QUATERNARY FAULT MAP OF THE RENO 1x2 QUADRANGLE

John W. Bell
Nevada Bureau of Mines and Geology
University of Nevada--Reno
Reno, Nevada 89557

USGS CONTRACT NO. 14-08-0001-18375
Supported by the EARTHQUAKE HAZARDS REDUCTION PROGRAM

OPEN-FILE NO. 81-982

U.S. Geological Survey
OPEN FILE REPORT

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INTRODUCTION

LOCATION

The Reno 1°x2° quadrangle is located in western Nevada between 39° and 40° north latitude, and 118° and 120° west longitude (Figure 1). It includes all or portions of Carson City, Churchill, Douglas, Lyon, Storey, and Washoe Counties, which contain approximately 34% of the State's population (U.S. Bureau of the Census, 1980 Census Preliminary Results, Governor's Office of Planning Coordination). The major cities in the quadrangle are Reno, Sparks, Carson City, Virginia City, Fernley, and Fallon.

PREVIOUS WORK

Although numerous selected studies of young faults have been made throughout the quadrangle, the only previous work to evaluate the Quaternary tectonics of the entire quadrangle has been the unpublished mapping of Slemmons (1968). This mapping provides the preliminary basis for recognition of young surface faulting in the area, but it is lacking in two respects: 1) it was conducted using primarily 1:60,000-scale AMS photography of variable quality, and 2) it was restricted to photo-geologic interpretation.

APPROACH

The goals of this study were three-fold:

1. To compile all existing published and unpublished maps showing young faulting in the quadrangle.
2. To cross-check existing data and map young faults in unstudied portions of the quadrangle.
3. To assess recency and recurrence of movement on all major fault zones in the quadrangle.

Low sun-angle, black and white aerial photography was flown for the entire 1°x2° area and provided complete, uniform coverage for the study. It was supplemented with existing 1:60,000-scale AMS photography and large-scale (1:12,000)

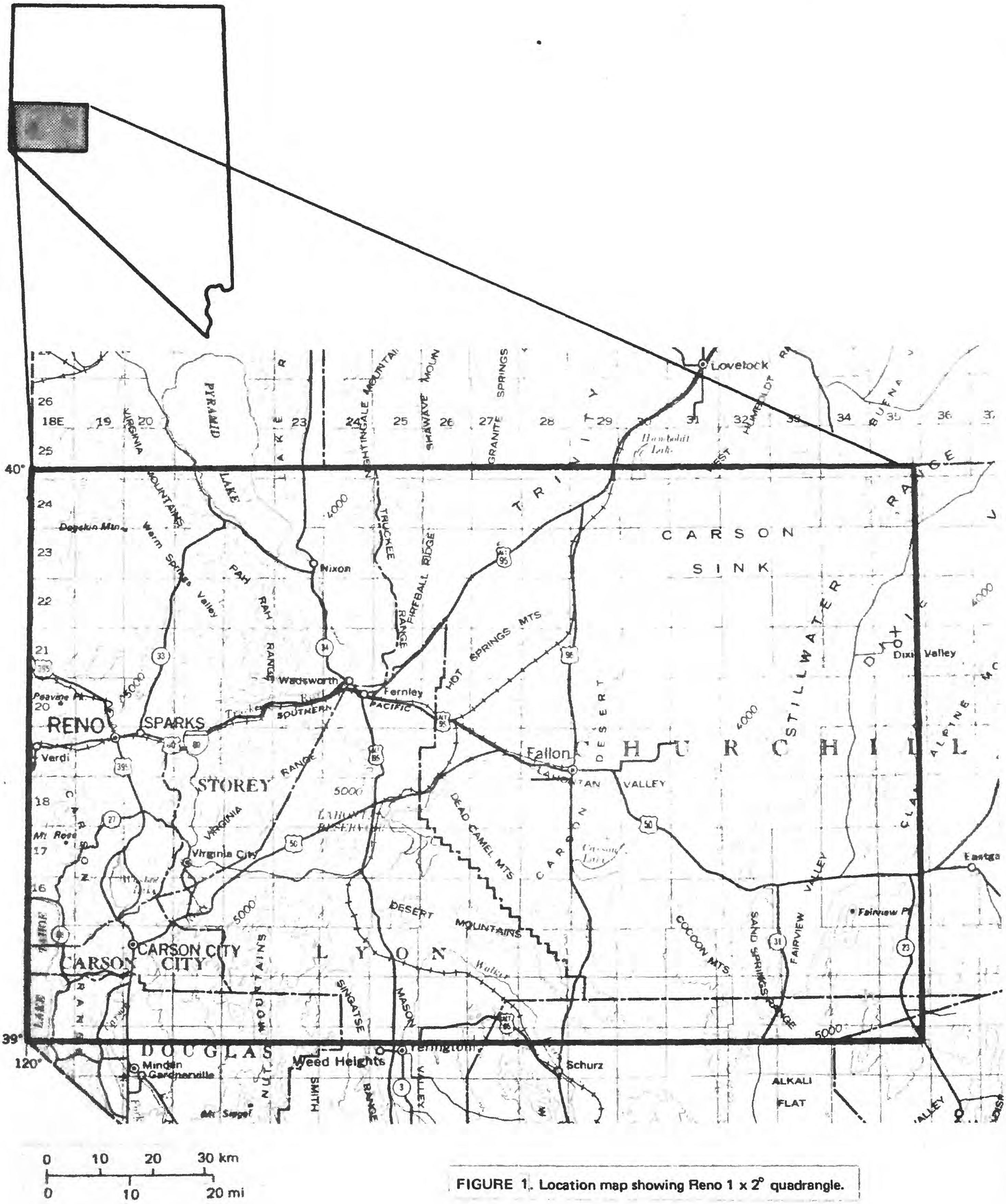


FIGURE 1. Location map showing Reno 1 x 2° quadrangle.

low sun-angle photography in certain portions of the quadrangle. Fault scarps, suspected fault scarps, and youthful-looking bedrock/alluvial contacts were mapped on the new photography. The mapped features were cross-checked against existing literature, and all major fault scarps were investigated by aerial and ground reconnaissance. Selected faults and suspected faults of regional significance were trenched. Interpretations of recency of fault movement have been made based upon an evaluation of the glacial-, alluvial-, fluvio-lacustrine-, and soil-stratigraphic record within the quadrangle.

Fault scarps are delineated on the 1:250,000-scale map on the basis of age of most recent movement:

1. Historic surface rupture
2. Post-high Lahontan shoreline scarp (less than 12,000-18,000 years old)
3. Mid- to late-Pleistocene scarp (pre-high Lahontan shoreline)
4. Youthful-looking bedrock/alluvial contact of probable tectonic origin, but of uncertain age.

INVESTIGATIVE PROCEDURE

LITERATURE COMPILATION

All relevant published and unpublished reports, papers, and maps were compiled for evaluation and cross-checking. The unpublished, preliminary 1:250,000-scale mapping of Slemmons (1968) provided a working base from which areas of more intensive study were selected. The 1:250,000-scale geologic maps for Washoe and Storey, Churchill, and Lyon, Douglas and Ormsby (Carson City) Counties (by, respectively, Bonham, 1969; Willden and Speed, 1974; and Moore, 1969) were additionally reviewed for evaluation of regional tectonic trends. It was found that although each of these 1:250,000-scale maps delineates many young faults, comprehensive detail and accuracy (primarily a function of available base materials) are not adequate.

Selected source maps at scales larger than 1:250,000 were collected for cross-checking and compilation. These are shown on Figure 2 and listed in Table 1.

Table 1 - Published and unpublished source maps used in compilation of Reno 1°x2° quadrangle (see Figure 2).

1. Soeller, S. A., and Nielsen, R. L., 1980, Geologic map, Reno NW 7 1/2-minute quadrangle: Nevada Bureau of Mines and Geology Map 4Dg.
2. Bell, J. W., 1978, Preliminary Quaternary geologic map, Verdi 7 1/2-minute quadrangle: unpublished Nevada Bureau of Mines and Geology Map.
3. Bonham, H. F., Jr., and Bingler, E. C., 1973, Geologic map, Reno 7 1/2-minute quadrangle: Nevada Bureau of Mines and Geology Map 4Ag.
4. Trexler, D. T., and Pease, R. C., 1980, Preliminary geologic map, Vista 7 1/2-minute quadrangle: Final Technical Report, U.S. Geological Survey Contract 14-18-0001-17774.
5. Bonham, H. F., Jr., Rogers, D. K., and Trexler, D. T., 1981, Geologic map, Mt. Rose NE 7 1/2-minute quadrangle: Nevada Bureau of Mines and Geology Map 4Bg (in press).

Table 1 (Con't)

6. Trexler, D. T., and McKinney, R. F., 1980, Preliminary geologic map, Steamboat 7 1/2-minute quadrangle: Final Technical Report, U.S. Geological Survey Contract 14-18-0001-17774.
7. Tabor, R. W., and Ellen, S., 1975, Geologic map, Washoe City 7 1/2-minute quadrangle: Nevada Bureau of Mines and Geology Map 5Ag.
8. Trexler, D. T., 1977, Geologic map, Carson City 7 1/2-minute quadrangle: Nevada Bureau of Mines and Geology Map 1Ag.
9. Bingler, E. C., 1977, Geologic map, New Empire 7 1/2-minute quadrangle: Nevada Bureau of Mines and Geology Map 59.
10. Pease, R. C., 1980, Geologic map, Genoa 7 1/2-minute quadrangle: Nevada Bureau of Mines and Geology Map 1Cg.
11. Bell, E. J., 1981, Neotectonic analysis of the Northern Walker Lane: Final Technical Report, U.S. Geological Survey Contract 14-08-0001-18288.
12. Rose, R. L., 1969, Geology of parts of the Wadsworth and Churchill Butte quadrangles, Nevada: Nevada Bureau of Mines and Geology Bulletin 71, 27 p.
13. Anctil, R. J., and others, 1960, Geology of Bradys Hot Springs and vicinity, Churchill County: Southern Pacific Company unpublished map.
14. Morrison, R. B., 1964, Lake Lahontan: Geology of the Southern Carson Desert, Nevada: U.S. Geological Survey Professional Paper 401, 156 p.
15. Tocher, Don, 1956, Movement on the Rainbow Mountain fault: Seismological Society of America Bulletin, v. 46, no. 1, p. 10-14.
16. Page, B. M., 1965, Preliminary geologic map of a part of the Stillwater Range, Nevada: Nevada Bureau of Mines and Geology Map 28.
17. Nevada Bureau of Mines and Geology and Desert Research Institute, 1963, Geological, geophysical, chemical and hydrological investigations of the Sand Springs Range, Fairview Valley, and Fourmile Flat, Churchill County, Nevada: U.S. Atomic Energy Commission, Vela Uniform Project, Project Shoal, Final Report VUF-1001, 369 p.

Table 1 (Con't)

18. Slemmons, D. B., 1957, Geological effects of the Dixie Valley-Fairview Peak, Nevada, earthquakes of December 16, 1954: Seismological Society of America Bulletin, v. 47, no. 4, p. 353-375.
19. Bryan, D. P., 1972, The geology and mineralization of the Chalk Mountain and Westgate Mining Districts, Churchill County, Nevada: University of Nevada, Reno, unpublished M.S. Thesis, 78 p.
20. Bell, E. J., 1978, Fault scarps in the Job Peak and IXL Canyon 7 1/2-minute quadrangles and the SE1/4 of the Dixie Hot Springs 15-minute quadrangle: Unpublished maps, Final Technical Report, Department of Energy Contract EY-76-S-08-0671.

AERIAL PHOTOGRAPHIC ANALYSIS

Low sun-angle, black and white photography at 1:40,000-scale was subcontracted to Cartwright Aerial Surveys, Sacramento, California. Specifications required that north-south flightlines be flown at specified times (early morning vs. late afternoon) depending upon general orientation of tectonic structures, and that the sun angle be 10-25° above the horizon for optimum shadow and illumination enhancement. More than 2030 line-miles of photography (1038 frames) was flown during the period November, 1979, to July, 1980. Contact prints and negatives are on file and available for use at the Nevada Bureau of Mines and Geology.

All photographs were analyzed by the Principal Investigator, and fault scarps, suspected faults, prominent bedrock lineaments and bedrock/alluvial contacts, and shoreline scarps were mapped on clear 9"x9" acetate overlays. Critical contacts or exposures were pinpointed for field reconnaissance.

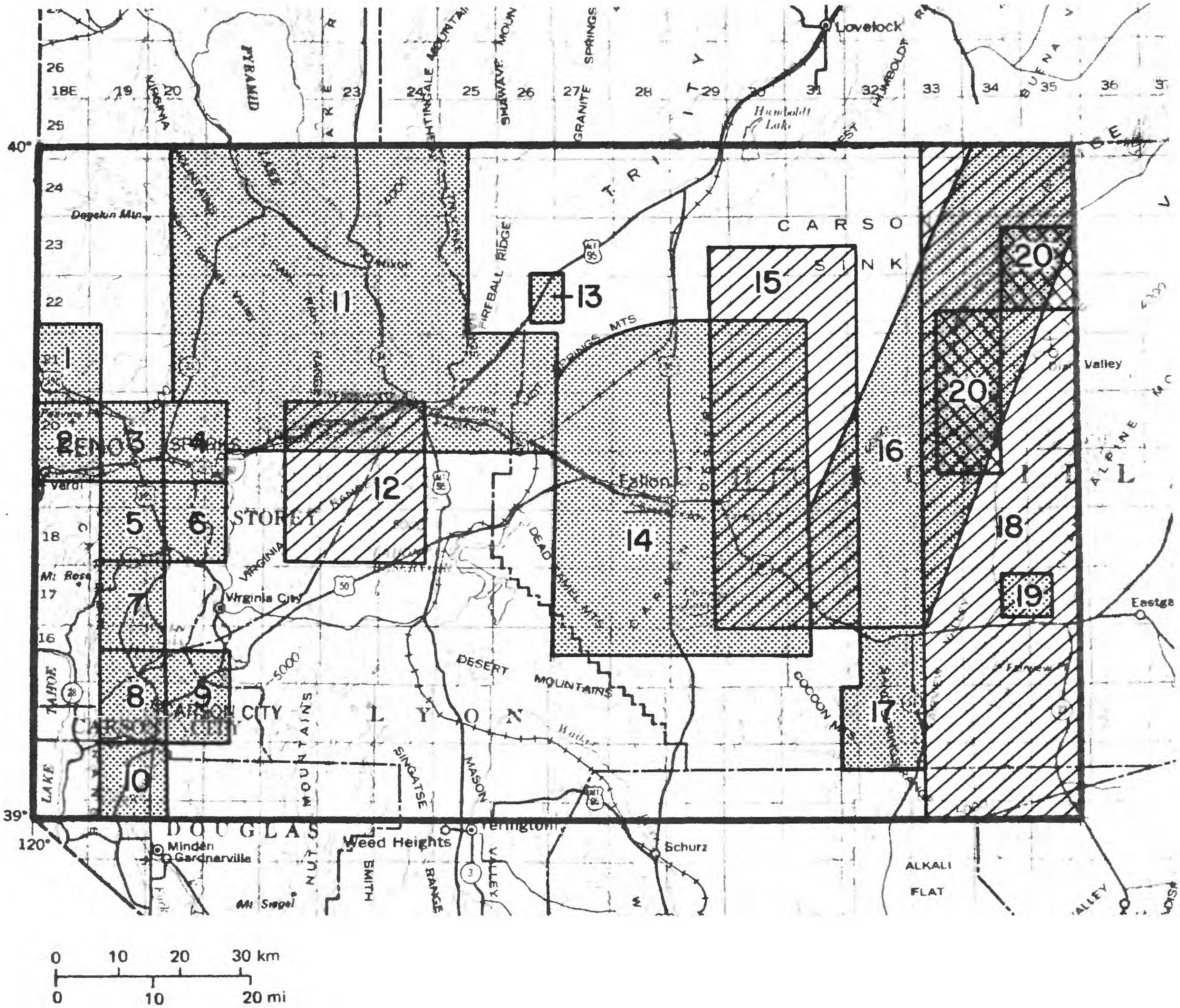


FIGURE 2. Index of published and unpublished maps of faults used in compilation of Reno 1 x 2° quadrangle. See Table 1 for reference.

