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GEOLOGY AND EARTHQUAKE HAZARDS
RENO NE QUADRANGLE

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This information should be considered preliminary.
It has not been edited.

Introduction

Part I of this study was to map the surficial geology of the Reno NE 7 1/2-minute quadrangle, with emphasis on the Quaternary stratigraphy, in order to determine the recency and magnitude of movement on major faults in the area. With the geologic map as a base, geotechnical, seismic, and groundwater data and trenching results were then compiled into Part II of the study, the earthquake hazards map. This map will provide planners, developers, and the public with information on 1) the suspected response of geologic units to seismic shaking, and 2) the location and recency of movement on faults in the quadrangle.

Location

The Reno NE quadrangle is directly north of the Reno quadrangle (Figure 1) in west-central Nevada. It encompasses several unnamed bedrock mountain ranges separated by the intermontane basins of Lemmon Valley in the southwest, Hungry Valley in the east and northeast, Antelope Valley in the north and a portion of the valley north of Stead, commonly referred to as Red Rock Valley, in the west. U.S. Highway 395 passes just outside the southwest corner of the quadrangle, and the eastern half of the Reno-Stead Airport lies just inside the quadrangle's western border.

The populated areas are centered around Lemmon Valley playa and are confined to the southwest quarter of the quadrangle. The southeast quarter and northern half of the area are virtually uninhabited.

Physiography

The Reno NE quadrangle is in the western Basin and Range Physiographic Province which is characterized by north-northwesterly-trending mountain ranges separated by deep, sediment-filled, intermontane basins. In this area, the intermontane valleys are closed hydrographic basins in which surface runoff discharges into one of several playa lakes, the largest of which is Lemmon Valley playa located in the southwest quarter of the quadrangle. The other playas, Silver

Figure 1. Quadrangle location map

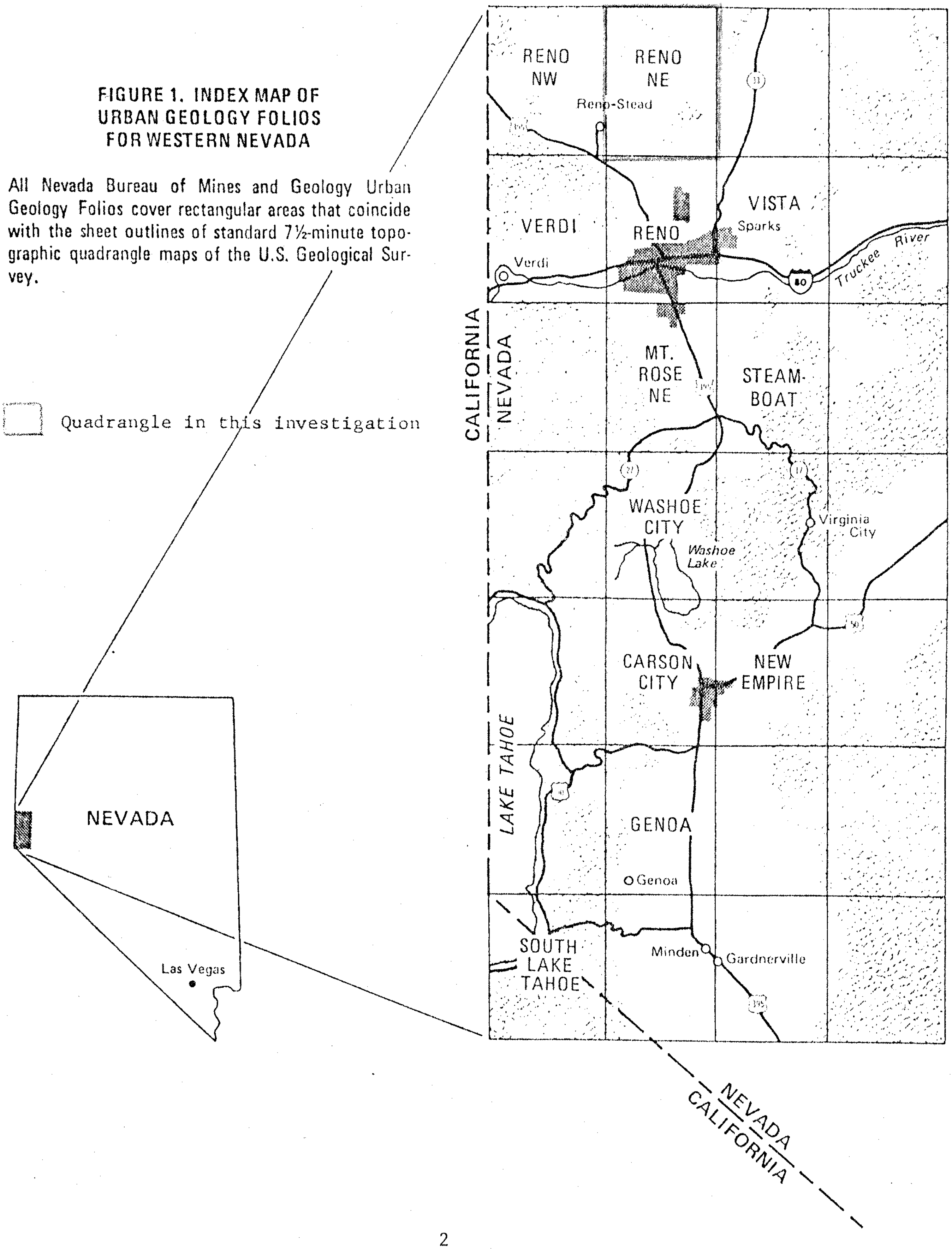


FIGURE 1. INDEX MAP OF URBAN GEOLOGY FOLIOS FOR WESTERN NEVADA

All Nevada Bureau of Mines and Geology Urban Geology Folios cover rectangular areas that coincide with the sheet outlines of standard 7½-minute topographic quadrangle maps of the U.S. Geological Survey.

Quadrangle in this investigation

Lake and Antelope Valley playas are located outside the quadrangle borders. These playas are commonly dry throughout the summer but may contain standing water in the wet winter months. Drainage from northern Hungry Valley does not discharge into a playa but flows north and eventually discharges into Pyramid Lake.

The maximum relief in the area is 379 m measured from Spanish Peak (1879 m) in the southeast to the floor of Lemmon Valley playa (1500 m). Several other peaks of approximately 1830 m occur at Hungry Mountain in the north and in the unnamed mountains north of Lemmon Valley.

Previous Investigations

Perhaps the earliest report of geologic significance on the Reno NE quadrangle was by Russel in 1885 in which he recognized the existence of a Pleistocene Lake in Lemmon Valley and showed it on a regional map of Lake Lahontan. Further work in the area was non-existent other than a few site-specific economic geology reports in the 1960's. Bonham's geologic map of Washoe and Storey Counties (1969; 1:250,000) marked the first published geologic mapping of the area. By 1973, Bonham and Bingler had mapped the Reno quadrangle directly south of Reno NE on a scale of 1:24,000, but it was not until 1978 that Soeller mapped Lemmon Valley and the deposits of Pleistocene Lake Lemmon in detail (1:24,000). He mapped approximately 64 km^2 of the area covered by the current study. Soeller and Nielsen (1980) then mapped the geology of the Reno NW quadrangle adjacent to Reno NE on a scale of 1:24,000. The earthquake hazards map for Reno NW has recently been published by the Nevada Bureau of Mines and Geology (Szecsody, 1983).

The groundwater conditions in Lemmon Valley have been covered in reports by Rush and Glancy (1967) and Harrill (1973). Mifflin and Wheat's (1979) investigation of pluvial climates based on studies of pluvial lakes included Pleistocene Lake Lemmon and the Antelope Valley Pleistocene lake.

Geology Map

Method of Investigation

Geologic mapping of Reno NE quadrangle began in March 1982 and continued for approximately one year. Following a reconnaissance of the quadrangle, photogeologic interpretation was used to map some areas. The quadrangle was then traversed on foot and by vehicle to check the photo interpretations, map more complicated areas, and collect samples. Mapping was completed on 1:12,000 low sun-angle photography and transferred to a 1:24,000 topographic base.

Of 34 sediment samples collected, grain-size analyses were performed on 31 of the samples (see Appendix A) for use in describing and determining the environment of deposition of the deposits. Over 100 rock and lithified sediment samples were collected for correlation and hand sample descriptions. Thin sections were made from twelve of the rocks in order to identify the mineralogy and lithology, many of which were not apparent in hand sample. The locations of samples used for grain-size analyses and thin sections are shown in Figure 2.

Numerous detailed soil profile descriptions were made at outcrops of key Quaternary units in order to differentiate and date the deposits. Bell and Pease (1980) have shown for the Reno area that the stage of soil profile development can be useful in determining the general age of Quaternary deposits and, in turn, the recency of fault movement. The reader is referred to the section "Recency of Fault Movement" in this paper for a more detailed discussion of this technique.

