nearness of these flows to the magnetic sensor.

From the crest of the range eastward, the magnetic intensity decreases irregularly. At intermediate elevations the magnetic pattern is still affected by the strong crestal anomaly, but at lower elevations, near and at the base of the range, the magnetic gradient is relatively gentle and the pattern trends northward, parallel to the range front. The character of the magnetic field along the east face of the range probably results from the combined effects of topography and lithology. Elevation drops abruptly about 5,000 feet from range crest to base, and the underlying mostly sedimentary and silicic volcanic rocks are relatively nonmagnetic. Thus, the magnetic sensor was considerably farther from less magnetic rocks in contrast to the crestal area.

On the west slope of the range, the north half of the area is characterized by a generally westward decreasing magnetic intensity with three superposed, low-amplitude, central lows. The general westward decrease probably is caused partly by a topographic effect, similar to that along the east face of the range. The northernmost central low is over an area nearly surrounded, but not underlain, by basaltic flows, suggesting a simple lithologic cause and effect, similar to the crestal anomaly. The middle low shows no simple correlation with topography or geology and is of very small amplitude; therefore, it probably is only a minor feature. The southern low generally lies over Mill Creek Valley. This feature probably reflects topography along the valley; this part of Mill Creek and vicinity is underlain entirely by mafic volcanic rocks.

The south half of the west slope of the range is dominated by two major central anomalies. A negative anomaly of about −1,000 gammas is centered about 1 mile west of Emerson Peak. The circular shape of this feature is characteristic of a cylindrical body. The anomaly source probably is a steep-sided mass of inversely polarized rock. Steep boundary gradients indicate that the source lies at shallow depths. The surface rocks near the center of the anomaly are olivine-pyroxene basalt flows containing 1 to 2 percent of magnetite. Laboratory study of oriented samples from the flows suggests that the total magnetic intensity of the rocks is dominated by strong reversed remanent magnetization. During fieldwork, it was discovered that locally the flows are so highly magnetic that the needle of a Brunton compass is strongly deflected when brought near an outcrop.

A northwest-trending elongate positive anomaly of about 300 gammas is centered in lower East Creek, near the southwest boundary of the wilderness. The center of this anomaly lies almost directly over the throat of an eroded mafic composite cone. Rock samples of ponded flows and dikes from the vent area have an average induced magnetization intensity of $1.47 \times 10^{-3}$ emu/cc and an average remanent intensity of $0.85 \times 10^{-3}$ emu/cc—values that suggest that the anomaly results principally from these rocks. Other nearby lava flows, however, probably affect the shape of the anomaly. For example, flows on Bald Mountain and Sunflower Knob to the north and south, respectively, may cause some of the elliptical shape of the anomaly; a more nearly circular pattern would be expected if the sole source was the circular throat area.

In summary, all of the variation in total magnetic intensity of the area can be explained by contrasting magnetic properties of the surface rocks. Thus, together with the geologic and geochemical data discussed in following sections, the aeromagnetic map does not suggest the presence of mineral deposits in the area.

## EVALUATION OF MINERAL RESOURCES

### SETTING AND MINERAL PRODUCTION

The South Warner Wilderness is in an area of low mineral potential. Gay (1966) has summarized the economic mineral deposits of the area and has shown that most of the limited mining activity was in areas surrounding the wilderness. About $3,500,000 in gold and silver was mined from the High Grade, Hayden Hill, and Winters districts, 30–35 miles outside the wilderness. Mining in these districts peaked in the early 1900's and has long since been inactive. A small mercury mine once was operated on the east slope of the Warner Mountains just a few miles north of the wilderness boundary; production figures are not known, but examination of what remains today suggests only a small short-lived operation. Obsidian, perlite, and pumice, products of late Tertiary silicic volcanism, have been recovered commercially in the Warner Mountains, but no deposits of these materials occur within the wilderness. Seams of low-grade coal a few inches thick are present locally in the lower part of the rock section exposed in the east face of the Warner Mountains, but these deposits are too small and too lowgrade for commercial exploitation. A commercial deposit of peat, however, occurs in Jess Valley, about 3 miles outside the southwest boundary of the wilderness. The peat deposit has been strip mined since 1939 and yields more than 10,000 tons of peat a year (Gay, 1966, p. 103); it is used primarily as a soil conditioner. A small tonnage of crude salt was recovered from brine pumped from shallow wells in Surprise Valley (Gay, 1966) in the early 1900's. The salt was fed to local livestock, but the operation was abandoned in 1925.

Deposits of sand and gravel lie adjacent to the wilderness on the east. The deposits have a high content of glassy volcanic rock that makes them too reactive for high-specification concrete, although they are commonly used locally for less exacting concrete aggregate and road construction (Gay, 1966, p. 103). The gravel was deposited at the mouths of major streams that drained the Warner Mountains when the Quaternary lake was at a high level in Surprise Valley. The deposits are triangular in plan view and are draped against the east front of the range at elevations ranging from about 4,600 to 4,800 feet. One of the deposits extends a few tens of feet into the wilderness near the mouth of Raider Creek, and parts of some deposits are only a few hundred feet from the boundary; however, it is unlikely that the small amount of gravel inside the wilderness will ever be exploited.

There are no comparable gravel deposits near the south, west, and north boundaries of the wilderness. At those places where gravel is not available, cinder cones provide road metal, or in their absence, lava flows are quarried and crushed. Both cinder deposits and lava flows occur in the wilderness, especially in the western part, but these materials are equally common outside the area.

Economic sources of geothermal energy may occur in Surprise Valley along the east boundary of the wilderness and they are currently under examination by Federal and State agencies and private industry. Exploration by industry includes eight drill holes ranging in depth from 90 to 7,000 feet (Duffield and Fournier, 1974). Surface indications of this potential resource are in the form of abundant hot springs, one of which exploded in a violent eruption of mud in 1951 (White, 1955). Many of these springs are near the east face of the range and are probably localized there by the range-front fault zone. All lie outside the wilderness, although two are within 1.5 miles of the boundary. However, if Surprise Valley geothermal energy proves to be an economically viable commodity, development most likely will be at or near the hot springs or nearby on the valley floor and, therefore, well outside the wilderness.

There are no hot springs, geysers, or other surface indications of geothermal energy in the wilderness; furthermore, most important geothermal resource areas in the world are associated with Holocene or Pleistocene volcanism, commonly rhyolitic in composition, whereas the youngest volcanic rocks in the wilderness are Miocene and mostly basalt.

