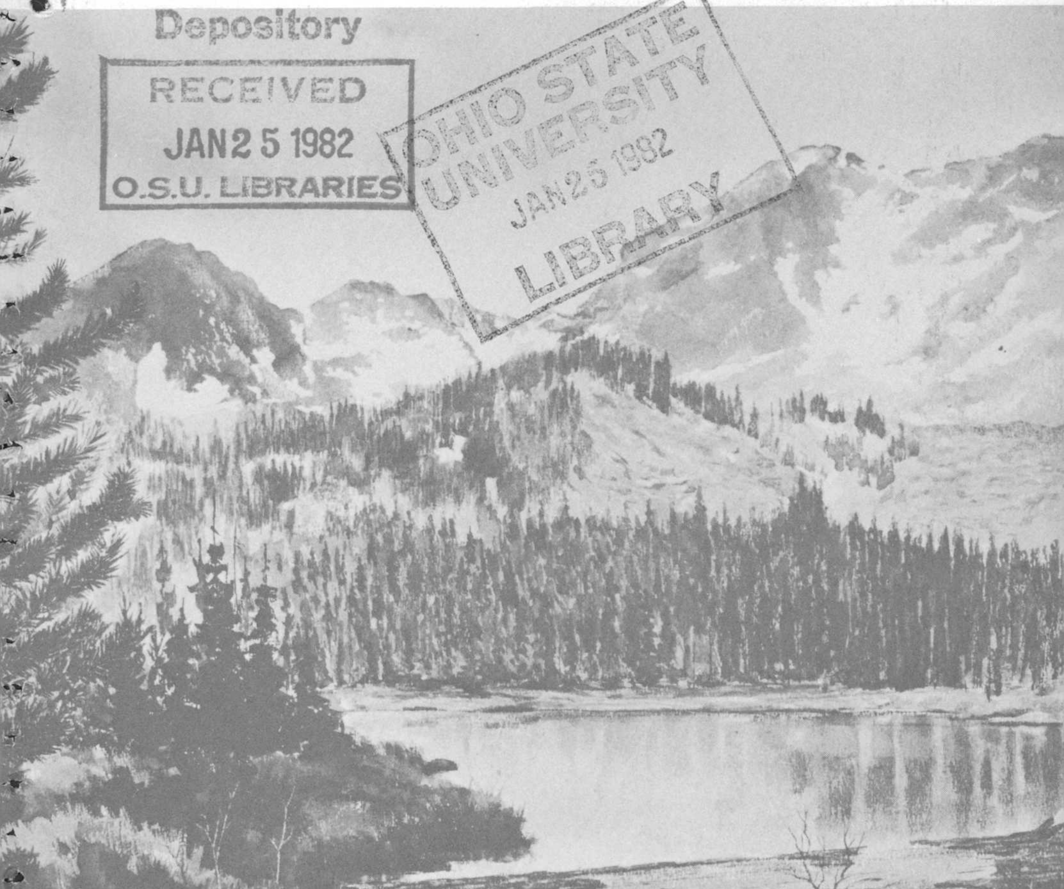
STUDIES RELATED TO WILDERNESS

WILDERNESS AREAS



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GEOLOGICAL SURVEY BULLETIN 1495

Mineral Resources of the Snow Mountain Wilderness Study Area, California

By ROBERT D. BROWN, JR., DAVID J. GRIMES, *and* REINHARD LEINZ,
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With a section on
INTERPRETATION OF AEROMAGNETIC DATA

By ANDREW GRISCOM *and* ROBERT D. BROWN JR.,
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STUDIES RELATED TO WILDERNESS— WILDERNESS AREAS

GEOLOGICAL SURVEY BULLETIN 1495

An evaluation of the mineral potential of the area

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STUDIES RELATED TO WILDERNESS

WILDERNESS AREAS

In accordance with the provisions of the Wilderness Act (Public Law 88-577, September 3, 1964) and the Joint Conference Report on Senate Bill 4, 88th Congress, and as specifically designated by Public Law 94-557, October 19, 1976, the U. S. Geological Survey and the U. S. Bureau of Mines have been conducting mineral surveys of wilderness and primitive areas. Studies and reports of all primitive areas have been completed. Areas officially designated as "wilderness," "wild," or "canoe" when the act was passed were incorporated into the National Wilderness Preservation System, and some of them are now being studied. The act provides that areas under consideration for wilderness designation be studied for suitability for incorporation into the Wilderness System. The mineral surveys constitute one aspect of the suitability studies. This bulletin reports the results of a mineral survey of certain national forest lands in the Snow Mountain Study Area, California, that is being considered for wilderness designation. The area studied is in the Mendocino National Forest in Colusa, Glenn, and Lake Counties.

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CONVERSION FACTORS

Length

1 centimeter (cm)	= 0.3937 inches (in.)
1 meter (m)	= 3.281 feet (ft)
1 kilometer (km)	= 0.6214 mile (mi)

Mass

1 gram(g)	= 0.03527 ounce avoirdupois (oz)
1 metric ton (t)	= 1.102 ton, short

Temperature

degrees Celsius (°C)	= (degrees Fahrenheit (°F) −32)/1.8

MINERAL RESOURCES OF THE SNOW MOUNTAIN WILDERNESS STUDY AREA, CALIFORNIA

By ROBERT D. BROWN, JR., DAVID J. GRIMES, and REINHARD LEINZ, U.S. GEOLOGICAL SURVEY, and
FRANCIS E. FEDERSPIEL and ANDREW M. LESZCYKOWSKY
U.S. Bureau of Mines

SUMMARY

The Snow Mountain Wilderness Study Area covers about 147 km^2. About 190 km north of San Francisco and on the divide between the Sacramento and Eel Rivers, it contains some of the highest terrain in the Coast Ranges. Snow Mountain and St. John Mountain, the most prominent landmarks in the study area, stand more than 2,000 m above sea level; the total relief is about 1,600 m m. Roads lead to the area from Willows and Maxwell in the Sacramento Valley and from Upper Lake near Clear Lake.

To evaluate the mineral resource potential, both existing and new data are collected and interpreted in this report. New work includes geologic field studies in the west half of the area; the interpretation of data from an earlier aeromagnetic survey; geochemical interpretation based on the analysis of samples of stream sediment, rock, and springs; and the examination and sampling of prospects. The results of these investigations indicate that the mineral resource potential is low.

The outline of the study area, its elevation, and many of its landforms are closely related to its geology. Bordered by steep slopes and dissected by deep narrow canyons, the area's rugged surface and elevation have kept it remote and roadless in comparison with other parts of the Coast Ranges. The proposed boundary of the wilderness area follows a major low-angle thrust fault. Flat or gently dipping for much of its extent, this fault, which branches from the Stony Creek fault zone to the east, separates volcanic rock from the underlying weakly metamorphosed sedimentary rock. The slab of volcanic rock above the fault stands high because it resists erosion more effectively than do other rock types in the vicinity.

The volcanic rocks are of Late Jurassic age and consist chiefly of finely crystalline flows of pillow basalt, most of which is now altered to spilite. The pillow lava contains beds of sandstone, mudstone, and radiolarian chert and a few thin sills of diabase. Most of these rocks accumulated in deep water during an episode of submarine volcanism.

These rocks are faulted over cataclastic (physically deformed) sedimentary rocks that underlie much of the northern Coast Ranges and that are commonly assigned to the Franciscan Formation. Originally mudstone, siltstone, and sandstone, these sedimentary rocks now are deformed to phyllonite and semischists. They contain a few thin flows of intensely altered pillow lava, evidence that they accumulated in a marine environment, probably during Late Jurassic and Cretaceous time.

A belt of sheared and crushed rock as much as 250 m thick separates the volcanic rock above the thrust fault from the cataclastic sedimentary rock below. The sheared and crushed debris is chiefly cataclastic sedimentary rock, but it contains some resistant masses derived from the volcanic slab and a few exotic rock types such as glaucophane schist. Most of the prospects and claims in the study area are in this belt of rocks or another that is similar but structurally lower.

Serpentinite, in tabular masses and in lenses, occurs both along thrust faults and along high-angle faults. The most extensive serpentinite body follows a northwest-trending fault along the Middle Fork of Stony Creek

Unconsolidated deposits cover a small portion of the study area. They include glacial and glaciofluvial deposits, landslide debris, terrace deposits, and alluvium.

The geology, as well as records of past mineral exploration and production, gives clues to the mineral resource potential. Chromium, copper, manganese, and mercury have been mined from similar rocks in other parts of the Coast Ranges. At The Geysers, a steam field in the northern Coast Ranges, geothermal power is produced in a somewhat similar geologic setting. The potential for these and other resources can be evaluated by analyzing and interpreting the geologic, geochemical, and aeromagnetic data. The results, summarized in this report, disclose no important resource potential within the study area. Variations in geochemical properties and anomalies in the aeromagnetic data can be explained by normal chemical and physical properties of the rock units within the area; nowhere do the geochemical or magnetic data indicate unusual concentrations of mineral commodities.

These findings are consistent with the history of exploratory activity; the little previous prospecting done in the Snow Mountain Wilderness Study Area has not revealed commercial mineral deposits. According to courthouse records, only 19 lode claims have been located in, or adjacent to, the study area. Most of the claims were for manganese. Samples from manganese-bearing chert beds east of the area have the highest manganese contents, as much as 33.6 percent. These deposits have been mined, mainly during World Wars I and II. Chert with manganese oxide coatings on bedding and fracture surfaces occurs in the study area, but the size and grade of these deposits are not sufficient for them to be considered a resource. Serpentinized peridotite crops out on some claims in the area, but analyzed samples contained no more than 0.47 percent Cr_2O_3 and 0.26 percent nickel. In the east part of the study area, one claim has been located for onyx and another for nephrite jade. No semiprecious gemstones were found during this investigation.

Mineral springs formerly exploited at a spa near Fouts Springs no longer appear to have much resource value. Volcanic rocks and diabase suitable for crushing and for use in construction cover much of the study area; they have not been commercially exploited.

INTRODUCTION

The Snow Mountain Wilderness Study Area is about 15 km long and 12 km wide and covers 147 km^2. It is located in the eastern part of the California Coast Ranges on the divide between coastal and Sacramento Valley drainage systems, about 190 km north of San Francisco (fig. 1). To evaluate the mineral resources of this area, scientists from the U. S. Geological Survey and the U. S. Bureau of Mines conducted field investigations of the study area and its surroundings during the summer of 1977. The results, described in this report, are consistent with previous interpretations of the geology and disclose no evidence of important mineral resources.

The study area is encircled by roads of the U. S. Forest Service in the Mendocino National Forest and is accessible by several alternate

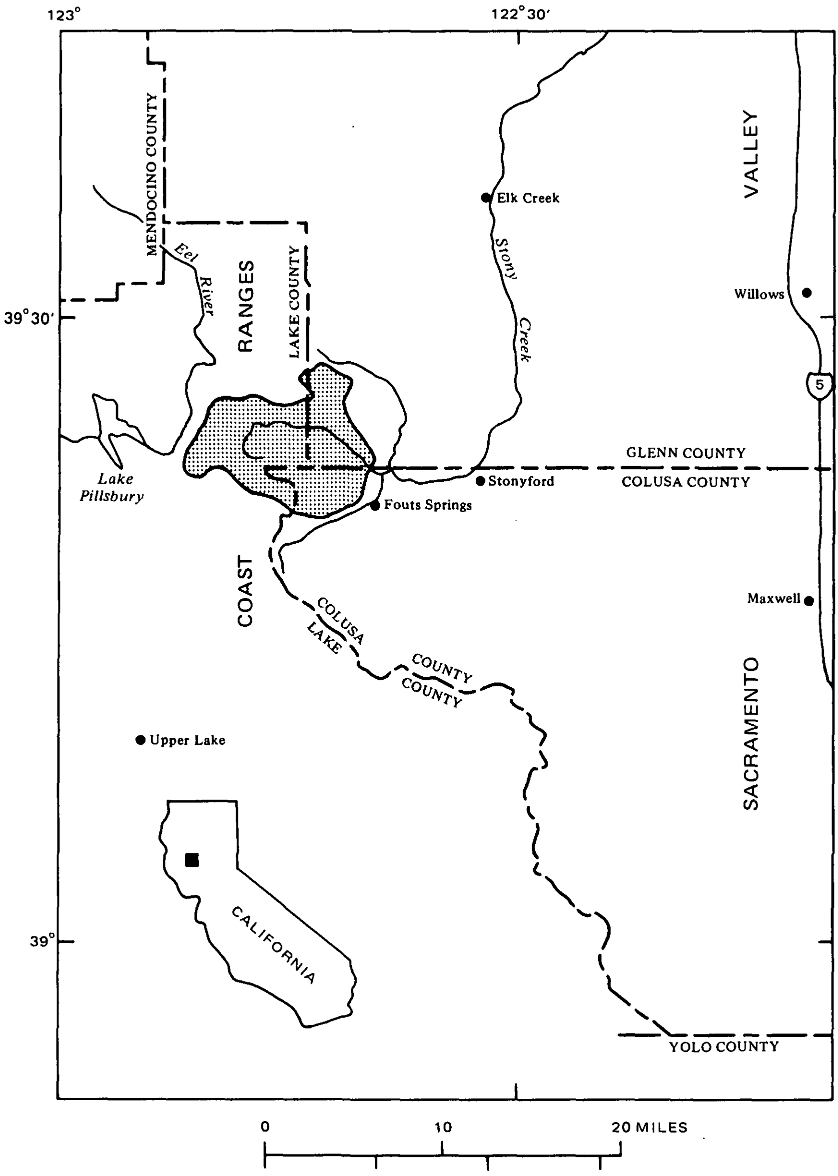

FIGURE 1.- Location of Snow Mountain Wilderness Study Area (shaded).

routes. From Maxwell on U. S. Interstate Highway 5, a paved road goes to Stonyford and from there to Fouts Springs on the east side of the area, a total distance of about 60 km. From Willows, also on Interstate Highway 5, State Route 251 (Willows to Elk Creek) and Forest Service roads 20No1 and 24No2 lead to the north side of the study area at Low Gap, a distance of about 60 km. From Upper Lake on State Route 20, the west side of the area is accessible via about 25 km of Forest Service roads. These roads link with roads that roughly follow the periphery of the study area. Some of the roads are improved but many are not, and at times access is difficult because of snow, washouts, or landslides. Advice on current road conditions is available at the Mendocino National Forest headquarters in Willows and at District Ranger Stations in Upper Lake and Stonyford.

Well-maintained trails penetrate the interior of the study area, with trail heads at, or near: West Crockett Camp, Upper Nye Camp, the switchback on the road near map elevation 3,760 feet (1,146 m) (3.2 km southeast of the summit of St. John Mountain, St. John Mountain $7\frac{1}{2}$-minute quadrangle), Bonnie View, Moon Glade near Fouts Springs, Deafy Glade, and Summit Spring. A designated vehicular access trail, suitable for four-wheel drive vehicles and trail bikes, follows the ridge west of the Middle Fork of Stony Creek for several kilometers; it joins Forest Service roads 18No4 and 24No2 about 0.5 km north of West Crockett Camp.