FIELD INVESTIGATION PROCEDURE

Selection of Field Reconnaissance Sites

Sites for detailed field reconnaissance were selected based on:

1. Photographic analysis
2. Previous mapping
3. Relationship to major structural features
4. Apparent youthfulness of the structure (e.g., geomorphic expression)
5. Significance for recurrence interval purposes
6. Significance for regional stratigraphic control purposes.

Field Methods

Approximately 7 man-months have been spent in the field by the Principal Investigator investigating young faults and Quaternary stratigraphy within the Reno quadrangle. Additionally, many low-altitude aerial reconnaissance flights have been made over most of the major fault zones in the quadrangle.

At the selected field reconnaissance sites, data was collected on fault scarp characteristics and stratigraphic relationships. Information was recorded on fault scarp data sheets describing: scarp morphology (height, slope angle, multiple bevels), relationship to major tectonic structures, parent material, stratigraphic interpretations, soils (morphology and age), and estimated age of most recent movement.

Natural and man-made exposures were examined in each site area for evidence of faulting and stratigraphic control. Soil pits were dug on upthrown and downthrown sides of the fault as well as on the scarp, and pedon descriptions were made. Selected soils of stratigraphic or age importance were profiled in detail.

Scarp morphology data was collected by measuring a representative scarp height and slope(s) at each site. Scarp heights were approximately determined (± 2 ft.) by hand leveling from the estimated scarp toe to the crest. Slope angles were estimated (± 2-3°) by laying a 12-foot stadia rod on the steepest recognizable slope segment and measuring the angle with a Brunton compass placed on the stadia rod. This technique is less precise than that used by Bucknam and Anderson (1979), but is believed to be satisfactory for the purposes of this study.

Trenching and ^{14}C Sites

Based on previous work, analysis of the photography, and field reconnaissance, sites believed to have regional tectonic significance were selected for trenching. Eleven backhoe trenches ranging in length from 100-650 feet were excavated and logged in the Fallon and Lahontan Dam areas. Three samples collected from the trench sites were submitted for radiocarbon age determination to the University of Texas at Austin.

Stratigraphic Dating Methods

Stratigraphic interpretations have been made, where possible, from previous Quaternary geologic mapping. In unmapped areas Quaternary stratigraphy has been extrapolated from adjacent mapped areas, if field reconnaissance suggested continuity in stratigraphic relationships, and soil stratigraphy was utilized in areas containing good soil-stratigraphic age control. The stratigraphic dating methods used in this study are based upon four major categories of previous work: 1) the glacial record of the Sierra Nevada, 2) the lacustrine record of pluvial Lake Lahontan, 3) the soil-stratigraphic record of western Nevada, and 4) the tephrochronologic record of western Nevada.

The glacial record for the Sierra Nevada in the Reno-Carson City area is well summarized by Birkeland (1968). Although previous glacial chronologies for parts of the Sierra Nevada have now been questioned (Burke and Birkeland, 1979), the chronology developed for the Reno region still appears sound (P. W. Birkeland, 1979, written communication).

The lacustrine record is based on the extensive study of Lake Lahontan by Morrison (1964), and it is correlative with the glacial record (Table 2). The

TABLE 2. Tentative Correlation of Quaternary Stratigraphy and Geologic Events Along the Truckee River (Birkeland, 1968).

Carson Range—Verdi Basin— Northern Truckee Meadows	Lake Lahontan Area
River alluvium Post-Tioga Soil	Fallon Fm. Toyeh Soil Turupah Fm.
Tioga Outwash	Sehoo Fm.
Most of Post-Tahoe Soil	Churchill Soil Wyemaha Fm.
Tahoe Outwash	Eetza Fm.
Most of Post-Donner Lake Soil	Cocoon Soil
Donner Lake Outwash	Paiute and Rye Patch Fms.
Post-Hobart Soil(s)	Humboldt Valley Soil
Hobart Outwash	Lovelock Fm.

pluvial history of Lake Lahontan allows detailed stratigraphic interpretations to be made based upon a late Quaternary chronology (Table 3). Lacustrine sediments of the Sehoo and Fallon Formations (late Pleistocene through Holocene age) occur extensively throughout the center of the quadrangle, and they have yielded numerous radiometric dates (Broecker and Kaufman, 1965; Broecker and Orr, 1958; Davis, 1978; Morrison and Frye, 1965). Dates on the Sehoo Formation range from 8500 to 25,000-30,000 years; ages from the Fallon Formation are in the mid- to late-Holocene range with numerous dates around 1000 to 3000 years.

Of particular importance to this study is the prominent shoreline cut by the last major highstand of Lake Lahontan at elevation 4370 ft.; it provides a key datum for making stratigraphic and tectonic interpretations for much of the quadrangle. The absolute age of this shoreline is, however, controversial. Broecker and Kaufman (1965) and Broecker and Orr (1958) have placed the age of the last highstand at about 12,000 years. Morrison and Frye (1965), however, based on the work of Morrison (1964), believe that the highstand is better dated at about 18,000 years. Morrison and Frye persuasively argue that stratigraphic evidence shows the highstand dates to be 6000-8000 years too young. More recent radiometric dating by Benson (1978), however, supports an age of 12,000 years for a major highstand, but also suggests another major highstand at 22,000-25,000 years ago. However, because of the nature of most ^{14}C samples used in these studies (calcareous tufa), the degree of carbon migration and original $^{14}C/^{12}C$ ratio may be uncertain and may possibly be yielding erroneously young ages. Consequently, the conflict in the ages of the last maximum highstand is unresolved, and the writer prefers to merely bracket the age as 12,000-18,000 years.

The soil-stratigraphic record is largely derived from the work of Morrison (1964) and Birkeland (1968), and its potential use for fault studies is discussed in detail in Bell and Pease (1980). Previous work has reasonably demonstrated that several key soil relationships can be recognized and used for

Elevations of lake-cycle maxima and minima are from the Truckee River badlands below Wadsworth unless indicated by F, which are from southern Carson Desert (Fallon) area, and by R, which are from Rye Patch Dam area.

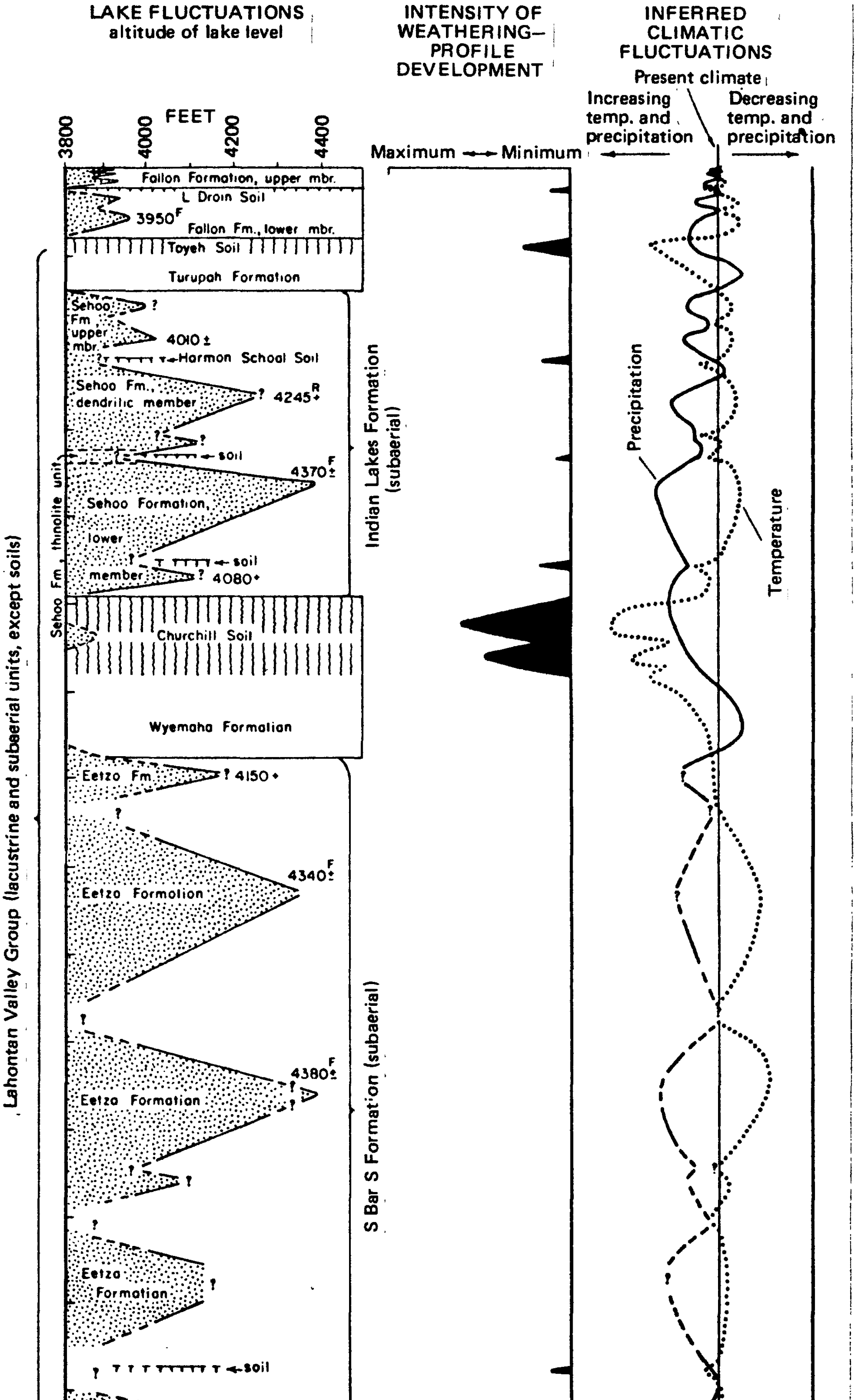


TABLE 3 . Stratigraphic, weathering and climatic relations in the Lake Lahontan area (Morrison and Frye, 1965)

first-approximations of recency of fault movement in areas lacking other stratigraphic controls. As shown in Table 4, major soil-stratigraphic units correspond well, based on field evidence, with characteristic soil morphologies (pedologic types). In particular, differentiations can clearly be made between pre- and post-highstand soils. Nettleton and others (1975) developed evidence, which has been substantiated by this study and previous earthquake hazard mapping, that no significant argillic soil formation has occurred (exclusive of salt-rich natric soils) since the last major highstand of Lake Lahontan. Therefore, pedologic types - in this case, entic and cambic versus argillic soils - can differentiate pre-highstand deposits from post-highstand deposits in areas peripheral to Lake Lahontan.

Davis (1978) has studied many of the mid- to late-Quaternary tephra in western Nevada and outlined petrographic criteria that can easily be used to identify most young ashes within this study area. These criteria include mineralogic content, glass morphology, and refractive index, and they provide useful evidence for differentiating Holocene-age sediments in certain portions of the quadrangle.

Recency of Fault Movement Categories

Young faults have been delineated by recency of movement, and they have been placed into four categories based on age of youngest demonstrable surface displacement:

1. Historic surface rupture, including scarps, fissures, and lurch features.
2. Post-high Lahontan shoreline scarp (less than 12,000-18,000 years old).
3. Mid- to late-Pleistocene scarp (pre-high Lahontan shoreline).
4. Youthful-looking bedrock/alluvial contact of probable tectonic origin, but of uncertain age.

TABLE 4. Key Soil-Stratigraphic Units
Reno-Carson City area

Soil-Stratigraphic Unit	Characteristic Relict Pedologic Type (Great Group or Order)	Approximate Age (yrs.)
Little or no soil (A-C) Profile	Entisol	<2000–3000
Toyeh-interval Soil	Camborthid; Haploxeroll	5000–12,000
Churchill-interval Soil	Haplargid; Argixeroll	35,000
Cocoon-interval Soil	Haplargid; Durargid; Paleargid; Durixeroll	100,000
Humboldt Valley-interval Soil	Durargid; Paleargid; Durixeroll (better developed than Cocoon Soil)	200,000

More specific determinations of ages of movement are possible in some areas (as, for example, on the 7 1/2-minute quadrangle mapping in the Reno-Carson City area), but they can not be made uniformly for the entire quadrangle. Furthermore, young Lake Lahontan sediments mask much of the mid- to late-Quaternary faulting in the central part of the quadrangle, and the Pleistocene history of movement in this area is incomplete. Consequently, the four above categories are believed to most adequately outline the young tectonics for the entire quadrangle.

The post-highstand fault scarps are identified where sufficiently clear evidence of Holocene-age movement is present. This category includes scarps that not only physically transect the 4370-foot shoreline, but also those that lie below the shoreline and can reasonably be interpreted to be post-shoreline features rather than pre-shoreline features that were submerged. This category also includes scarps that can be estimated to be Holocene-age based on soil stratigraphy. It should not be inferred that the mapped post-shoreline scarps represent all of the Holocene-age faulting in the quadrangle. The completeness of this map is a function of several factors: the size of the original scarp (small scarps are not preserved long in the Lake Lahontan sediments); the proximity of a scarp to similar shoreline scarps, which makes recognition of tectonic features difficult; and the occurrence of faulting in bedrock areas, such as the Olinghouse Fault Zone where scarps are difficult to recognize because of the steep terrain.

The mid- to late-Pleistocene scarp category includes all pre-Holocene (pre-high shoreline) scarps that can be recognized in alluvium. This category may also include undatable Holocene-age scarps. In other words, Holocene movement is not precluded on these faults, although available evidence suggests an older Pleistocene age for these features. The same limitations on completeness apply to this category as those described for the above category.

Youthful-looking bedrock/alluvial contacts are delineated on the map, but they are not differentiated by age. These lineaments are interpreted to be tectonic features, but they do not clearly exhibit fault scarp morphologies. For instance, portions of the Sand Springs Range are marked by abrupt, linear bedrock/alluvial contacts that probably represent Quaternary-age range-bounding faults. They do not, however, exhibit clear evidence of young fault movement in Quaternary-age deposits, and consequently should not be mapped as young fault scarps. The recency of movement on these lineaments, if any, is unknown; the lineaments may, however, be very young structures in some areas.