The only commodity produced commercially from within the wilderness was calcite, some of optical quality (Iceland spar). The only recorded Iceland spar production from the area, about 1,000 ounces, came from a calcite vein at the Bagley mine. The optical-quality material came from cavities or vugs surrounded by loose earthy material. In the current market, these deposits are not commercial; they are too small and synthetic polarizing materials serve most uses once provided by optical calcite. Small quantities of specimen-quality calcite could be recovered but not profitably because of a limited market and low price.

Nine zeolite minerals have been found in the wilderness. The maximum concentration of these is a few percent by volume, which is far from commercial grade.

TABLE 2.—*Average abundances of selected elements*

[The world values are for unmineralized basalt and granite. All values are in parts per million (ppm). The values for the South Warner Wilderness are probably only accurate to about ±40 percent because of the method of analysis. The values for the wilderness generally are closer to the world value for basalt than granite, probably a reflection of the predominance of basalt and andesite samples analyzed from the wilderness]

| Element | World (ppm) | | South Warner Wilderness (ppm[1]) |
|---|---|---|---|
| | Basalt | Granite | All bedrock samples |
| Barium (Ba) | 330. | 840. | 664.1 |
| Beryllium (Be) | 1. | 3. | 1.2 |
| Chromium (Cr) | 170. | 4.1 | 141.9 |
| Cobalt (Co) | 48. | 1.0 | 32.3 |
| Copper (Cu) | 87. | 10. | 61.1 |
| Lanthanum (La) | 15. | 55. | 33.0 |
| Manganese (Mn) | 1,500. | 390. | 996.4 |
| Mercury (Hg) | .09 | .08 | .05 |
| Nickel (Ni) | 130. | 4.5 | 43.8 |
| Scandium (Sc) | 30. | 7. | 23.2 |
| Vanadium (V) | 250. | 44. | 169.0 |
| Yttrium (Y) | 21. | 40. | 26.7 |

[1]Analysts: R. Babcock, W. D. Crim, D. J. Grimes, and D. Siems, U.S. Geological Survey.

## CHEMICAL ANALYSES OF BEDROCK AND STREAM-SEDIMENT SAMPLES

Chemical analyses of bedrock and stream sediment samples are in accord with the historically low mineral potential of the wilderness. Copies of the chemical analyses for all samples (553 bedrock and 315 stream-sediment) shown on plate 2 are available from the National Technical Information Service, U.S. Department of Commerce, Springfield, Va. The analyses show no chemical anomalies in or near the wilderness. In table 2, the average abundances of several selected chemical elements in igneous rocks of the world, as computed by Turekian and Wedepohl (1961), are compared with average abundances in bedrock samples of the wilderness. For all elements, except mercury, which is relatively low, the average values for rocks of the wilderness fall between the average values for basaltic and granitic rocks of the world. This is reasonable because samples from the South Warner area include rocks of basaltic, granitic, and andesitic (intermediate) compositions. But, more importantly, all averages indicate ordinary unmineralized material. The analytical data for gold also indicate ordinary unmineralized material. Of the 553 bedrock samples, gold was detected in only two, and these values were considerable below any commercially minable grade; no gold was detected in the stream sediments. In general the analytical data for stream-sediment samples are like those of bedrock material, with some systematic differences probably resulting from the processes of weathering and sorting during stream transportation. Thus, the chemical analyses of all samples give no indication of ore bodies in the wilderness.

## MINING CLAIMS

Modoc County records show about 110 mining claims, all recorded before 1955, in the South Warner Wilderness. The Bureau of Mines gave special attention to areas known to contain mining claims and prospects. There are no known current claims in the area. Most claims were located along the steep canyons in the east half of the study area. The earliest recorded claims were staked in 1896, in Cottonwood, Milk, Conklin, and Jackson Canyons. Nearly 40 mining claims were staked during 1901, mostly in Kaiser and Steamboat Canyons. Many of the claims located in the early 1900's were staked for oil. East of the study area, along Surprise Valley, large tracts of land are leased for oil, gas, and geothermal exploration, but there are no current leases inside the wilderness.

The only mine in the area, the Bagley, was mapped, examined, and sampled. Except for the King Fish adit, no other prospect workings were found. Nevertheless, samples were taken in every known mining claim, and the sample site locations (fig. 5) show the general distribution and relative concentrations of mining claims that have been staked.

### LODE CLAIMS

The only definite prospect workings found in the wilderness consist of a few trenches and small pits at the Bagley calcite mine and a 40-foot-long adit at the King Fish prospect.

According to Tom Lee, a Cedarville, Calif. prospector, most of the calcite veins in the wilderness were explored before the end of World War II. He knows of no serious prospecting in the area for the past 30 years, but he speculates that occasionally a deer hunter will stake a mining claim. This seems likely since local residents knew of no other prospectors, and none of the old mining claim holders could be found.

#### BAGLEY MINE

The Bagley Iceland spar mine is about 12 miles south of Cedarville, Calif., about 1 mile west of State Highway 81 and near the head of a small canyon (S–28, 29, W–4 through 11, 39, 77, fig. 5). Access from the mouth of the canyon to the mine is by a steep unmaintained foot trail for ¼ to ½ mile west.

The property was first brought to the attention of the Bureau of Mines by James D. Patterson in 1920 (Hughes, 1941, p. 12, 13). Much of the following information on history and production is taken from earlier Bureau of Mines reports, some of which are unpublished.

No statistics are available regarding the total quantity of Iceland spar produced. During the winter of 1920–21, which was apparently the most active period of development, about 1,000 ounces of Iceland