Much of the terrain is steep and rugged; the total relief is about 1,600 m. The highest points, Snow Mountain East, 2,151 m above sea level, and St. John Mountain, 2,056 m, are separated by the canyon of the Middle Fork of Stony Creek. Their lower slopes, both along the Middle fork and around the margin of the study area, are steep and in some places precipitous. Most of the land surface is deeply dissected by V-shaped canyons with steep stream gradients. An area of several square kilometers around Snow Mountain exhibits relatively low relief with many flat or gently sloping surfaces and broad accordant ridge crests. Stream gradients in this area are lower, and several streams that drain north and east from Snow Mountain occupy U-shaped hanging valleys above the 1,800-m level.

Except for the summit area around Snow Mountain and a few precipitous canyon walls, the terrain is covered with brush, timber, and grass. The density and kind of vegetation vary with elevation. Above 2,000 m the surface around Snow Mountain is barren or is dotted with a few stunted trees and shrubs. Below the summit and above about 1,350 m, virgin forest of pine, fir, and cedar cover most of the ridges and slopes. Below 1,350 m, dense chaparral with conifer thickets covers almost all of the surface, concealing rock exposures and making foot travel difficult. The chaparral cover is interrupted by a few of the larger streams and, on the south side of Snow Mountain, by grassy meadows or glades on the inclined, poorly drained surface of landslide deposits.

PREVIOUS INVESTIGATIONS

The earliest published geologic report on the area around Snow Mountain is that of Holway (1911), who cited evidence of Pleistocene glaciation on the north and east sides of the mountain and noted that the bedrock was deeply weathered and diabasic. Irwin (1960) described regional geologic relations in the northern Coast Ranges and Klamath Mountains, and on a small-scale (1:500,000) map he showed the Snow Mountain area as undifferentiated rocks of the Franciscan Formation. The Ukiah sheet (1:250,000) of the Geologic Map of California (Jennings and Strand, 1960), however, shows much the same area as greenstone of the Franciscan Formation. Irwin (1960, figs. 6-16) also documented known mineral commodities in the Coast Ranges and Klamath Mountains and assembled commodity data from a number of sources. None of the mineral deposits shown on his maps is within the Snow Mountain Wilderness Study Area.

Brown (1964a, b) mapped the geology of the wilderness study area east of long 122°45′ W. as part of a broader geologic study. He interpreted the volcanic rocks on Snow Mountain and St. John Mountain as the basal part of the Great Valley sequence and the lower contact of the volcanic rocks as a low-angle thrust fault. These geologic field investigations were supplemented in 1962 by an aeromagnetic survey that was bounded by long 121°52½′ and 123° W. and lat 39°15′ and 39°30′ N. (U. S. Geol. Survey, unpub. data, 1962). Parts of this survey that are germane to this report are discussed in the section "Interpretation of Aeromagnetic Data."

Regional gravity data by Chapman and others (1974) define a positive 20-milligal Bouguer anomaly that coincides approximately with the body of volcanic rock on Snow Mountain and St. John Mountain.

The sequence of volcanic rocks surrounding Snow Mountain and described in this report are now (1977) being studied by G. J. McPherson) and are considered by him him to represent an ancient seamount (McPherson, 1977).

Several published reports summarize data on mineral commodities in the northern Coast Ranges of California. No commodities are listed for the study area, but some are found nearby and others are reported from rock types or geologic settings that are similar to those in the study area. Manganese is associated with chert outcrops at several mines and prospects near Stonyford, a few kilometers east of the study area. Only a few hundred tons of ore have been produced, chiefly during World War I (Trask and others, 1943; Trask, 1950). Chromite deposits in dunite associated with serpentinite and other ultramafic rock have been mined in other parts of the Coast Ranges, and several chromite prospects in serpentinite are reported near Stonyford (Bradley and others, 1918; Dow and Thayer, 1946). No production from the Stonyford prospects is reported, but the Gray Eagle mine, 40 km north, produced more than 31,000 metric tons of milled chromite concentrates in 1942, 1943, and 1944 (Dow and Thayer, 1946, p. 9) and much smaller amounts in the 1950's (J. P. Albers, written commun., 1978). A few abandoned copper prospects, evidently with little or no production, are located in rocks along or near the Stony Creek fault zone south of Stonyford (Aubury, 1908; Eric, 1948). Mercury, associated with altered serpentinite or with sedimentary rocks of the Franciscan Formation, has been mined at many localities in the California Coast Ranges (Davis, 1957, p. 342). All of these localities are south of Snow Mountain, and no nearby mercury deposits are known.

Thermal springs, common in other parts of the Coast Ranges, are of interest in the search for geothermal energy. Waring (1965) included Fouts or Redeye Spring in his list of thermal springs and measured its temperature range as 16° to 24°C; Berkstresser (1968) found it slightly warmer, 25.5°C.

PRESENT INVESTIGATION

The geologic data and interpretations given here are partly from earlier field studies by R. D. Brown and partly from work by Brown and John Thompson during the summer of 1977. The geology east of long 122°45′ W., which passes near the summit of Snow Mountain, is from unpublished field notes, annotated aerial photographs, and maps that were made during the period 1960-63. These field data are recompiled on 7½-minute (1:24,000) base maps of St. John Mountain and Fouts Springs quadrangles, both published in 1968. The geology west of long 122°45′ W. is based partly on fieldwork done during June and July 1977 and partly on earlier geologic reconnaissance by Brown in 1962.

Geochemical samples of stream sediments and spring water were collected and analyzed by David Grimes and Reinhard Leinz during June and July 1977. They also analyzed many of the rock samples collected during the geologic fieldwork.

Francis Federspiel and Andrew Leszcykowsky examined and sampled claims and prospects and provided analytical data for these sampled localities. The geologic and geochemical field investigations were expedited by helicopter support obtained under a cooperative agreement with the U. S. Forest Service. Helicopters were employed chiefly to improve access to remote areas.

ACKNOWLEDGMENTS

The authors of this report appreciate the cooperation of property owners and local residents. Officials of the Mendocino National Forest, especially John Brooks, Resources Geologist, were particularly helpful.

GEOLOGY

The wilderness character of the Snow Mountain area - its relief, remoteness, and indirectly even its biota - is controlled by its geology. This is well shown by the boundary of the study area, roughly defined by roads. Though made by man, these peripheral roads follow a natural break in slope along a belt of easily eroded rock; these surface features delineate a major thrust fault that encircles and passes beneath the study area. The thrust fault is thus a natural and fundamental boundary that has guided and limited access routes around the margin of the wilderness.

The rugged interior of the study area is carved almost entirely from a single large rock mass, a klippe, or fault slab, of volcanic rocks that is in fault contact with sedimentary rocks beneath it. Made up of countless flows of dense, finely crystalline pillow lava, this klippe resists erosion more effectively than do the sedimentary rocks. Like a carapace, it protects this area from the rapid downcutting and mass wasting that have reduced surrounding parts of the Coast Ranges to much lower elevations. The elevation and areal extent of this volcanic upland are unique in the northern Coast Ranges, and the upland itself constitutes an environmental island, different from nearby areas in landforms, geology, and potential resources.

The geologic history is complex and not fully known, but major events can be sketched from the geologic data. The oldest rocks, pillow lava of Late Jurassic age, record an episode of submarine volcanic activity, probably in a deep-water marine environment and near the axis of a deepening trench. Toward the end of the Jurassic, volcanic activity diminished and was succeeded by an influx of marine sediment - chiefly mud, silt, and sand. Farther east, in the area now occupied by the Great Valley, clastic marine sediment continued to accumulate throughout the Cretaceous, and it may have persisted here as well.

After burial and lithification, the Jurassic and Cretaceous rocks were folded along north-trending axes, later displaced along low-angle thrust faults, and then cut by high-angle faults with northeast and northwest trends. Although the most intense folding preceded faulting, some of it persisted until much later. The emplacement of serpentinite, or ultramafic rocks, accompanied thrusting and continued during and after later high-angle faulting. Crustal deformation of this part of the Coast Ranges may not yet have ceased, for many geologic features and landforms are difficult to reconcile with long-term crustal stability.

The final chapter of geologic history is recorded in the present landscape. Alpine glaciers sculpted the highest peaks in late Pleistocene time. Postglacial stream erosion, which continues to the present time, deepened canyons and valleys and oversteepened some slopes so much that they became unstable and moved downhill as landslides.

VOLCANIC ROCKS OF LATE JURASSIC AGE

Snow Mountain, St. John Mountain, and Crockett Peak occupy an elliptical upland area of about 120 km^2 that stands more than a thousand meters above the surrounding terrain. The rocks in the upland are a distinctive assemblage of volcanic flows with interbeds of sedimentary rock rich in volcanic material and a few sills of diabase.

The basal contact of the volcanic rocks is a major low-angle thrust fault that truncates bedding and structures in the volcanic rocks, separating these rocks from deformed and weakly metamorphosed sedimentary rock that crops out at lower elevations. The basal contact is warped along a north-trending axis and is about 1,000 m lower east and west of Snow Mountain than it is to the north and south. The dissected and eroded slab of volcanic rocks above the contact is locally at least 900 m thick and may be even thicker. The total stratigraphic thickness of the volcanic rocks is at least 1,000 m and may be as much as 1,500 m because rocks within the slab are tilted and folded.

Although the slab of volcanic rocks is a klippe and structurally isolated by the fault surface at its base, its relation to other geologic units can be deduced from mapped geologic relations with rocks on the east. Similarities in both lithology and structural setting are cited in an earlier work (Brown, 1964a) as evidence that the volcanic rocks on Snow Mountain and those that crop out above a similar basal thrust fault a few kilometers to the east, near Stonyford, are part of the same volcanic unit. The outcrop area near Stonyford, about 25 km^2, is separated from that on Snow Mountain by the deeply eroded canyons of the North and South Forks of Stony Creek. Both of these streams cut below the level of the basal thrust fault, but the gap between the two bodies of volcanic rocks in most places is less than 3 km. Mapped field relations in the upper part of the volcanic rocks near Stonyford provide evidence that these rocks underlie and locally may interfinger with dark-gray tuffaceous siltstone and sandstone near the base of the Great Valley sequence. This 13,000-m-thick sequence of bedded siltstone, sandstone, and conglomerate underlies the Sacramento Valley of California and crops out in an east-dipping homocline in the range of low hills east of Stonyford. It includes rocks of Late Jurassic and Cretaceous age, but because rocks that immediately overlie the volcanic rocks at Stonyford are Late Jurassic, the volcanic rocks also have been considered to be of Late Jurassic age (Brown, 1964b).

The interpretation that the volcanic rocks in the slab above the thrust fault are a lower part of the Great Valley sequence (Brown, 1964a) is followed in this report. Older published geologic maps (examples are Irwin, 1960; Bailey and others, 1964; Jennings and Strand, 1960) include these volcanic rocks in the Franciscan Formation, the deformed and weakly metamorphosed rock that underlies much of the California Coast Ranges.

Pillow lava is the most abundant rock type in the volcanic sequence. It consists of finely crystalline volcanic rocks in pillow-shaped masses a meter or two in diameter that accumulated as piles or flows while the lava within individual pillows was still hot and plastic. The pillows exhibit draping and conformity of the base of younger pillows to the upper surface of those beneath. Discrete flows are difficult to distinguish, but most are probably a few tens of meters thick; thinner flows, 2 or 3 m thick, are associated with breccias or sedimentary rocks in a few places.

The pillow lava is dense, finely crystalline, and dark colored; individual pillows have thin devitrified or glassy rinds and contain a few small (1 to 2 mm) vesicles near the outer pillow surfaces. Freshly broken surfaces are dark greenish gray (5G4/1) (Goddard and others, 1963) or medium dark gray (N4), depending on the degree of weathering and alteration and the abundance of altered feldspar phenocrysts in the rock. Hand specimens from most flows are dense and megascopically nearly featureless; with a 10-power lens, laths and needles of feldspar, a few augite laths, and characteristic volcanic rock textures are visible. Most crystals of augite and feldspar are less than a millimeter long and are enclosed in a glassy or finely crystalline matrix. In some specimens, veins and masses of pyrite and vesicle fillings of calcite and chlorite are visible with a lens.

Porphyritic pillow lava, less common than the dense finely crystalline variety, crops out in a belt extending west from Signal Peak and at scattered localities west, north, and east of Snow Mountain. These rocks and similar massive porphyritic rocks without pillow structure contain large (5 to 10mm) phenocrysts of altered pale-green feldspar, which constitutes as much as 40 percent of the rock. The color (greenish gray, 5G6/1) and the abundance and size of the feldspar phenocrysts are distinctive in outcrop and hand specimens. The belt west of Signal Peak is differentiated on the geologic map (pl. 1).

Massive amygdaloidal flows without pillow structure crop out in a few places. These flows are medium dark gray (N4) on fresh surfaces but weather to grayish red (5R4/2). Although dense and finely crystalline, they are somewhat coarser textured than typical pillow lava and contain more and larger amygdules.

In thin section, volcanic rock samples exhibit chiefly variolitic and intersertal textures in which plagioclase and augite are enclosed in a devitrified groundmass. Plagioclase laths in the groundmass and plagioclase phenocrysts as much as 10 mm in diameter are clouded with alteration products; chlorite and calcite are the most abundant. Where the composition of the feldspar can be determined optically, it is albite, or, in a few rocks, sodic andesine. In many sections, the intensity of alteration precludes accurate determination of plagioclase. Neutral or pale-brown augite, much less abundant than either plagioclase or groundmass, forms granules and subophitic intergrowths. The groundmass in most sections is finely crystalline and consists of microcrystalline feldspar, chlorite, uralite, and rarely quartz or epidote; in a few sections it is opaque brown or black glass with an index of refraction greater than 1.540. Chlorite and calcite are the chief amygdule minerals, and in some rocks they are accompanied by quartz. Quartz, chlorite, and calcite fill veins and fractures.

The abundance of albite, the intensity of alteration, and the textures of these rocks are characteristic of spilite, a rock that is high in soda and low in silica and potassium but that otherwise resembles normal basalt. Similar spilitic pillow lava on the Olympic Peninsula in Washington State contains numerous small deposits of mangnese as well as one larger deposit at the Crescent mine, once the leading producer of manganese in the United States.

Chemical analyses of seven samples of pillow lava and diabase from the volcanic outcrop area near Stonyford (Bailey and Blake, 1974; table 1, this report) show many characteristics of spilite, but thin sections of some samples of Stonyford rocks contain labradorite rather than albite and therein more closely resemble normal basalt. The spilitic albitized rock appears to be more abundant to the west, on Snow Mountain, than eastward toward St. John Mountain and Stonyford. Geologic structure in the volcanic rock (pl. 1) can be interpreted as evidence that progressively younger rock is exposed to the east; if this is so, the intensity of albitization may be a function of stratigraphic position or depth of burial, or possibly both.

