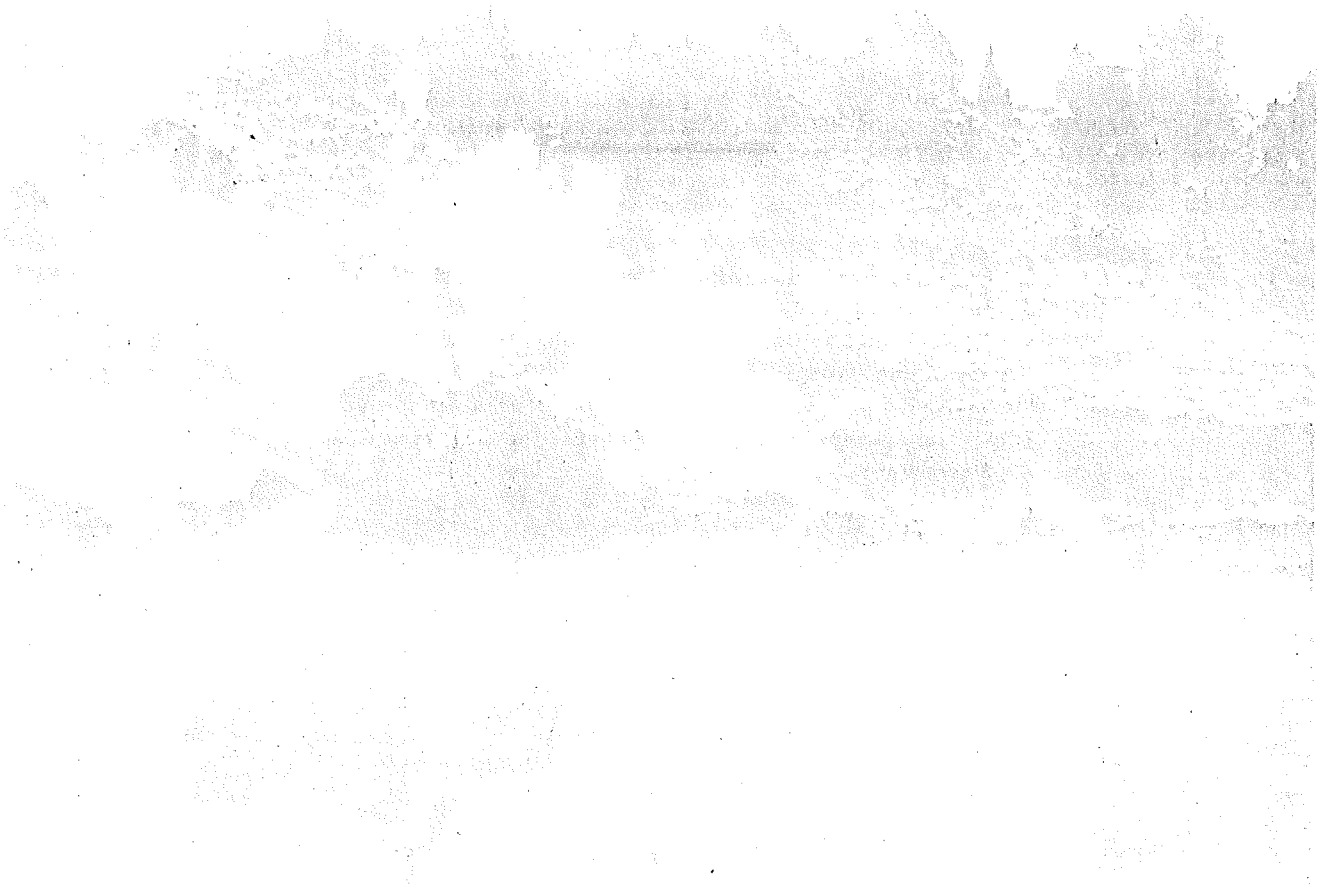


DESCRIPTIONS OF NORTHERN CALIFORNIA LOW TEMPERATURE GEOTHERMAL RESOURCE AREAS

Surprise Valley

Surprise Valley is a north-south trending basin, approximately 80 km long and 20 km wide, in Modoc County at the extreme northeast corner of California (Plate II). The valley floor is about 1,400 m above sea level; the Hays Canyon Range on the east exceeds 2,000 m altitude, and the Warner Mountains on the west reach an altitude of 2,998 m at Eagle Peak. The valley has internal drainage and contains three large lakes -- Upper, Middle, and Lower Alkali Lakes. The lakes are extremely saline, seldom more than 1.5 m deep, and often are dry in the summer. State Highway 299 goes through Cedar Pass, providing easy access from Alturas to Cedarville, Surprise Valley's largest town. The remainder of the valley's small population is scattered in three villages and on ranches along the western edge.

