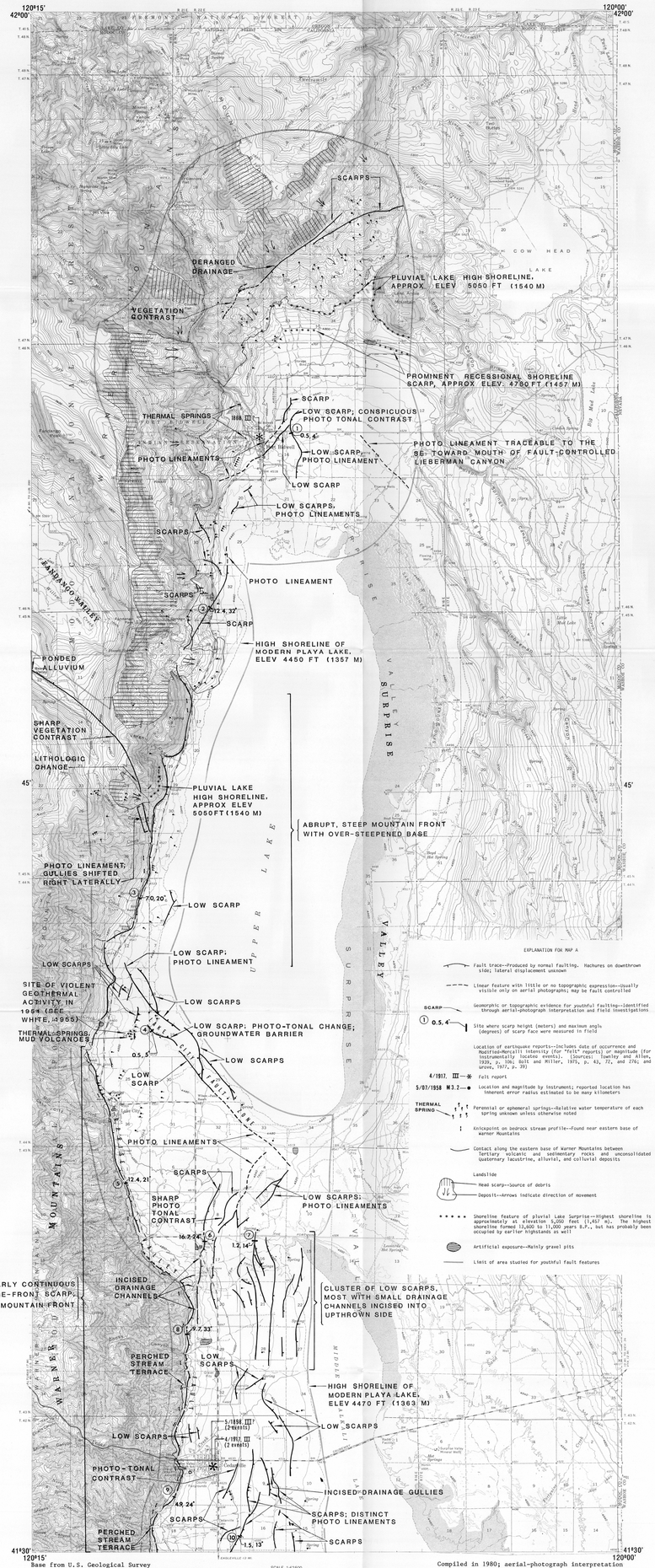
DEPARTMENT OF THE INTERIOR
UNITED STATES GEOLOGICAL SURVEY

MISCELLANEOUS FIELD STUDIES
MAP MF–1429
SHEET 1 OF 2



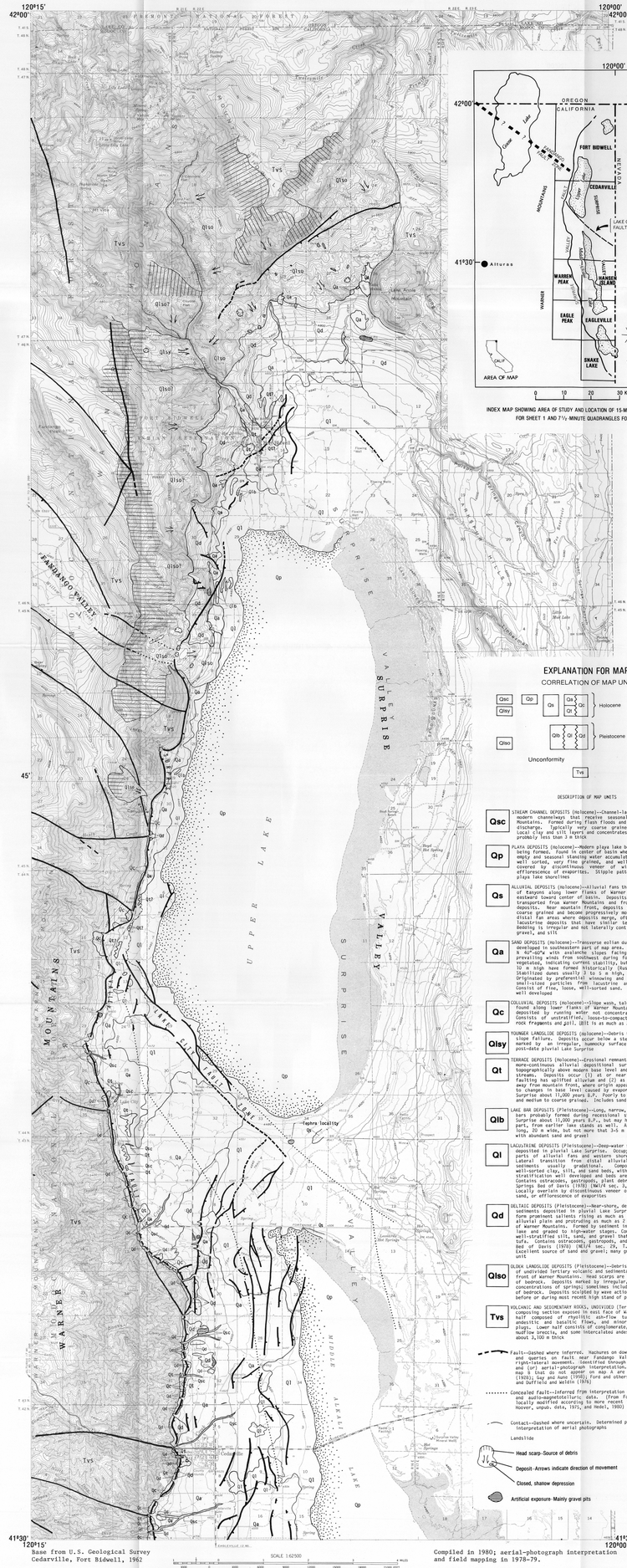
Base from U.S. Geological Survey
Cedarville, Fort Bidwell, 1962

SCALE 1:62 500

CONTOUR INTERVAL 40 FEET
NATIONAL GEODETIC VERTICAL DATUM OF 1929

MAP A—GEOMORPHIC FEATURES RESULTING FROM PREHISTORIC FAULT RUPTURES

Compiled in 1980; aerial-photograph interpretation and field mapping in 1978–79.



Base from U.S. Geological Survey
Cedarville, Fort Bidwell, 1962

SCALE 1:62 500

CONTOUR INTERVAL 40 FEET
NATIONAL GEODETIC VERTICAL DATUM OF 1929

MAP B—UNCONSOLIDATED DEPOSITS OFFSET BY FAULTS

Compiled in 1980; aerial-photograph interpretation and field mapping in 1978–79.

NORTHERN PORTION

MAPS SHOWING GEOMORPHIC AND GEOLOGIC EVIDENCE FOR LATE QUATERNARY DISPLACEMENT ALONG THE SURPRISE VALLEY AND ASSOCIATED FAULTS, MODOC COUNTY, CALIFORNIA

By
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1984

INTRODUCTION

The maps in this report are designed to show the location, nature, and age of fault traces and lineaments that are interpreted to be the result of late Quaternary movement along the Surprise Valley and associated faults. These characteristics are important in the evaluation of potential hazards from fault faulting and earthquakes and should also be helpful to those concerned with land use and development on or near faults in western Surprise Valley. In addition, faults apparently control the location of modern geothermal activity in Surprise Valley (Hedel, 1983) and are thus important to geothermal exploration.