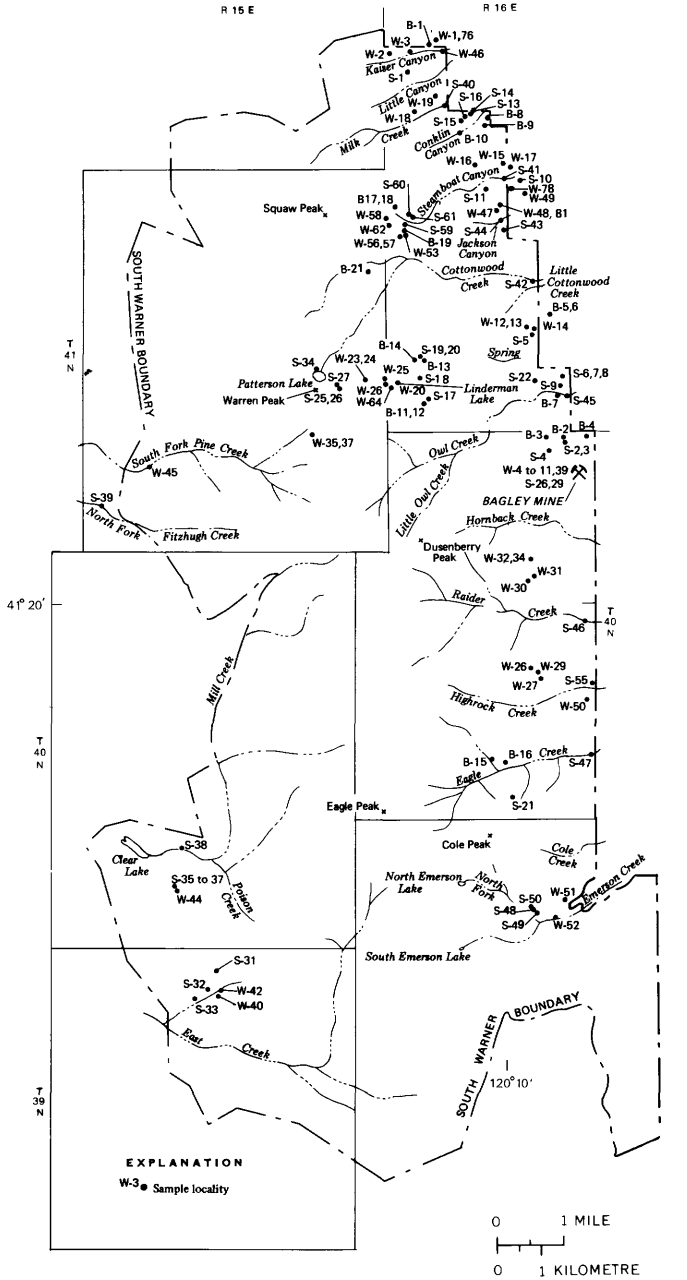


FIGURE 5.—Locations of samples collected from mining claim areas in the South Warner Wilderness.

spar were sold. The largest crystal shipped during that period weighed 12 ounces. Specimens ranged from half-ounce crystals to large crystal aggregates weighing 60–80 pounds. The percentage of flawless crystals was low, but selected crystals were of excellent quality. An undetermined quantity of Iceland spar was recovered during World War II for use in gunsights, and in the late 1940's about 1,000 pounds of chemically pure calcite were sold as standardizing agent for testing acids (Gay, 1966, p. 100). No subsequent production is known, and there was no indication of recent activity when the property was examined in 1972.

Principal mine workings consist of two open cuts, shown in figure 6 as trenches 1 and 2. According to Tom Lee (oral commun., 1972), about $1,500 worth of Iceland spar was recovered from one cavity exposed in trench 1, by James Patterson in one day during the early 1920's. The calcite crystals occurred in pockets or cavities ranging in size from a few inches to several feet. The largest crystals reportedly occurred in a clay matrix. Clear crystals were covered with a reddish coating and emitted a characteristic ringing sound when struck with a hammer.

The deposit (fig. 6) consists of several calcite veins, varying from a few inches to 3 feet thick. The veins normally strike about N. 40° E. and dip from nearly vertical to 55° SE. The principal calcite vein (fig. 7), which can be traced by intermittent outcrops for 500 feet or more has been explored to a depth of about 15 feet by a hand-dug trench.

Good specimens of Iceland spar of commercial size were not found in the old dumps or small stockpiles. It is likely that previous operators and passing collectors had removed the best material. A few hundred pounds of specimen-grade calcite crystals and cleavage fragments could be sorted from the old dumps and stockpiles.

Reserves were not estimated because of the erratic distribution of good-quality calcite crystals in the veins. In the past the yield has been an estimated 1 pound of good calcite crystals per ton of calcite vein material, and with careful mining and sorting a few percent of these crystals were recovered as Iceland spar. There is little demand for Iceland spar at the present time. The price paid by manufacturers of mineral sets, about $100 a ton for specimen-grade calcite crystals, is too low to support a profitable mining operation; furthermore, a few tons would satisfy annual demand. The calcite could be handsorted and washed to produce a product more than 99 percent pure $CaCO_3$, but calcium carbonate of high purity can be produced more cheaply from large tonnage sources closer to markets.

### KAISER CANYON PROSPECTS

More than 15 lode claims were staked along Kaiser Canyon in 1901. Three other claims, the Novice group, were staked near the head of the