Climate

Surprise Valley has a climate typical of high-altitude deserts. Average temperatures are -1°C in January and 22.1°C in July. The maximum and minimum temperatures recorded over a 40-year period are 44°C and -29°C. The valley receives an annual average precipitation of 31.1 cm, with a January average of 4.6 cm and a July

Hannah, Judith. "The Potential of low Temperature Geoth. Resources in No. Calif." 1975. Rep't. No. TR13

PLATE I

LOW TEMPERATURE GEOTHERMAL AREAS *

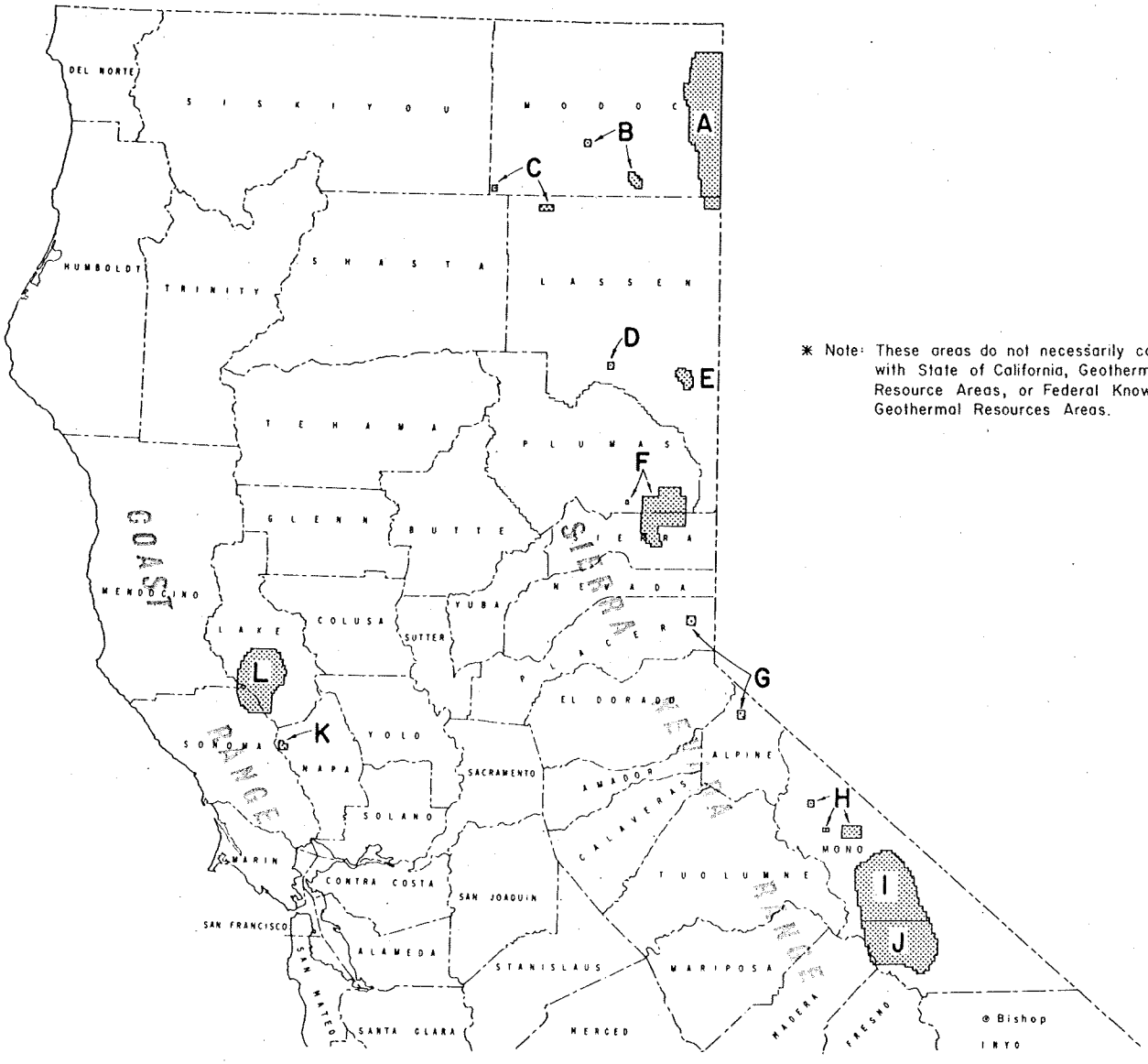
NORTHERN CALIFORNIA

SCALE

0 20 40 60 80 100 KILOMETERS

Geothermal Areas

A Surprise Valley
B Alturas Area
C Big Valley and Little Hot Spring Valley
D Susanville
E Wendel – Amedee
F Sierra Valley
G Eastern Sierra Springs
H Bridgeport Valley
I Mono Lake Basin
J Long Valley
K Northern Napa Valley
L The Geysers and Clear Lake



* Note: These areas do not necessarily coincide with State of California, Geothermal Resource Areas, or Federal Known Geothermal Resources Areas.

average of 0.4 cm. Precipitation is higher in the Warner Mountains on the west, exceeding 50 cm/yr. The average growing season of 126 days could easily be extended by the use of greenhouses because of the high annual percentage of sunshine. The average period of daily sunshine ranges from 5 hours in the winter to 13 hours in the summer.

Geology

The mountains adjacent to Surprise Valley are composed of Oligocene to Pleistocene volcanic and associated sedimentary rocks. The Cedarville Series, which includes andesitic tuff, agglomerate, and intercalated andesite and basalt flows, crops out extensively in the Warner Mountains. These rocks probably underlie most of Surprise Valley. Extensive volcanism in the Warner Mountains from the Miocene through the Pleistocene left a thick sequence of pyroclastic rocks, andesite and basalt flows, rhyolite tuffs, and shallow intrusions. The Forty-Nine Camp Formation, a unit of tuffaceous sand and volcanic gravel, overlies the Cedarville Series east of the valley, but pinches out under the valley fill. The valley fill material consists of Pleistocene and Holocene lake deposits, and Holocene alluvial fan deposits. The thickness of the sediments ranges up to 1,525 m.