Stratigraphy

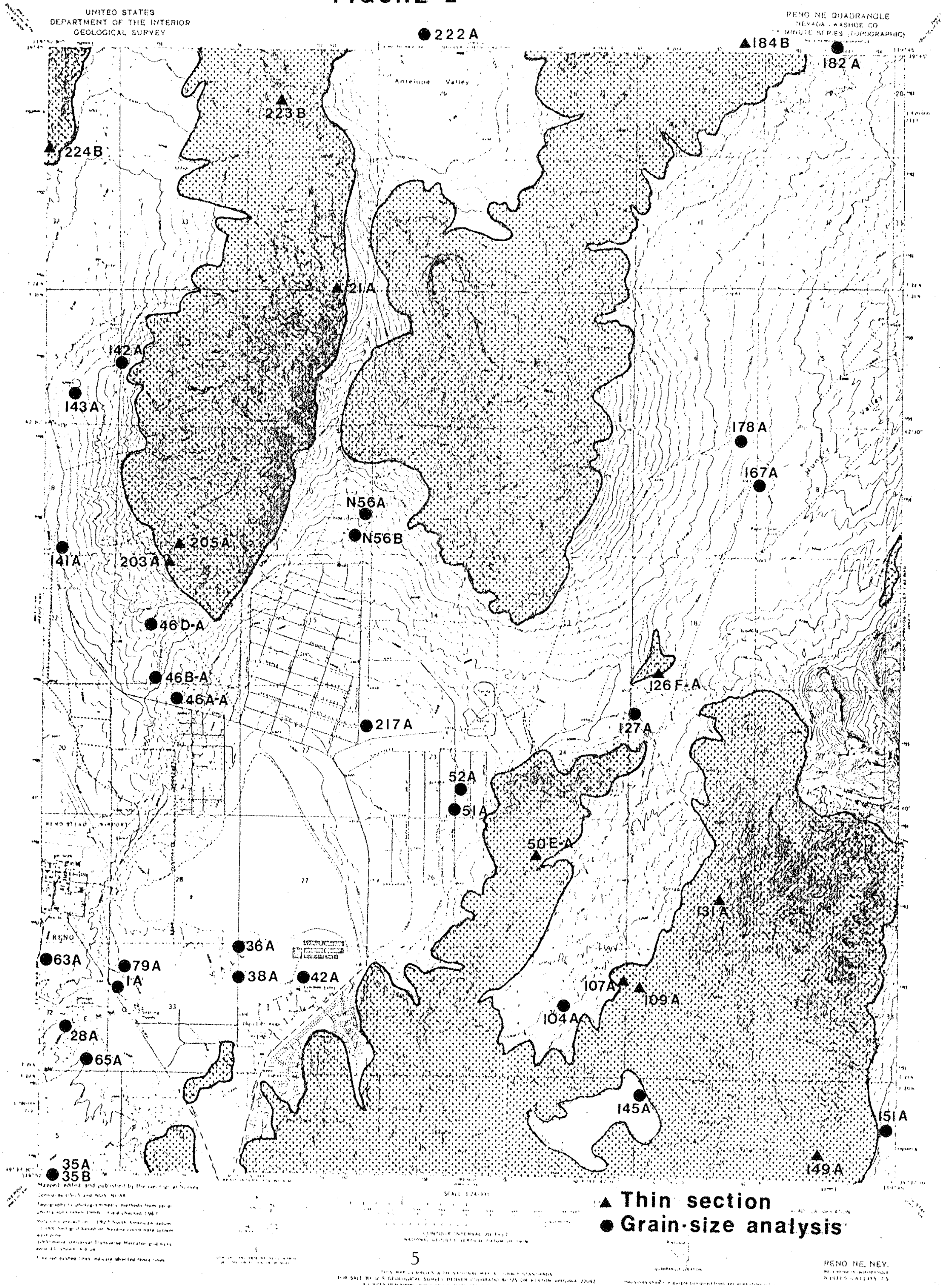
Brief descriptions of the geologic units described below can be found attached to the geologic map of Reno NE quadrangle at the back of the report.

Mesozoic

Peavine Sequence (Mzv) - The Peavine Sequence, tentatively dated as possibly Late Triassic to Early Jurassic, represents the oldest rocks exposed in the Reno NE quadrangle. This unit crops out in the southeast corner of the area and due

SAMPLE LOCATIONS

FIGURE 2



north of the Lemmon Valley playa as resistant knobby outcrops which form roof pendants in the granitic intrusives.

Lithologically the Peavine Sequence is quite variable. In the extreme southeast it is composed of dark gray, porphyritic meta-andesite which exhibits iron oxides and some copper mineralization at the contact with Mesozoic granodiorite (Mzgd). Mineralized areas are highly fractured and sheared. A thin section from this unit reveals an aphanitic groundmass of recrystallized feldspar, fine-grained biotite, and minor apatite, sphene, and magnetite surrounding subhedral to euhedral plagioclase phenocrysts up to 2 mm long.

The most common lithology noted in the outcrops of Mzv in the southwest and southeast is a gray, porphyritic meta-rhyolite to -rhyodacite. Massive to banded, mottled to porphyritic in texture, this unit consists of an aphanitic recrystallized matrix of quartz and potassium feldspar with some fine-grained plagioclase. Scattered euhedral plagioclase phenocrysts (5-10%) up to 3 mm in length and fine-grained clinozoisite (seen in thin section) characterize this unit.

Other lithologic variations include massive white to gray meta-rhyolite with abundant muscovite (in hand specimen) in the northwest, and a gray-brown meta-andesite with large, euhedral plagioclase phenocrysts (up to 9 mm long) noted just outside the northern boundary of the quadrangle on the slopes of Hungry Mountain.

Contacts between Mzv and the surrounding granodiorite range from mineralized and sheared to sharp, although Mzgd often exhibits flow structure and a mottled appearance at the contact with Mzv. The Peavine Sequence rocks have been subjected to regional metamorphism of the greenschist facies prior to intrusion and subsequent contact metamorphism (albite-epidote-amphibolite facies to pyroxene-hornfels facies locally) in the Jurassic to Late Cretaceous (Bonham, 1969; Hudson, 1977).

Granodiorite (Mzgd) - The predominent bedrock in the quadrangle is biotite-hornblende granodiorite, the most abundant plutonic rock in Washoe and Storey Counties (Bonham, 1969). This unit is light to dark gray, fine- to coarse-grained, and equigranular to porphyritic. As noted by Bonham (1969), the granodiorite is extremely variable both in the proportion of hornblende to biotite and the total amount of both present. It is not uncommon to see variations from quartz-monzonite to granodiorite to diorite in the same intrusive body at a single locale.

The texture of the granodiorite is as varied as the composition. In general it is porphyritic with subhedral to euhedral phenocrysts of plagioclase, biotite, and hornblende set in a medium- to coarse-grained groundmass of quartz and alkali feldspar; however, equigranular and granodioritic porphyry textures have also been noted. Xenoliths of andesitic rocks ("salt and pepper" texture) are relatively common within the unit.

Three joint systems at approximately right angles to each other cut the granodiorite in most areas forming jagged resistant outcrops. Some of the joint faces show slickensides, evidence of movement along the joints. Locally the unit is highly fractured and faulted, and in these areas, it is often highly weathered to disintegrated.

Ridge-forming aplite-pegmatite dikes,up to several meters wide,cut the granodiorite and are believed to be end stage differentiation products of the granodioritic and quartz monzonite (Mzqm) magmas. The aplite-pegmatite dikes are typically granitic in composition and consist of perthitic microcline, quartz, albite, and sparse micas (Bonham, 1969). A graphic granite texture is characteristic of the pegmatitic member. Basalt dikes and quartz and epidote veins also cut the granodiorite. Epidote can often be found as fillings along joints and fractures.

The granodiorite intrudes metavolcanics of the Peavine Sequence and is, in turn, intruded by quartz monzonite (Mzqm). Tertiary volcanics are in nonconformable contact with the granodiorite as are the Quaternary-Tertiary sediments (QTs) with the exception of local areas where faulting marks the contact. Many of the Pleistocene and younger deposits have been derived from weathering of the granodiorite and these deposits now lie unconformably atop or adjacent to their source.

The granodiorite is presumed to have been emplaced during the same period of time as the eastern part of the Sierra Nevada batholith and other major plutons in western Nevada. Isotopic age determinations on these plutons indicate ages from Jurassic to Late Cretaceous (Bonham, 1969); however, Bonham (1969) notes that direct stratigraphic evidence indicates possible emplacement as late as Early Tertiary.

Foliated granitic rocks (Mzfg) - These rocks are mineralogically identical to the granodiorite and consist of pinkish to dark gray, fine- to coarse-grained, equigranular diorite to granodiorite; however, unlike the granodiorite (Mzgd), these rocks are weakly foliated to gneissic in texture. Mzfg is believed to be part of or closely associated with the granodioritic intrusion based on mineralogical similarities of the two, the fact that local areas within Mzfg which lack foliation are similar in appearance to the granodiorite, and the lack of a definite contact between the two units. Therefore, this unit is probably of the same age as the granodiorite, Jurassic to Late Cretaceous.

Quartz monzonite (Mzqm) - Probably the second most abundant bedrock unit in the quadrangle, the quartz monzonite is pink to pale gray, medium- to coarse-grained, and equigranular to porphyritic. It ranges in composition from granite to quartz monzonite. According to Bonham (1969) the quartz monzonites are petrographically similar to the granodiorite with the exception of more abundant alkali feldspar in Mzqm. Biotite and hornblende are less abundant and locally absent in the quartz monzonite, although biotite appears to be most common when mafics are present.

Aplite-pegmatite dikes and large areas of granitic aplite commonly intrude the quartz monzonite. The dikes are particularly resistant to weathering and stand out as ridges in the more easily weathered quartz monzonite. Areas of Mzqm rich in biotite, are often deeply weathered (0.3-10+m) and disintegrated at the surface forming granular sand (grus).

Like the granodiorite, numerous fracture and joint systems cut Mzqm, and the unit is locally sheared with slickensides apparent on fracture faces. Xenoliths similar to those noted in the granodiorite are also present in Mzqm.

The quartz monzonite intrudes granodiorite and is, in turn, intruded by aplite and aplite-pegmatite dikes. Sedimentary units such as Quaternary-Tertiary sediments (QTs), older alluvium (Qoa), granitic alluvial fans (Qgs), and alluvial fan deposits (Qfg) lie in nonconformable contact with Mzqm and in many cases, are derived from it.

Mzqm like Mzgd, was probably emplaced during the same time period as the major granitic plutons in western Nevada. Therefore, it is presumed to be Jurassic to Late Cretaceous in age (Bonham, 1969).