TABLE 1. - *Chemical analyses of basalt, diabase, and spilite from volcanic rocks near Stonyford*
[From Bailey and Blake, 1974]

	1	2	3	4	5	6	7
SiO_2	46.2	46.5	47.5	48.2	49.0	49.2	49.5
Al_2O_3	16.6	14.6	13.5	13.2	14.8	13.0	13.0
Fe_2O_3	6.3	5.0	3.3	3.4	3.4	4.6	4.7
FeO	4.2	6.4	7.3	8.4	6.1	8.1	8.6
MgO	5.2	6.8	4.0	5.5	7.2	5.2	5.7
CaO	8.5	7.9	11.0	9.7	7.9	9.3	8.3
Na_2O	4.2	2.2	3.3	3.4	4.2	2.8	4.3
K_2O	.82	2.3	.54	.32	.78	.24	.53
H_2O+	---	4.2	2.3	---	---	2.0	---
H_2O-	4.8	---	.67	3.9	4.1	.73	2.40
TiO_2	2.3	2.5	2.5	2.3	1.9	3.0	2.3
P_2O_5	.44	.34	.31	.26	.32	.11	.27
MnO	.20	.38	.25	.18	.19	.22	.27
CO_2	.34	.70	3.8	.15	.27	.25	.14
Sum	100.1	99.8	100.3	98.9	100.2	98.7	100.0
Density	2.73	2.76	3.00	2.84	2.86	3.00	2.94

1. Spilite (BSO-108), Dry Creek, Glenn County, Calif. Analysis by I. Barlow, S. Botts, G. Chloe, and P. Elmore.
2. Diabase (BSO-91), Stony Creek, Colusa County, Calif. Analysis by I. Barlow, S. Botts, G. Chloe, and P. Elmore.
3. Basalt (SF-70-1), Stony Creek, Colusa County, Calif. Analysis by S. Botts.
4. Basalt (BSO-107), Stony Creek, Colusa County, Calif. Analysis by I. Barlow, S. Botts, G. Chloe, and P. Elmore.
5. Spilite (BSO-94), Stony Creek, Colusa County, Calif. Analysis by I. Barlow, S. Botts, G. Chloe, and P. Elmore.
6. Diabase (SF-70-2), Stony Creek, Colusa County, Calif. Analysis by S. Botts
7. Spilite (BSO-90), Stony Creek, Colusa County, Calif. Analysis by I. Barlow, S. Botts, G. Chloe, and P. Elmore.

Keratophyre, a light-colored silica-rich volcanic rock that often is associated with spilite and is reported from other localities in the California Coast Ranges (Bailey and Blake, 1974), is evidently uncommon here. One keratophyric rock unit containing microcrystalline albite and quartz crops out on Snow Mountain West; similar rocks were not found elsewhere in the study area.

Volcanic breccia and tuff are locally interbedded with pillow lava and massive volcanic rocks. Lenses and beds of breccia and tuff are especially abundant on ridges extending north and northeast from Snow Mountain East and on the north side of St. John Mountain. Breccia clasts resemble the rock in volcanic flows, and most clasts are angular and a few centimeters in diameter. A few beds of breccia and lapilli tuff grade laterally or vertically into marine sedimentary rocks, and some breccia units appear to interfinger with flows of pillow lava.

Beds of marine sedimentary rocks occur throughout the volcanic pile but are thickest and most extensive near the northern and eastern boundaries of the thrust slab, where some mapped sedimentary units are more than 100 m thick. The thickest sedimentary units were derived from mudstone or siltstone containing thin (1-5 cm) sandstone beds; they are now weakly metamorphosed to argillite and weather to pencil-shaped fragments bounded by cleavage surfaces. Most of the argillite is medium dark gray (N4) or medium gray (N5); tuffaceous beds are grayish red (5R4/2 to 10R4/2) or brownish gray

(5YR4/1 to 4YR6/1), but in outcrop, distinctively red or purple. Bedded chert as thick as 50 m immediately underlies or overlies many argillite sequences, and, in a few places, bedded chert also separates individual volcanic flows. Most chert units are red; some are green or white and a few are pale blue; many of the thicker units are contorted and folded with fold amplitudes of a few meters. Almost all of the chert is regularly bedded; beds are one to a few centimeters thick. A few beds are dotted with the tests of radiolarians, others coated with or veined by manganese oxides.

Although several manganese prospects are located on chert outcrops near Stonyford, no large or extensive deposits of manganese were found in the study area.

Sills of diabase are interlayered with the volcanic rocks. Only a few of the thicker (15-35 m) sills are shown on the geologic map (pl. 1), because thinner ones are difficult to trace. The mapped sills dip gently (30° or less), resist erosion well, and form broad smooth upland surfaces. Most of the sills, however, are only a few meters thick and are more subtly expressed in the topography. One sill about 8 m thick that overlies less resistant pillow lava forms the lip of a 15-m waterfall in the Middle Fork of Stony Creek about 750 m upstream from the pack trail crossing south of West Crockett Camp. Like most sills, it is emplaced along the bedding and follows a thin unit of sedimentary rocks and chert between much thicker flows of pillow lava.

Thin sections of diabase exhibit diabasic to intersertal textures with interstitial chlorite between plagioclase and augite. Both primary minerals and alteration products are similar to those described in pillow lava. Crystallization is more complete in the diabase, and large crystals of albite and augite are much more abundant than groundmass. The kinship of the diabase with the pillow lava is evident from chemical analyses of rocks from the Stonyford area (Bailey and Blake, 1974; table 1, this report). The similarity in mineralogy and chemical composition, the absence of contact metamorphism, and the general concordance of the sills with layering in the volcanic rocks support the view that the diabase is part of the same volcanic episode that produced the flows of pillow lava.

The thick piles of pillow lava, the interbeds of tuffaceous mudstone and siltstone, and the beds of radiolarian chert are evidence of volcanism on the sea floor in deep water. Similar rocks typically are found in subsiding marine depositional basins throughout the world (Turner and Verhoogen, 1960, p. 257-272). Some of the rock masses described here, especially the massive amygdaloidal flows, may have accumulated on volcanic islands or on land above sea level; they constitute a relatively small part of the volcanic rock sequence.

Indirect stratigraphic evidence that the volcanic rocks are of Late Jurassic age (Brown, 1964a) has been described earlier in this report. This age is confirmed by radiolarian fossils from two areas. Pessagno (1977, p. 63-66, 104) described radiolarians from a chert bed in volcanic rocks on Stony creek near Stonyford and assigned them to his radiolarian zone 2B, which is indicative of the early Tithonian (Upper Jurassic). Pessagno's locality (0.6 km downstream from the diversion dam on Stony Creek) is east of the study area in similar and presumably correlative rocks.

Another radiolarian chert locality near Bear Wallow Creek is within the area. Radiolarians from this locality, at map elevation 4,000 feet (1,219 m), on a ridge crest 450 m northeast of the confluence of Bear Wallow Creek and the Middle Fork of Stony Creek, were examined by D. L. Jones (oral commun., 1977) and are considered by him to indicate about the same stratigraphic level as those identified by Pessagno.

Although the volcanic rocks are considered to be of Late Jurassic age, some of them that are stratigraphically lower than the two chert localities may be older.

CATACLASTIC SEDIMENTARY (FRANCISCAN) ROCKS OF LATE JURASSIC AND CRETACEOUS AGE

The slopes bordering the study area rise steeply from incised streams: the Eel River on the west, the South Fork of Stony Creek on the southeast and east, and the North Fork of Stony Creek on the northeast. Above these streams and below intensely sheared rocks along the thrust fault at the base of the volcanic slab, the slopes are underlain by deformed and weakly metamorphosed sedimentary rocks that contain a few thin flows of pillow lava. The upper contact of the sedimentary rocks with the sheared and crushed rocks along the fault zone, or with volcanic rocks in the upper plate of the thrust, is flat or gently dipping. These contact relations, shown on the geologic map (pl. 1), are part of the evidence that the volcanic upland is a klippe and that the sedimentary rocks are continuous at shallow depth beneath it (cross sections, pl. 1).

Similar cataclastic rocks are well exposed for many kilometers south and east of the volcanic upland. North and west, the continuity of these rocks is partly obscured by younger rock units and landslide deposits, but here too they are probably continuous at shallow depth. These and similar cataclastic sedimentary rocks elsewhere in the California Coast Ranges formerly were considered a part of the Franciscan Formation by most geologists (Bailey and others, 1964; Jennings and Strand, 1960). Despite lithologic similarities, most of the evidence now available suggests that the Franciscan is not a fundamental lithologically homogeneous unit but a complex of tectonic slices of varied lithology derived from several sources. In this report, the term Franciscan Formation is not employed, although the affinity of the cataclastic sedimentary rocks with other Franciscan rock types is recognized. The largest area of outcrop of these rocks is on the southeast side of Snow Mountain between Fouts Camp and the South Fork of Stony Creek. There they are probably more than 800 m thick, but the absence of marker beds and small-scale folding and faulting make thickness estimates uncertain.

The sedimentary rocks are distinctively crushed and sheared and exhibit a cataclastic texture that is easily seen with a lens. Most of these rocks are fine grained and were probably derived from mudstone or siltstone. The fine-grained rocks are now weakly metamorphosed to phyllonite in which pervasive, closely spaced shear surfaces parallel or nearly parallel the bedding. Where metamorphism is most intense, the surfaces of schistosity exhibit a sheen that is probably a product of recrystallization. Exposed rocks are medium dark gray where fresh; most are weathered to light olive gray.

Semischist, derived from fine- to medium-grained arkosic wacke and sandstone, is interbedded with the phyllonite, and in some places predominates over the finer grained rocks. Beds of semischist are a few millimeters to several centimeters thick, are well bedded, and may or may not be graded. Some beds exhibit sole marks, slump folds, and load casts; these and other bedding features are difficult to distinguish where the degree of cataclastic deformation is high, as it is in much of the area described here. Individual grains in the semischist are flattened and sheared and are separated by streaks of sheared dark matrix so that the original grain outline and sedimentary texture is obscured in many rocks.

Pillow lava in flows no thicker than 100 m is interbedded with the cataclastic sedimentary rocks on Skeleton Creek both east and west of the road crossing and on the south Fork of Stony Creek below Deafy Glade. Pillow forms and other field relations resemble those in the volcanic rocks of Late Jurassic age except that the volcanic rocks interbedded with cataclastic sedimentary rocks are more broken and deformed and are more intensely altered. Although typical volcanic textures are visible with a lens, thin sections exhibit few identifiable primary minerals and are clouded with a nearly opaque mass of alteration products through which the original texture is vaguely outlined.

The marine origin of these rocks is indicated by pillow lava, by marine fossils collected from similar rocks a few kilometers southeast (Brown, 1964b), and by bedding features that reflect a deep-water environment. The cataclastic fabric is a product of deformation after deposition and lithification, and because this fabric is most intense near thrust faults, the cataclastic metamorphism probably is roughly contemporaneous with thrusting.

The Late Jurassic and Cretaceous age assigned these rocks is tentative and based on indirect evidence. Similar but somewhat less deformed sedimentary rocks with thin (100-m) flows of pillow lava, 8.5 km southeast of Fouts Springs, contain fossils that were identified by D. L. Jones (oral commun., 1961) as *Buchia piochii* (Late Jurassic) and *Buchia crassicolis* (Early Cretaceous). The rocks at the fossil localities cannot be traced continuously to the study area, but because they lie along the same structural trends and are lithologically similar, they are judged to be about the same age.

SHEARED AND CRUSHED ROCKS ALONG FAULT ZONES

Two belts of sheared and crushed rock debris were recognized and mapped. Most of the claims and prospects and many of the geochemical anomalies in the study area are within or near these two belts. The upper belt nearly circumscribes the volcanic upland about Snow Mountain and St. John Mountain, separating the volcanic rocks above it from cataclastic sedimentary rocks below. The lower belt follows the South Fork of Stony Creek from Fouts Springs to Deafy Glade. The rocks above and below the lower belt are chiefly cataclastic phyllonite and semischist. Near Deafy Glade, this belt appears to climb toward the west and may merge with the upper one beneath landslide deposits west of Summit Spring. Both belts follow major faults and are similar in field relations and lithology. The upper belt, better exposed and thicker, is described below.

The contact between the upper belt and the overlying volcanic rocks is abrupt and well defined in most places. The contact between the upper belt and the underlying cataclastic sedimentary rocks is less distinct. The upper belt is about 250 m thick where best exposed on the south and west flanks of Snow Mountain. It is thicker north and northwest of St. John Mountain and much thinner around the periphery of the volcanic slab between Crockett Peak and Copper Butte Creek. Along the southeastern and eastern margin of Snow Mountain, volcanic rocks are in fault contact with phyllonite and semischist, and no mappable belt of sheared and crushed rocks intervenes.

Most of these rocks consist of a finely divided, fragmented matrix that encloses much larger masses of resistant rocks. Angular matrix fragments are of argillite or mudstone and range in size from about a millimeter to 20 mm. Such debris is derived chiefly from the cataclastic sedimentary rocks of Late Jurassic and Early Cretaceous age or their unmetamorphosed equivalents.

Within this sheared argillaceous matrix are larger blocks of resistant rocks: graywacke, diabase, massive volcanic rocks, chert, glaucophane-bearing rocks, and glaucophane schists. These resistant masses range from about a meter to more than 100 m in diameter, the larger ones standing out like chaotic monuments above the surrounding terrain. Many are obviously recrystallized, and some show tectonically abraded and altered borders. They are most abundant near the upper contact of the sheared and crushed rocks with pillow lava, and where they are clearly in place, most of the exotic recrystallized masses, like glaucophane schist, are within a few tens of meters of the contact. Quartz veins cut both the finely divided debris and the resistant masses. Rock debris of this lithology was previously described and mapped as "friction carpet debris" (Brown, 1964a). Near St. John Mountain it is somewhat better indurated and contains more quartz veins than in the slopes above the Eel River, where it is less cemented and more easily eroded.

The lithologic character is somewhat different in the fault zone north of Summit Spring and south of Snow Mountain. Here discrete flat or north-dipping lenses of intensely sheared phyllonite and semischist 100-200 m long and 50 m thick are bounded by fault surfaces. Finely divided sheared rock is less abundant here than elsewhere, and resistant masses of glaucophane schist and other rocks mark the upper part of the belt.

Other features that help identify the belt of sheared and crushed rocks are serpentinite, large springs, and landslides. Several tabular bodies of serpentinite are mapped near the contact with the overlying volcanic rocks, and smaller wisps and irregular masses of serpentinite lie wholly within the belt of sheared and crushed rocks. Springs are abundant, especially near the upper contact, and many are surrounded by travertine aprons; only a few of the larger and most accessible springs are shown on published topographic maps. Landslides are much more numerous in these rocks than in the more resistant bedrock units above and below them. Although many of these landslides mask field relations and obscure the continuity of mapped rock units, the landslide debris is clearly derived from the belt of sheared and crushed rocks.

The sheared and crushed rocks along fault zones are a product of deformation during faulting. The age of faulting and deformation is not known but is presumed to be Tertiary for reasons discussed later in the section on "Structural Geology."

SERPENTINITE

Serpentinite is exposed along faults and shear zones at scattered localities shown on the geologic map. Tabular masses, sheets, and lenses of serpentinite as thick as 50 m crop out in the sheared rocks just below the volcanic rocks on the head of Bear Wallow Creek, on the east side of St. John Mountain, and on the southeast and south-west sides of Snow Mountain. These serpentinite bodies parallel major lithologic contacts and nearby fault surfaces; thinner bodies on the south and west side of Snow Mountain are oriented more erratically with respect to contacts and faults. All of these bodies are in the upper belt of sheared and crushed rocks, but serpentinite also crops out in the lower belt between Summit Spring and the South Fork of Stony Creek.