The dominant structural features of Surprise Valley are normal faults. The Surprise Valley fault zone defines the western boundary of the valley. The rapid formation of the valley as a result of faulting is evidenced by the large displacement of Plio-Pleistocene volcanic units. These rocks are found both high on the peaks of the Warner Mountains and deeply buried below the valley sediments. The less distinct eastern boundary of the valley consists of a series of parallel fault blocks that step upward and to the east. Clearly visible normal faults cut the Warner Mountains at nearly right angles to the Surprise Valley fault and extend beneath the valley fill. The inferred valley floor fault pattern is supported by geophysical studies which indicate that the bedrock beneath the sediments is broken into numerous tilted blocks. Hot springs are found along the entire length of the Surprise Valley fault. Other notable faults possibly related to thermal activity are: (1) two parallel faults extending north-south along the east side of Middle Alkali Lake, and (2) the Lake City fault trending northwesterly between Upper and Middle Alkali Lakes.

Hydrology

Numerous small creeks issuing from the Warner Mountains supply irrigation water for Surprise Valley. Because of generally low yields from wells, ground water is used mainly for stock-watering or domestic water supply. The major aquifers on the west side of the valley are the fan deposits; the volcanic rocks and lake deposits are largely impermeable. Therefore, ground water recharge is limited to infiltration of surface streams into alluvial fans at the base of the Warner Mountains. On the east side of the valley, the Forty-Nine Camp Formation is a good aquifer; however, the low rainfall in the Hays Canyon Range severely restricts recharge potential. In the central part of the valley, ground water may be of low quality. For example, a cold water well drilled in NW1/4, SW1/4, Sec. 5, T. 42N., R.17E. to a depth of 41 m produces water too highly mineralized for domestic use. In addition, wells drilled near thermal

Fort Bidwell Spring (artesian well) flows approximately 600 l/min at 37°C. The town, Fort Bidwell, can be seen in the background through the trees.

springs may produce water with excessive concentrations of sodium, boron, fluorine, or arsenic.