Hartford Hill Rhyolite - Originally named the Hartford Hill Rhyolite by Gianella (1936) and later called the Hartford Hill Rhyolite Tuff by Thompson (1956), the name has traditionally applied to all silicic tuffs in western Nevada that form the base of the Tertiary section and underlie andesitic volcanics of the Alta and Kate Peak Formations. More recent work by Bingler (1978) in the Carson City-Silver City area revealed that the Hartford Hill Rhyolite is made up of a diverse sequence of welded ash-flow tuffs erupted from widely separated sources. He was able to recognize four new formations within the Hartford Hill Rhyolite and therefore, suggested that the formational name be abandoned.

For the purposes of this localized study, the name "Hartford Hill Rhyolite" has been retained for familiarity sake, and refers to four distinct cooling units or formations mapped at the base of the Tertiary section. It was beyond the scope of this mapping project to determine the correlative relationship of these units to those described by Bingler (1978); however, one unit in the ash-flow tuffs of Reno NE quadrangle was recognized by H. F. Bonham, Jr. (verbal communication, 1982) as the Nine Hill Tuff of Bingler (1978) and was designated as such by the author. The remaining ash-flow tuffs were named on the basis of mineralogy or texture.

On the basis of compaction foliation and outcrop patterns, the tuffs of the Hartford Hill Rhyolite appear to strike approximately N10°-75°E, and dip 33°-55°NW. At the thickest part of the section, these volcanics are over 500 m thick, less than the total thickness of 800 m measured by Bingler (1978) in the Carson City-Silver City area.

Faulting of the Hartford Hill Rhyolite is relatively easy to trace due to the general continuity of the individual tuff units. Faults within the Hartford Hill Rhyolite are variously oriented and probably steeply dipping. The sense and magnitude of movement on these faults was not determined in this study. In many cases, the faults appear to extend from the granodiorite into the tuffs or from the tuffs into the Kate Peak Formation suggesting a Tertiary age for faulting. However, these faults do not appear to displace the Quaternary-Tertiary basin fill sediments adjacent to the Hartford Hill Rhyolite, and, thus, faulting must pre-date these sediments.

In Reno NE quadrangle, the Hartford Hill Rhyolite units nonconformably overlie Mesozoic Mzgd and are unconformably overlain by Tertiary volcanics of the Alta and Kate Peak Formations. Although no age determinations were made on the tuffs in Reno NE, Bingler (1978) reports radiometric ages ranging from 22 to 28 m.y. on tuffs of the Hartford Hill Rhyolite.

Vitric tuff (Thc) - Probably the most variable of the tuffs, the vitric tuff ranges in color from cream to yellowish-tan to pale purple rhyolite to rhyodacite. Texturally, it varies from vitric tuff to vitric-crystal tuff. The variability of the vitric tuff is attributable to the fact that it is composed of several mineralogically different ash-flow tuffs which appear to be part of a single cooling unit (see Smith, 1960, for explanation of "cooling unit"). These poorly to densely welded tuffs are composed of sanidine, sanidine-smokey quartz, plagioclase-biotite, and biotite phenocrysts in a fine-grained groundmass of devitirifed glass shards.

The most abundant of these tuff units is cream to tan, moderately to densely welded, vitric-crystal tuff with approximately 10-20% euhedral to subhedral sanidine phenocrysts (1-3 mm long). Biotite phenocrysts may or may not be present. The sanidine-smokey quartz, plagioclase-biotite, and biotite-rich varieties are generally poorly welded in comparison to the sanidine variety. These tuffs occur near the top of the vitric tuff and where they often contain collapsed, coarse ash to lapilli-size pumice fragments (generally <10%; although locally as much as 30%).

The vitric tuff is the thickest and most areally extensive of the four tuff units. Based on outcrop thicknesses, this unit ranges from roughly 61 m to over 350 m thick and forms the basal portion of the Tertiary section.

Where moderately to densely welded, Thc forms resistant knobby outcrops, generally near the base of the section. However, the poorly welded parts of the unit often form white, bulbous, crumbly masses of low relief which are strikingly visible from a distance.

Pumice tuff (Thp) overlies Thc, and they are separated by a thin layer of white, airfall tuff which crops out locally. This unconsolidated lense of fine-grained ash is thought to mark the break between two cooling units, Thc and Thp.

Pumice tuff (Thp) - The pumice tuff is the most easily identifiable of the tuff units. It is a pale to dark gray, glassy, very pumiceous (10-30%), vitric-crystal tuff. The fine- to medium-grained, shard-rich, ashy matrix surrounds white, collapsed pumice lapilli (up to 4 cm long), subhedral to anhedral phenocrysts of sanidine and quartz, and gray, subangular lithic pebbles.

The pumice tuff is usually poorly welded, although at one locale in eastern Hungry Valley (T21N,R20E, Sec. 30, center), Thp crops out as a densely welded, perlitic glass or vitrophyre. The glassy nature of Thp suggests that it was relatively cool when deposited; therefore, devitrification did not occur.

In T21N,R19E, Sec. 36, NE1/4, Thp is overlain locally by a tan vitric tuff with phenocrysts of wormy smokey quartz, sanidine, and biotite, and collapsed pumice lapilli generally smaller than those in Thp. There is no apparent break between these two units, suggesting that they are different ash-flow tuffs within a single cooling unit.

Pumice tuff ranges in thickness from a few meters to over 300 m at its thickest exposure in Reno NE quadrangle. Despite the fact that Thp is consistently present in the Hartford Hill Rhyolite section east of Hungry Valley, it crops out relatively rarely. Due to it's poorly welded nature it is easily disintegrated and, more commonly, covered by the extensive rubble formed by weathering of the Nine Hill tuff. Where it does crop out, Thp exhibits somewhat cavernous to badlands-type weathering, with isolated pinnacles and blocks protruding. In the densely welded area, Thp forms a resistant ridge of low relief.

Nine Hill Tuff overlies Thp, and they are separated by a red clayey soil layer approximately 1-2 m thick. The red soil represents not only a period of erosion prior to the deposition of Nine Hill Tuff, but a boundary between cooling units.

Nine Hill Tuff (Thn) - The Nine Hill Tuff was recognized as a distinct cooling unit and formation by Bingler (1978) around Nine Hill in the Virginia Range, northeast of Carson City. From comparisons with Bingler's descriptions and field recognition by H. F. Bonham, Jr. of the Nevada Bureau of Mines and Geology, the tuff which overlies Thp in Reno NE quadrangle, is believed to be the Nine Hill Tuff.

The Nine Hill Tuff is reddish purple to pale orangish red, although a dark red to blue-black desert varnish is common. It consists of pumiceous, rhyolite vitric tuff which is densely welded. It is usually distinctively banded and vuggy as a result of stretched, flattened pumice lapilli. The lense-shaped vugs, often several centimeters long, are filled by quartz and potassium feldspar intergrowths which are the product of vapor phase crystallization. The fine-grained devitrified shards of the groundmass surround approximately 5-10% phenocrysts comprised largely of sanidine and plagioclase with minor quartz and few small (<1 cm) lithic fragments. The percentage of pumice fragments range from 10-25%.

Nine Hill Tuff overlies Thp everywhere it crops out with the exception of the outcrop in T21N,R20E, Sec. 20, NW1/4, where it overlies Mzgd. It ranges in thickness from a few meters to roughly 240 m, and although it is not extensive within Reno NE quadrangle, it is an areally extensive ash-flow sheet in western Nevada (Bingler, 1978).

Resistant to weathering, the Nine Hill Tuff is a ridge-forming unit which often forms a protective cap over Thp, preventing the latter from being eroded away. Extensive platy fracturing of Thn results in abundant platy gravels covering the slopes below outcrops of Thn and obscuring Thp.

Stratigraphic relations described by Bingler (1978) indicate that the Nine Hill Tuff was erupted during the Oligocene, about 25 m.y. ago.

Smokey-quartz tuff (Ths) - The least extensive unit, Ths, marks the top of the Hartford Hill Rhyolite sequence in Reno NW. It is an orangish-yellow to yellowish-brown, crystal-rich tuff with 50%-60% phenocrysts in a poorly to moderately welded, devitrified rhyolitic matrix. Euhedral to subhedral sanidine and smokey quartz phenocrysts (up to 2 mm long) make up the bulk of the crystals with lesser amounts of biotite.

This unit ranges in thickness from 25 m to over 60 m and is resistant to weathering, forming knobby outcrops of low relief and prominent ridges. Ths is unconformably overlain by Quaternary-Tertiary basin-fill sediments (QTs) which are, in turn, overlain by volcanic alluvium (Qva) derived from the weathering and erosion of the Hartford Hill Rhyolite, Kate Peak Formation, and the granodiorite.

The smokey-quartz tuff is believed to be a separate cooling unit from the Nine Hill Tuff based on their differing phenocryst mineralogies and phenocryst content. However, the typical indicators of a break between cooling units (airfall tuff, soil profile, etc.) where not noted in the field at the contact between Thn and Ths.

<u>Alta Formation</u> (Ta) - Three minor outcrops of the Alta Formation were mapped in Reno NE quadrangle. This unit is a dark gray (fresh) to pale purple, gray, or orangish-gray (weathered surfaces) andesite which locally exhibits a reddish-brown desert varnish. The andesite consists of an aphanitic groundmass of plagioclase needles with interstitial pyroxene and accessory magnetite. Parallel orientation of the plagioclase needles results in a trachytic texture indicative of the flow character of Ta.

Platy fracture, giving the appearance of foliation, is the most notable feature of the Alta andesite. These fracture planes are generally steeply dipping (61°-68°) and probably represent flow planes within the andesite. As a result of the fracturing, the Alta Formation crops out as loose rubble (talus) surrounding infrequent fractured outcrops.

In the northwestern part of the quadrangle, Alta andesite unconformably overlies granodiorite (Mzgd) and appears to be relatively thin (<30 m). At the outcrop near the center of the quadrangle, Ta appears to be in fault contact with

Mzgd on the basis of a sharp break in slope at the contact between the two units. Ta unconformably overlies Mzgd and the Hartford Hill volcanics in the southeastern corner of the Reno NE.

According to Bonham (1969), the Alta Formation is early or middle Miocene in age and unconformably overlies or locally interfingers with the Hartford Hill Rhyolite (although, this relationship was not noted in Reno NE quadrangle).