Map A emphasizes geomorphic features that are interpreted to be the result of prehistoric displacement of the ground surface by rupture along faults in western Surprise Valley. The faults portrayed on Map A are those faults intended to be guidelines for locating fault traces on the ground and are not necessarily located with the precision demanded by some types of engineering or land-use projects. Map B shows the position of fault traces in western Surprise Valley with respect to unconsolidated late Quaternary alluvial and lacustrine deposits. The reported ages of these deposits have not yet been verified by radiocarbon dating of the deposits themselves; thus the chronology of events described in this report is based on inferred ages. Map users requiring specific age control on the past activity of individual fault segments will need to perform field investigations to obtain this information.

Much of the data in this report are summarized from Hedel (1980), whereas the formal age portions of the text are adapted from Brown (1992), Brown and Wolfe (1972), Clark (1973, 1982), Radbruch-Hall (1974), Ross (1969), Sarna-Wojcicki and others (1975), Sharp (1972), and Vedder and Wallace (1970).

THE SURPRISE VALLEY AND ASSOCIATED FAULTS

Surprise Valley and the Warner Mountains are located along the northwest margin of the Basin and Range Province. The Basin is an area that is transitional between the Basin and Range and the Modoc Plateau geomorphic provinces. Surprise Valley is a northwest-trending, fault-bounded, narrow graben that separates the westsloped Warner Mountains block to the west and the Fort Sage Mountains block to the southeastern Nevada. The north-trending Surprise Valley fault zone is a broad zone in the Earth's crust that is nearly continuous for about 84 km along the eastern base of the Warner Mountains and extends for perhaps 15 km below the surface. In a strict sense, the name applies only to the range-front faults and does not include the system of parallel and subparallel faults on the valley floor east of the range front. Most of the geomorphic features that are the result of late Quaternary faulting are relatively young and are apparently associated with one another during prehistoric earthquakes. The Surprise Valley and associated faults form a zone that is locally more than 4 km wide.

Faults within the Surprise Valley fault system are normal faults (dip-slip faults that react to extension of the Earth's crust). Movement of the blocks of the Earth's crust along the faults in the Surprise Valley fault system between the basin floor and the crest of the range has produced distinctly different geomorphic and equivalent rocks which underlie the thick section of Quaternary sediments that partially fills Surprise Valley. Episodic normal slip began about 15 million years ago (Duffield and McKee, 1974) and has continued into the Holocene, as proposed in this report. The age and amount of fault displacement between Surprise Valley and the Hays Canyon Range are not well known, but are probably similar to those of the Surprise Valley fault system.

Brittle fracture of the Warner Mountains accompanied the late Tertiary and Quaternary uplift of the range as shown by faults of variable strike that offset the lithologic section (map B). Similarly, subsidiary faults exist within the Surprise Valley block. Many of these structures are covered by great thicknesses of unconsolidated Quaternary lacustrine and alluvial deposits and are known only from subsurface data (Duffield and Mckee, 1974; Duffield, 1974, pl. 2), and are approximated here on map B. Relatively youthful movements along other faults have propagated to the surface and are manifested on the valley floor as fault scarps that are in varied stages of degradation.

No strong earthquakes or surface faulting have been recorded in Surprise Valley since settlement by pioneers in the early 1850's. However, small earthquakes occurred in 1914, 1915, 1917, 1932, 1954 (Gutenberg, 1939, 1948 Gutenberg and Richter, 1954, p. 136, 137, 1956, p. 174; Coffman and Miller, 1975, p. 42, 72, and 275). Because only 1950 earthquake was instrumentally located (resolution was poor) and the others were "felt" reports, specific correlation of these events with movements along the Surprise Valley fault, or any other structure in the vicinity, is equivocal.