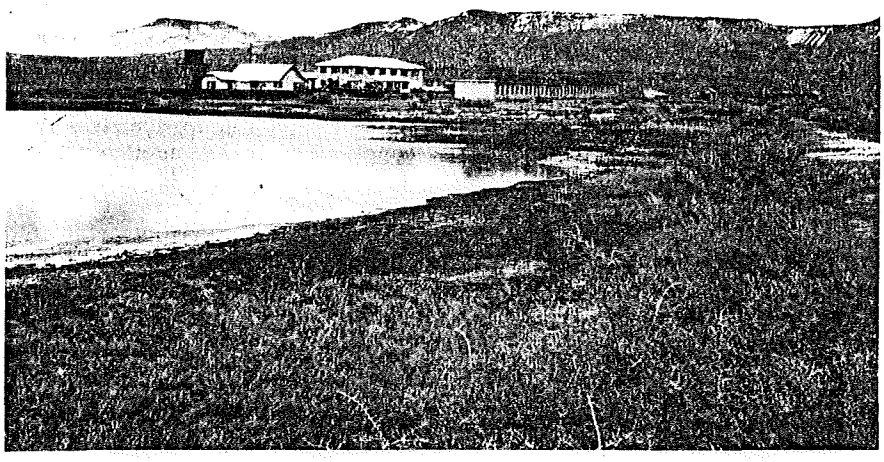
Known Springs and Wells

All of the wells and springs mentioned in this report are listed by geographical area in Appendix A. Numbers refer to the location on the map and the listing in the appendix.

There are two warm springs near the town of Fort Bidwell. The Fort Bidwell Spring (actually a well) (3) flowing 600 l/min at 37°C, is on an Indian reservation just west of town. The Peterson's Ranch springs (1), flowing 400 l/min at 36 to 42°C, are used to fill a small swimming pool 2 km north of Fort Bidwell. A well (2) directly between the two springs yields water at 36°C. A pump test produced 8,300 l/min with a drawdown of 18.3 m. All three sources of hot water occur near the Surprise Valley fault zone at elevations slightly above the valley floor. Road access is good, but the rugged terrain on the Warner Mountains escarpment might limit development, since sizable areas of flat ground are not immediately available for large agricultural developments.

Several mudpots and hot springs 3 km north of Lake City mark the site of a spectacular mud volcano eruption in March 1951 (4). Prior to the eruption, the springs were inconspicuous and their temperatures and flow rates were not definitely known. The eruption began without warning at about 11:30 p.m. on March 1, 1951, and continued with decreasing vigor for about four days. Initially, large chunks of mud were thrown several hundred meters in the air, and strong winds carried frozen mud pellets up to 7 km from the site. D.E. White (1955) gives a complete account of the eruption. The area has been quiet since then, and the springs maintain fairly constant temperatures ranging from 48 to 97°C. Their total discharge is about 400 l/min. The ground around the springs is swampy and unstable, and no use is made of the hot water.

Several other warm springs and wells are located along the mountain front north and south of the Lake City mud volcanoes. For example, an artesian well on the Lyle Hill Ranch 12 km north of Lake City discharges water in excess of 60°C. Exploration wells (5) drilled 3 km north of Lake City to a maximum depth of 1,368 m produced hot water up to 160°C with some steam flashover. None of the heat from geothermal resources in the Lake City area is being used, but the area has potential. Fresh surface water, extensive areas of flat ground, and natural hot water at moderately high temperatures are all available. The major impediments to development are the long distances to sizable markets and the small labor force available.

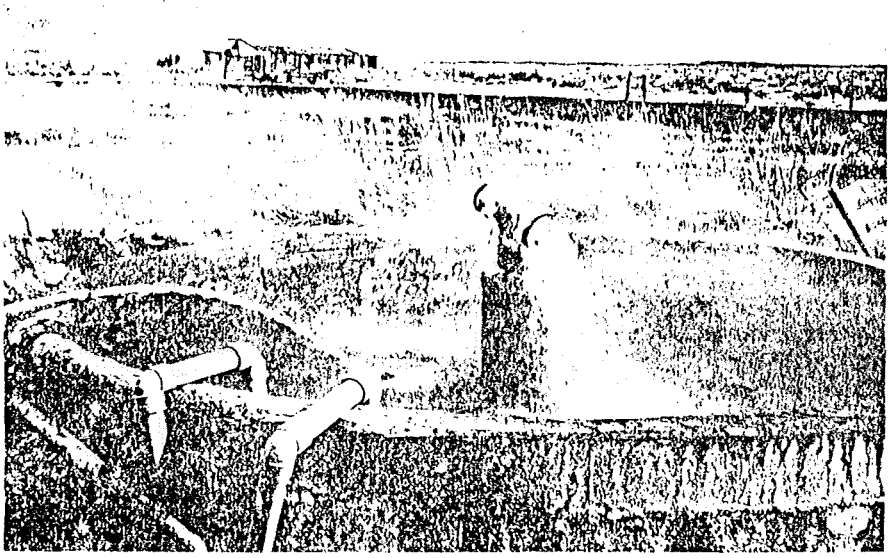


Hot Springs Motel, which uses geothermal energy for space heating and heating of an indoor pool (8 km east of Cedarville, Modoc County).