<u>Pyramid sequence</u> (Tp) - Bonham (1969) applied this informal name to an areally extensive suite of volcanic and sedimentary rocks which are typically developed around Pyramid Lake, northeast of the quadrangle. Locally, the Pyramid sequence was mapped by Soeller and Nielsen (1980) in the extreme northeast corner of the Reno NW quadrangle and it extends into the current study area.

The Pyramid sequence exposed in Reno NE quadrangle consists of dark gray to dull purple, porphyritic, basaltic andesite flows and reddish-purple volcanic agglomerate. An aphanitic groundmass of tiny, euhedral plagioclase needles surrounding phenocrysts of plagioclase (10-15%) and olivine (altered to iddingsite) comprises the basaltic andesite. The tops of flows are notably vesicular to scoriaceous. In general, the flows are dense and massive, though highly fractured locally. The volcanic agglomerate consists of angular, pebble-size fragments of vesicular, porphyritic andesite or basaltic andesite which are strongly welded together in an open framework, lacking matrix material.

Rocks of the Pyramid sequence are resistant to erosion and form knobs (agglomerate) and ridges (flows). These rocks unconformably overlie the granodiorite (Mzgd) and appear to be at least 30 m thick.

The age of the Pyramid sequence rocks is approximately late middle Miocene to Mio-Pliocene based on both radiometric dating and fossil floras (Bonham, 1969). However, Bonham (1969) points out that the majority of the sequence is late Miocene in age.

Kate Peak Formation (Tk) - The Kate Peak Formation crops out in the southeastern part of the study area. It is gray to reddish-gray (weathered), porphyritic to glomeroporphyritic, hornblende-biotite andesite. The fine-grained, vuggy groundmass surrounds approximately 20-25% euhedral to subhedral phenocrysts of plagioclase up to 1 cm long which often occur in aggregations (glomeroporphyritic texture). Euhedral to subhedral hornblende phenocrysts (8%) up to 5 mm long, anhedral biotite phenocrysts (3%) up to 2 mm across, and few lithic fragments are also visible in hand samples of Tk.

Outcrops of the Kate Peak Formation in Reno NE quadrangle are generally massive and resistant to weathering, forming irregular, bouldery outcrops. Tk unconformably overlies Mzgd and volcanics of the Hartford Hill Rhyolite and Alta Formation in the area.

On the basis of stratigraphic evidence in Washoe and Storey Counties and a radiometric age date of 12.9 m.y. outside the current sutdy area, Bonham (1969) places the age of the Kate Peak Formation as Mio-Pliocene to early Pliocene.

Note: The following descriptions of sedimentary units include references to soil profile development. Refer to the section "Recency of Fault Movement" in this report for a more detailed discussion of soil profile development as an indicator of the age of geologic units.

Quaternary-Tertiary gravels (QTg) - This unit crops out in the southeastern corner of the quadrangle and is well exposed in several man-made trenches. It consists of gray to brown, very poorly sorted, moderately indurated, stratified, bouldery cobble gravel and sandy gravel. The gravels include subangular to subrounded boulders (up to 1 m diameter), cobbles, and pebbles approximately 60% of which are Tertiary volcanics (Alta Fm and Hartford Hill Rhyolite), Mesozoic metavolcanics, and basalt. The remaining gravels and sand are granitic in composition and generally highly weathered to disintegrated. Near the base of the unit the gravels are interbedded with cream to pale green to red, poorly consolidated, fine- to medium-grained volcanic sandstones.

QTg exhibits a well developed soil profile with an 0.3 m thick, cobbly gravelly sandy A horizon and a 0.5 m thick, gravelly sandy clayey B horizon which overlies at least 3 m of gravelly duripan. Many of the gravels exhibit iron-staining.

This unit unconformably overlies the Hartford Hill volcanics in the study area, and shows evidence of having been faulted and tilted possibly along with the volcanics. QTg strikes approximately N25°W and dips 15°SW. Fault gouge and faulting subparallel to bedding are apparent in the finer-grained volcanic sediments.

QTg is believed to be time-equivalent to the Quaternary Tertiary basin-fill sediments (QTs) on the basis of three common factors: 1) Both are derived largely from Tertiary volcanic sources but include a granitic component (Quaternary deposits in the quadrangle are predominately granitic in composition); 2) Both have been faulted and tilted; and 3) Both are highly weathered and exhibit a well developed soil profile with a thick duripan. These gravels may be Pliocene to possibly early Pleistocene in age if they are equivalent to QTs. (See the following section for a detailed explanation of the age of QTs).

Quaternary-Tertiary sediments (QTs) - Though not the most abundant unit to crop out in Reno NE, QTs is certainly the most widespread unit, underlying Pleistocene and Recent sediments throughout most of the quadrangle. QTs is composed of thick (tens of meters to possibly thousands of meters), extremely variable deposits of interbedded alluvial, fluvial-lacustrine, and pyroclastic deposits. Typical outcrops of QTs range from cream to gray to pale green, unconsolidated to moderately well consolidated, fine- to coarse-grained deposits of predominately volcanic and reworked-volcanic origin, however, arkosic sediments are locally abundant.

QTs includes massive, arkosic sandy gravel, gravelly sand, and granular to very fine sand; slightly reworked tuffaceous sandstone with interbedded lenses of airfall tuff and pumiceous, very poorly welded (possibly slightly reworked) tuff; very fine- to medium-grained feldspathic sands and silts derived from volcanic rocks with interbedded well rounded gravels; and slightly diatomaceous siltstone.

In the extreme northwestern corner of the quadrangle QTs overlies volcanics of the Pyramid sequence. In this area, QTs consists of steeply dipping (strike-N20°W, dip 45°SW), highly fractured airfall tuff with interbedded fine-grained feldspathic sandstones (weakly indurated), lenses of fine, subrounded pebbles, coarse-grained, muddy sands (reworked volcanics), and lenses of biotite-rich and mafic-rich volcanic sandstone. This sequence is over 23 m thick.

Of particular note is one of the fine-grained volcanic sandstone beds which contains abundant ostracod fossils. In a quick examination, Dr. James Firby, paleontologist at Mackay School of Mines, indicated that the ostracods were of Lahontan age or younger (late Pleistocene to Recent). However, after researching ostracod morphology and occurrences in Nevada and viewing the samples under a binocular microscope, the author believes that these ostracods are of the genus _Candona_ which suggests deposition in alkaline fresh water which is seasonally cold (Solomon _et al_., 1979). Ostracods of the genus _Candona_ have been described in eastern Nevada as Eocene to possibly Oligocene in age (Solomon, _et al_., 1979; Winfrey, W. Jr., 1960). Various species of _Candona_ have existed through the Tertiary and Quaternary epochs to the present and therefore, without a definite species identification, the timespan of these ostracods is too great to make them a useful index fossil for dating QTs. (Note: The author found that the ostracods in Reno NE are particularly similar to those described by Swain (1947) in the Pliocene Salt Lake Formation of northern Utah (_Candona cachensis_) which would agree with the time span of QTs deposition). However, there is definite evidence to discount a Lahontan or younger age as suggested by Dr. Firby; mainly that the ostracod-bearing sediments have been faulted and steeply tilted whereas Lahontan age or younger deposits elsewhere in the quadrangle are undisturbed; and QTs is overlain by pediment gravels of probable early Pleistocene age near the locale where the ostracods were found.

Evidence of faulting and tilting of QTs can be seen in many outcrops such as that noted above. In contrast, folding of QTs is only apparent on the larger scale. Contorted bedding of QTs is particularly distinct along the northeastern edge of the quadrangle, and the most spectacular example extends just outside the northeastern corner of Reno NE where upturned beds are bent at nearly a 90° angle. This structure is visible on 1:35,000 aerial photos of the area.

Where it crops out, QTs forms highly dissected exposures on the highlands adjacent to the bedrock ranges. QTs is generally overlain by a thin veneer of alluvium or lag gravel in the low-lying areas, where it is exposed in stream cuts. QTs unconformably overlies Mesozoic bedrock and Tertiary volcanic rocks but may be in conformable contact with the Kate Peak Formation according to data noted by Bonham (1969).

Bonham (1969) maintains that the clastic sediments (QTs) in Hungry Valley contain andesitic clastic material derived from the Kate Peak Formation,and that these sediments locally overlie the Kate Peak Formation. On this basis, he assigns these deposits to the Coal Valley Formation of Mio-Pliocene to mid-Pliocene age. However, he does state that the Coal Valley Formation represents sedimentary and volcanic rocks laid down in a number of individual basins, contemporaneously, but the deposits do not form a continuous sequence over a large area.

The author of this report has included in QTs not only the Pliocene sediments of Bonham but massive granitic basin-fill deposits. Erosion and deposition of granitic materials appears to have been largely confined to the Quaternary Period in Reno NE. Apparently there were few granitic sources exposed to significant erosion prior to this time. On this basis, without radiometrically dated samples or distinctive fossils, these granitic basin-fill deposits are thought to be possibly late Pliocene to early Pleistocene in age and thus, a Quaternary-Tertiary age is applied to QTs.

Granitic boulder alluvium (Qbg) - This unit consists of gray to brown, very poorly sorted, sandy boulder gravel. The gravels are subangular and range from pea gravel to boulders up to 1.3 m in diameter. Lithologies of the sands and gravels are predominately arkosic (Mzgd, Mzqm, Mzfg, quartz) with minor amounts of subrounded volcanic and metavolcanic clasts (Ta, Mzv). A yellowish red, clayey B2t horizon from 0.6-1 m thick has formed on Qbg over a C horizon of weathered to disintegrated gravels in a coarse sandy matrix. Qbg unconformably overlies QTs and is designated as early Pleistocene based in the well developed soil.