Another serpentinite body, about 25-50 m thick, lies along a high-angle fault that parallels the Middle Fork of Stony Creek between Brittan Ranch and West Crockett Camp. It crops out almost continuously for about 14 km and evidently extends to substantial depth because it produces a well-defined magnetic anomaly.

Fresh unsheared serpentinite is medium dark gray (N4) or medium gray (N5) and exhibits relict textures of the parent ultramafic rock. Most serpentinite is intensely sheared and slickensided and is of paler color.

The extent to which these rocks are serpentinized makes it difficult to determine their original mineralogy and to identify the parent rock. Where original minerals can be identified, the abundance of pyroxene is considered evidence that most of the original rock was a peridotite. Dunite, a peridotite composed almost entirely of olivine, was not observed, although it or its serpentinized counterpart may be present in places. The paucity of dunite is significant because most of the known chromium deposits in the Coast Ranges and in southwestern Oregon occur in dunite.

Some of the serpentinite and other ultramafic rocks in the California Coast Ranges are believed to represent oceanic crust and to be pre-Cretaceous in age (Bailey and others, 1970; Lanphere, 1971). The age of crystallization and the history of the rocks described here is unknown. Although they may somehow be derived from ancient oceanic crust, their structural relation to other rocks shows that they were emplaced after a major episode of folding and probably during or after thrusting of the volcanic slab over cataclastic sedimentary rocks. Emplacement of the serpentinite along the Middle Fork of Stony Creek is almost surely later than thrusting, for the serpentinite follows a high-angle fault that displaces the basal thrust contact of the volcanic rocks. The age of serpentinite emplacement is therefore probably Tertiary.

UNCONSOLIDATED DEPOSITS

Evidence of glaciation on Snow Mountain was first recognized by Holway (1911), who described a number of glacial features and deposits on the north and east sides of the mountain. Although no systematic effort was made to map glacial deposits during the field investigations on which this report is based, one deposit of presumed glacial and glaciofluvial origin has been outlined in the drainage of Dark Hollow Creek, east of Snow Mountain, where it mantles benches, ridges, and slopes as much as 120 m above the present course of the creek. It consists chiefly of angular to subangular pebbly and sandy detritus of local origin and encloses large blocks of volcanic rocks and chert. This deposit and others described by Holway are associated with cirques, hanging valleys, and other glacial features, mostly above the 1,800-m level. These glacial deposits are the most southerly glacial features known in the Coast Ranges. They are assumed to be of late Pleistocene age.

Landslide deposits of jumbled debris cover broad areas north of St. John Mountain and south of Snow Mountain between North Glade and Summit Spring. These and many smaller landslides originated in the sheared and crushed rocks along thrust faults. The deposits are easily recognized by hummocky surfaces lacking any well-established drainage network; by springs, ponds, and undrained depressions; and by steep arcuate headwalls. Landslide deposits on the south side of Snow Mountain are mottled with grassy hummocky meadows or glades, some of which (North, Mauser, Deafy, Rattlesnake, Welton) are identified on the topographic map. The landslide debris is a chaotic mixture of varied rock types. Finely divided and intensely sheared debris has enclosed and carried along resistant blocks as much as several tens of meters long and equally thick; these blocks include volcanic rocks, serpentinite, diabase, chert, and exotic rock masses from the belt of sheared and crushed rocks.

Landslide deposits also are derived from other rock units. Several large landslide deposits along the north side of the Middle Fork of Stony Creek contain both serpentinite and volcanic debris. Failure probably began in or near the belt of serpentinite. Dense vegetation and uniform lithology make landslide deposits difficult to recognize in the volcanic rocks of Late Jurassic age unless distinctive landforms such as headwalls or hummocky topography are evident or the landslide debris overrides lower rock units of different lithology. Landslide deposits in the volcanic rocks may therefore be more abundant than indicated on the geologic map.

Some landslide deposits appear to be stable and may be as old as Pleistocene, but others are still moving. The large slide area between North Glade and Summit Spring (pl. 1) and several smaller slides along the Forest Service road between Deer Creek and Copper Butte Creek are active, at least locally. At one of the smaller slides, on Hummingbird Creek, the removal of rock in a roadcut has accelerated sliding and has caused a series of steplike failures marked by open fractures and tilted and toppled trees. Other active landslides are found where stream erosion has carved steep unstable slopes in the sheared and crushed rocks beneath the volcanic slab; many of these are too small to show on the geologic map.

Terrace deposits along the North and South Forks of Stony Creek record earlier higher levels of stream deposition. Terrace remnants, a meter or two thick, are found at several levels from a few meters to tens of meters above present stream channels. The deposits are chiefly subangular to subrounded pebble and cobble gravel and consist of debris derived from upstream within the present drainage area of Stony Creek.

Alluvial deposits are thin and of local extent. Only those near Milk Ranch and near West Crockett Camp are large enough to show on the geologic map (pl. 1), but small patches of alluvium are found in relatively flat reaches of the upper course of the Middle Fork and along some of the smaller streams. On many streams, cones and fans of alluvium mark the confluence of steeper tributaries with the trunk stream. The alluvial deposits are sand and gravel, chiefly subangular to subrounded and of local origin. They are probably all of Holocene age, and some of those on the Middle Fork, upstream from Bear Wallow Creek, are so recent that vegetation on them is only poorly established.

STRUCTURAL GEOLOGY

The structural relations shown on the geologic map and on the cross sections (pl. 1) are interpreted chiefly from the distrubution of the major lithologic units. Because of the high relief (more then 1,600 m), the geologic map provides an approximate three-dimensional model of the structure. Bedding in the sedimentary rocks and layering of pillow lava, both represented by strike and dip symbols on the geologic map, help in interpreting the structural relations. Although not all pillow flows accumulate as horizontal sheets, most flows mapped here evidently formed nearly horizontal deposits when extruded. Attitudes from several exposures of pillow lava in the same area are consistent within 5° to 10° in both strike and dip, and where pillow lava and marine sedimentary rocks are found together or in proximity, their strike and dip are similarly consistent. The contacts of younger pillows draped over older, visible at most exposures, demonstrate that nearly all of the volcanic rocks are right side up; in only a few places near faults are they overturned.

FOLDS

Pillow flows and sedimentary beds in the volcanic rocks of Late Jurassic age are tilted, and most of them dip at angles of 60° or less. The direction of dip and the trend of bedding and layering in pillow flows vary but are generally consistent with a series of ill-defined north- to northeast-trending fold axes. The best defined fold is anticlinal, trends a little east of north, and passes through the alluvial meadows at the Milk Ranch. It plunges toward the south and appears to die out northeastward toward the Middle Fork of Stony Creek. Volcanic rocks on the limbs of the fold dip about 40°, on the average, and those on its south-plunging nose dip about 30°.

Large folds are less well defined in the intensely deformed rocks immediately beneath the thrust; at deeper structural levels to the south and southeast (Brown, 1964b), the cataclastic sedimentary rocks are folded along north-trending axes.

The north-trending folds in rocks above and below the thrust fault parallel structural trends to the east in the Great Valley and are evidently part of a major regional fold system that deformed rocks as young as Paleocene near the southwestern boundary of the study area (Berkland, 1973). The folds evidently predate thrusting, as they are truncated by gently warped and relatively undeformed thrust faults.

Small folds with other trends deform the volcanic rocks immediately above the thrust fault and the cataclastic sedimentary rocks immediately beneath it. Some of these folds, tens of meters in amplitude, are represented on the map by changes in strike and dip, by local overturning, or by plotted fold axes (pl. 1). Although they vary in trend and plunge, their character is consistent with relative northward movement of the rocks above major thrust faults.

FAULTS

Thrust faults that are nearly horizontal and steeply dipping normal faults cut the rocks shown on plate 1. The low-angle thrust fault that underlies Snow Mountain is one of several similar faults that converge eastward and merge with the Stony Creek fault zone (Brown, 1964b). At several places in this area (pl. 1) and nearby, drag folds and field relations (Brown, 1964b, and unpub. data) indicate relative northward movement of upper plate rocks. Underthrusting of lower-plate rocks toward the south is equally consistent with this evidence and is more compatible with present knowledge of the regional geology; still other directions of transport have been proposed for thrust faulting in the northern Coast Ranges (Bailey and others, 1970).

The fact that surfaces of thrusting, the belt of sheared rocks along thrust faults, and the serpentinite bodies that locally occupy shear zones are not folded like the rocks in the upper and lower plate shows that thrust faulting was later than most of the folding. Because the thrust faults are much less deformed than folded rocks of Mesozoic and early Tertiary age exposed elsewhere in northern California, they are presumed to be Eocene or younger.

Most of the steeply dipping faults trend northeastward. They exhibit no consistent sense of vertical displacement, and some of them may have slipped obliquely or along the strike of the fault. Two of these faults on St. John Mountain are down to the southeast, and the more westerly one displaces the base of the volcanic rocks by at least 130 m. Northeast-trending faults on Snow Mountain exhibit equivocal evidence for direction of displacement, but where the evidence is best, they appear to be down on the northwest.

A northwest-trending fault parallels the Middle Fork of Stony Creek and is distinguished on the geologic map by a thin belt of serpentinite. On this fault, the direction and minimum amount of relative movement, down to the south and at least 420 m, are determined by the displacement of the base of the volcanic rocks between Crockett Peak and Bear Wallow Creek. North of the fault, the base of these rocks is approximately level and about 1,560 m above sea level; south of the fault volcanic rocks crop out along the Middle Fork at an average elevation of about 1,140 m. This fault, too, may have a significant strike-slip component; in places it truncates bedded sequences hundreds of meters thick.

Both the northwest- and northeast-trending faults appear to cut the base of the volcanic rocks and to penetrate the belt of sheared and crushed rocks along the thrust fault. They are therefore at least in part younger than the thrust fault.

Except for spring deposits in the belt of sheared and crushed rocks along the thrust fault, none of the faults mapped is unusually mineralized or hydrothermally altered.

INTERPRETATION OF AEROMAGNETIC DATA

By Andrew Griscom and Robert D. Brown, Jr.

Some rock types and some kinds of ore bodies contain magnetic minerals in quantities sufficient to affect the intensity or direction of the Earth's magnetic field. Magnetic surveys, which employ magnetometers to measure magnetic intensity, are a proven method of locating magnetic ore bodies and of evaluating the mineral resource potential of unexplored areas. Because magnetic rock can be detected through forest and soil cover, nonmagnetic rock, and water, these surveys can contribute new information even where surface geology is well known. And because magnetic effects follow simple physical laws, they enable the geophysicist to test geologic interpretations through models that reproduce observed variations in the magnetic field.

Although magnetic surveys may be made on the surface, aerial surveys are commonly employed where a large area must be examined or where ground access is difficult. In the U. S. Geological Survey's wilderness evaluation program, aeromagnetic surveys are an important part of most investigations.

In the Snow Mountain area, aeromagnetic data were already available from a survey conducted by the U. S. Geological Survey in 1962. The original data were obtained along a strip 100 km long and 26 km wide that extends east from Lake Pillsbury to about the center of the Sacramento Valley. Flight lines were oriented east-west with a 1-mile (1.6 km) spacing and were flown at an average barometric altitude of 7,000 feet (2,100 m). Magnetic intensity along the flight path was continuously recorded by an airborne magnetometer, and the data were later contoured, relative to an arbitrary datum, at intervals of 10 and 50 gammas. The western one-third of this survey, which includes the Snow Mountain Wilderness Study Area, is displayed here superimposed on a generalized map of the geology (pl. 2).

The aeromagnetic map, like most similar maps, shows two levels of information, the Earth's main field and local magnetic features. The gradient caused by the main magnetic field of the Earth increases toward the north magnetic pole, and in this part of California it increases about 6 gammas per kilometer in the approximate direction N. 17° E. (Fabiano and others, 1976; Fabiano, 1975). This regional gradient amounts to about 200 gammas across the map.

The gradient of the main field is interrupted or obscured by several magnetic anomalies that yield significant information on the magnetic properties and configuration of nearby rock masses. Most of the anomalies are positive and linear; their trends vary between north and west. The largest anomaly in the study area is about 100 gammas in amplitude, trends a little north of west, and approximately parallels the Middle Fork of Stony Creek, It merges to the southeast, outside the study area, with an even larger anomaly (labeled 2,728 gammas) that trends north-northwest. Several broader anomalies are outlined in the western and southern part of the aeromagnetic map area; two of these are near the southern boundary of the study area.

That none of these anomalies shows any systematic correlation with topography is significant. Local topographic relief here is as mch as 1,200 m, and where magnetic rocks underlie such a rugged terrain, local magnetic anomalies of this kind appear on the map. Slight irregularities in the magnetic contours over Snow Mountain may be a subtle effect of very weakly magnetic rocks, but the absence of positive anomalies over ridge crests and peaks and of negative anomalies along deeply incised canyons is evidence that the volcanic rocks and the cataclastic sedimentary rocks are at most only weakly magnetic and incapable of producing the relatively large positive anomalies mapped.

The magnetic anomalies do show a systematic relation to serpentinite bodies. Most of the well-defined anomalies correspond to surface exposures of serpentinite and follow the trend of these rocks. The largest anomalies, with one exception, are associated with thick or relatively continuous bodies of serpentinite, the smaller ones with thin or less continuous bodies. The exception is the large circular anomaly that peaks at 2,728 gammas and is about midway between Stonyford and the eastern boundary of the wilderness study area. This anomaly probably represents a large serpentinite mass at relatively shallow depth beneath a cover of volcanic rocks.

The largest magnetic anomaly within the study area follows a narrow belt of serpentinite along the Middle Fork of Stony Creek. A model study of the serpentinite belt (fig. 2) indicates that it can cause the magnetic anomaly if the belt is the expression of a dike extending below sea level in the subsurface with a dip to the north of about $70° \pm 5°$. The absence of a sharp magnetic low on the north side of the anomaly implies that the dike is not vertical (see fig. 2 for the magnetic effect of a vertical dike) and that the dike extends down to sea level at least. The calculated magnetic susceptibilities range from 0.002-0.003 emu/cm^3 depending on the dip of the dike, typical values for serpentinite of the northern Coast Ranges (Griscom, unpub. data, 1977). The interpretation of the magnetic data given here supports the geologic conclusion that the serpentinite dike cuts, and is younger than, the major flat-lying thrust fault.

A less regular and smaller positive anomaly trends northwesterly from Deafy Glade to the Eel River. The ridgelike eastern part of this anomaly closely follows a thin serpentinite belt along a fault zone. To the west, the geology is obscured by landslide debris in most places, but small bodies of serpentinite are alined in the landslide deposits and at a few places where bedrock is exposed. These masses, though sparse, can be interpreted as evidence of a more continuous body at depth.

A major regional feature is the magnetic gradient sloping down to the west from the north-trending ridgelike high, which peaks at 2,728 gammas on the east side of the map. This gradient as discussed by Griscom (1966) is interpreted to be caused by a deeply buried magnetic mass whose top is about 1 km below sea level at the axis of the ridgelike high and slopes down to the west, reaching a depth of 8 to 10 km about 18 km west of the axis of the high. The magnetic rocks are tentatively assumed to be serpentinite.