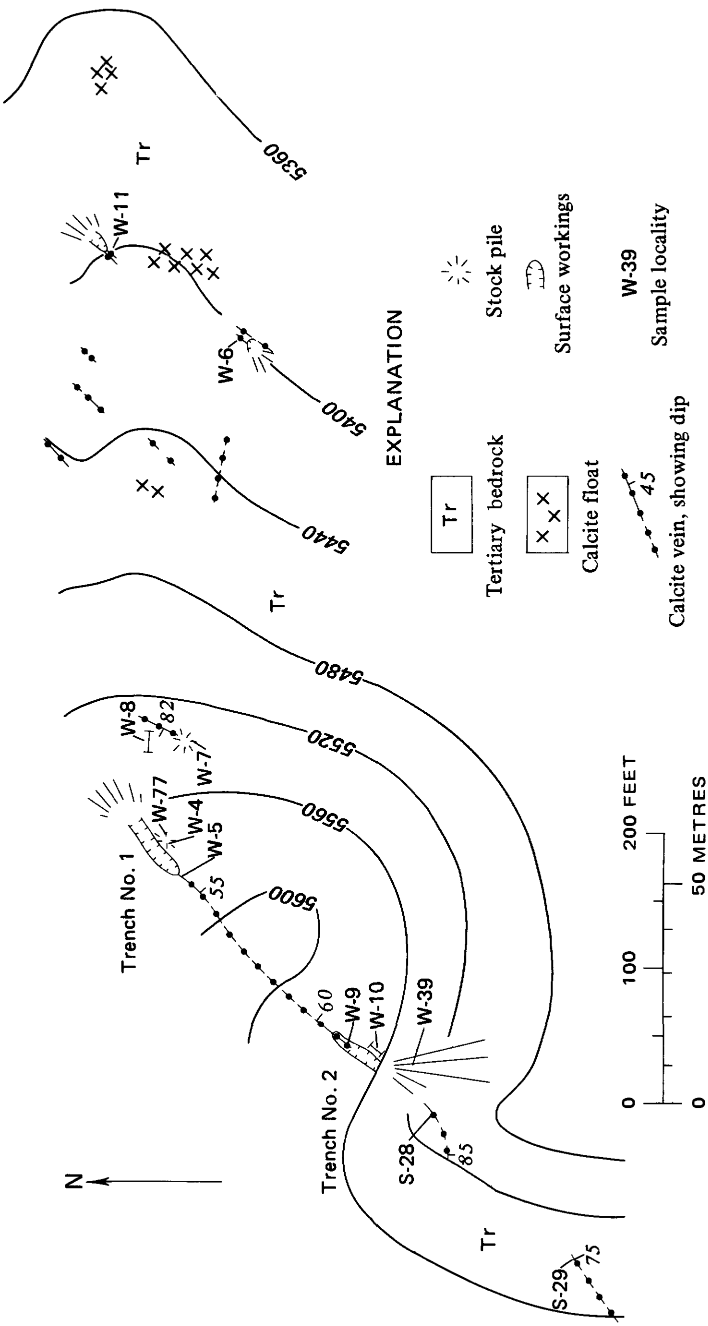


FIGURE 6.—The Bagley mine.

FIGURE 7.—Face of trench 2, Bagley mine, showing a 1.7-foot-thick exposure of the principal calcite vein.

*Data for samples shown in Figure 6*

[Tr, trace; NA, not assayed; ----, none detected]

| Sample No. | Sample Type | Locality or length (ft) | Gold (ounce per ton) | Silver (ounce per ton) | $CaCO_3$ (percent) | Description |
|---|---|---|---|---|---|---|
| S-29 | Chip | 0.5 | Tr | 0.7 | 98.2 | Across calcite vein. |
| S-28 | do | 2.0 | ---- | .1 | 89.3 | Do. |
| W-39 | Select | Dump | NA | NA | NA | Calcite crystals sorted from dump |
| W-10 | Chip | 10.0 | Tr | ---- | NA | Wallrock from trench. |
| W-9 | do | 1.7 | Tr | .1 | 90.1 | Across calcite vein. |
| W-5 | do | 1.3 | Tr | .1 | 80.4 | Do. |
| W-4 | Grab | Stockpile | ---- | Tr | NA | Handcobbed pile of calcite crystals. |
| W-8 | Chip | 20.0 | Tr | .1 | NA | Wallrock adjacent to calcite vein. |
| W-7 | Grab | Stockpile | Tr | ---- | NA | Handcobbed pile of calcite crystals. |
| W-6 | Chip | 1.0 and 1.6 | NA | NA | 94.6 | Across two calcite veins. |
| W-11 | do | 3.0 | Tr | .1 | 98.8 | Across calcite vein. |
| W-77 | Select | Stockpile | NA | NA | 99.78 | Best calcite crystals available. |

canyon in 1920. Little evidence of prospecting was found, but a few calcite veins and petrified wood seen in the general area may have attracted the attention of prospectors.

The calcite veins strike generally northeast, dip steeply to the northwest and vary in thickness from less than 1 inch to nearly 4 feet. The largest veins are on the north side of the canyon, about one-fourth mile west of the mouth of the canyon and 100–400 feet outside the wilderness boundary. Samples from calcite veins (W–1, S–1, B–1, and W–76, fig. 5) contained between 84.0 and 98.7 percent calcium carbonate, a trace of gold, and 0.1–0.2 ounce silver per ton. Some of the vein material is crystalline. No Iceland spar was noted, but careful handsorting might produce calcite specimens and possibly some Iceland spar.

Petrified logs as much as 7 feet long and 1–3 feet in diameter were noted near the head of Kaiser Canyon. Bands of milky-white chalcedony up to ½ inch thick that occur in some of the petrified wood may be suitable for jewelry.

### STEAMBOAT CANYON PROSPECTS

Fifteen lode claims were staked along Steamboat Canyon between the years 1901 and 1920, apparently for Iceland spar, petrified wood, potash, and coal. No prospect pits or evidence of claim staking was noted, but reconnaissance samples (table 3) were taken at each recorded claim locality. Samples S–59 and S–60 contained the highest lead and molybdenum assays, respectively, of any sample taken in the study area. These values are too low to be of economic importance. No coal, or rocks valued for potash content, were found.

A few calcite veins were found near the head of the canyon. They vary in thickness from a few inches to 20 feet and in length from 30 to

TABLE 3.—*Sample analyses, Steamboat Canyon prospects*

[Tr, trace; NA, not assayed; ----, none detected]

| Sample No. (fig. 5) | Gold (ounce per ton) | Silver (ounce per ton) | Copper (percent) | Lead (percent) | Nickel (percent) | Chromium (percent) | Molybdenum (percent) | Description |
|---|---|---|---|---|---|---|---|---|
| S–10 | Tr | ---- | 0.01 | ---- | 0.004 | 0.01 | ---- | Basalt dike. |
| S–11 | Tr | ---- | .01 | ---- | .004 | .01 | ---- | Basalt porphyry sill. |
| S–59 | Tr | 0.1 | NA | 0.05 | NA | NA | NA | Calcite vein, 0.7 foot thick (86.7 percent $CaCO_3$). |
| S–60 | Tr | ---- | .004 | ---- | .02 | .003 | 0.003 | Iron oxide-stained zone in mudflow breccia. |
| S–61 | ---- | Tr | ---- | ---- | ---- | ---- | ---- | Calcite vein, 0.75 foot thick (98.3 percent $CaCO_3$). |
| W–15 | Tr | Tr | .01 | ---- | .002 | .01 | ---- | Greenish mudflow breccia. |
| W–16 | Tr | ---- | .004 | ---- | .002 | .003 | ---- | Basalt sill. |
| W–17 | Tr | ---- | .01 | ---- | .002 | .01 | ---- | Greenish mudflow breccia. |
| W–62 | Tr | .2 | .004 | ---- | ---- | ---- | ---- | Do. |
| W–78 | NA | NA | NA | NA | NA | NA | NA | Jasper with green, milky-white, lavender, and brownish bands (in float). |
| B–19 | Tr | .01 | ---- | ---- | ---- | ---- | ---- | Calcite vein, a few inches to 2.0 feet thick (99.3) percent $CaCO_3$). |

FIGURE 8.—Petrified log at the head of Steamboat Canyon.

200 feet. The veins contain some crystalline calcite, but Iceland spar was not seen.