Lake City mud volcano and hot spring area, 3 km north of Lake City, Modoc County. View toward the southwest. Note the sunken area with grove of trees in front of the Warner Mountains.

Hot water flows from 2 wells and 5 springs near the Hot Springs Motel about 8 km east of Cedarville. Two wells (13) near the hotel have temperatures of 98°C and 84°C and have flows of about 300 l/min each. These wells provide hot water for a 646 m^3 indoor pool, for domestic use, and for space heating in the motel units. Bluegill and catfish are raised in the outflow from the wells, but trout cannot survive the high temperature. Waste water from the heating system has been used successfully to irrigate a small vegetable garden.

Five springs (12, 14, 15) issue from alluvial deposits northeast and southwest of the hotel. They range in temperature from 50°C to 97°C. All these springs occur between two north-south trending faults (Calif. Dept. Water Resources, 1963). A shallow well drilled east of this block



One of two artesian wells at Hot Springs Motel that have flow rates of 300 l/min with temperatures from 84 to 98°C.

produced cold mineralized water. It seems likely that the hot water is largely confined to a north-south zone within the fault block.

Three small groups of springs, Leonard Hot Springs (west) (10), Seyferth Hot Springs (9), and Leonard Hot Springs (east) (11), occur 8 to 10 km north of the Hot Springs Motel. These springs may be related to the Lake City fault. All have been used sporadically for bathing, irrigation, and stock watering. Development is limited to a few dilapidated wooden shacks at the Old Leonard Baths (Leonard Hot Springs). The terrain is nearly flat and access is provided by a good gravel road and fair dirt roads. Availability of good quality water may be limited; the thermal water has high electrical conductivity and may contain excessive concentrations of boron, fluoride, sodium, sulphate, or arsenic.

There are two hot springs along the highway south of Eagleville: Menlo Hot Springs (16), 6 km south of the town, discharging 1,000 l/min at 57°C; and Squaw Bath (17), 11 km south of the town, discharging 450 l/min at 49°C. Menlo Hot Spring was once used for bathing, but there are no improvements at the present time. Squaw Bath, once popular with Eagleville residents, was closed to the public in August of 1973 because of increasing vandalism. Several warm wells at nearby ranches indicate an extensive hot-water zone parallel to the Surprise Valley fault zone.

Summary

The greatest deterrents to development in Surprise Valley are its isolation and small population. Reno, the nearest large market and transportation center, is 400 km to the south. Cattle ranching is the predominant land use in the valley; related agricultural developments are therefore recommended for utilization of the geothermal heat. Thermal water could be used for processing of cattle feed and waste and for stock watering.

The exploration wells drilled at Lake City indicated reservoir temperatures marginally sufficient for electrical power generation. If the reservoir is developed, consideration should be given to a multiple-use project utilizing the waste heat for agriculture. All four towns in Surprise Valley are near geothermal resources; municipal heating services may be practical, particularly for any new developments.

Alturas Area

Alturas, with a population of about 3,000, is the county seat of Modoc County and the main service center for an extensive area. Most of the remaining population is clustered near the small farming communities of Likely (in South Fork Pit River Valley) and Canby (in Warm Springs Valley). The town of Alturas is located in central Modoc County near the confluence of the North and South Forks of the Pit River at an altitude of 1,336 m (Plate III). There are two areas of interest near Alturas: a small area within the South Fork Pit River Valley, 5 to 8 km northeast of Likely, and Warm Springs Valley in the vicinity of Kelly Hot Spring 3 km east of Canby. Warm springs outside these two areas include several at Hot Creek, 14 km west of Alturas on State Highway 299, and one on the east shore of West Valley Reservoir, 10 km east of Likely.