As a final point, it should be emphasized that the mapped faults are primarily structures that can be recognized in alluvium or at alluvial boundaries. Fault movement in bedrock areas has been delineated where possible, but it should not be inferred from the map that additional Quaternary bedrock faulting has not occurred. Most of the tectonic activity by its nature, however, has occurred at basin-range contacts.

RESULTS

REGIONAL TECTONICS

The Reno quadrangle is transected by four major structural-tectonic features (Figure 3): the Sierra Nevada Frontal Fault Zone, the right-lateral Walker Lane and its conjugate systems, the left-lateral Carson Lineament and the Olinghouse Fault Zone.

The Sierra Nevada Frontal Fault Zone in this quadrangle is the northern segment of a series of north-trending fault zones extending from Reno south to Owens Valley, California, and separating the Sierra Nevada from the Great Basin. This northern segment is approximately 70 miles long and extends from Reno south to near Markleeville, California. Fault movement on this zone is dominantly normal based on displaced Quaternary units. VanWormer and Ryall (1980) note, however, that fault-plane solutions for present seismicity in this zone suggest a component of strike-slip movement.

The northern end of this zone merges with, or is possibly truncated by, northwest-trending faults probably related to the Walker Lane system. At Carson City, the zone merges with northeast-trending faults of the left-lateral Carson Lineament, and at Reno the zone may similarly merge with the northeast-trending Olinghouse Zone, although this relationship is not as clear.

The Walker Lane is a right-lateral shear zone striking about N45-60W and extending from near Honey Lake, California, southeastward through the Reno 1°x2° quadrangle to southern Nevada where it is believed to merge with the right-lateral Las Vegas Shear Zone. This feature has been divided into two main segments - northern and southern areas - and the northern segment covering the Reno quadrangle is summarized in Bell (1981).

The Walker Lane is believed to be a major right-lateral wrench fault system similar, and parallel, to the San Andreas Fault Zone (Bonham, 1969). Characteristics of such a system are discussed in Moody and Hill (1956) and Wilcox and others (1973), and similarities between basic wrench tectonics and observed

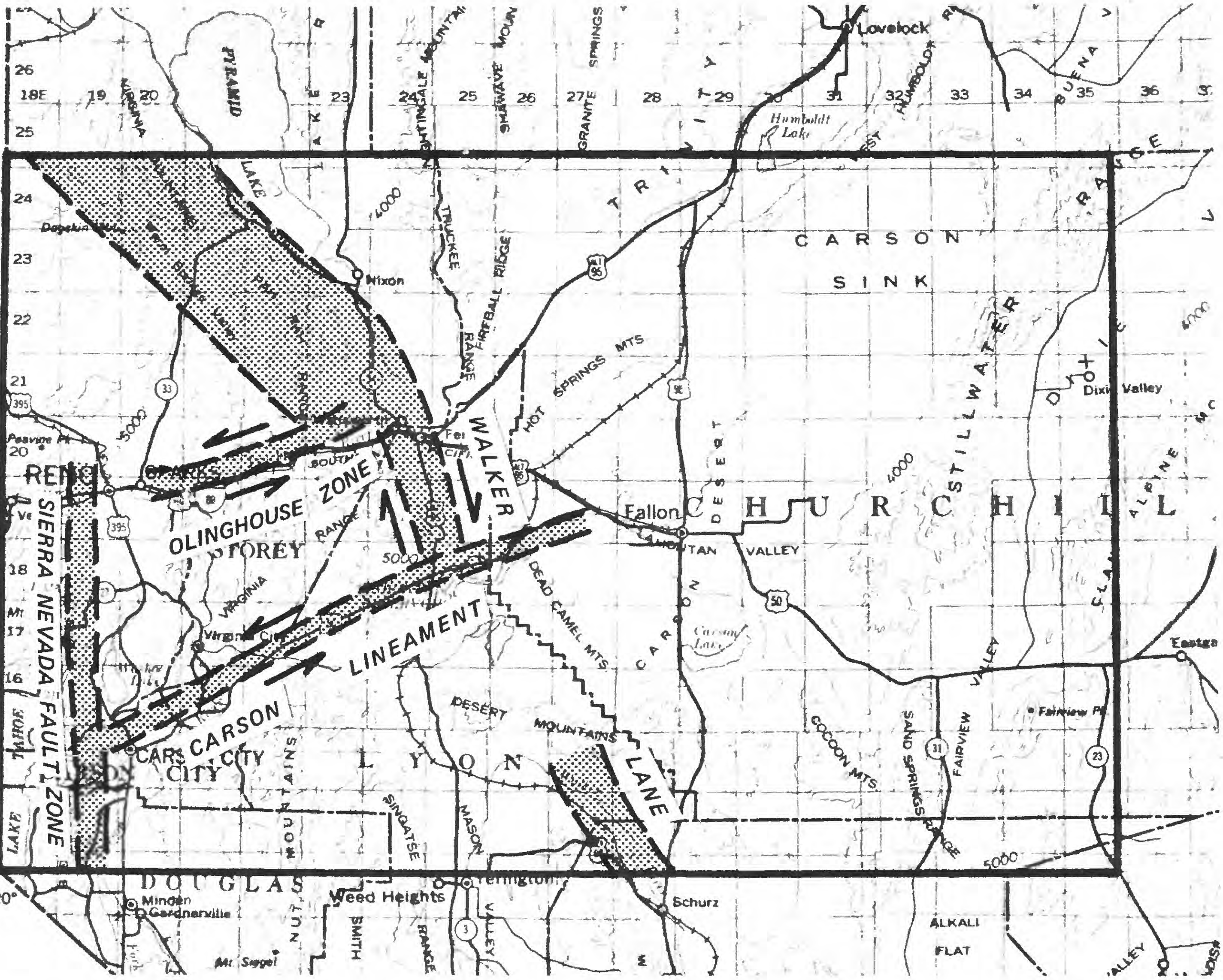


FIGURE 3. Major structural features within the Reno 1 x 2° quadrangle.

Walker Lane tectonics are discussed in Bell and Slemmons (1979), Bonham (1969), Livaccari (1979), and Shawe (1965). This previous work suggests that a series of secondary and tertiary conjugate fault sets (or Riedel Shears) exist at oblique angles to the main zone of right-lateral displacement. Major second-order left-lateral conjugate shears occur along the Carson Lineament and Olinghouse Fault Zone at about N60-80E, and faults trending approximately N-S are believed to be second-order right-lateral conjugate shears. For example, a right-lateral conjugate feature termed the Churchill Arc by Shawe (1965) is believed to be responsible for the 1954 Rainbow Mountain-Dixie Valley-Fairview Peak earthquakes. Other similar-trending structures may include the Truckee Range and the Hot Springs Mountains. Faults oriented at about N60E may be third-order right-lateral conjugate faults. Of additional interest to this study are the associated compressional tectonics (en echelon folding) described by Wilcox and others (1973). These related wrenching structures may explain compressional features found during this study near Lahontan Reservoir and Rainbow Mountain, and they are discussed in the section "Description of Faulting".

The Carson Lineament and Olinghouse Fault Zone, as mentioned, are believed to be major left-lateral conjugate shear zones of the Walker Lane. The Carson Lineament extends northeastward from Carson City for about 50 miles to near Lahontan Reservoir. Rogers (1975) suggests recent left-lateral displacement of stream channels, but this study failed to verify such offsets along the zone.

The Olinghouse Fault Zone extends westward from near Wadsworth for about 20 miles to Patrick. Rose (1969) describes left-lateral offset in this zone, the most recent of which is believed to have occurred in 1869 (Sanders and Slemmons, 1979). This northeast-trending zone merges with northwest-trending Walker Lane structures in the southeastern part of the Pah Rah Range. Its western extent and structural relationship to the Sierra Nevada Frontal Fault Zone are uncertain.

In contrast, the Carson Lineament appears structurally linked to the Sierra Nevada Frontal Fault Zone (Bell and Trexler, 1979; Trexler and Bell, 1979), but it appears to truncate a segment of the Walker Lane rather than merge with it (Figure 3). The young northeast-trending faults along the lineament are clearly through-going at the Walker Lane/Carson Lineament junction; and northwest-trending Walker Lane faults are absent from this junction southeastward through the Desert Mountains to Weber Reservoir where they are again recognized. This truncation and "gap" in the Walker Lane is at present unexplained. It may, however, be the result of crustal warping in this area or what Albers and Stewart (1972) describe as arcuate "oroflexing". As discussed later, there is evidence found during this study of numerous young north- and northwest-facing arcuate faults and lineaments that may be related to such crustal flexuring.

SEISMICITY AND HISTORIC SURFACE RUPTURES

Instrumental and pre-instrumental historic seismicity for the period 1854-1960 is shown on Figure 4. Seismicity for the period 1960-1969 is on file at the University of Nevada-Reno Seismological Laboratory but is presently unplotted. Seismicity for the years 1969 through 1978 is summarized in Ryall (1977) and Ryall and VanWormer (1980).

Major pre-instrumental earthquakes are catalogued in Slemmons and others (1965). Of particular interest to this study is a large earthquake ($M>7?$) reported to have occurred in 1852. Slemmons and others place the epicenter near Pyramid Lake, but Ryall (1977) places it farther east near Stillwater in the Carson Sink and believes it occurred in 1845. Unpublished records of the Nevada Historical Society appear to support a date of 1852 but do not pinpoint a location (E. J. Bell, 1981, personal communication). Fissuring, strongly rolling ground, and water spouting were common both at Pyramid Lake and in the Carson Sink, and as indicated by Historical Society records, a major landslide occurred at Slide

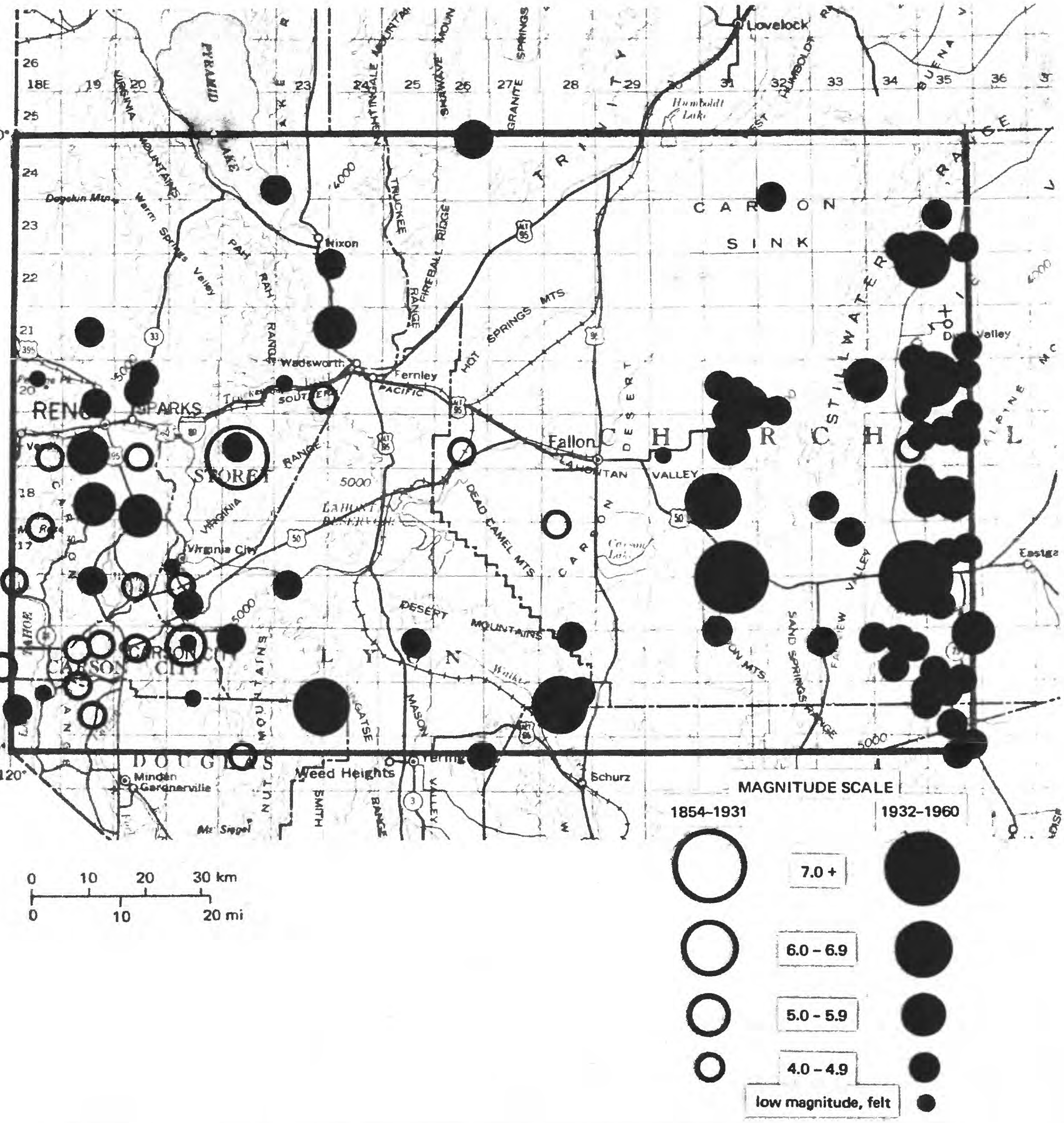


FIGURE 4. Distribution of earthquake epicenters in the Reno 1 x 2° quadrangle, 1854-1960 (Slemmons and others, 1964).

Mountain south of Reno. The results of this study provided no definitive evidence for pinpointing the epicenter. Numerous Holocene fault scarps exist in both areas, as well as in areas in between (such as near Lahontan Reservoir), that could have generated the widespread severe shaking and liquefaction.

As suggested by Figure 4 and Ryall and VanWormer (1980) and VanWormer and Ryall (1980), instrumental seismicity within the quadrangle is distributed along several major fault structures: the Sierra Nevada Frontal Fault Zone, the Walker Lane, the Rainbow Mountain faults, and the Dixie Valley-Fairview Peak faults. The latter two areas still exhibit aftershock activity associated with the large 1954 earthquakes. The Olinghouse Fault Zone, on the other hand, shows no significant indication of aftershock activity from the 1869 earthquake, and the Carson Lineament has little significant seismicity beyond the normal, regional background activity.

Estimates of maximum possible magnitudes have been made based upon fault length/earthquake magnitude relationships. Bell and Slemmons (1979) estimate that the Pyramid Lake Segment of the Walker Lane (Pyramid Lake to Fernley) is capable of generating an earthquake of M = 6.75-7.5 based upon world-wide length/magnitude relationships. Similarly, Sanders and Slemmons (1979) suggest that the Olinghouse Fault Zone is capable of generating an earthquake of M = 7 based on the same criteria. Ryall and VanWormer (1980) have derived a length/magnitude relationship based on historic western Basin and Range activity, and suggest that the segment of the Sierra Nevada Frontal Fault Zone lying within the Reno quadrangle is capable of generating an earthquake of M = 7.5-7.8.