The best petrified wood locality in the study area is at the head of Steamboat Canyon (W–53, 56, 57, 58, and S–60, fig. 5). Petrified logs up to 8 feet long and 2.5 feet in diameter occur in mudflow breccia (fig. 8). The petrified wood is blackish to dark gray with some tan growth rings. Bluish-white to milky-white chalcedony fills fractures in some petrified wood. Yellow, brown, and reddish-brown jasper and bluish-white chalcedony float are found in the vicinity of the petrified logs. Some of the petrified wood and jasper may be suitable for cutting and polishing or tumbling.

## LINDERMAN LAKE AREA PROSPECTS

Several claims were staked on erosional remnants of volcanic tuff about midway between Linderman Lake and Patterson Lake. The claims, located and relocated between the years of 1920 and 1935, were recorded as the Circus Tents, Hay Stacks, and Mineral Soap groups.

They probably were staked for mineral soap because of the natural abrasive quality of the tuff. The deposit contains an upper bed of white lightweight volcanic tuff. More than 90 percent of its grains are subrounded cryptocrystalline glass with less than 10 percent broken fragments of quartz, plagioclase, and biotite. It occurs only as erosional remnants, and the total deposit is less than 40,000 tons. A fine-grained gray brecciated volcanic tuff underlies the white volcanic tuff. It too has an abrasive texture and may also have been thought valuable as mineral soap. It consists of a wide variety of volcanic rock clasts up to 1 cm long, set in a much finer grained devitrified glassy matrix containing mineral chips of quartz, plagioclase, and altered mafic grains. Some calcite replacement was noted in the matrix. This bed is more extensive than the overlying white tuff, and several hundred-thousand tons of this material are available. Even if the material has the abrasive qualities needed in soap or cleaning compounds, it appears certain that mining and transportation costs would exceed its value as a natural abrasive.

About 100,000 tons of poor-quality claylike material occurs beneath and around the edge of Linderman Lake. Claims recorded in 1925 refer to the occurrence as the Owl Creek clay mine, however, no evidence of past mining or prospecting exists. The claylike material is silt with some montmorillonite group clays. About 35 percent of the material is particles coarser than 325 mesh (44 micrometre), composed mainly of nonclay mineral fragments such as feldspar, quartz, and glass shards. Indefinite results by differential thermal analysis indicate that the clay fraction is poorly crystallized calcium bentonite or possibly silt. A low swelling index of 54 percent indicates that it is not suitable for bentonite. No market for this type material is evident, as better clays are available elsewhere.

The Potash King claim group, staked in 1920, extends north and east of Linderman Lake and appears to take in a thick bed of rhyolite tuff. A sample (S–17, table 4) of the rhyolite tuff contained only 1.7 percent potassium oxide, not enough to be a commercial source of potash.

Several lode claims, staked in the early 1940's, take in a prominent, north-trending, basalt dike that crops out several hundred feet east of Linderman Lake. Samples from this dike and others in the area contain small quantities of cobalt, chromium, and nickel, normal for basalt, but no economic concentrations of metals (table 4).

### JACKSON CANYON PROSPECTS

The Cliff, Resumption, and Flying Pigeon mining claims were located in the Jackson Canyon area in 1896. No exploration pits or other evidence of prospecting were seen, but reconnaissance samples taken in the area contained anomalous amounts of copper and silver

TABLE 4.—*Sample analyses, Linderman Lake area prospects*
[Tr, trace; NA, not assayed; ----, none detected]

| Sample No. (fig. 5) | Gold (ounce per ton) | Silver (ounce per ton) | Copper (percent) | Lead (percent) | Nickel (percent) | Chromium (percent) | Cobalt (percent) | Description |
|---|---|---|---|---|---|---|---|---|
| W-20 | Tr | Tr | 0.004 | 0.04 | ---- | 0.01 | ---- | Linderman Lake clay (poor quality). |
| W-23 | Tr | ---- | .002 | ---- | ---- | .003 | ---- | White volcanic ash or tuff. |
| W-24 | Tr | ---- | .004 | ---- | ---- | ---- | ---- | Brecciated volcanic tuff. |
| W-25 | Tr | ---- | .004 | ---- | ---- | ---- | ---- | Mudflow conglomerate. |
| W-26 | Tr | ---- | .01 | ---- | ---- | .003 | ---- | Mudflow breccia. |
| S-17 | Tr | 0.2 | .002 | ---- | ---- | ---- | ---- | Rhyolite tuff. |
| S-18 | Tr | ---- | .01 | ---- | 0.002 | .01 | ---- | Basalt dike. |
| S-19 | Tr | ---- | .02 | ---- | .008 | .03 | 0.007 | Pyroxene basalt dike. |
| S-20 | Tr | ---- | .01 | ---- | .004 | .01 | ---- | Contact of basalt dike with rhyolite tuff. |
| B-11 | Tr | ---- | .02 | ---- | ---- | .007 | ---- | Basalt dike. |
| B-12 | Tr | ---- | .02 | ---- | ---- | .01 | ---- | Silicified contact zone of basalt dike. |
| B-13 | Tr | Tr | .01 | ---- | ---- | .007 | ---- | Vesicular basalt dike. |
| B-14 | Tr | Tr | .02 | ---- | .002 | .02 | .004 | Iron oxide-stained basalt dike. |
| W-64 | NA | NA | NA | NA | NA | NA | NA | Multicolored jasper float. |

(table 5). None of the samples, however, contained sufficient amounts to represent a potential mineral resource.

## PATTERSON LAKE-WARREN PEAK AREA PROSPECTS

The Wild Indian claim was staked on the east slope of Warren Peak in 1915. The Modoc claim was staked near Patterson Lake in 1931 and relocated as the Lookout in 1940. No prospect workings were found, and values in reconnaissance samples (table 6) were not sufficient to represent a potential mineral resource.

Samples S-27 contained the highest concentrations of nickel and chromium of any sample taken in the study area; however, nickel and chromium concentration like these are not uncommon for basalt. Hyalite opal was found as thin layers on a few pieces of basalt float north of Patterson Lake.