All of the features shown on the aeromagnetic map can be accounted for satisfactorily by the magnetic properties of recognized geologic units. There may be local or disseminated magnetic mineral deposits, but within the limits of scale and level of detail of the aeromagnetic data, no evidence of such deposits was detected.

GEOCHEMICAL INVESTIGATIONS

The geochemical investigation in the Snow Mountain Wilderness area consists of (1) the sampling and analysis of rocks, stream sediments, pan concentrates, and spring water; (2) the plotting of geochemical maps; and (3) the interpretation of the data in relation to the geologic setting.

The rocks in the study area are similar to rocks in other parts of the California Coast Ranges that contain deposits of chromite, man-

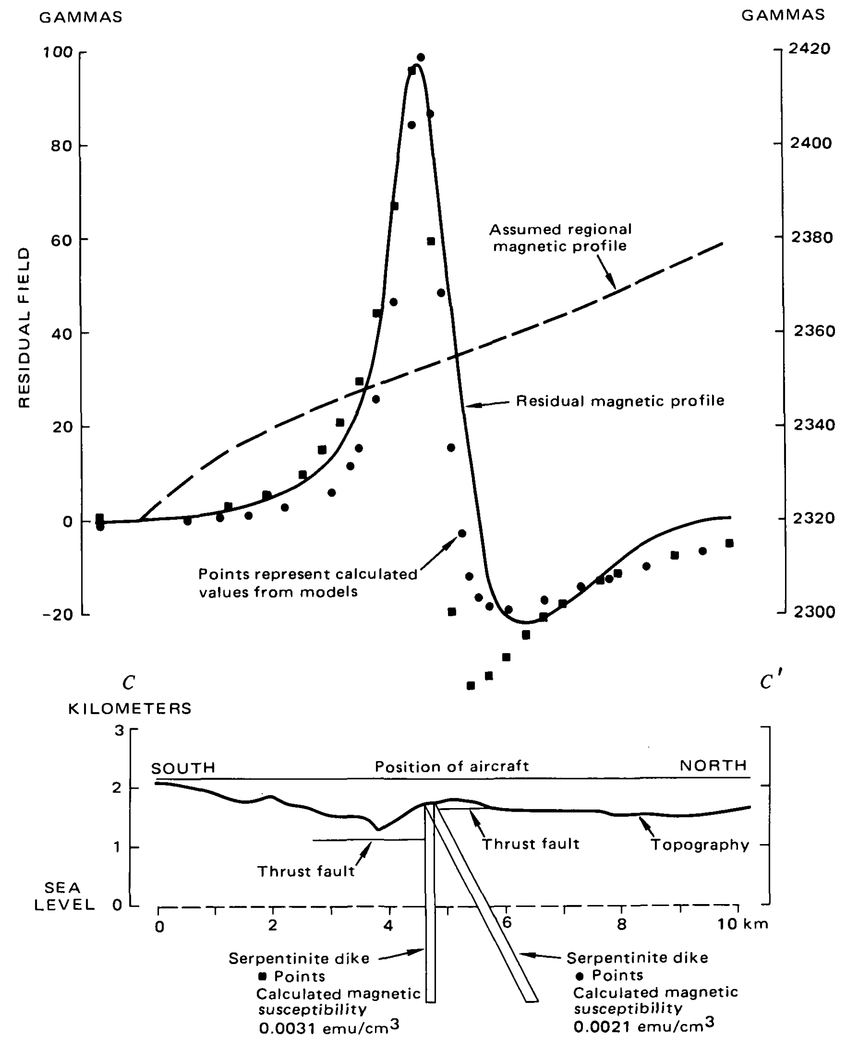

FIGURE 2.- Cross section *C-C'* calculated for two alternative models of a magnetic serpentinite dike. See text for discussion. Regional field values correspond to those on plate 2.

ganese, mercury, and massive sulfides containing copper (Davis, 1966). Orientation studies around several of these deposits just east of the study area provided comparative data useful for the geochemical evaluation. Most of the samples were analyzed in the field in mobile laboratories by a semiquantitative emission spectrographic technique. The geologic and analytical data were treated statistically to determine the normal or background concentrations of different elements and to determine threshold concentrations above which geochemical anomalies can be recognized. Geochemical maps (figs. 3-6) were plotted for selected elements and evaluated relative to the geology. The results of the geochemical investigation suggest a low potential for any metallic mineral deposit of economic significance in the study area. The complete data set on samples collected and analyzed during this study is available on tape from the U. S. Department of Commerce, National Technical Information Service (McDanal and others, 1977).

SAMPLING AND ANALYTICAL METHODS

Rock samples of all the major rock types in the study area were collected during geologic mapping (pl. 1). Most of these rocks were relatively fresh and unaltered and provided data on the normal concentration ranges of elements important in the mineral evaluation. Float rocks and stream pebbles were examined in most of the drainages, and those with visible signs of mineralization or alteration were collected.

The rock samples were reduced to minus 6 mm in a jaw crusher, split with a Jones splitter, and ground to minus 0.1 mm in a vertical pulverizer equipped with ceramic plates. All samples were analyzed for 20 elements by a semiquantitative emission spectrographic method (Grimes and Marranzino, 1968) and for mercury by a vapor detector technique (Vaughn and McCarthy, 1964). The precision of the spectrographic method is given by Motooka and Grimes (1976). Selected samples were analyzed for gold by an atomic absorption method (Ward and others, 1969) and for uranium by a modification of a fluorimetric technique (Grimaldi and others, 1954).

Sediment samples were collected from selected drainages in and around the study area (pl. 1). Where possible, the sediment was taken at midchannel or in the most active part of the stream. The samples were stored in metal-free paper envelopes, air dried, and sieved to minus 0.18 mm. They were analyzed for 20 elements by the emission spectrographic method and for zinc by an atomic-absorption technique (Ward and others, 1969). The sediments were leached with oxalic acid to separate the iron and manganese oxide fraction for spectrographic analysis. The ability of these oxides to scavenge metals from solution and their significance in geochemical investigations is described by Chao and Theobald (1976). Pan concentrates were collected in many of the drainages (pl. 1), air dried, sieved to minus 0.4 mm, separated into magnetic and nonmagnetic fractions with a hand magnet, and hand ground in an agate mortar to minus 0.1 mm. Both fractions were analyzed for 20 elements by the emission spectrographic method and for mercury by the vapor-detector technique.

Water samples were collected from nine springs in the area and analyzed for copper, lead, zinc, and molybdenum by an atomic-absorption method and for sulfate by a turbidimetric technique (Tabatabai, 1974).

METHODS OF EVALUATION

The geochemical evaluation was based on the distribution, variation, and geological association of selected elements in rock, stream sediment, pan concentrate, and water samples. The threshold value for an element separates normal or background concentrations from those that are significantly above backgrounds. Threshold values vary with different sampling methods; those given here (table 2) were determined using percent cumulative frequency plots as described by Boyle (1971). Where data were insufficient for statistical treatment, the threshold value was chosen by inspection. Concentrations above threshold are considered anomalous; only those samples containing an element in amounts exceeding its threshold were shown on geochemical maps. Distribution of copper, lead, and chromium in stream sediment is mapped as figures 3, 4, and 6, respectively, distribution of mercury in rock as figure 5. Partial analytical results for all samples containing anomalous amounts of one or more selected elements are given in table 3.

TABLE 2. - *Threshold values, in parts per million, for selected elements for different kinds of samples*

[Analytical methods: Mn, Cr, Cu, and Pb by emission spectroscopy for Hg by a vapor-detector method; N.d, not determined]

Sample type	Mn	Cr	Cu	Pb	Hg
Rocks	2,000	150	80	20	0.08
Stream sediments	1,800	550	90	20	N.d.
Oxalic acid leach	2,000	1,000	200	40	N.d.
Nonmagnetic concentrate	2,000	1,000	70	20	.08

GEOCHEMICAL INTERPRETATION

COPPER

Minor amounts of copper are associated with manganiferous chert in several prospects a few kilometers east of the study area. Stream-sediment samples were collected near these prospects during a preliminary orientation study to provide data for geochemical compari-

TABLE 3. - *Partial analytical results of samples containing anomalous amounts of one or more selected elements*

[Analytical methods: S-Mn, S-Cr, S-Cu, S-Pb, S-Ag, S-Mo, and S-Zn by emission spectroscopy; INST. Hg by mercury vapor detector; and AA-Cu, AA-Pb, and AA-Zn by atomic absorption. N, indicates not detected at value shown; <, indicates less than value shown; >, indicates greater than value shown. Analysts: D. J. Grimes, R. W. Leinz, and W. H. Ficklin]

Rocks

Sample No.	Easting	Northing	S-Mn	S-Cr	S-Cu	S-Pb	INST. Hg	Other	Description
				(Parts per million)					
BS23	53375	436725	>5,000	70	150	N20	5	···	Mn prospect.
BS214	52960	436130	1,500	300	70	N20	N.02	···	Volcanic.
BS217	53072	436028	3,000	50	300	50	N.02	···	Schists.
BS218	53070	436084	1,500	150	100	N20	N.02	···	Volcanic.
BS219	52634	435638	1,000	300	20	20	.02	···	Sediment.
BS229	52638	435968	1,500	70	100	N20	<.02	···	Volcanic.
BS232	52484	435755	1,500	200	150	N20	.04	···	Do.
BS233	52588	435774	1,500	200	200	N20	N.02	···	Do.
BS250	52668	435886	2,000	150	150	N20	N.02	···	Metasediment.
BS254	52956	436145	1,500	500	100	N20	N.02	···	Sediment.
BS255	52924	436205	1,500	500	200	N20	<.02	300 Zn	Do.
BS256	52842	436308	1,500	500	150	N20	.04	···	Volcanic.
BS271	52744	436715	1,500	500	150	N20	.02	···	Do.
BS2119	52498	436297	1,500	500	100	30	<.02	···	Sediment.
BS2120	52522	436275	5,000	N50	50	N20	N.02	···	Chert (Mn).
BS2131	52336	435767	1,000	150	100	N20	N.02	···	Volcanic.
BS2140	52196	436150	1,500	100	100	N20	N.02	···	Diabase.
BS2154	52256	435648	1,500	500	70	N20	<.02	···	Volcanic.
BS2166	52211	436296	2,000	100	100	N20	N.02	···	Diabase.
SM1R	53296	435831	>5,000	70	50	N20	.02	10 Mo 300 Zn	Mn prospect.
SM2R	53400	435920	>5,000	70	20	N20	.40	30 Mo 300 Zn	Do.
SM5R	51641	436127	1,500	200	50	N20	.04	···	Volcanic.
SM8R	51936	435624	500	50	300	N20	N.02	···	Chert float.
SM9R	51807	435718	2,000	N50	7	N20	.06	7 Mo	Diabase.
SM12R	52476	436798	5,000	N50	100	70	.20	700 Zn	Fe-stained float.
BCP711	51800	436311	1,500	50	20	N20	.04	15 Mo	Volcanic.
BCP717A	51751	436374	2,000	100	150	N20	.06	···	Do..
BCP728	51363	436535	1,500	300	70	N20	N.02	···	Do..
SM15R	52334	435471	>5,000	200	200	30	.22	20 Mo 500 Zn	Float with sulfides.
SM16R	52685	436863	>5,000	N50	5,000	30	.10	···	Do.
BCP732	52011	435988	1,000	200	70	N20	.06	···	Diabase.
BCP742	51725	435909	1,000	200	50	N20	.06	···	Volcanic.
SM21R	52629	435491	500	100	10	20	.30	.5 Ag	Fe-stained float.
SM24R	51349	436147	700	N50	15	N20	.50	···	Chert.
SM30R	51484	435851	1,500	200	30	N20	.04	···	Volcanic.
SM31R	51596	435844	700	300	30	N20	.08	···	Sediment.
SM32R	51752	436443	1,500	2,000	20	N20	.08	···	Serpentine.
SM33R	51754	436450	700	1,500	7	N20	.30	···	Do..
SM35R	53111	436572	700	200	5	N20	<.02	···	Gneiss.
BCP749	51980	435952	1,500	150	100	N20	<.02	···	Diabase.
SM36AR	52680	436868	>5,000	100	5,000	50	.16	200 Zn	Float with sulfides.
SM36BR	52680	436868	1,000	70	100	30	.20	···	Do.
SM36CR	52680	436868	5,000	50	100	N20	.08	···	Do.
SM36DR	52680	436868	700	N50	1,500	50	.38	3.0 Ag 50 Mo 700 Zn	Do.
SM36ER	52680	436868	3,000	3,000	10	N20	.06	···	Float with minor sulfides.

TABLE 3. - *Partial analytical results of samples containing anomalous amounts of one or more selected elements*—Continued

Stream sediments

Sample	Easting	Northing	S-Mn	S-Cr	S-Cu	S-Pb	Other
SM1SS	53292	435848	1,500	70	100	N20	---
SM2SS	53290	435825	3,000	150	150	N20	---
SM3SS	53300	435975	2,000	500	100	N20	---
SM4SS	53391	435824	2,000	300	100	N20	---
SM6SS	53331	436154	2,000	>5,000	70	N20	300 Zn
SM11SS	51959	435621	1,500	700	70	<20	---
SM12SS	51970	435613	1,500	700	70	20	---
SM13SS	51825	435727	2,000	100	50	N20	---
SM14SS	51704	435796	1,500	2,000	70	N20	---
SM21SS	52952	436736	1,000	700	70	<20	---
SM22SS	52874	436789	1,000	700	70	<20	---
SM23SS	52818	436815	1,000	700	50	<20	---
SM24SS	52440	436782	1,000	700	50	<20	---
SM25SS	52426	436760	1,000	1,000	30	N20	---
SM28SS	52256	435486	700	300	50	20	---
SM29SS	52273	435500	1,000	200	50	30	---
SM30SS	52332	435463	1,000	500	70	30	---
SM31SS	52438	435421	1,000	200	70	20	---
SM33SS	52641	435560	1,500	150	50	20	---
SM34SS	52651	435577	1,500	150	50	20	---
SM35SS	52800	435586	1,500	1,000	50	<20	---
SM37SS	52607	436821	1,000	1,000	30	<20	---
SM38SS	52714	436869	1,000	1,500	30	N20	---
SM39SS	51976	435863	2,000	150	30	N20	---
SM40SS	51856	435962	2,000	150	50	<20	---
SM43SS	52438	436486	700	700	50	<20	---
SM44SS	52476	436357	1,000	5,000	30	<20	---
SM45SS	52494	436338	1,000	1,000	50	N20	---
SM46SS	52529	435696	1,000	1,000	50	20	---
SM47SS	52712	435657	1,000	1,000	50	20	---
SM53SS	52221	436321	1,000	700	50	N20	---
SM54SS	52141	436264	1,500	150	50	20	---
SM55SS	52050	435568	1,000	700	50	20	---
SM56SS	52536	435498	1,000	300	50	50	---
SM63SS	51373	436126	1,500	200	70	20	---
SM64SS	51365	436144	1,500	300	100	N20	---
SM67SS	51232	435824	1,000	700	50	<20	---
SM68SS	51196	435852	700	3,000	20	N20	---
SM69SS	51177	436048	1,500	700	50	N20	---
SM70SS	51233	436127	1,000	1,500	50	N20	---
SM81SS	51847	436350	1,000	1,000	50	N20	---
SM82SS	52025	436494	1,500	700	70	N20	---
SM83SS	52821	436622	1,000	700	70	20	---
SM85SS	52912	436566	1,000	300	70	20	---
SM87SS	53144	436504	700	700	50	<20	---
SM88SS	52908	435746	1,000	150	70	20	---
SM89SS	52660	436852	500	500	50	20	---
SM91SS	52746	436878	700	300	50	20	---
SM92SS	52448	436859	700	500	70	20	---