The zones of historic surface faulting within the quadrangle are shown on Figure 5. Table 5 also lists these zones with others that have occurred in the western Basin and Range. Note that of the eleven areas of historic surface faulting, six have occurred within this quadrangle, and several of the other areas (e.g., Cedar Mountain, Pleasant Valley, Fort Sage) occur close to the study area.

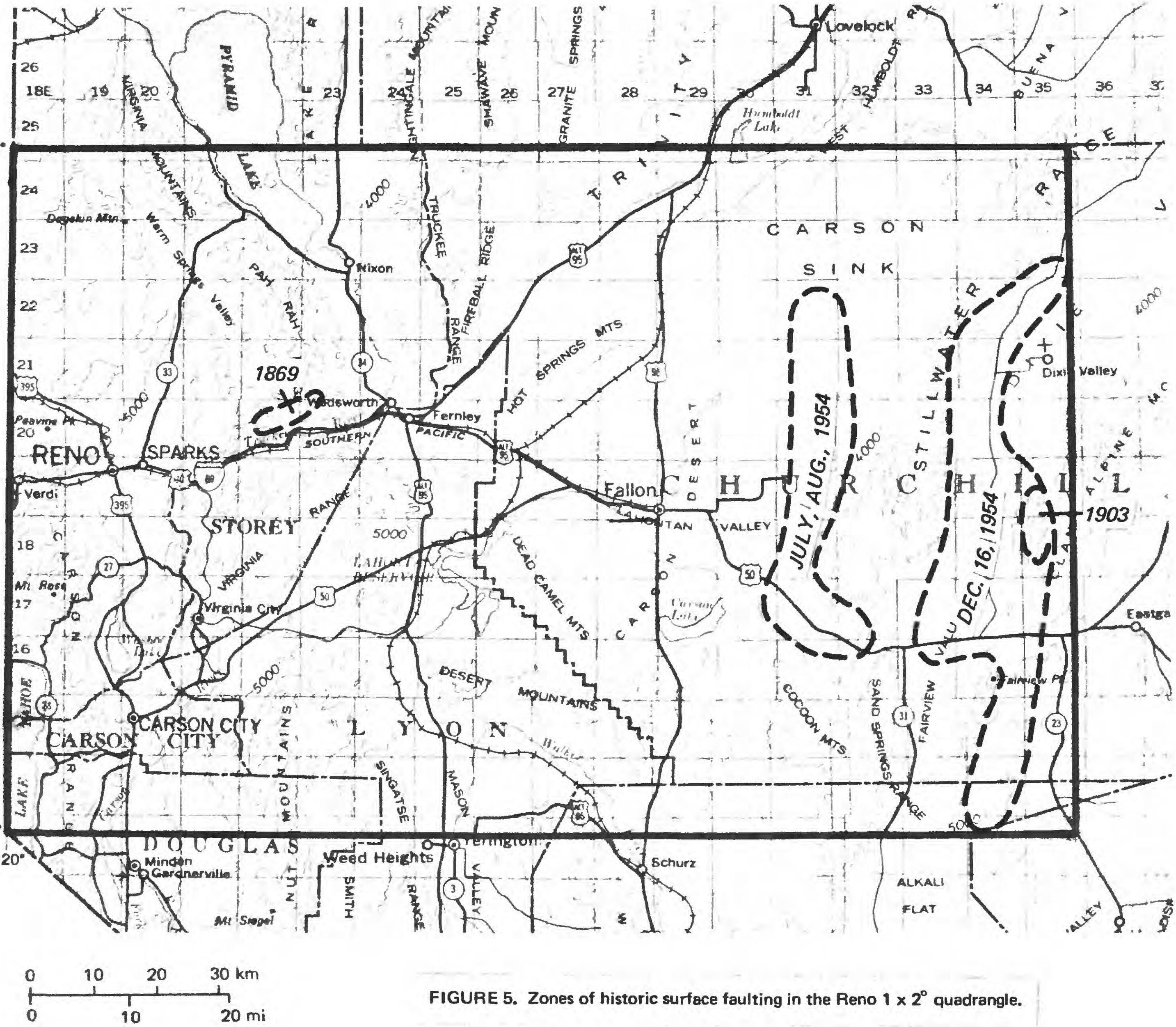


FIGURE 5. Zones of historic surface faulting in the Reno 1 x 2° quadrangle.

TABLE 5. Historic surface faulting in western Basin and Range Province (after Slemmons, 1967, table 1)

Year	Richter magnitude	Fault
*1869	7.0±0.5	Olinghouse Fault Zone, NV
1872	8.3±0.5	Owens Valley Faults, CA
*1903	?	Gold King Fault, NV
1915	7.6±0.2	Pleasant Valley Faults, NV
1932	7.3±0.2	Cedar Mountain Area Faults, NV
1934	6.3±0.2	Excelsior Mountain Fault, NV
1950	5.6±0.2	Fort Sage Mountain Fault, CA
*1954a	6.8±0.2	Rainbow Mountain Fault, NV
*1954b	6.8±0.2	Rainbow Mountain Fault, NV
*1954c	7.3±0.2	Fairview Peak Fault Zone, NV
*1954d	6.9±0.2	Dixie Valley Fault Zone, NV

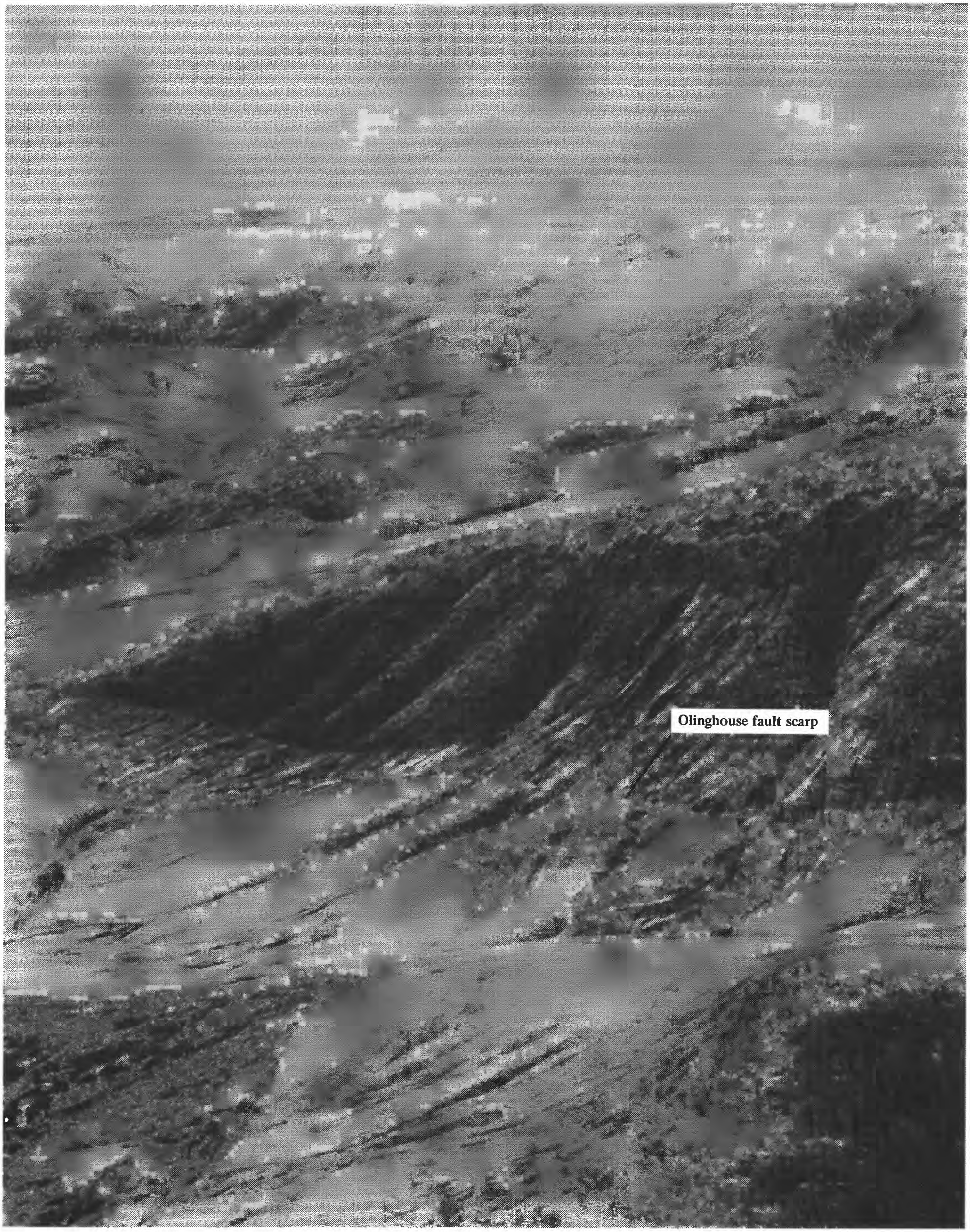
*Faults within the Reno 1° x 2° sheet.

Newspaper accounts indicate a major earthquake occurred in the study area (I = VIII to IX at Virginia City) on December 27, 1869 (Slemmons and others, 1965). Based on verbal reports of ground rupture near Olinghouse, Sanders and Slemmons (1979) place the epicenter on the Olinghouse Fault Zone and assign it a magnitude 6.7. They suggest that although present evidence of recent ground breakage is visible for only 1.4 miles, historic accounts indicate the breakage was at least 8.7 miles long, and that field mapping shows the breakage zone could have been 14.3 miles long or more. Because of this uncertainty, the extent of surface faulting is shown as questionable on the results of this study.

Based on unpublished data compiled by F. C. Schrader in 1911 and other historical accounts, Slemmons and others (1959) have documented a large earthquake (unknown magnitude) and related surface rupturing near Wonder in the Louderback Mountains in 1903. Schrader's mapping indicates that faulting, primarily in the form of bedrock fissuring, occurred along at least 3 miles of the Gold King Fault, and Slemmons and others suggest that at least 12 miles of surface faulting occurred. The exact nature of the surface movement is vague because the Gold King Fault was reactivated along the same trace in 1954. Schrader's descriptions, however, indicate the movement appeared as a north-south-trending fissure 3 to 5 feet wide and up to 5 feet deep with local graben-like structures.

Only the well-documented 3-mile Gold King Fault rupture is shown on this map. Slemmons and others speculate, however, that the zone of 1903 rupturing may have extended south to near the northern end of Chalk Mountain.

On July 6 and August 23, 1954, two large earthquakes occurred with related surface faulting along the east flank of Rainbow Mountain. The associated fault movements are described by Tocher (1956), and the damage caused by the earthquakes is listed in Steinbrugge and Moran (1956). Both earthquakes had maximum intensities of IX (Cloud, 1956), and were both initially assigned magnitudes of



Aerial view looking northwest at Olinghouse Fault Zone, believed to be location of 1869 earthquake (M = 6.7?).

6.8 (e.g., Slemmons and others, 1965). Subsequent studies assign the July earthquake a magnitude of 6.6 rather than 6.8 (e.g., Ryall, 1977).

Faulting associated with the July earthquake extended from the southern end of Rainbow Mountain north for about 11 miles toward Stillwater. Extensive areas of lurch cracking and scarp formation occurred around the northern edges of Eightmile and Fourmile Flats. Scarp heights ranged from 1 to 12 inches with fault movement down to the east.

The August earthquake re-ruptured areas of the July faulting, but extended an additional 14 miles into the Carson Sink, making the total rupture length at least 25 miles. Many of these scarps were on the order of 18 to 30 inches high, and were generally more continuous than the July breaks. Extensive lurching and cracking occurred in many of the same areas as occurred during the the July activity.

Numerous scarps, fissures, and/or lurch features are shown on this map in the Carson Sink area that were not originally mapped by Tocher (1956). These features, in Townships 22 and 23N, Ranges 29, 30, 31, and 32W, are believed to be related to the July and August, 1954, earthquakes, and they have been mapped here based on the mapping of Slemmons (1968) and a reevaluation of the 1956 AMS aerial photography. Most of these features are no longer visible on the low sun-angle photography flown for this study.

The surface faulting along Rainbow Mountain is generally within poorly indurated lake sediments and young alluvial fan material. Consequently, field reconnaissance indicates that many of the scarps mapped by Tocher are no longer visible, and many others are extremely subdued. Only in areas where scarps cut coarse alluvial fans are fresh-looking scarps, with some vertical free-face, still preserved.

The Rainbow Mountain faulting occurs along a zone showing no recognizable surficial evidence of previous Quaternary faulting. Although this may be due to a poor preservation record in the soft lake sediments, it seems likely that the numerous inundations of Lake Lahontan have obliterated any other Quaternary scarps. This faulting may, therefore, be the first rupture of the zone since the last major highstand, 12,000-18,000 years ago.

Because of the low population in the Rainbow Mountain area, most of the damage caused by the July and August earthquakes occurred in and around Fallon (15 miles west) where shaking intensities of VII to VIII were experienced. Numerous buildings in Fallon were damaged, and extensive liquefaction in the Fallon-Stillwater area caused considerable damage to canal and irrigation systems.

On December 16, 1954, two large earthquakes occurred in the Dixie Valley-Fairview Peak area. Spectacular surface faulting and other related effects accompanied both earthquakes, and these are mapped and described in Slemmons (1957). An initial shock of magnitude 7.1 was centered just north of Fairview Peak, and it was followed about four minutes later by a second shock, initially assigned a magnitude of 6.8, centered on the west side of Dixie Valley, about 30 miles north of the first epicenter. Subsequent studies (e.g., Slemmons and others, 1965; Ryall and VanWormer, 1980) assign a magnitude of 6.9 to the second shock. Based on damage, the earthquakes are assigned Modified Mercalli Intensities of only VII because of their location in a poorly populated area (Cloud, 1957); however, based on the extensive surface breakage they could be assigned an intensity X (Tocher, 1957).

As discussed by Slemmons (1957), there were four main zones of surface faulting, comprising a north-south trending belt about 60 miles long and 20 miles wide: 1) the western Dixie Valley zone, 2) the southeastern Dixie Valley zone, 3) the Fairview-Bell Flat zone, and 4) the Westgate zone.

Normal dip-slip faulting occurred on the western margin of Dixie Valley from near Dixie Hot Springs south to near Elevenmile Canyon. Most of the scarps occur on or in close proximity to the bedrock/alluvial contact along the east flank of the Stillwater Range. Near IXL Canyon, the main fault trace

1954 fault scarp near Alameda Canyon in Dixie Valley. Scarp has well-preserved vertical free-face in foreground and delined slope in background.

bifurcates into several splays toward the north with scarps occurring both at the bedrock/alluvial contact as well as downslope across the alluvial piedmont. At several locations, the faulting occurred along prominent pre-existing scarps cutting the alluvium: near IXL and East Job Canyons, East Lee Canyon, and Elevenmile Canyon. Scarp heights ranged from 5 to 20 feet, and much of the faulting was accompanied by extensive graben formation which exaggerated the apparent displacement. Displacement in this zone was down to the east along an east-dipping fault plane.