## OWL CREEK AREA PROSPECTS

Several mining claims were staked in the Owl Creek area between the years 1915 and 1952, inclusive. Many of the mining claim descriptions are vague and simply refer to the prospect as being in the Owl Creek mining district. Analyses of reconnaissance samples taken

TABLE 5.—*Sample analyses, Jackson Canyon prospects*
[Tr, trace; NA, not assayed; ----, none detected]

| Sample No. (fig. 5) | Gold (ounce per ton) | Silver (ounce per ton) | $CaCO_3$ (percent) | Copper (percent) | Nickel (percent) | Chromium (percent) | Cobalt (percent) | Description |
|---|---|---|---|---|---|---|---|---|
| W-43 | Tr | 0.8 | 99.2 | ---- | ---- | ---- | ---- | Calcite vein, 0.5 foot thick. |
| W-47 | Tr | .2 | NA | 0.03 | 0.004 | 0.007 | ---- | Basalt porphyry, 8.0 feet thick, cut by several chalcedony stringers. |
| W-48 | Tr | .4 | NA | .008 | .004 | .01 | ---- | Purplish mudflow conglomerate. |
| W-49 | Tr | .2 | NA | .02 | .004 | .007 | 0.004 | Iron oxide-stained dike, 6 to 12.0 feet thick. |

TABLE 6.—*Sample analyses, Patterson Lake–Warren Peak area prospects*

[Tr, trace; NA, not assayed; ----, none detected]

| Sample No. (fig. 5) | Gold (ounce per ton) | Silver (ounce per ton) | Copper (percent) | Nickel (percent) | Chromium (percent) | Cobalt (percent) | Description |
|---|---|---|---|---|---|---|---|
| S–25 ------ | Tr | ---- | 0.003 | ---- | ---- | ---- | Iron oxide-stained volcanic breccia. |
| S–26 ------ | Tr | 0.1 | .002 | ---- | ---- | ---- | Gray-white calcareous layers in andesite. |
| S–27 ------ | Tr | ---- | .01 | 0.02 | 0.05 | 0.004 | Basalt dike trending N. 30° E. |
| S–34 ------ | Tr | NA | NA | NA | NA | NA | Hyalite opal. |

from calcite veins, fault zones, dikes, and mudflow breccia are shown in table 7. None of the samples contain amounts sufficient to represent a potential mineral resource. Calcite veins in the area are small, but some cloudy and fractured crystalline material was seen, indicating that better quality crystals may exist beneath the zone of weathering.

## CONKLIN CANYON PROSPECTS

The Slide claim and the Summit group of four claims were staked in 1896 about three-fourths of a mile southwest of the mouth of Conklin Canyon; no prospect workings were found in the area.

Several irregular calcite veins ranging from less than 1 inch to more than 1 foot thick occur near the mouth of the canyon. The veins are discontinuous and are rarely exposed for more than 50 feet. Cloudy and fractured calcite crystals weighing as much as 3 pounds were found in the float below some of the vein outcrops. Samples (S–13, 14, and B–8, fig. 5) of the calcite veins contained 94.5 and 97.5 percent calcium carbonate and a trace to 0.1 ounce silver per ton.

Reconnaissance samples (B–10 and S–15, 16, fig. 5) of basalt flows and dikes taken in the vicinity of the lode claims contained as much as a trace of gold, 0.1 ounce silver per ton, and 0.004 percent nickel.

TABLE 7.—*Sample analyses, Owl Creek area prospects*

[Tr, trace; NA, not assayed; ----, none detected]

| Sample No. (fig. 5) | Gold (ounce per ton) | Silver (ounce per ton) | $CaCO_3$ (percent) | Copper (percent) | Nickel (percent) | Chromium (percent) | Molybdenum (percent) | Description |
|---|---|---|---|---|---|---|---|---|
| S–2------ | Tr | 0.1 | 90.4 | 0.006 | ---- | ---- | ---- | Calcite seam in fault zone about half a mile long. |
| S–3------ | Tr | ---- | NA | .008 | 0.002 | ---- | ---- | Fault zone with much calcite. |
| S–4------ | Tr | .2 | 99.0 | .002 | ---- | ---- | ---- | Calcite vein to 1 to 1½ feet thick. |
| S–6------ | Tr | Tr | NA | .004 | .002 | 0.003 | ---- | Bleached basic dike, 10 feet thick |
| S–7------ | Tr | ---- | NA | .02 | .004 | .01 | ---- | Contact zone of dike. |
| S–8------ | Tr | .1 | NA | .01 | .004 | .01 | ---- | Do. |
| S–9------ | Tr | ---- | NA | .01 | .004 | .01 | ---- | Basalt dike, 1.5 feet thick. |
| S–22 ---- | ---- | ---- | 88.7 | ---- | ---- | ---- | ---- | Calcite vein, 0.3 foot thick. |
| B–2 ---- | ---- | ---- | 97.5 | .002 | ---- | ---- | ---- | Calcite vein, 0.75 foot thick. |
| B–3 ---- | Tr | .2 | 96.2 | .004 | ---- | ---- | ---- | Calcite vein, 0.5 foot thick. |
| B–4 ---- | Tr | ---- | NA | .008 | ---- | .007 | 0.002 | Mudflow breccia. |
| B–7 ---- | Tr | ---- | NA | .008 | ---- | .007 | ---- | Fault zone with much calcite. |

TABLE 8.—*Sample analyses, Cottonwood Creeks prospects*

[Tr, trace; NA, not assayed; ----, none detected]

| Sample No. (fig. 5) | Gold (ounce per ton) | Silver (ounce per ton) | $CaCO_3$ (percent) | Copper (percent) | Nickel (percent) | Chromium (percent) | Description |
|---|---|---|---|---|---|---|---|
| B-5 | Tr | 0.2 | 95.7 | ---- | ---- | ---- | Calcite vein averaging 0.75 foot thick and exposed a few hundred feet long. |
| B-6 | Tr | .1 | 98.6 | ---- | ---- | ---- | Calcite crystals from above vein. |
| B-21 | Tr | Tr | NA | 0.004 | ---- | ---- | Rhyolite tuff. |
| S-5 | Tr | .1 | 98.8 | ---- | ---- | ---- | Calcite vein 0.5-foot thick with calcite crystals. |
| W-12 | Tr | ---- | NA | .01 | 0.002 | 0.003 | Basalt dike. |
| W-13 | Tr | ---- | NA | .01 | .002 | .01 | Contact zone of above dike. |
| W-14 | Tr | Tr | NA | .004 | ---- | .003 | Greenish basalt. |

## COTTONWOOD CREEKS PROSPECTS

At least three lode claims recorded in 1896, 1931, and 1939 are described as being near the mouth of Little Cottonwood Creek, but no prospect workings were found there. Two other claims were staked in 1932 at the head of Cottonwood Creek, south of Tom Smith's cabin.