Boulder alluvium (Qbv) - The only outcrop of Qbv is located in T.21N., R.20E., Sec. 31, NW/4. It is composed of tan to dark gray, very poorly sorted, sandy boulder gravel. The gravel component includes pebbles, cobbles, and abundant boulders up to 3 m in diameter. Lithologies are predominately granitic with lesser amounts of Hartford Hill volcanics, Kate Peak Fm, Peavine Sequence, and Mesozoic basalt clasts. Qbv unconformably overlies QTs and the Hartford Hill Rhyolite. This unit appears to be the remnant of a boulder fan or a paleo-channel filling which may have debouched from the steep, narrow canyon east of the Qbv outcrop. The remainder of the fan or channel filling has been eroded away leaving only a remnant of the original deposit. Qbv is considered to be early Pleistocene in age on the basis of the granitic lithology, relationship to QTs, and dissection.

Old alluvial gravels (Qag) - This unit is composed of dark reddish gray, very poorly sorted, sandy cobble to boulder gravel. The gravels are predominately subrounded to well rounded Tertiary volcanic clasts up to 1 m in diameter with most in the 7-15 cm range. Most clasts have a reddish-brown desert varnish. Qag is approximately 2-2.5 m thick but was probably thicker in the past and has been deeply eroded leaving remnants of the original deposit. It overlies QTs in apparent angular unconformity and has a strongly developed soil with a duripan suggesting at least an early Pleistocene age and possibly older.

Old alluvium (Qoa) - This unit occurs as deeply dissected, old alluvial fan remnants extending out from the granitic mountain fronts. Qoa is composed of tan to brown, very poorly sorted, moderdately consolidated, pebbly silt to unconsolidated gravelly sand and muddy, sandy, pebble gravel. In most outcrops Qoa is predominately arkosic in nature, being derived from adjacent granitic mountains; however, locally the unit contains subangular, multilithic gravels of Ta and Mzv. Locally deposits of Qoa contain varying amounts of angular to subangular pebbles, cobbles, and boulders up to 0.3 m in diameter. Ventifaceted gravels are common at the surface of Qoa. The unit ranges in thickness from less than 1 m to probably tens of meters, although an exposure of the total thickness of Qoa was not seen in the field.

Qoa unconformably overlies QTs or granitic bedrock near the mountain fronts. It exhibits a strongly developed soil profile with a duripan approximately 0.5 m thick, and is believed to be of early Pleistocene age on the basis of the soil development and relationship to QTs.

Old gravelly alluvium (Qgv) - The only outcrop of Qgv is in the extreme southeast corner of the quadrangle. Here it is composed ot tan to reddish brown, very poorly sorted, cobbly, muddy fine sand to gravelly sand containing boulders up to 1.4 m in diameter locally. The deposit is predominately angular to subangular arkosic sand and pebble gravel (approx. 30%) with some rounded, carbonate-coated volcanic pebbles and cobbles (probably derived from QTg).

Qgv is generally poorly consolidated and appears to be at least 5.5 m thick. This unit exhibits a strongly developed soil profile with a weak duripan (carbonate lenses and stringers) and is considered to be early Pleistocene in age.

Alluvial fan deposits of Peavine Mountain (Qpf) - These deposits are extensive in the Reno area and crop out in the extreme southwest corner of Reno NE quadrangle. Qpf consists of reddish brown to dark yellowish brown, poorly to very poorly sorted, poorly bedded, muddy sandy pebble gravel. It is distinctive in that it forms a multi-colored desert pavement composed primarily of subangular, white, altered andesite pebbles (derived from the metavolcanics of Peavine Mountain). The deposit also includes gray to pink arkosic sand, and lesser amounts of red jasper, white quartz, and green to black metavolcanic(?) clasts.

The outcrops of Qpf in Reno NE represent the distal edge of an alluvial fan and thus, Qpf thins out to the northeast ranging in thickness from more than 2 m to a few cm at the distal edges. Qpf unconformably overlies QTs with QTs being exposed along stream cuts and dissected areas. A well developed soil profile with a clayey B2t horizon approximately 0.8 m thick has formed on Qpf suggesting an early Pleistocene age. Bingler and Bonham (1976) verify that Qpf is "the product of early Quaternary deposition related to rapid erosion or denudation of piedmont and mountain slopes."

Pediment gravels (Qpg) - The pediment gravels crop out as highly dissected remnants of an old pediment surface. This unit is tan to dark reddish brown, very poorly sorted, cobbly gravelly sand to sandy gravel with subangular to notably subrounded pebbles, cobbles, and boulders up to 0.4 m in diameter. The gravels and sands are predominately granitic; however, a significant component of Tertiary volcanic rocks and Mesozoic metavolcanic clasts are usually present, including Hartford Hill Rhyolite, Tp, Tk, and Mzv. Locally the gravels are ventifaceted and form a desert pavement, most of the clasts exhibiting a dark red desert varnish.

At the type locality, a wash cut in T.21N.,R.19E., Sec. 29, NE 1/4, exposures of Qpg show highly weathered and iron-stained, bedded sandy gravels underlain by cross-bedded, coarse granular sand. These sediments are approximately 2-3 m thick and unconformably overlie QTs. A thin soil with a well developed duripan, 0.6 m to over 1 m thick, has formed on Qpg coating the gravels with carbonate and forming a weak cement. The well developed soil and relationship with QTs suggest an early Pleistocene age for Qpg.

At this locale (and elsewhere along the Airport Fault scarp), the pediment gravels have been faulted and tilted by movement of the Airport Fault in early to possibly mid-Pleistocene time. Qpg strikes N12-20°E and dips 9-15°NW in this exposure, and several high angle faults with small offsets (<0.3 m) are visible cutting Qpg.

Based on the well developed duripan, the extent of weathering and dissection, and the unconformable relationship with QTs, the pediment gravels have been assigned an early Pleistocene age.

Volcanic alluvium (Qva) - The volcanic alluvium crops out in southern Hungry Valley adjacent to the Hartford Hill Rhyolite outcrops. This unit consists of brownish red to dark yellowish brown, very poorly sorted, pebbly muddy sand to muddy gravel and bouldery gravelly sand. Lithologies of this unit are highly variable, particularly on the east side of Hungry Valley where gravels and sands have been derived by erosion of Hartford Hill Rhyolite units and Mzgd. For example, near outcrops of Thn, Qva is composed almost entirely of Thn gravels and granitic sands. Farther from the Hartford Hill outcrops the granitic component increases and locally predominates.

Exposures of Qva indicate that it is at least 2 m thick although it thins in some areas to a surface of lag gravels over QTs. Qva unconformably overlies QTs and a moderately developed soil with a B2t, 0.15-0.3 m thick, has formed on Qva, thus, this unit is thought to be of mid- to possibly late Pleistocene age.

Granitic alluvial fan deposits (Qgs) - These deposits consist of pinkish to yellowish brown, poorly to very poorly sorted granular sand to locally gravelly sand. This unit is derived from local bedrock sources, Mzgd, Mzqm, and Mzv, and is predominately arkosic in composition; however, locally, minor volcanic gravels are present, probably derived from erosion of QTs or Qpg. Pebble and cobble gravels are common at the surface of Qgs in the northwest corner of the area, where they have been faceted (ventifacts) by windblown sand.

Qgs forms broad, slightly dissected alluvial fans which overlie Mzqm and possibly Qoa in the northwest, and QTs and Qoa in the northeast. In general, a well developed B2t horizon of probable Churchill-interval age has formed on Qgs; however, locally Qgs exhibits little or no soil profile development suggesting that this unit may be of possible Holocene age locally. On the basis of B2t horizon development in most areas, the age of Qgs is designated as mid- to possibly late Pleistocene with the acknowledgement that Qgs may be as young as Holocene locally.

Alluvium of Stead Airport (Qas) - The alluvium of Stead Airport, so named because it blankets the site of the Reno-Stead Airport, is a relatively extensive deposit on the west side of the quadrangle. It is comprised of reddish brown, very poorly sorted, pebbly muddy sand. The sediments are predominately arkosic in nature (especially the sand fraction). In contrast, the pebble component may include 50-60% subrounded volcanic and angular metavolcanic clasts. The volcanic/metavolcanic pebbles appear to be derived from Qpg and Qpf, respectively; whereas, the granitics are derived locally from erosion of uplifted Mzgd.

Qas appears to have had its source in the granitic bedrock north of Lemmon Valley playa. During faulting and uplift of the mountain range, (mid-Pleistocene?), rapid erosion caused alluvial streams to carry arkosic sands downslope where they mixed with and picked up gravels from Qpg. At the distal edges of Qgs, the alluvium incorporated clasts from Qpf. The Airport Fault scarp which had attained its current height prior to this time, was breached by Qas deposits which spilled over the fault scarp and were deposited on the downthrown side of the scarp.

Qas deposits are generally weakly dissected, form a broad, relatively smooth fan surface sloping to the southwest and unconformably overlie QTs. Thickness of this unit ranges from a few cm of lag gravel and sand to more than 2 m thick.

The soil formed on Qas has a moderately well developed, clayey B2t horizon, 20-30 cm thick and is believed to be a Churchill-interval Soil. On the basis of the soil development, and the fact that Qas breaches the early to mid-Pleistocene Airport Fault, a mid- to possibly late Pleistocene age is assigned to Qas.

<u>Older alluvium, colluvium, and decomposed granite</u> (Qfgo) - This unit includes three different types of deposits which range from grayish tan to reddish brown, very poorly sorted, muddy coarse sand and sandy pebble gravel to gravelly sand. The deposits are generally unconsolidated (locally moderately consolidated), arkosic, and have angular to subangular clasts derived from the adjacent and/or underlying granitic bedrock (Mzgd). Qfgo consists of 1) arkosic sediments eroding off of surrounding granitic knobs and depositing in small upland basinal areas or along the mountain front, 2) granitic colluvial deposits on bedrock slopes, generally less than 2-3 m thick, and 3) decomposed granite which has probably weathered in place with little movement of material. With the exception of Qfgo along the southeastern edge of the quadrangle, these deposits overlie Mzgd. In the southeast, Qfgo probably overlies Qgv.