MAPPING METHODS

Fault traces and geologic contacts shown on the maps were identified chiefly by stereoscopic study of 1:20,000-scale color and color-infrared photographs taken by the U.S. Forest Service in 1974 (symbol "MQ QIT"), 1:34,000-scale black-and-white aerial photographs taken by the U.S. Geological Survey in 1950 and 1950 (symbols "GS-VRL" and "GS-VRM," respectively), and nominal 1:120,000-scale U.S. Forest Service black-and-white aerial photographs taken during the 1970's (no symbols on photos). After fault traces and geologic contacts were recorded on the photographs, they were transferred to 1:24,000-scale base maps. The geologic maps by a combination of visual inspection and projection, and then visually transferred to 1:62,500-scale base maps. Lateral accuracy of faults and geologic contacts delineated on the maps are believed to be within ±75 m of the correct field location of these features. The map location of fault traces is best in areas of low relief where cultural features are present and where fault-generated topography influences the position and shape of topographic contours. Fault locations are less accurate in areas of high relief and where topography is greatest, where roads, houses, or fence lines are not present, and where the topographic expression of fault-zone geomorphic features is not well defined. Geologists, engineers, and others using specific use of these maps will need to make ground surveys to independently verify the position of fault traces in relation to structures and land boundaries and to confirm whether the geomorphic features described on map A are truly fault controlled.

Reconnaissance was conducted in the field to verify features observed on the aerial photographs. Only about one third of the area of the field checked on the ground, is constraints on time and accessibility did not permit comprehensive field checking in all areas. Conclusions drawn from geomorphic features which were verified in the field were applied to features that have a similar manifestation on the aerial photographs, but were not field checked.

RECOGNITION OF YOUTHFUL SURFACE FAULTING

Geologically youthful faults in western Surprise Valley were distinguished on aerial photographs and in the field by (1) their distinctive topography, (2) their displacement of youthful, unconsolidated deposits, (3) their influence on local erosion, deposition, and drainage, and (4) by contrasts in vegetation that reflect varying ground-water depths or soil differences across the fault. This evidence is summarized in figure 1. The annotations on map A describe the features used to recognize prehistoric fault ruptures. Many of the examples in the descriptions are clear because they are exceptionally clear well preserved but such features are generally present to some degree along all of the faults on map A. One or more of these criteria usually demonstrates geologically youthful surface faulting because fault-generated features are generally ephemeral: they may be obliterated by erosion, buried by alluvium or other sediment, obscured by soil creep and landslides, or modified or subdued by human activities. The obliteration of the landscape by humans, fragile fault features persist only in places where the rate of tectonic growth exceeds the rate of erosion. Such places are uncommon, generally in areas where surface faulting is so recent that the process of destruction has not yet erased them. The fact that surface features are preserved and are similar to features of geologically active faults elsewhere in the Great Basin that have comparable climate implies that the Surprise Valley and related faults have generated earthquakes accompanied by surface rupture in the recent geologic past.

In western Surprise Valley, topographic features are the most obvious indicators of youthful faulting. Fault-facing fault scarps occur along most of the eastern base of the Warner Mountains as well as on the valley floor east of the mountain front. Vertical displacement has produced scarps from successive dip-slip fault movements ranging from a few centimeters to a few meters during prehistoric earthquakes and (or) intervals of slow fault creep between earthquakes. These features appear to have a large range of ages and represent a long history of repeated fault displacements. Numerous geomorphic features such as fault-line scarps, offset stream channels and alluvial fans and fault ramps in height from 0.5 m to nearly 9 m probably record the most recent surface faulting in western Surprise Valley. They may range in age from hundreds to several thousands of years. In contrast, 50- to 10-m-high scarps in relatively older fluvial lake sediments were apparently formed by several fault displacements and have an age of 70,000 years old, and possibly older. Large, steep eastern escarpments on the Warner Mountains has grown over a far longer period than the youthful fault scarps and may be a rough measure of the rate of displacement along particular fault segments (Wallace, 1977). Unfortunately, we have very meager knowledge of the manner in which scarp erosion rates in northeastern California are influenced by variables such as texture, induration, and composition of scarp-forming materials, as well as the effects of regional temperature and rainfall (both of which have changed many times during late Quaternary time). Therefore, at present, it is impossible to accurately date the youthful fault scarps. The youngest fault scarps in Surprise Valley based on their degree of preservation.