The southeast side of Dixie Valley exhibited faulting of less magnitude; displacements were down to the west along west-dipping bedrock/alluvial contact faults bounding the west side of the Louderback Mountains. Displacements were normal and generally 2 to 3 feet high with only minor graben formation. The zone extended from near Wonder south to the northwest flank of Chalk Mountain where only a few inches of displacement was observed. Of particular interest in this zone was the re-rupturing of the Gold King Fault previously discussed. As noted by Slemmons and others (1959), this is one of only a very few documented examples of historic re-rupturing of the same fault trace in the United States.

The Fairview-Bell Flat zone is an apparent southerly extension of the zone just described, but displacements are predominantly down to the east along east-dipping fault planes. The zone extends from the northeastern end of Chalk Mountain south along the east flank of Fairview Peak to the Mineral-Nye County line at the south end of Bell Flat. Scarp heights at the northern end of the zone are about 3 to 4 feet, but they increase to the south near Fairview Peak where they exceed 20 feet. True vertical displacements are on the order of 7 to 12 feet, and the scarps exceeding 20 feet in height are due to height exaggeration along graben structures. In the Fairview Peak-Bell Flat area, as much as 14 feet of right-lateral slip was noted. Detailed mapping of these features by Larson (1957) suggests that they are related to right-lateral conjugate movement of the Walker Lane wrench system. Similar conclusions are drawn by Shawe (1965) who relates these right-slip features to a major right-lateral zone referred to as the Churchill Arc. Ryall and Malone (1971), however, show that focal mechanisms suggest a simple, extensional block faulting pattern that displays apparent right-lateral slippage because of a zig-zag fault trace.

The fourth zone of December 16 faulting occurred in the West Gate-Stingaree Valley area. The faulting generally followed the bedrock/alluvial contact along the west flank of the Clan Alpine Mountains from Twin Peaks south to a few miles south of Highway 50. Scarp heights are generally 2 to 3 feet, and displacement is down to the west along west-dipping fault planes.

Field reconnaissance conducted for this study in all four of the above December 16 zones indicates that most of the scarps are still exceptionally well preserved. Only in areas where displacements were less than 1 foot (e.g., west flank of Chalk Mountain) is evidence of surface faulting gone. Most scarps still exhibit extensive exposures of the original vertical free-face, although this is highly variable in areas of poorly lithified alluvium where numerous scarps are at a 30° angle of repose, or less.

An important observation to be made from the December 16 faulting is that there is clear evidence for re-rupturing of Quaternary-age alluvial fault scarps. Because Dixie Valley was occupied by a pluvial lake smaller in extent, and separated from, Lake Lahontan, the mid- to late-Quaternary alluvial and fault scarp record is well preserved. As mentioned, re-rupturing occurred in 1954 along several prominent alluvial scarps in the west part of Dixie Valley. Field reconnaissance of the scarps near IXL and East Job Canyons suggests that the pre-1954 scarps are pre-Holocene age; and reconnaissance in the other areas indicates that this western part of Dixie Valley has an alluvial-, soil-, and tephro-stratigraphic record with a high potential for providing re-rupture interval data with additional work.

Damage associated with the December earthquakes was considerably less than that related to the July and August shocks even though the magnitudes were larger and the area of surface faulting was much more extensive (Steinbrugge and Moran, 1957). This was due to the very low population in the epicentral area. Most of the related damage occurred at Frenchman's Station and several places across Highway 50. Little noticeable damage occurred at Fallon, 30 miles west, where shaking intensities of about VI were observed. An oddity noted by Steinbrugge and Moran was that the worst damage occurred in Sacramento, California, 185 miles from the epicenter, where surging water in reservoirs and tanks damaged structures.

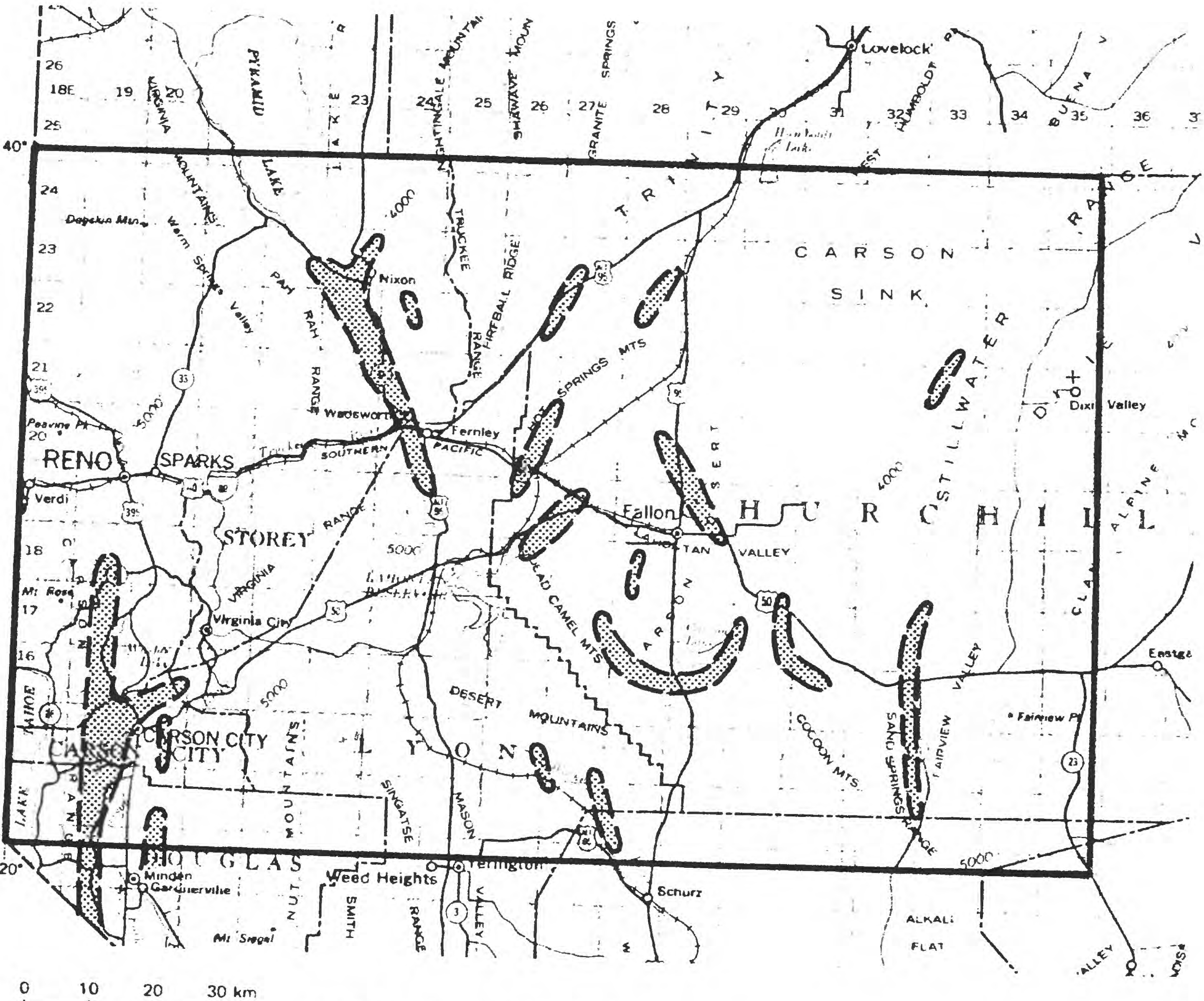
DESCRIPTION OF FAULTING

The results of this study indicate that there are numerous areas of recognized prehistoric Holocene faulting within the Reno 1°x2° quadrangle (Figure 6). These recent scarps delineate a pattern of late Quaternary tectonics that is related to the major structural elements in the quadrangle (Figure 3). For the purposes of discussion, young faults are described in terms of separate areas outlined on the basis of general tectonic trend or structural grain (Figure 7). Each of these areas is discussed below.

Area A: The Sierra Nevada Frontal Fault Zone

This area of faulting extends from Reno south to Genoa. North-south-trending Sierran faults are present just south of the Truckee River in downtown Reno, but are absent north of the river where northeast- and northwest-trending faults predominate. This may be the result of structural merging, or truncation, between the Sierran faults and Walker Lane and Olinghouse Fault Zone structures.

Faulting becomes progressively more complex, and also apparently progressively younger and more recurrent in the areas to the south of Reno. The Sierran fault scarps in the Reno area are pre-Holocene, and are possibly pre-Wisconsinan (Bingler, 1974; Bonham and others, 1981). No clear evidence of faulting in Holocene-age



0 10 20 30 km
0 10 20 mi

FIGURE 6. Recognized areas of prehistoric Holocene faulting within the Reno 1 x 2° quadrangle.

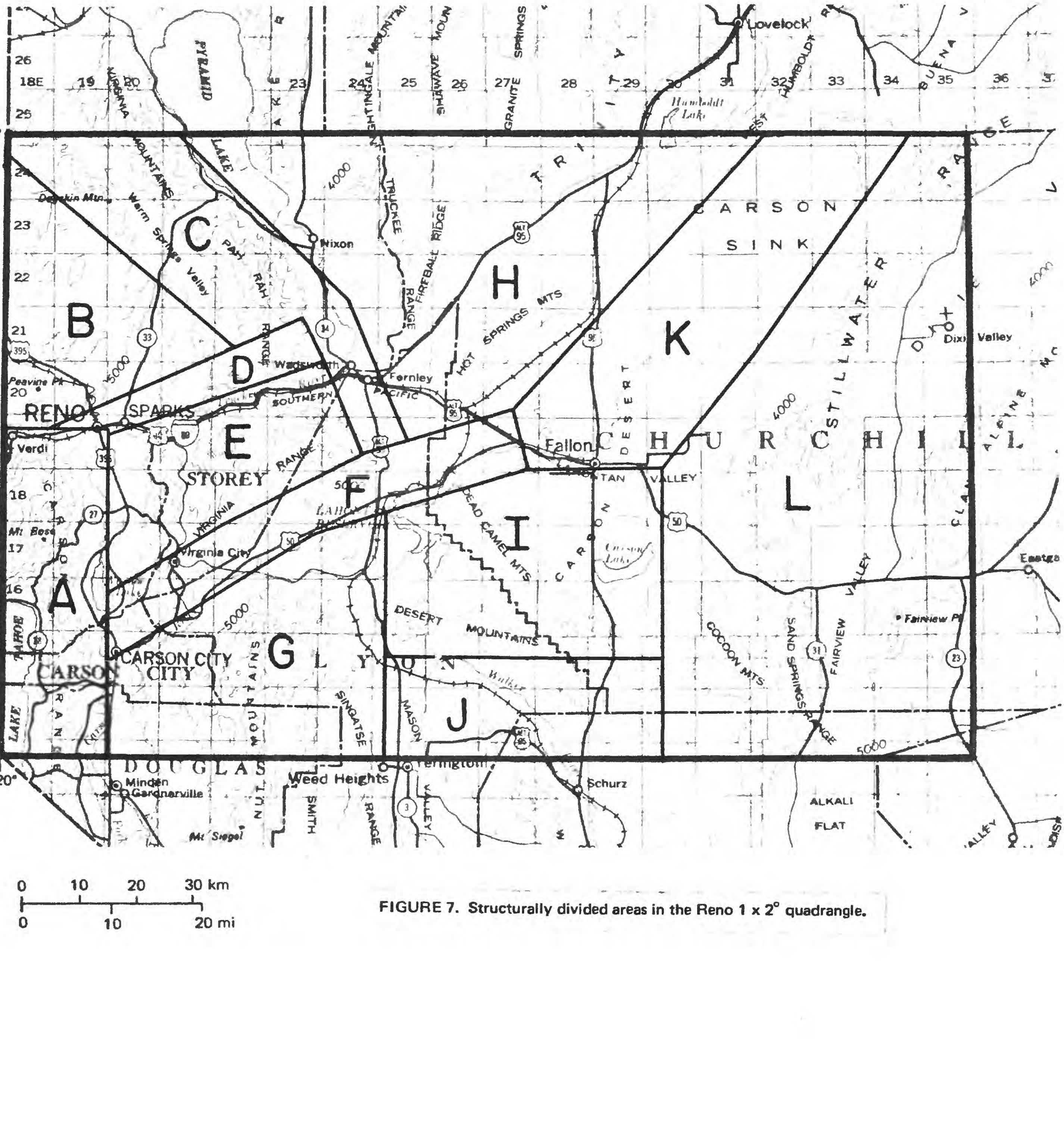


FIGURE 7. Structurally divided areas in the Reno 1 x 2° quadrangle.

sediments has been observed, and the author has studied several trench locations across prominent scarps which display unfaulted argillic and durargillic soils of pre-Tahoe age.

Young faulting in the Steamboat Hills area is complex due to its distributive nature across a zone about 6 miles wide. Faulting occurs in a system of normal, antithetic, and graben structures. The youngest faulting is that recognized by Tabor and others (1978) near Jones Creek where scarps cut stream deposits of Tioga age. This is the northernmost recognized extent of Holocene surface faulting in the Sierran zone in this quadrangle.

Near Washoe Lake, Sierran faulting is generally marked by a single trace bounding the west side of Washoe Valley. Tabor and others (1978) believe this faulting to be pre-Holocene, but soil-stratigraphic interpretations suggest these scarps are probably Holocene age.

At Carson City, the north-south trend of the zone becomes more northeasterly, and Sierran frontal faults appear to merge with Carson Lineament faults (Trexler and Bell, 1979). Soil-stratigraphic and trenching studies (Bell and Pease, 1980) indicate that these faults are Holocene age, and some may be no more than a few hundred years old.

South of Carson City, the Sierran frontal zone consists of two main splays which join south of Hobo Hot Springs to form the Genoa Fault. Geologic and trenching studies by Pease (1979) indicate that both splays are less than several thousand years old. The Genoa Fault scarp is geomorphically very young, and may be less than a couple of hundred years old according to Pease. Historical records indicate that it formed prior to 1854, however (Lawson, 1912).

Area B: Peavine Mountain and Northwestern Valleys Area

This area consists of a group of relatively small mountain ranges and basins that lie between the major structures of the Sierra Nevada Frontal Fault Zone, the Walker Lane, and the Olinghouse Fault Zone. Peavine Mountain may be a structural outlier of the Sierran block, but it is bounded on the southeast and northeast sides by, respectively, northeast- and northwest-trending faults. Fault scarps around Peavine Mountain are moderately dissected and do not appear to cut any known Holocene deposits; they appear restricted to mid- to late-Pleistocene age alluvial fan and pediment deposits flanking the mountain.

Similarly, there is no present evidence for Holocene scarp formation on any of the other young faults in the Northwestern Valleys area. Scarps are dominantly northeast- and north-northeast-trending, and they occur in all of the major valleys: Spanish Springs, Lemmon, Cold Springs, and Hungry Valleys. One of the geomorphically youngest scarps in this area is the one bounding the east flank of Fred's Mountain. It cuts an alluvial fan surface of uncertain age, but its relatively slightly dissected nature suggests a possible late Pleistocene age. This scarp is part of a zone extending south into Lemmon Valley where it is marked by a large (120 ft high) scarp bounding the east side of the Reno-Stead Airport, and it is informally referred to as the "Airport Fault". This scarp may, however, be in part lacustrine in origin.