Because the deposits of Qfgo have formed or been deposited by several different geologic processes and on slopes of varying degrees of steepness, the soils formed on these units are highly variable. For example, exposures of Qfgo along the southeast quadrangle boundary exhibit a well developed B2t horizon approximately 0.6 m thick (aridic Argixeroll) locally overlying a very weak duripan from 15 to 30 cm thick (aridic calcic Argixeroll). These soils may represent a time span from early to mid-Pleistocene. Elsewhere (in the upland basins) the soils formed on Qfgo are Churchill-interval Soils of probable mid- to possibly late Pleistocene age. On this evidence, Qfgo is designated as early mid-Pleistocene to possibly late Pleistocene in age.

Beach and lake deposits of late Pleistocene Lake Lemmon - The beach bar, forebeach, and lake deposits in Reno NE were deposited by waters of a late Pleistocene pluvial lake named Lake Lemmon by Hubbs and Miller (1948). Elongate, beach bar deposits indicate that Lake Lemmon occupied Lemmon Valley to an elevation of at least 1519 m (4980 ft) and apparent overflow into Hungry Valley (indicated by the small playa in T.21N.,R.19E., Sec. 24) suggested that the lake reached a maximum level of 1540 m (5050 ft). Using 1540 m as a maximum and 1501 m (4920 ft) (the current level of the valley floor), it appears that the lake reached a depth of almost 40 m (130 ft). At this maximum elevation, the lake had a surface area of 62 km^2 (24 mi^2) in the southwest quarter of the quadrangle (Soeller, 1978).

Included in these descriptions are the similar, contemporaneous beach bar and lake deposits in Antelope Valley at the center of the northern quadrangle boundary. Mifflin and Wheat (1979) note the lake altitude there as 1559 m (5112 ft); however, they do not indicate a maximum lake level due to the relatively poor preservation of lake features. The current author notes that beach bars at 1561 m (5120 ft) elevation indicate that the lake reached at least that level.

Figure 3 shows an aerial view of Lemmon Valley playa and the associated beach bar, forebeach, and lake deposits.

Beach bar deposits (Qb) - This unit is composed of yellowish tan to brown, moderately to poorly sorted, granule sand to muddy sand with interbedded pebbly lenses. Deposits of Qb are are well exposed in excavations at the She Neva borrow pit (T.21N.,R.20E., Secs. 14, 23). Here the deposits are unconsolidated to weakly carbonate-cemented, arkosic sands which are laminated to thickly bedded and exhibit parallel- and cross-bedding.

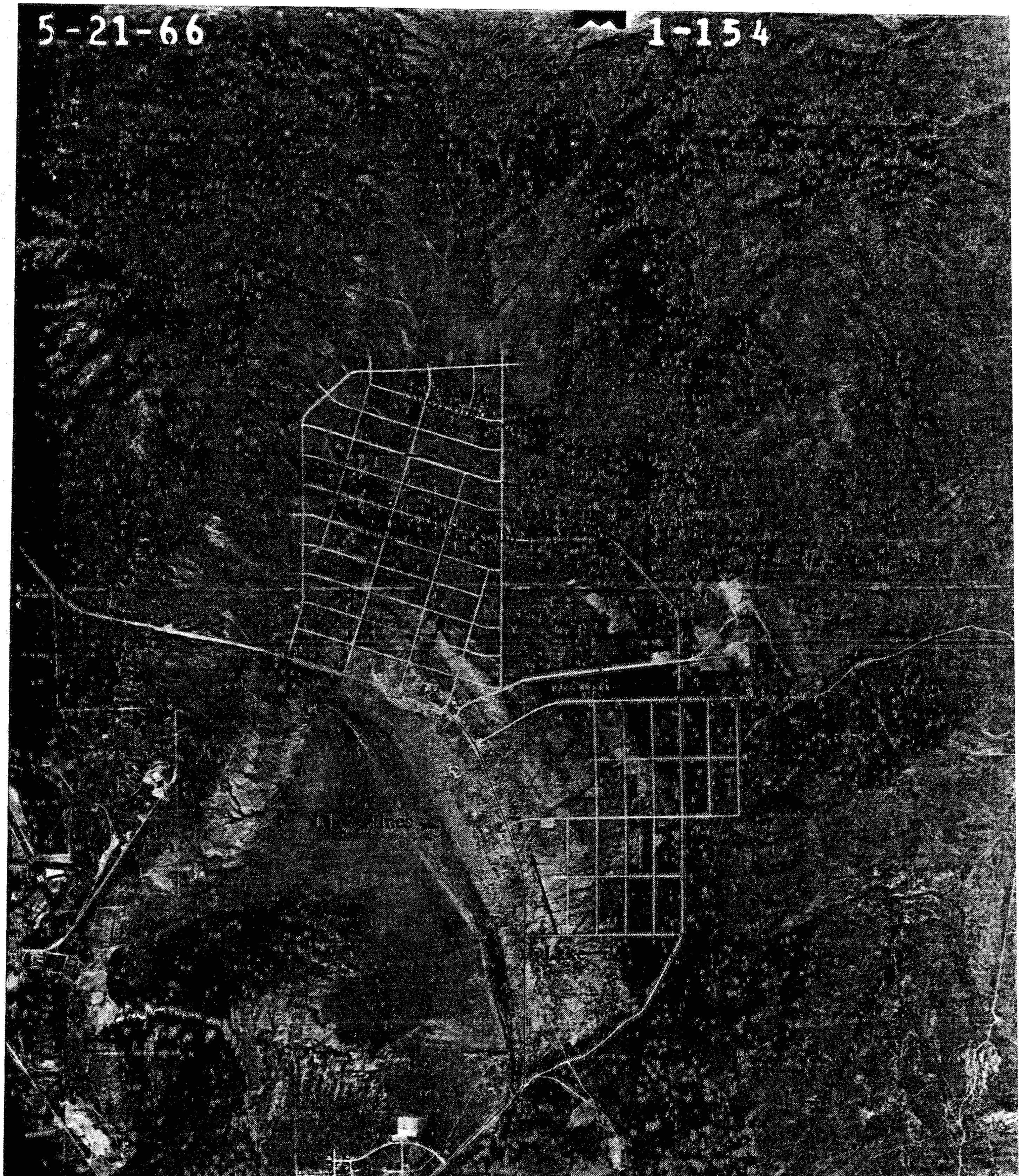


Figure 3. Aerial photograph of Lemmon Valley playa and vicinity

The sands of Qb form strands of sediments or beach bars at equal elevations on sloping to nearly flat ground. These bars may represent fluctuating lake levels or stable lake levels combined with strong wave action (Soeller, 1978). In any case, the beach bar deposits are best preserved northeast of Lemmon Valley playa at an elevation of 1519 m (4980 ft) and in Antelope Valley at an elevation of 1561 m (5120 ft).

Qb unconformably overlies granitic, basin-fill alluvium (QTs?) in a deep trench at the Sha Neva pit. To the west of the pit, Qb unconformably overlies Qoa, and south of the Sha Neva pit, Qb probably overlies other lake and beach deposits. Of particular note are the remnants of Qb which overlie Qas in T.21N., R.20E., Secs. 15, 16. Qas was determined from trenching and soil profile development to be of Tahoe-outwash age, about 60,000 years old. Thus, Qb is younger than 60,000 years. In addition stream channels of most recent alluvium (Qa) have breached the beach bars.

The exposures at the Sha Neva pit showed a yellowish-brown Camborthid soil formed on Qb; however, clayey sand, evidence of a possible B2t horizon was noted several centimeters below the surface on Qb in Antelope Valley and locally on Qb in Lemmon Valley. These soils are suggestive of a late Pleistocene to early Holocene age for Qb. In addition, Soeller (1978) reports that fossil bones of Camelops sp. found in Qb in the Sha Nevada pit (approximately 2.4 m below the original ground surface) were identified by Dr. James Firby, and he suggested an age of 10,000 to 70,000 years b.p. for the bones. The author searched for other fossils in Qb for dating purposes, but preservation of fossils must have been a rare occurrence due to the coarse-grained nature of the deposits. Thus, on the basis of the soils formed on Qb, the relationship to Qas, and the fossil identification, Qb is designated as late Pleistocene to early Holocene in age.

Forebeach deposits (Qfb) - The forebeach deposits lie between the beach bar and lake deposits in Lemmon Valley (see Figure 3) and are thought to be contemporaneous with them. They consist of brown to yellowish brown, poorly sorted, granular muddy sand to moderately well sorted, very fine sand. These gently-sloping deposits represent subaqueous sediments formed in shallow near-shore waters of Lake Lemmon (Soeller, 1978). They grade from coarser material near the beach bars to finer material near the lake deposits and exhibit faint strand lines visible on aerial photos. Forebeach deposits overlie and possibly interfinger with the lake clays (Ql).

Lake deposits (Ql) - These sediments are easily distinguishable from other Quaternary deposits because they consist of pale yellow to gray, well sorted, slightly sandy silt to clay. Subsurface drilling indicates that they are interbedded with fine to coarse sands, probably the result of fluctuating lake levels.

The lake deposits are generally flat-lying, thin-bedded sediments surrounding the perimeters of the Lemmon Valley playa, the small playa in Hungry Valley, and the Antelope Valley playa. Ql is cut by numerous shallow stream channels which eventually empty into the respective playas. Because of it's high clay content Ql is often the site of standing water in the winter months.

Although no exposures were noted in the field, Ql is believed to unconformably overlie basin-fill sediments (QTs). It is, in turn, overlain by most of the Holocene deposits including Qcd, Qpa, Qfg, Qa, Qws, Qsu, and Qp.

Soeller (1978) notes that the main thickness of Ql probably accumulated when Lake Lemmon was at or near it's highest level; however, the forebeach deposits which overlie Ql formed when the lake was at a lower level. All of the lake and associated deposits (Qb, Qfb) are considered to be of late Pleistocene to early Holocene age.