The topographic features described on map A are not necessarily evidence for youthful surface faulting in themselves. The youthfulness of faulting is indicated only where these features are clearly related to displacement of young deposits. Topographic fault features that occur in geologically young deposits, and hence are younger than the deposits themselves, unequivocally demonstrate young surface faulting. Geologic mapping of surficial deposits in western Surprise Valley (map B) shows fault scarps in alluvial and colluvial deposits that have an apparent Holocene age (≤ 10,000 years; Hopkins, 1975). These relations are described more fully below. Demonstration of Holocene or historic displacement along a fault is commonly recognized criteria for the fault to be considered capable of generating future surface faulting and regarded by the state of California as "active" for engineering and land-use planning purposes (Hart, 1977, p. 7).

Faults have influenced local erosion and deposition in western Surprise Valley. Where vertical offset of the land surface has occurred, streams that flow from the warner Mountains to the playa lakes in the center of Surprise Valley have entrenched the relatively upthrown sides of fault scarps along the mountain front. Alluvial fans, which are the result of the deposition of drainages, from ephemeral gullies to trunk streams, are entrenched in the upthrown fand surfaces. On aerial photographs fault traces are marked by fault scarps and by the alinement of the mouths of drainage channels along the length of the scarp. Incised streams have eroded and transported debris from upthrown fault surfaces and deposited sediment onto downthrown land surfaces producing small alluvial fans and cones that emerge from the mouths of entrenched channels along the base of fault scarps. These small alluvial fans and cones are in discoformable contact with older, underlying deposits on downthrown land surfaces.

Faults in western Surprise Valley have locally dammed moving ground water in young deposits and have formed springs and vegetation boundaries along their lengths. Also, displacements have locally juxtaposed contrasting deposits and soils to produce linear contrasts in color, texture, or distinctive vegetational effects. Lineaments of photo-tonal contrasts, vegetation, and springs are shown on map A. Lineaments are intended to represent fault traces that have little or no topographic expression. This conjecture seems justified where photo lineaments line up well with the trend of nearby fault scarps. However, the assumption could not be verified through interpretation of aerial photographs or field reconnaissance. Such features are therefore shown on the maps as dashed lines, indicating uncertainty regarding their significance.

Other geomorphic evidence that suggests late Quaternary faulting in western Surprise Valley includes faceted spurs along the eastern base of the warner Mountains and knickpoints in stream channels of the mountains.

The eastern face of the Warner Mountains forms an abrupt and imposing escarpment rising prominently above Surprise Valley, and planar faceted spurs are locally well developed along the mountain front. Such spurs are described, in general, by Wallace (1978, p. 641-643), as representing the intersection of a fault plane with the land surface. Such features are formed by repeated faulting events as a surface that is initially inclined at 60° to 90°, and then eroded to slopes of 25° to 35° through time. Faceted spurs are estimated to ensure as characteristics of fault-generated mountain fronts in the Great basin on the order of 10K years (Wallace, 1978, p. 648). Their presence along the eastern face of the Warner Mountains suggests episodic rejuvenation of the range during Quaternary time.

An abrupt step or break in the longitudinal profile of stream channels in the warner Mountains occurs near the mouth of many canyons and gullies along the range front. These knickpoints are manifested as waterfalls up to 10 m high when seasonal runoff flows through the channels. Incremental faulting at a rate greater than the rate at which affected streams are downcutting their channels is commonly thought to have produced disruptions to base level with knickpoints developing at the mouths of the affected drainages. Knickpoints and radiusmi canyons are regarded as definitive evidence for faulting (Blackwelder, 1928, p. 297). For example, the presence of a particularly resistant lithology or hydraulic effects that cause erosion rates to vary in drainage basins and streams (Russell, 1928, p.481) are complicating factors that must not be disregarded. The great abundance of knickpoints along the front of the warner Mountains in close association with the youthful range-front fault, however, is evidence that faulting is the chief factor causing the knickpoints. Knickpoints and genesis of these features by knickpoints are found in drainage channels in the warner Mountains and in fault scarps.