A sample (B-21, table 8) of decomposed rhyolite tuff from a small prospect pit one-fourth of a mile south of Tom Smith's cabin contained no economic concentration of valuable metals. Small calcite veins (B-5 and S-5, table 8) occur near the mouth of Little Cottonwood Creek. Both veins contain some rhombohedral crystals of calcite. There may be some Iceland spar in these veins, but it could not be recovered at a profit.

## EAST CREEK AREA PROSPECTS

The Black Diamond and Anthracite claims in sec. 3, T. 39 N., R. 15 E. may have been staked for coal. No coal was found in the area, but samples (table 9) were taken from a 10-foot-thick, black to dark brown, glassy volcanic flow that resembles anthracite. The glassy matrix contains less than 10 percent plagioclase and amphibole phenocrysts. Less than 25 percent of the rock consists of dark glassy fragments of other rocks. Flow banding is apparent in the dark glassy matrix. The rock contains small, but anomalous, amounts of lead (0.01 percent), far less than that required for a potential mineral resource.

TABLE 9.—*Sample analyses, East Creek area prospects*

[Tr, trace; NA, not assayed, ----, none detected]

| Sample No. (fig. 5) | Gold (ounce per ton) | Silver (ounce per (percent) | Copper (percent) | Lead (percent) | Nickel (percent) | Chromium (percent) | Description |
|---|---|---|---|---|---|---|---|
| W-40 | Tr | 0.1 | 0.01 | ---- | 0.002 | 0.007 | Basalt. |
| W-42 | ---- | ---- | .002 | 0.01 | ---- | ---- | Dark-gray glassy volcanic rock. |
| S-31 | NA | NA | NA | NA | NA | NA | Hyalite on pieces of olivine basalt float. |
| S-32 | ---- | Tr | .001 | .01 | ---- | ---- | Black glassy volcanic rock. |
| S-33 | Tr | Tr | .008 | .01 | ---- | .006 | Do. |

TABLE 10.—*Sample analyses, Highrock Creek prospect*
[Tr, trace; NA, not assayed; ----, none detected]

| Sample No. (fig. 5) | Gold (ounce per ton) | Silver (ounce per ton) | Copper (percent) | Chromium (percent) | Description |
|---|---|---|---|---|---|
| W–27 | Tr | ---- | 0.01 | 0.003 | Basalt porphyry. |
| W–28 | Tr | ---- | .004 | .003 | Greenish mudflow breccia. |
| W–29 | NA | NA | NA | NA | Tan jasper with brown bands. |
| W–50 | Tr | 0.2 | .004 | ---- | Rhyolite dike. |
| S–55 | Tr | ---- | .01 | .003 | Greenish volcanic breccia dike |

Hyalite was found coating pieces of olivine basalt float in the East Creek area. Red and brown iron oxide staining beneath the thin layers of hyalite makes this material more colorful than any seen elsewhere in the study area.

## KING FISH PROSPECT

The King Fish claim is about three-fourths of a mile southeast of Clear Lake by way of the Bald Mountain trail (S–35 thru 37 and W–44, fig. 5). The claim was staked in 1934. There is no evidence of recent activity.

Prospect workings consist of a 40-foot-long adit trending N. 75° E. in iron oxide-stained vesicular basalt. Four samples of the basalt contain as much as a trace of gold, 0.2 ounce silver per ton, 0.008 percent nickel, 0.03 percent chromium, and 0.004 percent cobalt.

## HIGHROCK CREEK PROSPECT

The Hawkins mining claim was staked near the mouth of Highrock Canyon in 1920. Presumably, the claim was staked on one of the conspicuous basalt dikes that occur in the area. Samples taken from the dikes and a greenish mudflow breccia did not contain sufficient metal to represent a potential resource (table 10). Tan and brown banded jasper is plentiful in the rock float about 1 mile west of the mouth of Highrock Canyon.

## EMERSON CREEK PROSPECT

A lode claim was located approximately 2 miles northeast of Emerson Peak in 1955. No evidence of the claim was found. None of the reconnaissance samples taken in the claim area contained amounts close to that needed for a potential resource (table 11).

## RAIDER CREEK PROSPECT

The Whippoorwill mining claim was apparently staked on a conspicuous basalt dike that can be traced from Raider Creek Canyon across the ridge top to Hornback Canyon (W–31, 32, and 34, fig. 5). The

TABLE 11.—*Sample analyses, Emerson Creek prospect*

Tr, trace; NA, not assayed; ----, none detected

| Sample No. (fig. 5) | Gold (ounce per ton) | Silver (ounce per ton) | Copper (percent) | Nickel (percent) | Chromium (percent) | Description |
|---|---|---|---|---|---|---|
| W–51 | Tr | ---- | 0.004 | ---- | ---- | Greenish-gray volcanic flow. |
| S–48 | Tr | Tr | .004 | ---- | 0.003 | Rhyolite dike. |
| S–49 | Tr | 0.1 | .02 | 0.002 | .02 | Basalt flow. |
| S–50 | Tr | ---- | .01 | .008 | .02 | Altered basalt(?) dike. |

dike fills a probable fault zone that strikes N. 20° W. and dips 65° NE. It is as much as 18 feet thick. Samples taken across the greenish-stained basalt dike contain a trace of gold, 0.01 percent copper, 0.003–0.007 percent chromium, and 0.002 percent nickel. Pieces of petrified wood float were found on the ridge crest in the vicinity of the dike (W–30, fig. 5).

### MILK CREEK PROSPECT

The Hedgepath claim was staked in 1896 on the north side of Milk Creek about 1 mile southwest of the mouth of the canyon. No prospect pits were found, but two reconnaissance samples were taken. A sample (W–18, fig. 5) taken from a 1- to 4-inch-thick iron oxide-stained chalcedony vein assayed a trace of gold. Sample W–19 (fig. 5) from a 6-foot-thick green-stained volcanic conglomerate contained a trace of gold and 0.1 ounce silver per ton.

### PINE CREEK AREA PROSPECTS

The Question Mark and Two Question Marks claims were staked on two or more pyroxene andesite dikes at the head of Pine Creek (W–35, fig. 5). The dikes contain no anomalous concentrations of valuable metals.

Hyalite-coated pieces of float in the vicinity of sample sites W–45 and S–39 (fig. 5) were found along the South Fork of Pine Creek and the North Fork of Fitzhugh Creek.