Stream sediments — oxalic acid leach fraction

Sample	Easting	Northing	S-Cr	S-Cu	S-Pb	Other
SM1X	53292	435848	300	700	N20	---
SM2X	53290	435825	500	1,000	N20	---
SM3X	53300	435975	1,000	1,000	N20	---

TABLE 3. - *Partial analytical results of samples containing anomalous amounts of one or more selected elements—Continued*

Stream sediments — oxalic acid leach fraction—Continued

Sample	Easting	Northing	S-Cr	S-Cu	S-Pb	Other
SM4X	53391	435824	1,000	1,000	N20	...
SM6X	53331	436154	5,000	1,000	50	...
SM11X	51959	435621	1,000	30	N20	...
SM12X	51970	435613	700	70	100	...
SM15X	51679	435710	300	300	N20	...
SM20X	53118	436318	1,000	100	N20	...
SM21X	52952	436736	1,000	50	50	...
SM22X	52874	436789	1,000	100	70	...
SM23X	52818	436815	1,000	100	70	...
SM24X	52440	436782	700	70	70	...
SM25X	52426	436760	1,000	150	70	...
SM26X	52434	436752	1,000	200	70	...
SM27X	52492	436784	1,000	30	50	...
SM31X	52438	435421	300	150	50	...
SM32X	52461	435426	300	300	30	5 Mo 500 Zn
SM33X	52641	435560	300	150	50	...
SM35X	52800	435586	1,000	100	<20	...
SM36X	52581	436813	1,000	100	<20	...
SM37X	52607	436821	1,000	30	N20	...
SM44X	52476	436357	2,000	30	N20	...
SM45X	42494	436338	2,000	100	N20	...
SM46X	52529	435696	1,500	50	30	...
SM47X	52712	435657	1,500	50	30	...
SM53X	52221	436321	1,500	150	N20	...
SM55X	52050	435568	500	50	100	...
SM56X	52536	435498	300	100	100	...
SM57X	52397	436212	200	150	<20	...
SM63X	51373	436126	500	300	20	...
SM64X	51365	436144	700	300	N20	...
SM67X	51232	435824	1,500	30	N20	...
SM68X	51196	435852	3,000	50	20	...
SM70X	51233	436127	2,000	30	N20	...
SM72X	51347	436436	1,000	100	N20	15 Mo
SM74X	51503	436565	1,000	70	30	...
SM89X	52660	436852	500	50	50	...
SM90X	52734	436880	500	300	20	300 Zn
SM91X	52746	436878	700	30	50	...
SM92X	52448	436859	700	20	70	...

Pan concentrates — nonmagnetic fraction

Sample	Easting	Northing	S-Mn	S-Cr	S-Cu	INST. Hg	Other
SM3CNL	53300	435975	1,500	700	100	0.02	...
SM4CNL	53391	435824	1,500	1,000	100	.04	...
SM6CNL	53331	436154	3,000	1,000	100	.06	...
SM11CN	51959	435621	2,000	200	100	.18	...
SM12CN	51970	435613	1,500	200	50	.12	...
SM14CN	51704	435796	2,000	300	100	.12	...
SM20CN	53118	436318	1,500	3,000	50	.16	...
SM21CN	52952	436736	1,500	500	50	.14	...
SM25CN	52426	136760	1,000	2,000	30	.16	...
SM26CN	52434	436752	1,000	1,000	30	.16	...
SM27CN	52492	436784	1,000	3,000	30	.08	...
SM28CN	52256	435486	1,000	3,000	30	.10	...
SM35CN	52800	435586	1,500	3,000	50	.08	...
SM36CN	52581	436813	1,500	2,000	70	.06	...
SM37CN	52607	436821	1,500	3,000	30	.04	...

TABLE 3. - *Partial analytical results of samples containing anomalous amounts of one or more selected elements—Continued*

Pan concentrates — nonmagnetic fraction—Continued

Sample	Easting	Northing	S-Mn	S-Cr	S-Cu	INST. Hg	Other
SM38CN	52714	436869	1,500	3,000	30	.04	...
SM42CN	52435	436481	1,500	5,000	50	.08	...
SM43CN	52438	436486	1,500	2,000	50	.06	...
SM44CN	52476	436357	1,500	5,000	50	.04	...
SM46CN	52529	435696	1,500	1,500	30	.08	...
SM49CN	52678	436131	1,500	2,000	50	.04	...
SM55CN	52050	435568	1,000	3,000	50	.12	...
SM63CN	51373	436126	1,500	300	50	.10	...
SM64CN	51365	436144	1,500	1,500	50	.06	...
SM66CN	51399	436040	1,500	3,000	50	.06	...
SM67CN	51232	435824	1,500	2,000	50	.06	...
SM68CN	51196	435852	1,000	5,000	10	.04	...
SM70CN	51233	436127	1,500	1,500	50	.02	...
SM73CN	51508	436553	1,500	1,500	50	.02	...
SM74CN	51503	436565	1,000	3,000	50	.06	...
SM75CN	51559	436327	1,500	300	50	.06	15 Mo
SM81CN	51847	436350	1,500	1,500	50	.04	...
SM83CN	52821	436622	1,000	2,000	50	.04	...
SM86CN	53116	436573	1,500	1,500	50	.08	...
SM87CN	53144	436504	1,000	3,000	50	.06	...
SM92CN	52448	436859	1,000	2,000	30	.04	...

Water samples — springs

Sample	Easting	Northing	AA-Cu	AA-Pb	AA-Zn	Other
SM1SP	51935	435978	.0012	0.0007	0.0250	...
SM41SP	52004	435936	.0110	.0210	.0150	.0006 Mo

sons. In one such comparison, a significant contrast is apparent in the distribution of anomalous amounts of copper in the oxalic acid fraction of stream sediments (fig. 3). Samples (1SS, 2SS, 3SS, 4SS, 6SS) from near the prospects contain 700-1,000 ppm copper in the leach fraction and are clustered; all other samples with anomalous values (15SS, 32SS, 63SS, 64SS, 90SS- pl. 1) contain no more than 300 ppm copper and occur sporadically. Copper minerals were seen in only a few float rocks collected immediately outside the study-area boundary. A sample from Bear Creek (8R- pl. 1) contained minor amounts of malachite (300 ppm copper) in chert, and several rocks from the North Fork of Stony Creek (16R, 36AR, 36DR- pl. 1) contained chalcopyrite (1,500-5,000 ppm copper) associated with pyrite in fractured sedimentary rocks. The Stony Creek rocks are probably float material from a group of prospects located on the north side of the creek outside the study area. One water sample (4SP- pl.1) collected from a spring about 2 km northwest of Snow Mountain East was anomalously high in copper (0.011 ppm). This anomaly, however, appears to be very localized, as other samples collected nearby contained only normal amounts of copper. Distribution maps are not shown for copper in the other sample media collected because anomalous values were few and their distribution erratic. From the geochemical data, there is no reason to suspect that the study area contains significant economic deposits of copper.

LEAD

The anomalous lead values in the stream sediments along the South Fork of Stony Creek (fig. 4) are from detritus of the cataclastic sedimentary rocks that crop out in the southeastern part of the study area (pl. 1). These rocks contain 20-50 ppm background lead; the volcanic and ultramafic rocks in the area average below 20 ppm. This geochemical lead anomaly, then, reflects only a difference in local geology and is not of economic significance. The highest lead values in the stream sediment and rocks were 50 ppm (56SS- pl. 1) and 70 ppm (12R- pl. 1), respectively. No visible lead minerals were identified in any of the samples collected.

MERCURY

Mercury was detected in anomalous amounts in nine rock samples scattered throughout the study area (fig. 5). The highest mercury content (5.0 ppm) was found in a sample of manganiferous chert (BS23) collected from a prospect outside the study area on Elephant Hill about 8 km northeast of St. John Mountain. All other anomalous rock samples contained 0.5 ppm or less and showed no geochemical pattern indicative of an economic deposit. No mercury minerals were seen in any of the pan concentrates nor were any significant amounts of mercury detected in any other sample types.

CHROMIUM

Stream-sediment samples that contain anomalous amounts of chromium (fig. 6) show where serpentinite bodies (pl. 1) are being eroded, for the background chromium content of serpentinite (1,000-3,000 ppm) is much greater than that of other rocks in the area (100-300 ppm). The anomalous chromium values are therefore not considered to be of economic importance, and no visible chromite was observed in any of the rocks collected.

MANGANESE

No geochemical map for manganese is given in this report, as only a few samples contained anomalous concentrations of manganese. Several prospects east of the study area containing manganese associated with chert in volcanic rocks were examined during the orientation study. The geochemical data suggest there is little probability that such deposits exist within the study area.

OTHER METALS

No geochemically significant amounts of gold, silver, zinc, cobalt, nickel, niobium, barium, boron, uranium, nor the rare earth elements were found during this study.

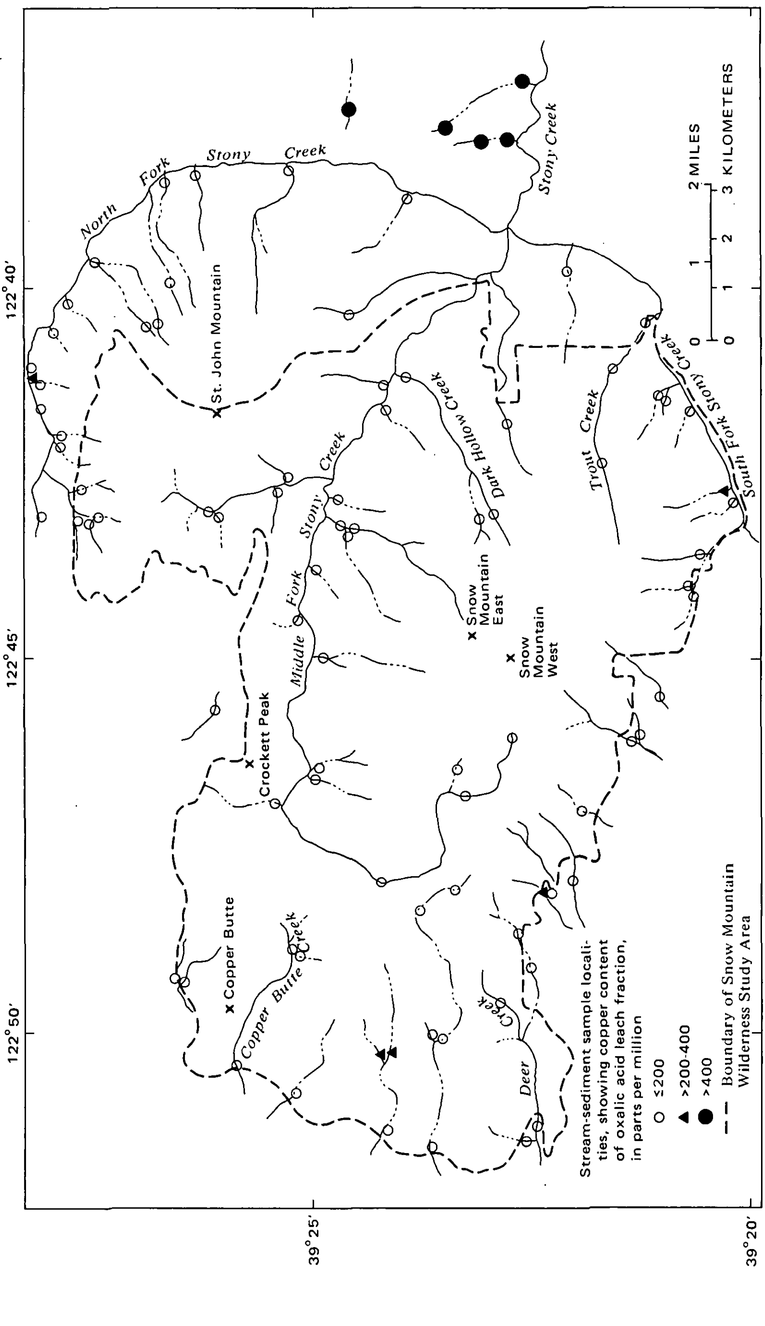

FIGURE 3.- Distribution of copper in the oxalic acid leach fraction of stream sediments.

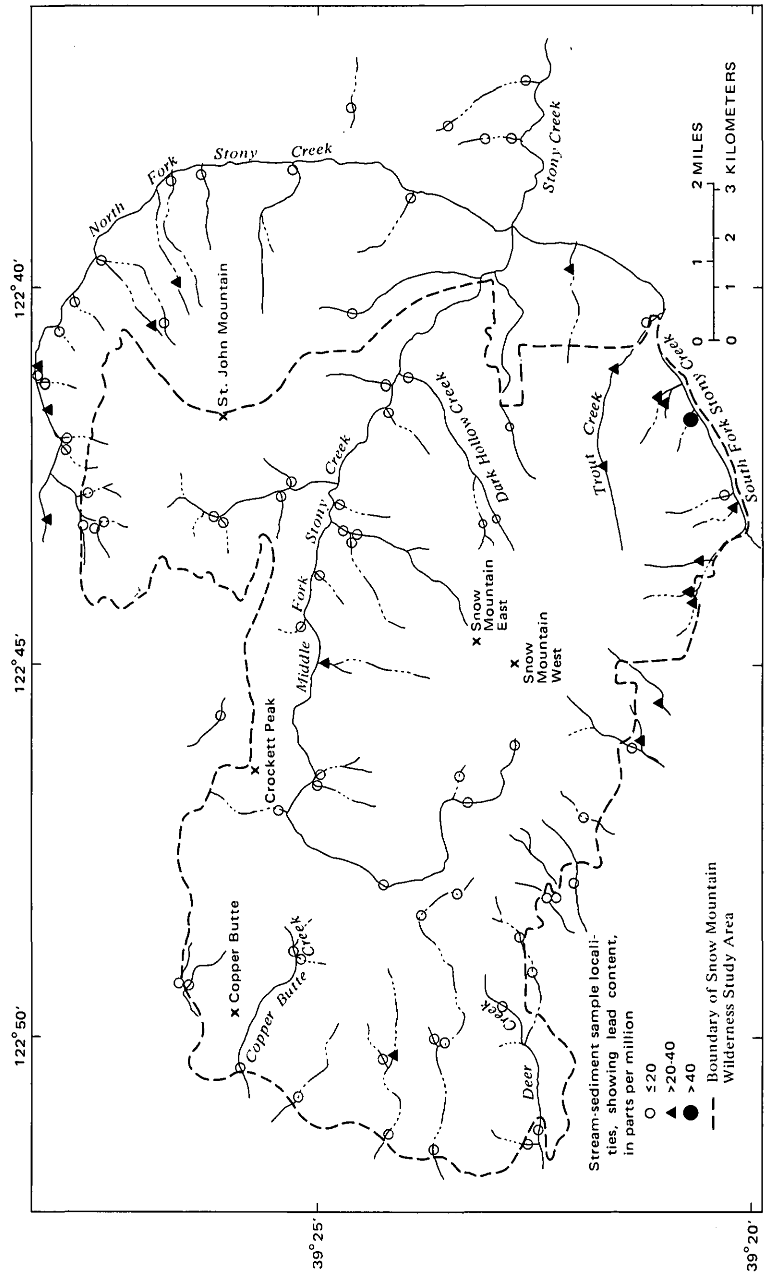

FIGURE 4.- Distribution of lead in stream sediments.