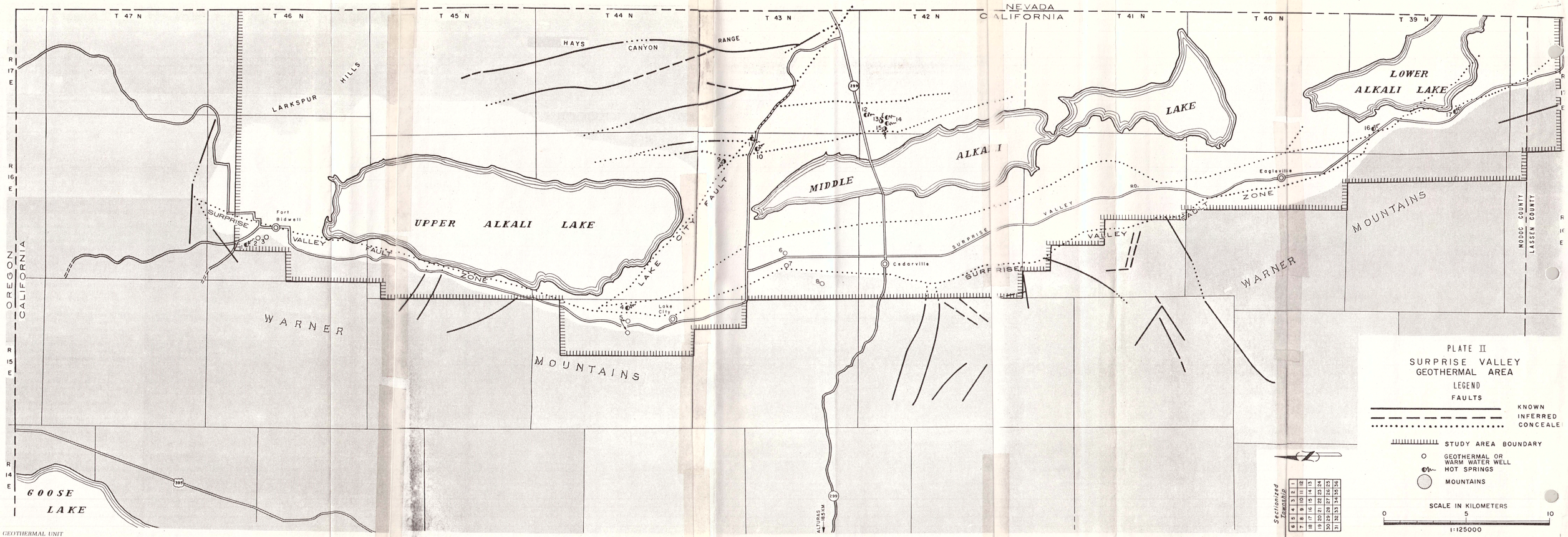
Climate

The Alturas area has a rigorous semiarid climate with an average growing season of only 77 days. Average temperatures are -2.9°C in January and 19.6°C in July. The maximum and minimum temperatures recorded over a 22-year period are 41°C and -36°C. Alturas receives an annual average precipitation of 32.0 cm, with a January average of 5.3 cm and a July average of 1.3 cm. Precipitation decreases somewhat in the South Fork Pit River Valley, but exceeds 50 cm in the surrounding mountains. The Alturas area is ideal for greenhouse agriculture because of the high percentage of sunshine, an average of 5 hours in midwinter and 13 hours in midsummer.

Geology

Warm Springs Valley and South Fork Pit River Valley are underlain to a depth of 290 to 450 m by the Plio-Pleistocene Alturas Formation. The formation includes similar upper and lower members composed of tuffs, sands and gravels, and diatomite which were deposited in a large ancient lake. These units are randomly separated by massive, scoriaceous olivine basalt flows, and the Warm Springs Tuff Member, which includes welded tuff, lapilli tuff, and ashy sandstone. The formation has been gently folded and extensively faulted in a northwesterly direction. Widespread highly jointed olivine basalt flows with interbedded scoriaceous zones overlie the Alturas Formation north of Alturas and on the sides of South Fork Pit River Valley. Coarse fan deposits and unconsolidated sandy alluvium flank both valleys, but the valley floors are blanketed with unconsolidated basin deposits of clay, silt, and very fine sand.

Numerous northwest-trending normal faults cut the Tertiary and Quaternary units. Major thermal activity occurs along the Likely fault and smaller associated faults. The Likely fault extends about 100 km from a point 18 km northwest of



GEOTHERMAL UNIT