### EAGLE CREEK PROSPECTS

Several lode mining claims, located between 1918 and 1941, were vaguely described as being in the Eagle Peak or Eagleville mining districts. A few of the old claim descriptions were slightly more specific and placed the claims north of Cole Peak, near the confluence of the North Fork of Eagle Creek with the main stream. However, no prospect workings were found in the area. Reconnaissance samples (B–15 and 16, S–21, fig. 5) of greenish mudflow breccia, basalt porphyry, and vesicular basalt contained no anomalous metal values.

TABLE 12.—*Reconnaissance placer samples, South Warner Wilderness*

| Sample No. (fig. 5) | Gold pans, number and diameter | Black sand concentrate | | | Description |
|---|---|---|---|---|---|
| | | Weight (gms) | Pounds per cubic yard | Magnetite (percent) | |
| S-38 | 3, 10-inch pans | 97.10 | 28 | 37 | Mill Creek, above Clear Lake. Narrow canyon; minor alluvial deposits. |
| S-39 | 3, 10-inch pans | 123.23 | 36 | 22 | North Fork Fitzhugh Creek. Minor alluvial deposits. |
| S-40 | 1, 16-inch pan | 253.65 | 98 | 42 | Milk Creek. Small alluvial deposits, about 2 feet wide and 5 feet deep, bordered by steep canyon walls. |
| S-41 | 1, 16-inch pan | 119.76 | 46 | 27 | Steamboat Canyon. Alluvial deposits about 8 feet wide and 2 to 3 feet deep, bordered by steep canyon walls. |
| S-42 | 1, 16-inch pan | 258.21 | 100 | 67 | Cottonwood Creek. Alluvial deposits as much as 50 feet wide and 5 feet deep in the canyon; larger deposits east of the study area. |
| S-44 | 3, 10-inch pans | 97.21 | 36 | 11 | Jackson Canyon. Narrow steep canyon with minor alluvial deposits. |
| S-45 | 2, 16-inch pans | 165.43 | 32 | 57 | Owl Creek. Alluvial deposits, as much as 100 feet wide and 5 feet deep confined to canyon. |
| S-46 | 1, 16-inch pan | 188.94 | 73 | 67 | Raider Creek. Large alluvial deposits, mostly outside the study area. |
| S-47 | 1, 16-inch pan | 92.40 | 36 | 32 | Eagle Creek. Insignificant alluvial deposits confined to narrow canyon; large deposits outside the study area. |
| W-45 | 1, 16-inch pan | 47.19 | 18 | 45 | South Fork Pine Creek. Minor alluvial deposits. |
| W-46 | 1, 16-inch pan | 72.68 | 29 | 62 | Kaiser Canyon. Minor alluvial deposits inside the study area. |
| W-52 | 1, 16-inch pan | 44.01 | 17 | 40 | Emerson Creek. Minor alluvial deposits. |

## PLACER PROSPECTS

Placer claims were staked on Kaiser, Milk, Owl, and Eagle Creeks between 1901 and 1941, but no test pits or evidence of placer mining activity was found on any of the drainages in the study area. Most of these claims were staked for petroleum.

Alluvial deposits inside the wilderness are small. Larger alluvial deposits occur outside the study area, especially near the eastern boundary where they are mined for sand and gravel.

Reconnaissance pan samples were taken from 12 streams in the study area (table 12). The alluvial deposits contain an unusually large amount of black sand, averaging about 46 pounds per cubic yard. Three black sand concentrates (S-42, W-36, and S-46) studied petrographically contained 62-67 percent magnetite and 33-38 percent clinopyroxenes. Other heavy detrital minerals, listed in approximate order of abundance, are hematite, amphibole, ilmenite, epidote, garnet, zircon, and apatite. No gold was observed in any of the black sand concentrates.

Minable placer deposits do not occur in the South Warner Wilderness.

## OIL AND GAS PROSPECTS

Modoc County mining claim records indicate that many of the early placer claims (now invalid) were actually located for petroleum.

In 1901 T. W. Foster and others located 32 of these claims (8–20 acres each) along Milk Creek and Kaiser Canyon. There is no record or evidence that the claims were ever drilled for oil, and there are no productive wells in the vicinity of the study area.

## GEOTHERMAL ENERGY PROSPECTS

Modoc County records indicate that much of the privately owned land in Surprise Valley, including most of that bordering the east side of the South Warner Wilderness, is leased for geothermal purposes. According to Bureau of Land Management records, no geothermal leases are issued on land inside the South Warner Wilderness. The potential for development of geothermal energy lies along or east of the Surprise Valley fault zone, outside of the wilderness.

## CONCLUSIONS

A geochemical study and examination of mining claims and a aeromagnetic map reveal no valuable concentrations of mineral resources in the South Warner Wilderness. Semiprecious varieties of $SiO_2$ and several zeolite minerals are present but not in concentrations that could be mined profitably. Minor amounts of optical grade calcite are present too, but this material is similarly of no economic value. The many hot springs in Surprise Valley suggest the presence of a potentially valuable concentration of geothermal energy there; however, there is no evidence of such a geothermal resource beneath the wilderness itself. We conclude that economically valuable mineral deposits do not exist in the South Warner Wilderness.

## REFERENCES CITED

Duffield, W. A., and Fournier, R. O., 1974, Geothermal resources of Modoc County, California: U.S. Geol. Survey open-file report, 18 p.

Gay, T. E., Jr., 1966, Economic mineral deposits of the Cascade Range, Modoc Plateau, and Great Basin region of northeastern California: California Div. of Mines and Geology Bull. 190, p. 97–104.

Grimes, D. J., and Marranzino, A. P., 1968, Direct-current arc and alternating-current spark emission spectrographic field methods for the semiquantitative analysis of geologic materials: U.S. Geol. Survey Circ. 591, 6 p.

Hughes, H. H., 1941, Iceland spar and optical fluorite: U.S. Bur. Mines Inf. Circ. 6468R, 19 p.

Hulbe, C. W. H., and Emerson, D. O., 1969, Volcanic sequence of the Warner Mountains, northern California [abs.]: Geol. Soc. America Abs. with Programs 1969, pt. 3, p. 28.

Russell, R. J., 1928, Basin range structure and stratigraphy of the Warner Range, northeastern California: California Univ. Pubs. Geol. Sci., v. 17, no. 11, p. 387–496.

Turekian, K. K., and Wedepohl, K. H., 1961, Distribution of the elements in some major units of the earth's crust: Goel. Soc. America Bull., v. 72, no. 2, p. 175–191.

White, D. E., 1955, Violent mud-volcano eruption of Lake City hot springs, northeastern California: Geol. Soc. America Bull., v. 66, no. 9, p. 1109–1130.