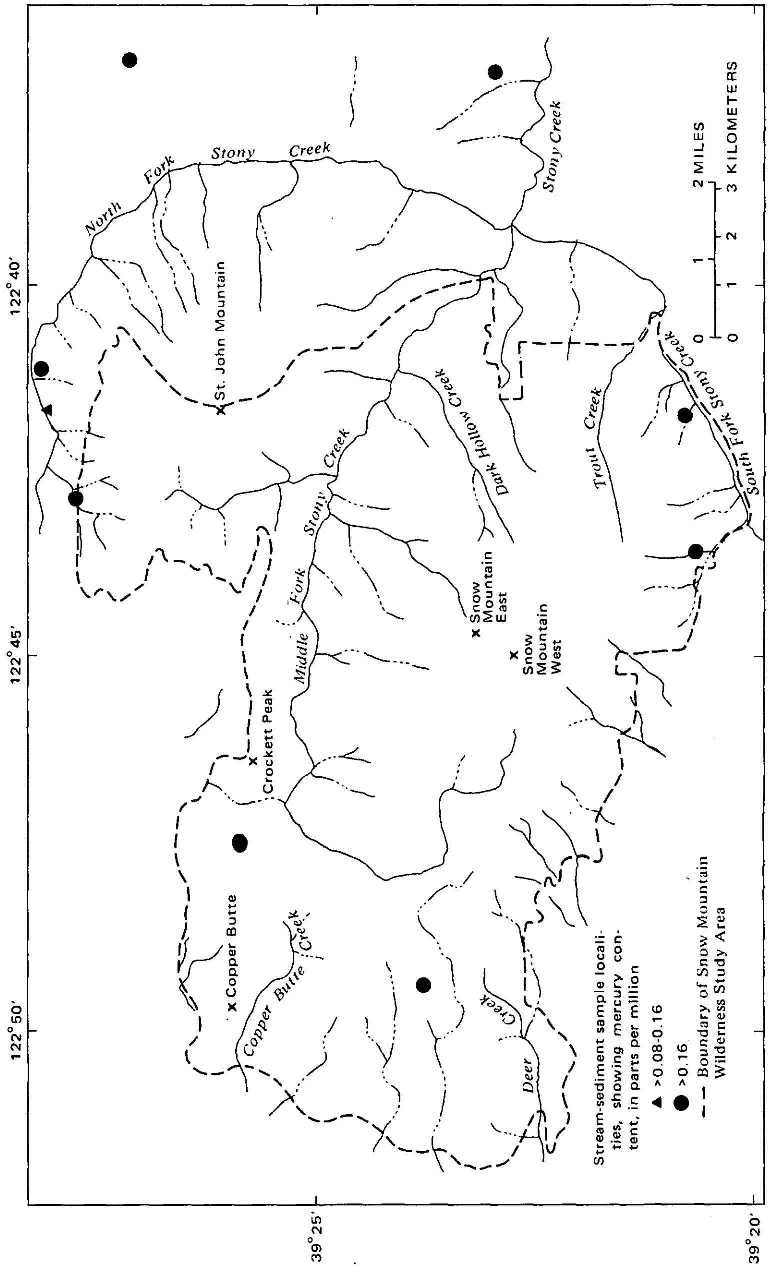

FIGURE 5.- Distribution of rocks containing anomalous amounts of mercury.

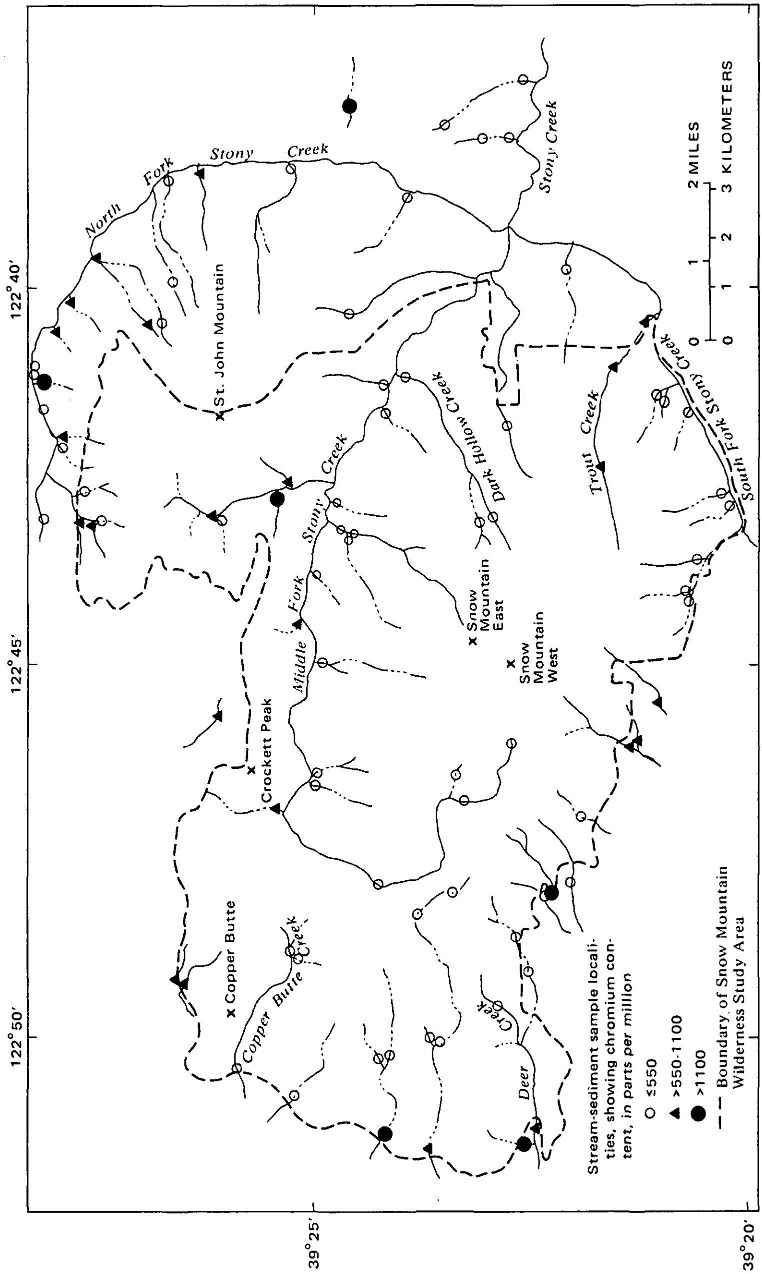

FIGURE 6.- Distribution of chromium in stream sediments.

CONCLUSIONS

The results of the geochemical investigation suggest that the Snow Mountain Wilderness Study Area has a low potential for economic deposits of lead, chromium, manganese, mercury, gold, silver, and other related matals. The potential for massive sulfide deposits containing copper is also low as judged by the geochemical evidence, but this evaluation must be qualified somewhat because the entire klippe of volcanic rocks is considered geologically favorable terrane for deposits of the massive sulfide type.

ECONOMIC APPRAISAL

The Snow Mountain Wilderness Study Area has been superficially prospected since the late 1800's. At least 19 claims have been staked, but no minable deposit has been found.

Most of the 19 unpatented lode claims in or near the study area were located for manganese. Samples of chert with manganese oxide coatings and veinlets from outcrops and prospect workings in or adjacent to the study area contained as much as 9.1 percent manganese. Small production has come from manganese oxide deposits 4.0 to 6.0 km east of the study area (fig. 7, and table 4, Nos. 6-11, 12-15). Samples from these deposits contained as much as 33.6 percent manganese. Nine samples of serpentinized peridotite with finely disseminated chromite from localities 2-5, 16, 17, 19, 27, and 32 (fig. 7) contained as much as 0.51 percent Cr_2O_3 and 0.26 percent nickel. Claims at these localities probably were located for chromite.

Nephrite and onyx are reported to occur in or near the study area, and at least one claim has been staked for each of these gemstones. Nephrite, one of the varieties of jade, is a tough, compact mineral in the isomorphous tremolite-ferroactinolite series, and is formed by metamorphism of ultramafic rocks. The P & C claims (fig. 7, Nos. 16, 17) were located for nephrite and are underlain by serpentinized peridotite with accessory chromite; only actinolite was found in rocks on the surface. One claim near the headwaters of Bear Wallow Creek in sec. 12, T. 18 N., R. 8 W., was located for onyx, a variety of chalcedony, or chert, with parallel bands of alternating colors. Chert does occur in the local sedimentary rocks, but no onyx was found during this investigation.

Surficial deposits of sand and gravel are along most drainages, especially along the Middle Fork of Stony Creek. Many of these deposits could be used for fill or aggregate locally. Rocks in the study area are not exceptionally good for use as building or dimension stone. Similar or better quality stone or rock could likely be found closer to markets.

All mines and prospects and many outcrops on claimed lands in and near the study area were sampled. Thirty-two rock samples in all were taken at sample localities shown on figure 7; table 4 gives sample descriptions and values. Sample localities in, or within 0.4 km of, the study are described in more detail at the end of this section.

The Snow Mountain Wilderness Study Area has a low mineral potential. Irwin (1960), in summarizing the mineral deposits in the northern Coast Ranges and Klamath Mountains, shows little past mineral production in the vicinity. Small amounts of manganese and chromite ores were mined near the area.

During World Wars I and II, manganese ore was mined about 5 km east of the study area. The Black Diamond mine (fig. 7, Nos. 12-15) produced 180 metric tons of ore according to U. S. Bureau of Mines records. Trask (1950, p. 62) reported that 4.5 metric tons of ore was shipped from the K. B. mine (fig. 7, Nos. 6-11), and about 45 metric tons of ore was stockpiled on the property at the time of his investigation. This ore is no longer on the property and presumably has been sold.

The Black Diamond mine is in thin-bedded northeast-striking steeply dipping red chert beds. Manganese oxides coat bedding and fracture planes. Scattered pods of psilomelane as much as 0.3 m in diameter and stringers to 1.3 cm wide occur in the beds. Four bulldozer cuts about 20 m long have been dug on the deposit. Three chip samples contained a maximum of 3.1 percent manganese and 10.3 percent iron. A select stockpile sample contained 19.3 percent manganese and 5.8 percent iron.

The K. B. mine, about 10 km north of the Black Diamond mine, is in folded and faulted thin-bedded highly iron oxide-stained chert beds with shale partings. A bed as much as 1.2 m thick on the K. B. No. 1 claim contains pyrolusite. Two manganese-bearing beds, 4.0 and 5.5 m thick, are exposed on the K. B. No. 4 claim. Chert containing pods and coatings of manganese oxides crops out on K. B. No. 4. The workings consist of seven bulldozer cuts trending east-west and one prospect pit. A caved adit was reported by Trask (1950, p. 62). Three chip samples taken across manganese-bearing beds contained as much as 5.7 percent manganese and 3.7 percent iron. Three grab samples of stockpiled material contained as much as 33.6 percent manganese and 7.6 percent iron.

The Old Glory (fig. 7, nos. 20-22) manganese property, south of Fouts Springs, is explored by a bulldozer cut and one circular prospect pit on a north-trending steeply-dipping manganese-bearing bed as much as 1.5 m thick. Two chip samples across the bed contained as much as 9.1 percent manganese and 29.5 percent iron.

Small-scale chromite mining from ultramafic rocks 8 km east of the area was done during World Wars I and II. Several northwest to east-west-trending peridotite (or serpentinite) bodies, emplaced

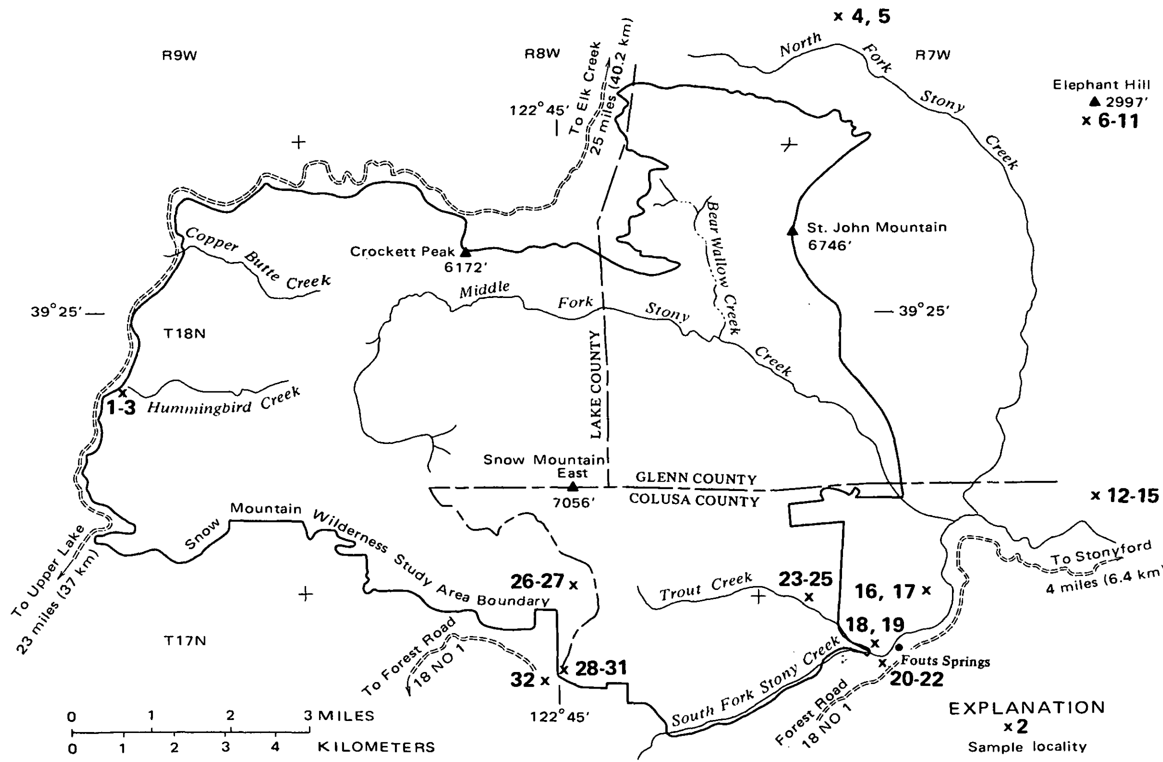

FIGURE 7.- Sample localities for U. S. Bureau of Mines samples.

along faults, extend into the study area. Finely disseminated chromite occurs sporadically in the peridotite. Nine samples of chromite-bearing peridotite, taken at the Long Shot claim (fig. 7, Nos. 2, 3), Queen Ann claims (fig. 7, Nos. 4, 5), P & C claims (fig 7, Nos. 16, 17), Moon Glade prospect (fig. 7, No. 19), Coyote claim (fig. 7, No. 29), and Summit Springs outcrop (fig. 7, No. 32), contained from 0.19 to 0.51 percent Cr_2O_3; most chrome-to-iron ratios were greater than 1 to 10.