Area C: Pyramid Lake Segment of the Walker Lane

This area of northwest-trending faults constitutes the Pyramid Lake Segment of the Walker Lane (Bell and Slemmons, 1979). The main fault zone extends from Pyramid Lake to south of Fernley where it is truncated by the Carson Lineament; secondary en echelon zones occur in the Dogskin Mountain-Warm Springs Valley area southwest of Pyramid. The youngest and most intense deformation has occurred along the main zone betwen Pyramid Lake and Wadsworth. Here many prominent northwest-trending scarps cut post-highstand deposits, and some scarps occur in low, young terraces of the Truckee River. No useable radiometric dates have been obtained from these young deposits (except for those cited in Born, 1972, which are not in faulted areas), so the exact date of most recent movement is uncertain. However, as mentioned, this area is suspected of having been one of the possible locations for the large-magnitude 1852 earthquake.

Many of the young scarps in this main zone show evidence of strike-slip tectonics, although no clear evidence of right-lateral movement is recognized. Geomorphic features such as sag ponds, pressure ridges, deformed shorelines, and elongated troughs are common in the zone around T22N,R23E. The larger features, such as the troughs, are truncated by the high Lahontan shoreline but have small, post-shoreline scarps associated with them, suggesting continuing strike-slip movement in the zone.

It is likely that not all young faults have been recognized in the main zone. Many of the faults pre-date the last inundation of Lake Lahontan, based upon numerous exposures seen during field reconnaissance, and have no clear surficial expression. Furthermore, the northwest trend of the faulting parallels the suite of shorelines in the area, and it is difficult to differentiate between fault and shoreline scarps. Consequently, it seems most useful to merely describe this area as a zone of faulting and deformation about 4 to 5 miles wide that has experienced repeated Pleistocene and Holocene movement.

The northern end of the main zone appears to die out near the south tip of Pyramid Lake, although it may well extend beneath the lake or extend along through the sequence of shorelines on the west side of the lake. To the south, the main zone diminishes near Fernley, and the last recognizable scarps occur about 8 miles southeast of Fernley. Clear evidence of Holocene movement is seen only as far south as the southeast-quarter of T20N,R24E, where several small scarps cut post-high shoreline deposits.

En echelon fault zones occur southwest of Pyramid Lake, but they appear to have less neotectonic significance than the main zone. Prominent northwest-trending scarps and pressure-like features occur in Winnemucca and Warm Springs Valleys and in the valley on the southwest side of Dogskin Mountain. All of these scarps, except for one in Warm Springs Valley, are pre-Holocene. The scarps in Winnemucca Valley, for example, are truncated by the high Lahontan shoreline. The scarp in Warm Springs Valley does, however, cut post-high shoreline deposits (Bell, 1981). It is a single, small, subdued scarp about 2 miles long that appears to be an extension of the Winnemucca Valley faults (E. J. Bell, 1981, personal communication).

Area D: Olinghouse Fault Zone

As previously discussed, the Olinghouse Fault Zone is probably a left-lateral conjugate shear zone of the Walker Lane. Near Olinghouse Road (southeast quarter of T21N,R23E), northeast-trending faults appear to structurally merge with northwest-trending Walker Lane faults. Alluvial scarps here are generally less than a few feet high, and appear geomorphically young; they cut post-high shoreline deposits, but younger stratigraphic dating has not yet been done. Sanders and Slemmons (1979) suggest that, based on verbal reports, surface faulting occurred in the Olinghouse Road area in 1869. Displacements were reportedly small (less than 1 foot), and field reconnaissance for this study found no present evidence suggesting historic movement on these scarps.

Southwest of Olinghouse, the fault zone follows a curvilinear trace through bedrock and is difficult to map. In T20N,R22E the zone is recognized as a set of parallel and subparallel scarps that appear to bound rhomb-shaped depressions suggestive of strike-slip movement (Sanders and Slemmons, 1979). Left-lateral stream offset has also been recognized in this area, and offsets on the order of 12 to 15 feet may be related to the 1869 event (Bonham, 1969; Sanders and Slemmons, 1979). The extent of 1869 rupturing to the east is unclear; no evidence of young faulting is visible, but this may be a function of the steep bedrock terrain.

In the southwest part of the Pah Rah Range, strong bedrock/alluvial lineaments trend northeast, and they may be related to the Olinghouse Fault Zone. These features bound elongated, northeast-trending troughs in the bedrock areas south and southwest of Spanish Springs Peak, and they trend into young structures in Area B.

In the Reno-Sparks area, there is slight evidence of northeast-trending faults related to the Olinghouse Zone. Bingler (1974) mapped several east-west- and northeast-trending scarps that may possibly represent the junction of the Sierran Fault Zone and the Olinghouse Zone, but the regional structural relationship between these two features is unclear. It is interesting to note, however, that the only clearly Holocene fault scarp mapped by Bingler in this area is a northeast-trending one in Sparks.

Area E: Virginia Range and Eastern Part of Truckee Meadows

The Virginia Range is characterized by scattered, variously oriented bedrock/alluvial lineaments, and no recognizable surficial evidence of young faulting is present in the glacial and lacustrine sediments filling the Truckee Canyon.

The western flank of the Virginia Range, however, is marked by a prominent range-bounding fault that extends from the Truckee River south along the mountain front for about 7 miles. The zone is characterized by a series of discontinuous scarps cutting mid- to late-Pleistocene alluvial fans, with displacements down to the west. Preliminary geologic mapping and trenching data suggest that the scarps are pre-Holocene age (Trexler and Pease, 1980).

Area F: Carson Lineament

The Carson Lineament is marked by numerous northeast-trending scarps occurring along the southern margin of the Virginia Range in a zone about 4 to 5 miles wide. Previous studies and field reconnaissance conducted for this study indicate that both ends of the Lineament show evidence of Holocene movement, but that the central part of the Lineament is pre-Holocene in age. Scarps at the southwest end of the zone, at its junction with the Sierran front, are very young based on soil-stratigraphic and trenching data (Bell and Pease, 1980), and they are confined to the area immediately north of Carson City. Older scarps occur between Carson City-New Empire and Silver Springs, and these scarps are confined to mid- to late-Pleistocene alluvial fan deposits. Reconnaissance mapping and soil-stratigraphic studies suggest that these older scarps are pre-Holocene, and many are probably pre-Wisconsinan. The northeast end of the zone, from Silver Springs east to Carson Dam, is the junction of the Lineament with the Walker Lane, and a broad area of Holocene faulting occurs in the Lahontan Reservoir-Swingle Bench area.

All of the scarps in this latter area cut a broad beach terrace extending from Lahontan Reservoir to Swingle Bench. This surface, referred to as the "Dendritic Terrace" by Morrison (1964) and others is mid- to late-Sehoo age; it was a stillstand level of Lake Lahontan as the lake receded in late Pleistocene and early Holocene time from the 4370-ft highstand. Numerous ^{14}C dates have been obtained on calcareous tufa from this shoreline level in other parts of the Lahontan basin, and they range between 11,000 and 20,000 years (Broecker and Kaufman, 1965; Benson, 1978). A nodular sample of dendritic tufa was also collected and submitted for dating during this study, and the results are pending.

Many of the scarps in the Lahontan Reservoir area appear to be very young geomorphically. The low sun-angle photography flown for this study delineated a subtle but continuous scarp more than 4 miles long extending from the reservoir northeast to the Carson River. Aerial reconnaissance and field investigation show that this scarp is only one of several similar and parallel features, 1 to 2 feet in height, that cut a surface mantled by a blanket of eolian sand. Because these scarps are small in height, and occur in noncohesive eolian sand, it is believed that they are very youthful, and they should be evaluated as a possible location for the 1852 earthquake. Several exploratory backhoe trenches were emplaced across these scarps for this study, and the results are described in the section "Trenching Results".

Two additional structural features are of interest in this area. The young, subtle scarps described above are part of a zone of compressional deformation that is recognized both on the surface and in the exploratory trenching. A

Aerial view looking north along arcuate fault in southwest Carson Lake area.

series of parallel northeast-trending ridges and troughs occurs a few miles northeast of the reservoir, and field examination shows them to be compression folds in the Sehoo Formation (Dendritic Member). The folds range in length from 1/4 to 1/2 mile, and they have apparent amplitudes of 10 to 15 feet. These features have been delineated on the map as post-high shoreline fault scarps.

A second area of interest is located along the western margin of Swingle Bench where an arcuate compound fault scarp about 15 feet high cuts mid-Sehoo (dendritic) deposits. The scarp nearly forms a 90 degree bend, concave to the northwest, and geomorphic evidence suggests that the latest movement of this fault may also be relatively recent.

Area G: Pine Nut Mountains Area

This area includes the Pine Nut Mountains and associated mountain areas: Prison Hill, Hot Springs Mountain, Churchill Butte, and the Buckskin and Singatse Ranges.

Most of the youngest and intense faulting occurs in the western part of this area in a broad north-south-trending range-bounding fault zone. South of Hot Springs Mountain along the eastern side of Carson Valley a zone of distributive faulting occurs across a zone about 6 miles wide. Normal, antithetic, and graben structures displace alluvial fan deposits containing Holocene-age soils. Most displacements show relative movement down to the west.

North of Prison Hill along the west side of the Carson River, several north-south scarps cut late Pleistocene and Holocene fluvial terraces. Scarps are as much as 12 ft. high, and show displacements down to the east. Similar scarps also occur several miles farther north near the Carson City Airport where they appear to transect northeast-trending Carson Lineament scarps.

A series of north-northwest-trending scarps is located at the south end of Flowery Ridge and at the mouth of Eldorado Canyon. The faults near Flowery

Ridge are all pre-Holocene (probably pre-Wisconsinan) except for one which displaces Holocene alluvium near Highway 50. At Eldorado Canyon, all scarps appear to be pre-Holocene and are also probably pre-Wisconsinan.

Near Yerington, the east flank of the Singatse Range is marked by a fault scarp that predates the 4370-ft. shoreline.

Other young faults within the Pine Nut Mountain area generally consist of north-south-trending bedrock/alluvial lineaments with scattered occurrences of well-defined pre-Holocene scarps.

Area H: Truckee Range and Hot Springs Mountains Area

This area includes the Truckee Range, Hot Springs Mountains, and the Trinity and West Humboldt Ranges, as well as Winnemucca Lake, Copper Valley, the Humboldt Sink, and the northwest edge of the Carson Sink. The structural grain in this area is typically northeast-oriented, and it may represent a conjugate relationship to the Walker Lane which lies immediately west.

Prominent northeast-trending scarps and bedrock/alluvial contacts bound the east flank of the Truckee Range. They all appear to predate the high Lahontan shoreline. To the north, north-south scarps bound both sides of Fireball Ridge. The western scarp along the Ridge is possibly Holocene age based on geomorphic and soils evidence, but clear age relationships are lacking. Several similar scarps also occur slightly west of Fireball Ridge in North Valley.

The western part of the Truckee Range has northeast- and northwest-oriented scarps which show clear evidence of movement in the last 12,000-18,000 years. South of Marble Bluff northeast-trending scarps branch from the Walker Lane and cut post-high Lahontan shoreline deposits. In Little Valley, T22N,R24E, a group of northwest-trending fault scarps also break post-high shoreline deposits.

The scarps in the Copper Valley area are Pleistocene features, and a number of them are geomorphically old with well-dissected morphologies. The older scarps in T25N,R26E, however, are the southern end of a prominent range-bounding fault zone along the east flank of the Shawave Mountains. This zone is much younger to the north of the Reno quadrangle where a very prominent scarp displaces alluvium that is probably less than a few thousand years old.

The most extensive evidence of Holocene faulting in this area is seen in the Hot Springs Mountains area. North of Hazen, a series of northeast-oriented scarps bound an interior valley of the Hot Springs Mountains. Scarps on the east side of the valley range in height from 5 to 10 feet, while those on the west side are much smaller, generally about 1 ft. in height. Soil-stratigraphic evidence suggests these scarps are Holocene age. The scarps trend toward other faults south of Hazen which do displace mid- to late-Sehoo shorelines.

At Bradys Hot Springs a group of fault scarps transect a mid- to late-Sehoo shoreline at about elevation 4200 ft. A road cut exposes evidence of a displaced strong post-highstand soil, suggesting that movement has occurred since about mid- to late-Sehoo time.

At the northeast end of the Hot Springs Mountains, a group of scarps align with strong bedrock/alluvial faults and cut post-high shoreline deposits. Their northeasterly extent is uncertain because of the presence of an active playa.

It should be noted that the southeast flank of the Hot Springs Mountains and both the northwest and southeast flanks of the West Humboldt Range are marked by many numerous, linear, northeast-oriented scarps. All evidence indicates, however, that these scarps are all lacustrine in origin, although they may overlie pre-Sehoo Pleistocene faults.