AGE OF MOST RECENT FAULTING

Late Quaternary deposits of pluvial Lake Surprise, the large glacial-age lake that occupied Surprise Valley, and associated alluvial fans from the warner Mountains provide a chronology of events and of faulting activity along the Surprise Valley and associated faults once their age and offset, or lack of offset, by faults is known. Geologic mapping of surficial deposits in Surprise Valley distinguishes eleven lacustrine and alluvial units that are differentiated by morphology, superposition, sedimentary characteristics, and the occurrence of fossils. Most of these units appear to be offset by faults.

Surficial units are described on map B according to the criteria noted above. All of the sediments are unconsolidated and formed in response to late Quaternary pluvial events and tectonic uplift of the warner Mountains. The mineralogic composition of the various units reflects the composition of the sedimentary and volcanic rocks in the warner Mountains, which are not differentiated on map B. Generally, textures are coarse near the mountain front and become more fine-grained toward the center of the valley. In most cases, thicknesses are unknown because both the top and bottom of each unit are not always exposed.

Age of deposits

The age of surficial deposits in western Surprise Valley and the resultant age of the faults that displace them are closely related to late Quaternary pluvial events in the Great Basin. The age of the youngest fault movement must be younger than the deposits lineameles. Unfortunately, an absolute chronology of fluctuations of Lake Surprise, based on radiometric dates from within the basin, has not yet been developed. The late Wisconsin oscillations of pluvial lakes in the western United States, however, are known to have been more or less synchronous, as shown in well-documented histories from diverse locations in the Great Basin, such as Searles Lake (Smith, 1968), Lake Lahontan (Broker and Orr, 1981), and Lake Bonneville (Scott and others, 1983). Late Wisconsin levels of Lake Lahontan, the great pluvial lake of northwestern Nevada, are particularly germane to the history of Lake Surprise primarily because the two were so near each other.

Lake Lahontan analogue

With the benefit of earlier, pioneering studies of late Wisconsin levels of the Lahontan system (Broeker and Orr, 1958; Broeker and Kaufman, 1965; Morrison, 1964; and Morrison and Frye, 1965), as well as his own geochemical and radiocarbon data, Benson (1978) developed the first internally consistent-absolute chronology of middle and late Wisconsin oscillations of Lake Lahontan (fig. 2). Benson (1978, p. 313) recognized two high stands of Lake Lahontan within the past 35,000 radiocarbon years, during which the lake rose to maximum levels of Lake Lahontan, the great pluvial lake of northwestern Nevada, are particularly germane to the history of Lake Surprise primarily because the two were so near each other.

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SUMMARY

Geomorphic and topographic evidence for youthful faulting in Surprise Valley is abundant. The Surprise Valley and associated faults display surface features that are characteristic of historically active faults elsewhere in the Great Basin. While there has not been significant historic seismicity in Surprise Valley, geologic mapping of surficial deposits that are displaced by faults suggests that surface faulting has occurred, perhaps repeatedly, along the faults in the late Quaternary period. The youthfulness and the apparent recency of multiple earthquakes in Surprise Valley, as interpreted from the geologic record, suggests that surface faulting and earthquakes are likely to occur. They, on the basis of this preliminary study, the Surprise Valley and related faults should be considered capable of movement at any time.

The faults on map A and the surficial deposits shown on map B were identified primarily from geomorphic evidence revealed by study of aerial photographs and by reconnaissance fieldwork. Therefore, the evaluation of recent faulting in Surprise Valley requires additional investigation that will support or modify conclusions drawn in this preliminary study. Investigations using trenches, borings, and natural exposures to investigate faulted young deposits and faulted-related deposits may yield carbon-14 ages and displacement rates along the various strands; so far none has been carried out in Surprise Valley. As more detailed geologic mapping and special fault studies continue, additional young faults will be identified and added to fault maps of the area, and others will be eliminated. Such investigations will gradually increase our knowledge of rates, amount, and type of past movement along the Surprise Valley and associated faults.

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