Clay dunes (Qcd) - The unique, elongate clay dunes consist of brown to grayish brown, loose, moderately well sorted, muddy fine sand and fine to medium, sand-size aggregates of clay derived from the playa (Qp) and lake (Ql) sediments. The clays are highly expansive, sticky and plastic when wet, and dry to form polygonal dessication cracks up to 0.15 m deep.

Clay dunes in Lemmon Valley and Hungry Valley have accumulated on the leeward sides of the playas, transverse to prevailing southwesterly winds, although the current wind direction is westerly to northwesterly. The deposits form dunes which are stabilized by sagebrush and dissected by recent stream channels.

Several factors suggest that Qcd is pre-late Holocene. Clay dunes overlie the lake deposits (Ql) which set a late Pleistocene-early Holocene older limit on Qcd. In addition, the dunes formed under different prevailing winds than those currently in effect, and thus, they are stabilized and do not appear to be accumulating new material. The fact that recent stream channels have dissected the dunes also suggests a pre-late Holocene age.

Floodplain deposits (Qfp) - These sediments are brown to yellowish brown, well sorted, slightly sandy mud to fine sand. They represent fine-grained materials from higher elevations which have washed downslope into the lowest part of the Red Rock Valley area where they were carried and deposited by axial streams. They are relatively flat-lying deposits which may be saturated or flooded during periods of runoff.

Qfp probably began accumulating in late Pleistocene and continued to receive sediments into the Holocene. Recent stream channels cut through Qfp and deposited lag gravels (Qa) at the surface suggesting that Qfp may not have been accumulating in latest Holocene.

Alluvium derived from Peavine fan (Qpa) - Similarities in appearance and clast lithology indicate that Qpa is derived, in part, of material eroded from Qpf (alluvial fan deposits of Peavine Mountain). Qpa consists of yellowish to reddish brown, poorly sorted, granule sand to pebbly muddy sand. The pebbly component includes angular to subangular, multilithic gravels (20-40%) of predominately white altered andesite and granitic rocks (as in Qpf). The sand fraction is arkosic.

Qpa tends to grade from coarse-grained (more, larger gravels) in the southwest near the outcrops of Qpf and Mzgd to sands at the distal edges of the deposit near Lemmon Valley playa. At the perimeter of the playa, Qpa thins out over Ql forming a thin lag deposit on the lake clays.

The age of Qpa can be bracketed by several factors. First, these deposits overlie lake (Ql) deposits of probable late Pleistocene to early Holocene age and they are, in turn, dissected by younger, recent stream channels. In addition, Qpa generally has no clayey B2t soil development, although locally a B2t of 0.3 m was noted (T.21N.,R19E., Sec. 33). These factors indicate that Qpa may be late Pleistocene to pre-latest Holocene in age.

Alluvial fan deposits (Qfg) - The alluvial fan deposits are composed of material derived from the weathered bedrock hills which has debouched from bedrock canyons and spreads as fans of alluvium on the adjacent lowlands. Where two or more fans coalesces they from an alluvial apron or bajada. In Reno NE, the alluvial fan deposits are comprised of grayish to yellowish brown moderately well sorted to very poorly sorted, granular coarse sand to sandy boulder gravel. The clasts are highly angular to subangular and are composed of local lithologies, mainly arkosic in nature. These deposits are poorly bedded and locally exhibit cut and fill structures. Boulder debris flows occur locally at the mouths of steep bedrock canyons. Qfg generally exhibits a gradational contact with other Holocene alluvium (Qa, Qsu).

Qfg forms broad, gently sloping, relatively undissected fan surfaces and steep colluvial slopes. The soils formed on these sediments range from those with a poorly developed B2t to Camborthids to those with no soil formation at all where fan surfaces are actively receiving material. On the basis of the soil evidence and the lack of dissection, these fans appear to range in age from late Pleistocene to the present.

Sheetwash, stream channel, and other Holocene alluvium (Qa) - Qa contains material derived from almost all of the geologic units in the quadrangle. These sediments are incorporated into sheetwash, slopewash, stream channel and lake margin deposits. Qa is composed of gray to yellowish brown, poorly sorted cobbly to pebbly sand and muddy sand to moderately well sorted, fine to coarse sand. Deposits range from thinly laminated or cross-bedded to massive and non-bedded. For the most part, these sediments are arkosic in nature with a small component of other rock types; however, in the northwest corner of the quadrangle, the stippled pattern on Qa indicates gravelly sand with a large component (approximately 40%) of volcanic and metavolcanic clasts (presumably derived from Qpg).

Included in Qa are interbedded to cross-bedded, sands to pebbly sands exposed in the small sand pit in T.21N.,R.19E., Sec. 33, NW 1/4. These sediments appear to have been deposited in Holocene time possibly by a stream which emptied at the margin of retreating Lake Lemmon. Less than a meter of fine-grained, massive sand (eolian or alluvial?) overlies these lake margin deposits and a cambic soil indicative of Holocene age has formed atop the fine sands.

In general, deposits of Qa are relatively thin, ranging from a couple of centimeters (sheetwash, slopewash) to several meters thick (3-7 m at the small sand pit). Qa generally occurs in narrow stream channels incised in bedrock and older sedimentary units, and as very gently sloping, thin sheets of sediment spread on the lower parts of the quadrangle.

No B2t soil horizon development was noted at any of the outcrops of Qa and, in many cases, no soil had formed on these deposits. This soil evidence and the fact that Qa is actively accumulating at the present time suggests a Holocene age for these deposits; however the lake margin sands may be late Pleistocene in age.

Windblown sand (Qws) - Abundant windblown sand occurs as small dunes to sand sheets throughout the quadrangle. These deposits consist of yellowish to orangish brown, poorly to moderately well sorted, medium sand. They are relatively thin deposits (less than 3-4 m) of arkosic, massive to cross-bedded, subangular to subrounded sands which have been deposited atop or mixed with most of the other deposits in Reno NE quadrangle. The sand dunes of Qws are more common than they appear on the geologic map because, in many cases, their small areal extent prevented mapping at the scale of this map (1:12,000 to 1:24,000).

The sands of Qws have probably been derived predominately by deflation of Tertiary and Quaternary sediments (i.e. QTs, Qfb, Qb). Ventifacts are commonly incorporated in Qws, and gravels or bedrock faces in adjacent geologic units are often fluted and ventifaceted. Many of the dunes and sand sheets are stabilized by vegetation; however, some of the sheet-like sands appear to be actively accumulating sand.

Poorly developed B2t soil horizons on some deposits of Qws, and the fact that these sands generally accumulated on the north or northeast sides (leeward) of ridges suggest that portions of Qws were deposited in possibly late Pleistocene to pre-late Holocene times when prevailing winds were southwesterly (see Qcd description). However, Qws deposition has continued, to a lesser extent, into the present.

Undifferentiated sand (Qsu) - The undifferentiated sand deposits mapped in Antleope Valley consist of yellowish brown to tan, moderately sorted, arkosic, medium to fine sands. Qsu probably forms a thin deposit of sand over the late Pleistocene to early Holocene lake deposits. The sediments of Qws appear to be a mix of windblown sands and sands derived from the adjacent beach bar deposits (Qb). They have a gradational contact with Qfg and some Qfg is incorporated into Qsu at the contact.

Qsu is considered to be Holocene in age based on its association with Qfg, the composition of the deposit (derived from late Pleistocene to Holocene deposits), and it's lack of a clayey B2t horizon.

Playa deposits (Qp) - Two outcrops of Qp occur in Reno NE quadrangle, the largest of which is Lemmon Valley playa and the smaller, a playa in Hungry Valley. The Antelope Valley playa is just outside the northern border of the quadrangle. These playas are best described in a definition by Thompson (1929) as "nearly level areas of alluvium in the lowest part of closed basins in arid regions which in wet seasons may be covered with temporary lakes and which are generally devoid of vegetation".

The playa sediments are composed of light brown to brown, moderately well sorted, slightly sandy to granule mud with interbedded fine sand and silt. Similar to the lake deposits (Ql), the surface of Qp exhibits extensive networks of polygonal dessication cracks.

In the Pleistocene to early Holocene, these playas were the sites of deposition for lake sediment (Ql) as indicated by the occurrence of Ql at the perimeters of the playas. Deposition of fine-grained sediments from runoff into the playas has continued through Holocene time to the present. In addition, deflation of Qp during the dry summer months has also taken place throughout Holocene (i.e. clay dune deposition) and continues to present a problem for local residents of Lemmon Valley today.

Landfill (Qlf) - The area marked as Qlf is the old Reno landfill site. This dump is no longer in operation and has been covered by a layer of machine-compacted sediment.