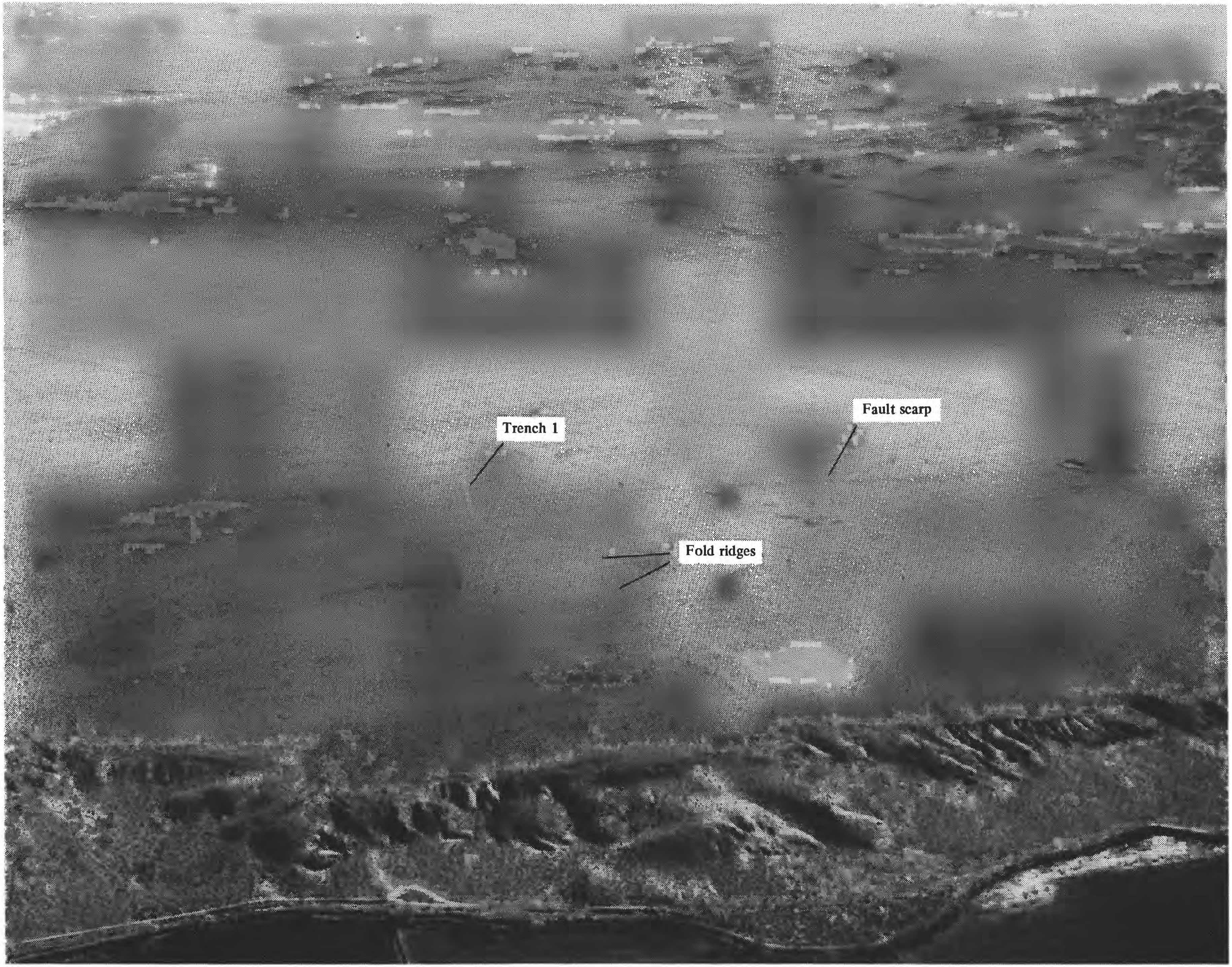
Area I: Dead Camel, Desert Mountains, and Carson Lake Area

This area constitutes a structurally anomalous fault zone that has in part been discussed previously. This area lies in the "gap" of northwest-oriented Walker Lane faulting, and is generally characterized by arcuate and curvilinear fault patterns. Analysis of 1:250,000-scale side-looking radar (SLAR) imagery for this area shows that several prominent structural-geomorphic features exist in the Dead Camel Mountains-Churchill Valley-Desert Mountains region which are probably reflections of bedrock structural grain. These are in part delineated on the map as bedrock/alluvial faults; other structures appear to be pre-Pleistocene in age. The structures are generally characterized by an east-west trend in the western part of the area, becoming a more northeasterly trend in the central part of the area. The faults along the southern margin of the Wild Horse Basin, for example, exhibit these trends.

In the Carson Lake area, Morrison (1964) mapped a broad series of arcuate faults bounding the southern margin of the basin, the southeast part of which he termed the Wildcat Fault Zone. Because these faults occur in young deposits of the Fallon Formation (less than 4000 to 5000 years old), they were investigated in detail for this study, and eight exploratory backhoe trenches were dug at several places along these faults. The detailed results of the trenching are described in the section "Trenching Results".

The southeast part of the area - the Wildcat Fault Zone - was interpreted by Morrison as a concealed fault zone lying along, and parallel to, young shoreline scarps. Although Morrison did locally map some of these scarps as tectonic, this study indicates that all scarps are lacustrine in origin, and no definitive evidence of faulting was recognized in trenching in this area. However, this zone is still delineated on the map as a young structure because as noted by Morrison, the shoreline scarps appear to tectonically deformed (uplifted) based on a comparison of shoreline elevations.

The arcuate structure in the southwest part of the area near the Baker 16 bombing range is interpreted to be a tectonic fault scarp based on several lines of evidence. Trenching results and exposures near Highway 95 indicate clear evidence of faulting in the Sehoo and Fallon Formations, including apparent displacement of the Turupah Flat Ash (as named by Davis, 1978). Field mapping of this structure indicates that it does not coincide with any recognized



Aerial view looking south at fault scarp and fold ridges near Carson Dam.

shoreline elevation; it does, in fact, traverse areas of varying elevation and cuts both the post-Sehoo Indian Lakes and Fallon Formations. In the Baker 16 area, the structure is marked by an apparent west-facing scarp 1 to 3 feet high suggesting antithetic movement. Two samples of detrital charcoal from faulted Fallon Formation sediments were collected for this study and yielded ^{14}C ages of 1550 ± 140 (TX-4079) and 1680 ± 110 years (TX-4080).

Area J: Mason Valley-Weber Reservoir Area

This area includes Mason Valley, Campbell Valley (Weber Reservoir), Long Valley, Terrill Mountains, and parts of the Wassuk Range and Rawhide Flats.

Most of the young faults in this area occur in the vicinity of Weber Reservoir where a number of them are less than 12,000 to 18,000 years old. These faults are dominantly north-northwest trending and are interpreted as probable Walker Lane structures. Although no definitive evidence exists in this area to indicate right-lateral strike-slip movement, the morphology of the scarps is similar to that seen in the post-high shoreline scarps in the Pyramid Lake Segment. These scarps also trend to the south into northwest-oriented faults along the east flank of the Wassuk Range that Bingler (1978) believes to be possible Walker Lane structures.

Similar northwest-trending faults of pre-Holocene age bound the west side of Long Valley and the east flank of the Terrill Mountains. No recognizable fault scarps were mapped in Mason Valley, which was inundated by Lake Lahontan.

Area K: Carson Sink Area

In the southern part of this area, Morrison (1964) mapped several northwest-oriented fault scarps of post-high shoreline age, the largest of which he termed the Sagouspe Fault Zone. This zone of faulting is about 8 miles long and is exposed in canal ditches near Sagouspe Dam, where displacements of the Sehoo Formation can be seen. The faults offset late Sehoo lithoid tufa, but not late Sehoo lake sand or Fallon Formation sand. Faulting therefore appears to be late Sehoo (Holocene) in age.

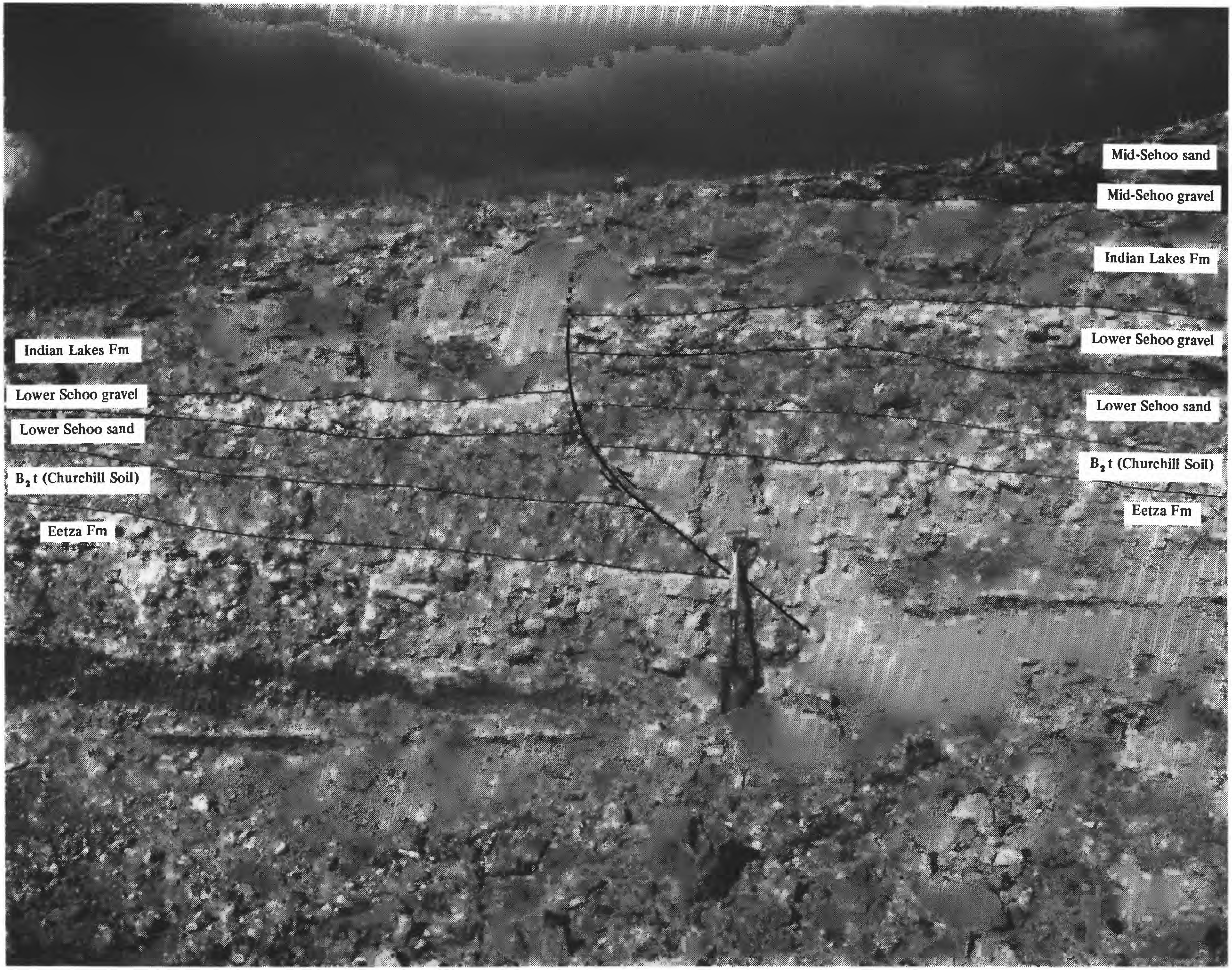
The northern part of the area has numerous features derived from the 1954 Rainbow Mountain earthquakes. These features, as previously discussed, consist primarily of fissures, lurch cracks, and other liquefaction-related features. As noted, most of these features are no longer visible.

Area L: Stillwater Range-Sand Springs Range-Fairview Peak-Dixie Valley Area

This area is characterized by dominant north-south- to north-northeast-trending structural grain, and it contains several zones of historic surface faulting which have been previously discussed in detail.

Of particular interest in this area is the relationship between the historic breakage and the prehistoric Holocene faulting. For example, south of Rainbow Mountain, the 1954 scarps trend into Holocene faults along the flanks of the Bunejug and Cocoon Mountains. These faults had no 1954 movement, but show clear evidence of post-early Sehoo movement (Morrison, 1964). Similarly, the 1954 Dixie Valley faulting trends into scarps showing evidence of Holocene movement. The 1954 faulting extended along the west side of Dixie Valley only as far south as Elevenmile Canyon, but field reconnaissance indicates this faulting is part of a zone of Holocene faulting extending south along the Sand Springs Range. Holocene-age scarps occur near the mouth of LaPlata Canyon and along nearly the entire length of the east side of the Sand Springs Range, where the range-bounding fault scarp looks geomorphically very young.

Also of interest in this area is the evidence found during this study of compression tectonics. Exposures in a series of gravel pits in Wyemaha Valley show evidence of high-angle reverse faulting and folding in Lahontan sediments of Eetza through early-Sehoo age. All of the structures have northeast orientations (generally about N45°-50°E) and recurrent movement is apparent on some of them. For instance, on one high-angle reverse fault trending N45°E, successively smaller displacements can be seen through a nearly complete sequence of lacustrine and subaerial deposits ranging in age from Eetza through mid-Sehoo. A number of these faults predate the mid-Sehoo Dendritic Member and show no surficial expresssion.



High-angle reverse fault in Lahontan sediments exposed in gravel pit in Wyemaha Valley.

The west flank of the Sand Springs Range has several dissected normal and antithetic fault scarps that, based on field reconnaissance, are Pleistocene age.

The west side of Black Eagle Hill is marked by a series of prominent scarps forming a zone more than 6 miles long. Field investigations indicate that these scarps are blanketed by a mantle of eolian sand, and stratigraphic relationships are obscured.

The west flank of the Stillwater Range shows only scattered evidence of pre- and post-high shoreline faulting. Almost all of the scarps are lacustrine in origin, and tectonic scarps can be clearly differentiated in only a few locations. In the shoreline zone between Cox and Shanghai Canyons, for example, several fault scarps transect the higher shoreline, but cannot be traced for more than about 1 mile each because of the presence of many parallel shoreline scarps. South of White Cloud Canyon, a group of pre-high shoreline fault scarps is preserved in a small reentrant not inundated by Lake Lahontan.

There is little doubt that a large range-bounding fault zone exists along western flank of the Stillwater Range. Unpublished studies by W. N. Melhorn indicate that several thousand feet of Pleistocene lacustrine sediments have been deposited in the Carson Sink just slightly west of this fault zone, based on an analysis of the log of the Standard-Amoco S.P. Land Co. Well #1 (S33,T24,R33E). And it seems likely that the scattered fault scarps described above are merely part of a much longer fault zone that is obscured by the numerous Lahontan shorelines. Consequently, that portion of the zone which can reasonably be interpreted to be Pleistocene in age is inferred on the map.

TRENCHING RESULTS

Eleven exploratory backhoe trenches were dug in the Carson Lake and Lahontan Dam-Swingle Bench areas (Figures 8, 9). Both of these areas have young faults that are believed important in interpreting the regional tectonics within the quadrangle.

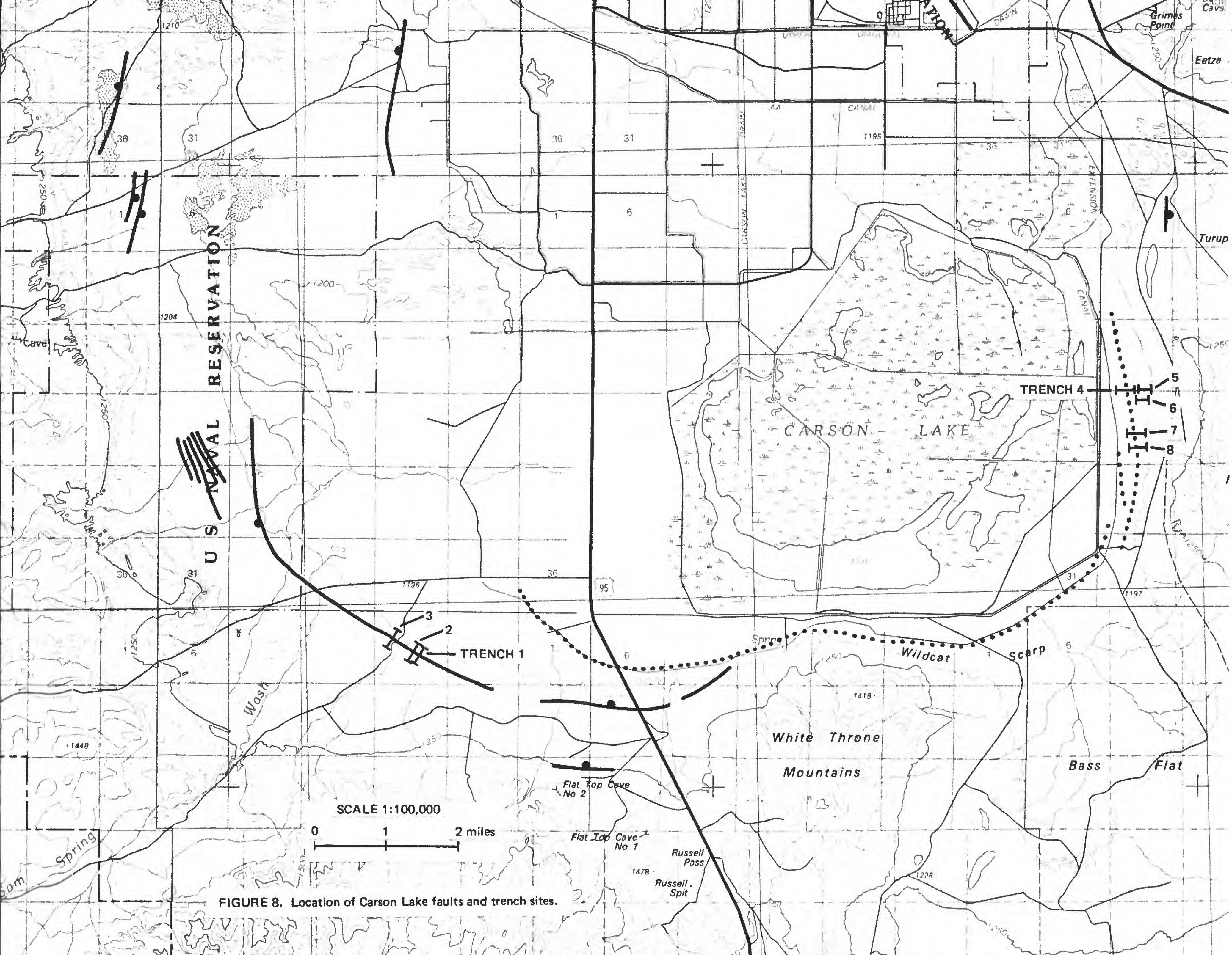


FIGURE 8. Location of Carson Lake faults and trench sites.