MINING CLAIMS

According to courthouse records for Colusa, Glenn, and Lake Counties, 19 lode claims were located in or adjacent to the study area between 1896 and 1976. No claims in the study area appear to be actively held.

METHODS OF EVALUATION

Colusa, Glenn, and Lake County records, U. S. Forest Service files, and previous reports were examined to determine mining claim locations. Some claims were not found in the field because of vague location descriptions and (or) dense vegetation. All mines and prospects found in the study area were sampled and mapped. Some mines outside the study area, in particular the Black Diamond and K. B. manganese mines, were examined because similar host rocks occur in the area.

Data on production, history, and geology, of the Snow Mountain area were collected from published and unpublished reports and from claim owners. This information supplemented the field investigations.

Most of the 32 samples taken on or near claimed areas were chip samples from mineralized structures at workings or outcrops. Grab samples of dumps, or selected outcrops, were taken at caved or otherwise inaccessible workings. All samples were fire assayed for gold and silver and analyzed for other commodities where warranted. Each was checked for radioactivity and fluorescence. At least one sample from each prospect and select samples of serpentinized peridotite were analyzed for 42 elements by spectrographic methods to determine the presence of unsuspected minerals of possible value.

MINES AND PROSPECTS

Prospects examined in, or within 0.4 km of, the Snow Mountain Wilderness Study Area are described in alphabetical order.

Name: Coyote prospect
Index Map No.: Fig. 7, Nos. 28-31
Location: SW1/4 sec. 3 and NW1/4 sec. 10, T. 17 N., R. 8 W., west of Fouts Springs

TABLE 4. - *Sample localities*

[Tr, trace; N, none detected; N.d., not determined]

Name	Sample No.	Sample Type	Sample Length (ft)[1]	Sample Description	Gold (oz per ton)[1]	Silver (oz per ton)[1]	Manganese (percent)	Iron (percent)	Cr_2O_3 (percent)
Long Shot claim	1	Chip	20.0	Iron oxide-stained metasedimentary and metavolcanic rocks.	Tr	N	0.16	8.4	N.d.
	2	do	50.0	Serpentinized peridotite	Tr	0.1	N.d.	5.1	0.42
	3	do	100.0	do	N	N	N.d.	7.2	.35
Queen Ann claims	4	do	15.0	do	N	Tr	N.d.	5.2	.51
	5	do	15.0	do	N	.1	N.d.	5.8	.44
K & B mine	6	do	5.0	Chert with manganese oxide coatings and veinlets.	Tr	N	2.7	3.5	N.d.
	7	Grab	--	Stockpiled chert with manganese oxide veinlets and coatings.	N	N	33.6	3.6	N.d.
	8	do	--	do	N	N	26.3	7.6	N.d.
	9	do	--	do	N	N	16.5	4.9	N.d.
	10	Chip	18.0	Chert with manganese oxide coatings and veinlets.	Tr	N	4.5	2.3	N.d.
	11	do	13.0	do	Tr	N	5.7	3.7	N.d.
Black Diamond mine	12	do	25.0	do	N	N	.5	10.3	N.d.
	13	Grab	--	Stockpiled chert with manganese oxide veinlets and coatings.	N	.1	19.3	5.8	N.d.
	14	Chip	28.0	Chert with manganese oxide coatings	Tr	N	1.7	5.9	N.d.
	15	do	20.0	do	Tr	N	3.1	6.7	N.d.

P & C claims	16[2]	do	100.0	Serpentinized peridotite	Tr	N	N.d.	8.2	.19
	17[3]	do	100.0	do	N	Tr	N.d.	4.7	.44
Moon Glade prospect	18	Grab	--	Siltstone and chert with quartz stringers.	Tr	N	N.d.	N.d.	N.d.
	19[4]	Chip	10.0	Serpentinized peridotite	N	N	N.d.	5.0	.47
Old Glory claim	20	do	2.0	Across chert with north-trending steeply dipping manganese oxide veinlets.	N	N	9.1	29.5	N.d.
	21	Grab	--	Chert with manganese oxide coatings	N	N	4.7	22.8	N.d.
	22	Chip	5.0	Across chert with north-trending manganese oxide veinlets.	N	N	5.3	25.6	N.d.
Trout Creek prospect	23	do	.5	Across shear zone in siltstone	N	N	N.d.	N.d.	N.d.
	24	do	1.0	do	N	N	N.d.	N.d.	N.d.
	25	do	5.0	Across iron oxide-stained chert	N	N	N.d.	N.d.	N.d.
Snow Mountain claim	26	do	10.0	Across chert with manganese oxide coatings.	Tr	N	.37	6.8	N.d.
	27	do	15.0	do	Tr	N	.28	11.1	N.d.
Coyote claim	28	do	20.0	Serpentinized peridotite	N	N	N.d.	6.3	.38
	29	do	2.0	Across chert with manganese oxide coatings.	N	N	.11	17.7	N.d.
	30	do	2.0	Across quartz vein	N	N	N.d.	N.d.	N.d.
	31	do	3.0	do	N	N	N.d.	N.d.	N.d.
Summit Springs outcrop.	32	do	30.0	Serpentinized peridotite	N	N	N.d.	5.8	.39

[1]Metric conversions: feet × 0.3048 = meters; ounces (troy) per ton × 34.285 = grams per metric ton.
[2]Nickel content: 0.084 percent.
[3]Nickel content: 0.23 percent.
[4]Nickel content: 0.26 percent.

Elevation: 1,573 m (5,160 ft)
Access: Gravel and dirt roads southwesterly from Fouts Springs.
History: The claim was located by Emmett R. Wilkinson, June 30, 1940, for manganese.
Geology of deposit: Country rock is massive buff-colored chert and serpentinized peridotite. Fracture surfaces in the chert are coated by manganese oxides. The peridotite locally contains finely disseminated chromite. A 0.3- 0.9-m-thick quartz vein strikes N. 10° E. and dips 60° SE. in the chert; no sulfides were identified in the vein.
Sampling: Two chip samples of the quartz vein contained no concentrations of metallic minerals. One chip sample of the manganese oxide-coated chert had 0.11 percent manganese and 17.7 percent iron. A chip sample of the peridotite contained 0.38 percent Cr_2O_3, and 6.3 percent iron.
Conclusion: The property has low mineral potential.

Name: Long Shot claim
Index Map No.: Fig. 7, No. 1
Location: NE$^1/_4$ sec. 22, T. 18 N., R. 9 W., along Hummingbird Creek.
Elevation: 792 m (2,600 ft)
Access: Paved and gravel roads westerly from Elk Creek, Calif.
History: The claim was located by Harold Wilkinson in 1950 as the Golden Bear; in 1957, he restaked it as the Long Shot.
Geology of deposit: Chert, siltstone, sandstone, and intercalated greenstone beds overlie serpentinized peridotite. About 10 percent of the overlying rocks are iron oxide stained. No concentrations of metallic minerals are exposed.
Sampling: Two chip samples of serpentinized peridotite outcrops contained 0.35 and 0.42 percent Cr_2O_3, and 7.2 and 5.1 percent iron. An outcrop sample of overlying sedimentary and metamorphic rocks contained 8.4 percent iron and 0.16 percent manganese. No sample had more than a trace of gold and (or) 3.42 g silver per metric ton (0.1 oz silver per ton).
Conclusion: The property has low mineral potential.

Name: Moon Glade prospect
Index Map No.: Fig. 7, Nos. 18, 19
Location: SW$^1/_4$ sec. 5, T. 17 N., R. 7 W
Elevation: 634 m (2,080 ft)
Access: By road and trail west from Fouts Springs.
Geology of deposit: Country rock consists of serpentinized peridotite,

siltstone, and chert with quartz stringers less than 1.3 cm thick. The stringers are slightly coated by iron oxides but contain no concentrations of metallic minerals.

Development: One sloughed prospect pit 4.6 m long and 1.5 m wide trends northerly. The pit's dump is large enough to indicate a short caved adit at the pit's north end.

Sampling: A grab sample of quartz stringers from the dump contained no gold or silver. One random chip sample of a serpentinized peridotite outcrop near the pit was 0.47 percent Cr_2O_3 and 0.26 percent nickel.

Conclusion: Sample analyses indicate that the property has a small potential for the discovery of nickel or chromium resources.

Name: Snow Mountain No. 1 and No. 2 claims

Index Map No.: Fig. 7, Nos. 26, 27

Location: SE¼ sec. 34, T. 18 N., R. 8 W., about 1.6 km south of Snow Mountain East.

Elevation: 1,935 m (6,350 ft)

Access: By road and trail westerly from Fouts Springs.

History: The claims were staked by F. C. Wood in 1913.

Geology of deposit: Bedded red chert underlies the property. The beds strike N. 50° to 70° E., dip 30° to 45° SE., and are 5 to 15.2 cm thick. Manganese oxide coatings are as much as 0.6 cm thick on bedding and fracture surfaces.

Sampling: Two chip samples across the bedding planes contained 0.28 and 0.37 percent manganese and a trace of gold.

Conclusion: The property has low mineral potential.

Name: Trout Creek prospect

Index Map No.: Fig. 7, Nos. 23-25

Location: NE¼ sec. 6, T. 17 N., R. 7 W., on north side of Trout Creek.

Elevation: 914 m (3,000 ft)

Access: By road and trail northwest from Fouts Springs.

Geology of deposit: Grayish-black siltstone and chert highly stained with iron oxide underlies the property. Northwest-trending steeply dipping shear zones 5 to 20 cm thick that contain brecciated country rock and vein quartz offset the strata.

Development: A 70-m-long adit is driven northeasterly in siltstone and chert.

Sampling: Two chip samples of shear zones and one chip sample of iron oxide-stained chert in the adit contained no concentrations of gold, silver, or other metallic minerals.

Conclusion: Sample analyses indicate low mineral potential.

EVALUATION OF MINERAL RESOURCES

The geologic, geochemical, and geophysical data-gathering techniques and methods of interpretation described in this report are designed to test for those resources that geologists believe are most likely to be found in the geologic environment of the wilderness study area. They enable investigators to evaluate large areas rapidly and at relatively low cost. But to achieve these economies in time and cost, some sacrifices are made both in the level of detail and in the scope of the investigation. Unusual or unanticipated resources may or may not be detected, and even anticipated resources may escape detection if they are present in small amounts. Even taking into account these investigative limitations, the outlook for major mineral resources here is unpromising.

Neither the results of this investigation nor the records of previous work hint at any important undiscovered resources. Known resources such as mineral springs or volcanic rock suitable for crushing are not now being exploited, nor are they likely to be without unforeseen social or economic changes.

The potential for manganese, chrome, mercury, and copper was specifically examined because mineral deposits containing these elements have been mined in nearby areas in the past or because they have been mined in similar geologic settings elsewhere in the Coast Ranges. Mercury is an important commodity farther south in the Coast Ranges, but the nearest mines with a history of production are about 45 km southeast of Snow Mountain. No evidence of prospecting activity for mercury nor significant geochemical evidence for mercury deposits was found in the study area or in its surroundings.

Small amounts of manganese, chrome, and copper have been produced from rocks within a few kilometers of the study area, and the Gray Eagle chromite mine, with a sporadic history of production prior to 1945, was located about 40 km northeast of Snow Mountain (Rynearson and Wells, 1944; Dow and Thayer, 1946). Mining and exploration for these three elements peaked during World Wars I and II and at other times when normal sources of supply were interrupted. Despite geologically favorable terrane, especially for massive sulfide deposits, no evidence of important deposits of manganese, chrome, or copper was found in the study area.

Energy resources include oil and natural gas, coal, uranium, and geothermal energy. Some natural gas fields in the Sacramento Valley are only about 50 km east of Snow Mountain, but the gas fields are in different rocks and in a simpler structural setting than that near Snow Mountain. Most petroleum geologists view the abundant volcanic rock and the degree of structural deformation in this part of the Coast Ranges as unfavorable for the accumulation of petroleum fluids, and their exploration work has been concentrated in more favorable areas.

For somewhat different geologic reasons, the area is unlikely to contain important coal resources. Most coal is derived from woody vegetable matter that accumulates in a near-shore swampy or lagoonal environment at the margin of a relatively stable landmass. The rocks here record a different geologic environment, one dominated by volcanism, crustal instability, and deep-water depostition, an unlikely environment for deposits of coal.

Geothermal energy is exploited at the Geysers steam field, about 64 km south of Snow Mountain, and in 1977, other parts of the Coast Ranges were being explored for new sources of geothermal energy. Although the area around Snow Mountain has not been tested by drilling, the geothermal resource potential appears to be low. Only a few springs near Red Eye or Fouts Springs at the southeastern boundary of the study area are above normal groundwater temperature, and their thermal character is so slight as to be barely detectable.

Construction materials such as sand and gravel, limestone, and crushed rock are essential and widely distributed commodities whose values depend greatly on their proximity to a local market. Sand and gravel deposits in this area are smaller, of poorer quality, and less accessible than other deposits that are closer to present-day markets. Elsewhere in the Coast Ranges, limestone is found as lenses associated with volcanic rocks, and in some of these places it has been quarried for making cement. In this area, fist-size masses of limestone fill the spaces between pillows in a few flows of volcanic rock, but no larger bodies of limestone were observed. Crushed rock suitable for road surfacing and other uses could probably be obtained from some of the hardest little-altered volcanic rocks and diabase in the study area. Similar rocks near Stonyford have been used in this way, although most of the quarries were small and the crushed rock was used close to the quarry sites. The volume of rock judged suitable for crushing is large, but its value as a resource is diminshed because of its remoteness and poor accessibility and because similar volcanic rocks near Stonyford are closer to most of the potential markets for crushed rock.

Considerable resource potential was formerly attached to some of the mineral springs that issue from bedrock and from the bed of the South Fork of Stony Creek near Fouts Springs. The springs flow at rates of a few liters to 35 l per minute and several of them are thermal (24°C). Some are carbonated and palatable; others are sulfurous. Four of these springs, including Red Eye Spring, were once the chief attraction of the resort that operated at Fouts Springs from 1905 until about 1920. The water was used for both bathing and drinking, and some of it was bottled and marketed (Waring, 1915, p. 205-207, 267). Most of these springs are outside the boundary of the study area, but a few smaller mineral springs are inside. Partly because those inside the boundary are relatively small, but also because mineral spring resorts have declined in popularity, the resource potential of these springs is at best marginal.

At a few localities, the rocks in the study area exhibit mineralogic or color characteristics that are prized by amateur rock collectors. Deeply colored chert or jasper in the volcanic rocks and well-crystallized glaucophane schists are among the types most often collected. Specimen-quality material, however, is rare and is so widely scattered that in the context of this report it is not considered a resource.

From this summary of mineral resources, crushed rock appears to be the only significant potential resource. The volcanic rocks and diabase that could be used as a source of crushed rock are so located that their value would be greatest to a single user, the U. S. Forest Service. Although the Forest Service administers the area, few of these rocks have been crushed for surfacing the Forest Service roads that encircle it. This degree of nonuse can be interpreted as evidence that at this time even the crushed rock resource is not valued very highly.

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