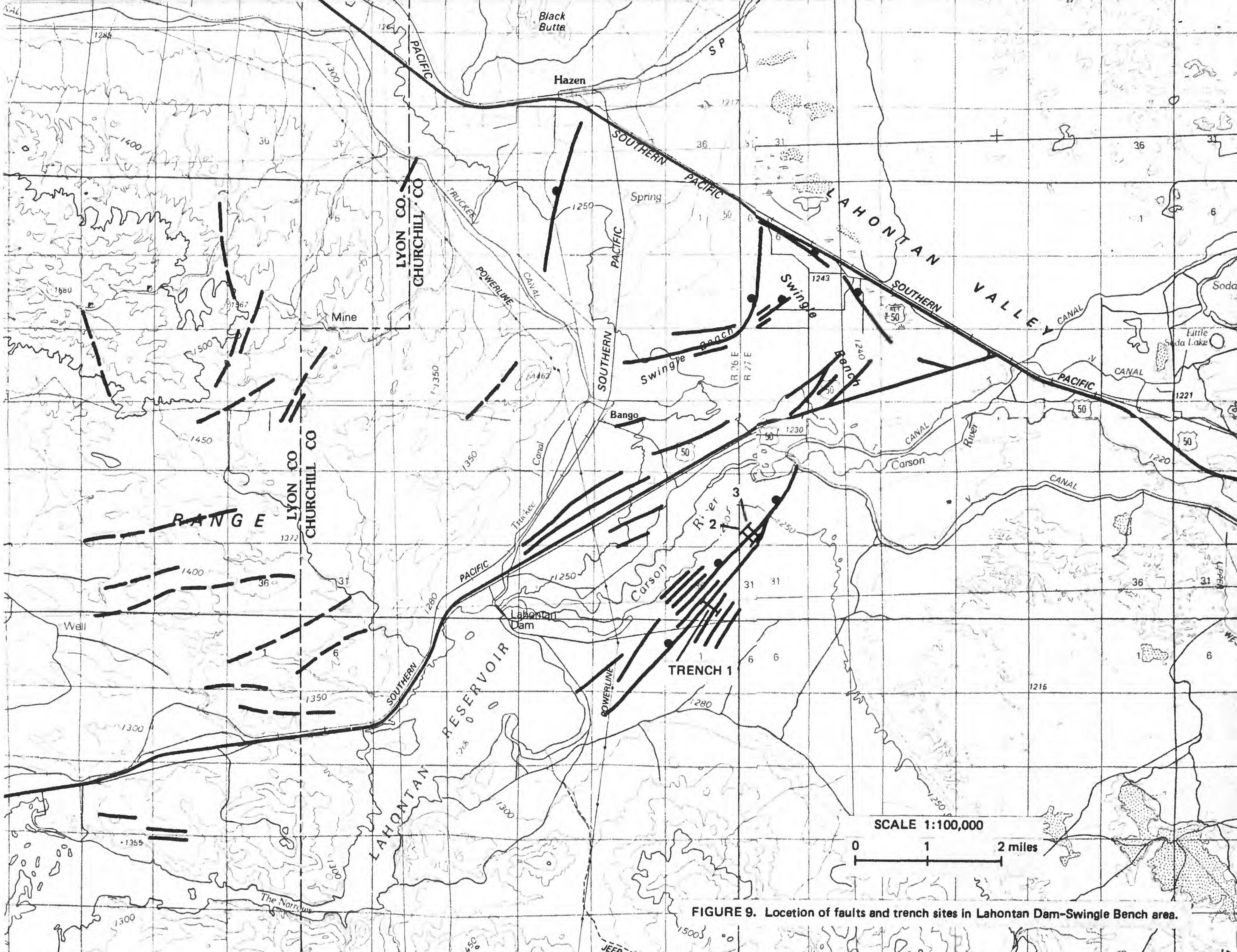


FIGURE 9. Location of faults and trench sites in Lahontan Dam–Swingle Bench area.

In the Carson Lake area eight trenches ranging in length from 75 to 200 feet were placed across the broad, arcuate faults mapped by Morrison (1964). Trenches 1, 2 and 3 were excavated across the fault in the southwest part of the area, but only Trench 1 exposed stratigraphy suitable for recognition of structural discontinuities (Figures 10, 11). This trench revealed multiple offsets in the Sehoo Formation, and probable displacements in the overlying Fallon Formation. Of particular interest in this trench is the exposure of the Turupah Flat Ash, which appears to be faulted, and which is a key late Holocene stratigraphic marker-horizon in the Fallon area. As previously discussed, two samples of detrital charcoal were collected and dated from this trench. One sample (TX-4080) clearly underlies the Turupah Flat Ash, and it yielded a ^{14}C age of 1680 ± 110 years. The second sample (TX-4079) appears to stratigraphically overlie the ash, but the depositional relationship is not definitive; this sample yielded a ^{14}C age of 1550 ± 140 years. These ages agree well with those cited for the ash by Davis (1978). These relationships suggest that movement on this structure has occurred in the last 1680 years.

Trenches 4 through 8 were excavated across scarps on the east side of Carson Lake along the Wildcat Fault Zone. The trenches in general showed no clear evidence of faulting; all scarps in this area showed cut-and-fill shoreline contacts and hence are believed to all be lacustrine features. Only in Trench 5 was slight evidence of faulting noted, where a small reverse offset was found in the Turupah Flat Ash.

In the Lahontan Dam-Swingle Bench area, three trenches were excavated across both the small subtle scarps and across the larger fold structures. Trench 1 was more than 650 ft. long and crossed both of the above mentioned structures. Generally well-stratified and continuous lacustrine beds were exposed along nearly the entire length of the trench, but little evidence of clean fault rupturing was observed. Rather, the sediments are deformed by folding and gentle warping. Two anticlinal folds separated by a syncline were exposed in the

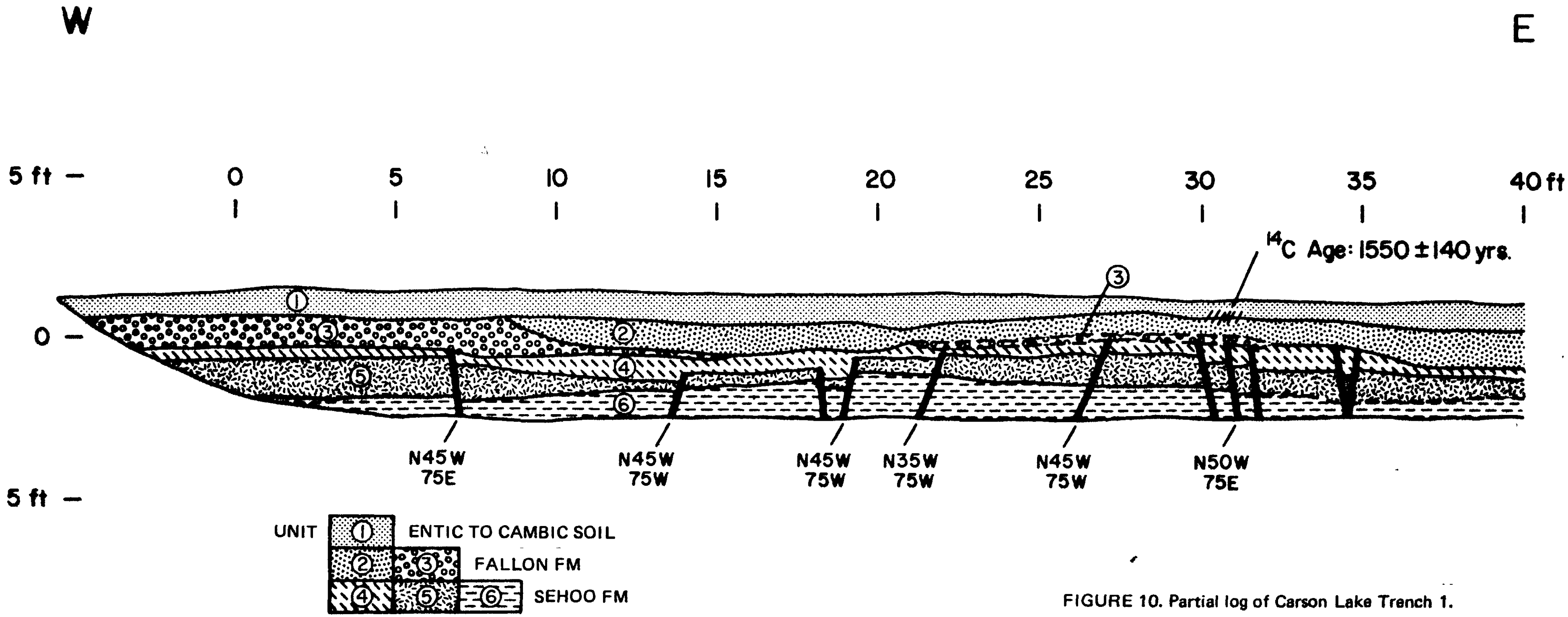


FIGURE 10. Partial log of Carson Lake Trench 1.

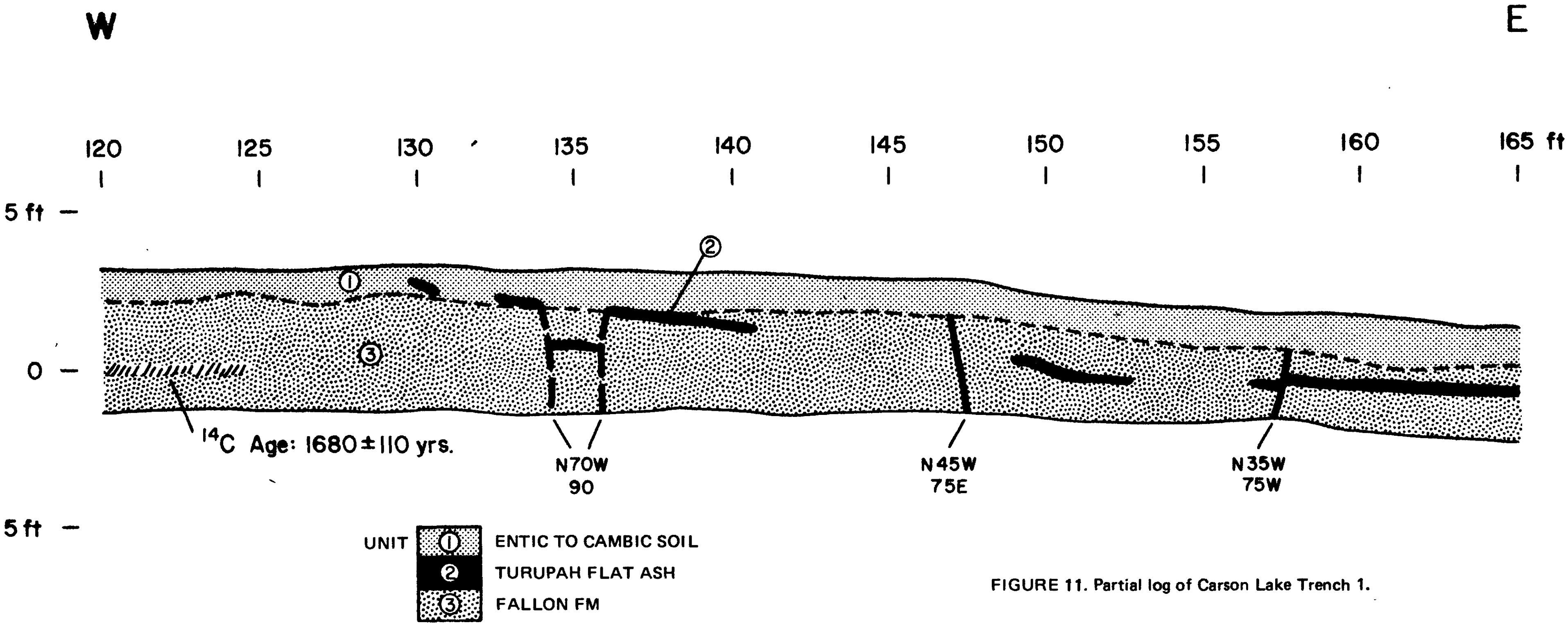


FIGURE 11. Partial log of Carson Lake Trench 1.

Sehoo sediments, and an auger hole indicated that the folds have an amplitude of at least 10 feet and a wave length of about 100 feet. Similarly, Trenches 2 and 3 exposed little evidence of a fault shear, even though the structure had clear surficial expression. Trench exposures indicate, however, that the sediments have been slightly warped about 1 to 2 feet, corresponding to the observed surface displacement.

All of the faults occur across a broad Lahontan terrace referred to as the mid-Sehoo Dendritic Terrace (Morrison, 1964). As mentioned, radiometric ages obtained from this terrace level have ranged between 11,000 and 20,000 years (Broecker and Kaufman, 1965; Benson, 1978). During this study, a sample of nodular dendritic tufa was collected from Trench 1 and submitted for ^{14}C dating; the results are pending.

ACKNOWLEDGEMENTS

The Principal Investigator would like to thank the following people for their assistance in reviewing and interpreting field relationships for this study: E. J. Bell; H. F. Bonham, Jr.; L. J. Garside; F. F. Peterson; and R. J. Watters.

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