Relationship of Faulting to Regional Structure

The Reno NE quadrangle is in a tectonic area dominated by three major structural features: the Sierra Nevada Frontal Fault Zone, the Walker Lane, and the Olinghouse Fault Zone (Figure 4). All three features are presently seismically active and have been shown through previous regional reconnaissance to have had recurring activity during Quaternary time (Bell and Slemmons, 1979; Van Wormer and Ryall, 1980; Bell, 1981). The lack of apparent Holocene fault movement in

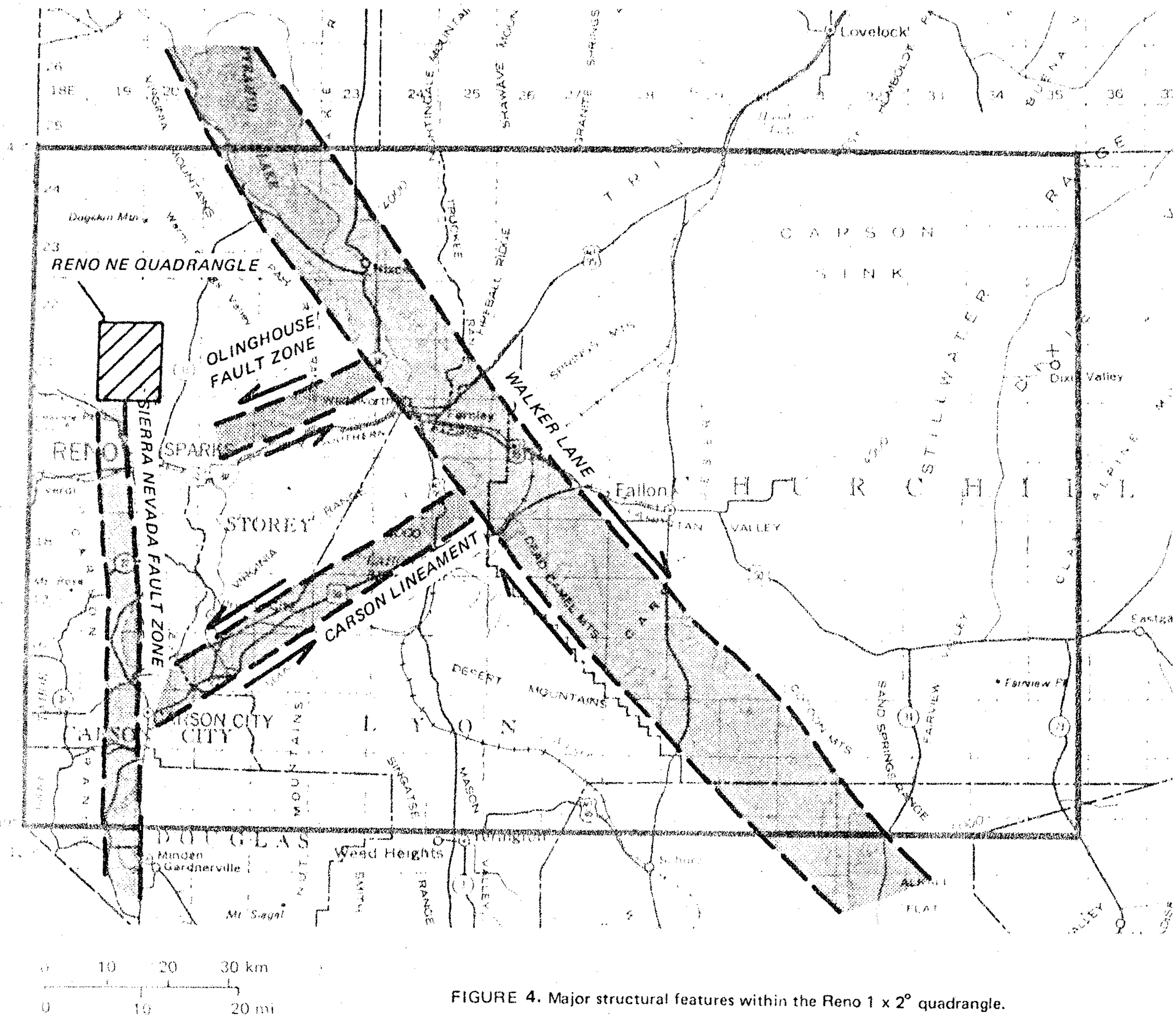


FIGURE 4. Major structural features within the Reno 1 x 2° quadrangle.

Reno NE quadrangle (see "Age of Youngest Fault Displacement" in this report) suggests that Holocene seismicity related to these features has not caused surface displacement on faults in the quadrangle. However, faulting and lineaments in Reno NE do appear to be related to at least one of these fault zones as discussed below.

Bell (1981) compiled a Quaternary fault map for the Reno 1°x2° quadrangle which includes Reno NE quadrangle. The open-file report which accompanies this map contains excellent explanations of the regional tectonics, seismicity and historic surface ruptures, and descriptions of faulting. The reader is referred to this map and report for more detailed information on regional structure and tectonics.

Faulting in Reno NE quadrangle can be divided into four categories based on trends of faults and geologic units displaced by faults. These categories are described below.

1) Bedrock faults mapped in the quadrangle trend predominately northwest; however, some do trend to the northeast. Locally these faults are draped by basin-fill sediments (QTs) but they generally do not appear to cut these deposits. The youngest rocks cut by the bedrock faults are Tertiary Kate Peak volcanics. Therefore, the bedrock faults are presumed to be pre-Pleistocene in age. The sense and magnitude of movement on these faults was not determined. These faults are probably related to the latest orogenic episode which began in middle Tertiary time and produced the present landscape (Bingler and Bonham, 1976). This period of tectonism consisted of major extensional normal faulting (basin-and-range faults) and strike-slip faulting which have continued into the present.

2) Range-bounding faults trending predominately north in Reno NE are also considered to be the result of basin-and-range faulting. These are apparently normal faults which have large displacements (300 m or more) and have resulted in the uplift of the bedrock mountains and the downdropping of intermontane

valleys. The range-bounding faults have probably had numerous tectonic movements since mid-Tertiary time with the most recent movements possibly in late Pleistocene.

3) The alluvial faults in the quadrangle generally trend northeast and northwest. In many cases, they appear to be extensions of bedrock or range-bounding faults into alluvium (i.e. faulting in the southwest corner of area; Airport Fault), or they parallel the range front but occur at some distance from the front (i.e. northeast corner of area). Where they displace Pleistocene alluvium, they may represent the surface expression of more recent movement on the range-bounding or bedrock faults. As described in the section on "Age of Youngest Fault Displacement", several movements on individual alluvial faults have taken place, with the most recent being in early to late Pleistocene.

4) The lineaments trend approximately N50°E in Reno NE quadrangle. They are very subtle features which are notable only on aerial photos. Originally these structures were thought to reflect the tilted, upturned bedding of the basin-fill sediments (QTs) underlying younger Pleistocene deposits. Field measurements and closer study of aerial photos indicate that QTs trends approximately N30°E compared to the N50°E trend of the lineaments and thus, the two are apparently unrelated.

Although the lineaments do not appear to be faulted structures at the surface, they still may be expressions of subsurface bedrock structures which are reflected in the sediments. On the Quaternary fault map by Bell (1981), the lineaments in Reno NE parallel bedrock/alluvial lineaments in southern Spanish Springs Valley, possibly associated with the Olinghouse Fault Zone. Therefore, the lineaments in the current study area may also be related to left-lateral movement on the Olinghouse Fault Zone.

The section "Age of Youngest Fault Displacement" in this report describes faulting in Reno NE quadrangle in more detail and discusses the evidence for age of latest displacements as shown on the "Earthquake Hazard Map". The reader requiring further information on faulting is referred to the map and text.

Earthquake Hazards Map

Introduction

The earthquake hazards map of Reno NE quadrangle provides information on 1) the suspected response of geologic units to seismic shaking, and 2) the location and recency of movement for faults in the quadrangle. The geologic map of Reno NE included with this report is the base from which the earthquake hazards map is derived. Geologic units mentioned in this part of the report are described in detail in the section entitled "Geology Map".

Method of Investigation

To provide information on the probable (suspected) response of geologic units to earthquake-induced stresses, data on the following parameters were compiled: 1) physical properties of the geologic units such as degree of weathering and induration, grain size, and degree of sorting; 2) geotechnical data on bulk density and standard penetration resistance; 3) saturation of the units based on depth to groundwater; 4) seismic velocities (longitudial (P) and shear (SH)) in the geologic units.

The geologic units were then categorized according to their probable seismic shaking response on the basis of shear wave velocities and bulk densities. Medvedev (1965) was the first to recognize a relationship between the degree of damage to structures and the geologic materials on which they were situated. He classified units into preliminary shaking intensity categories based on "seismic rigidity", a product of the longitudinal (P) wave and the density (ρ).

Similarly in this study each unit was categorized according to a "rigidity product", the product of the shear wave (SH) velocity and bulk density (ρ). This procedure was initiated by Bingler (1974) and modified by Trexler and Bell(1979). Classifications are modified by the presence of groundwater within 3 meters (10 ft) and 10 meters (33 ft) of the surface where saturation may result in liquefaction of unconsolidated, well sorted, fine-grained deposits.

Determination of the age of last movement along faults in this quadrangle is an important factor in preparation of the earthquake hazard map; however, age determinations can only be as accurate as the dating of the geologic units which the faults displace. In addition to using stratigraphic position, geomorphic surfaces, and degree of weathering for determining the age of last fault movement, the ages of soils which have formed on the fault scarps and adjacent surfaces have been used successfully in the Reno-Carson City area (Trexler and Bell, 1979; Trexler and Nichol, 1981, Bell, 1981).

Soil age relationships were developed for the western basin and range and the eastern Sierra Nevada by Morrison (1964) and Birkeland (1968). They found that unique soils have formed during each of the interglacial/interpluvial periods, and that these soils represent rather discrete time-stratigraphic horizons that can be age-bracketed by glacial, interglacial, pluvial, and interpluvial deposits of known age. Bell and Pease (1980) have adapted the work of Morrison and Birkeland specifically for earthquake hazard mapping. By using USDA Soil Conservation Service maps, aerial photographic interpretation, surface investigation, and trenching, the age of last fault movement (Pleistocene or younger) can, in many cases, be refined by examining the stage of soil development on the scarp and adjacent surfaces. The reader is referred to the section "Recency of Fault Movement" in this paper for a more detailed discussion of this technique.

The earthquake hazard map produced by this study is based upon currently available data. This map is intended to be used as a generalized guide and will be subject to change as new data become available. Assessment of potential seismic hazards at individual sites requires detailed engineering and seismic studies and such assessments should not be inferred from these maps.

Geotechnical Data

Geotechnical data for the Reno NE quadrangle is sparse largely because three-quarters of the quadrangle is uninhabited and thus, engineering and foundation studies have not been needed. The files of the City of Reno Engineer's Office and

SEA Engineers-Planners provided most of the geotechnical data used for this study. Eighteen geotechnical reports were reviewed. The areas covered by these reports are shown in Figure 5. From these reports, data on bulk density, standard penetration blow counts, and depth to groundwater were compiled from 139 borehole logs, 34 test pits, and 6 trenches. This information is summarized in Appendix B.

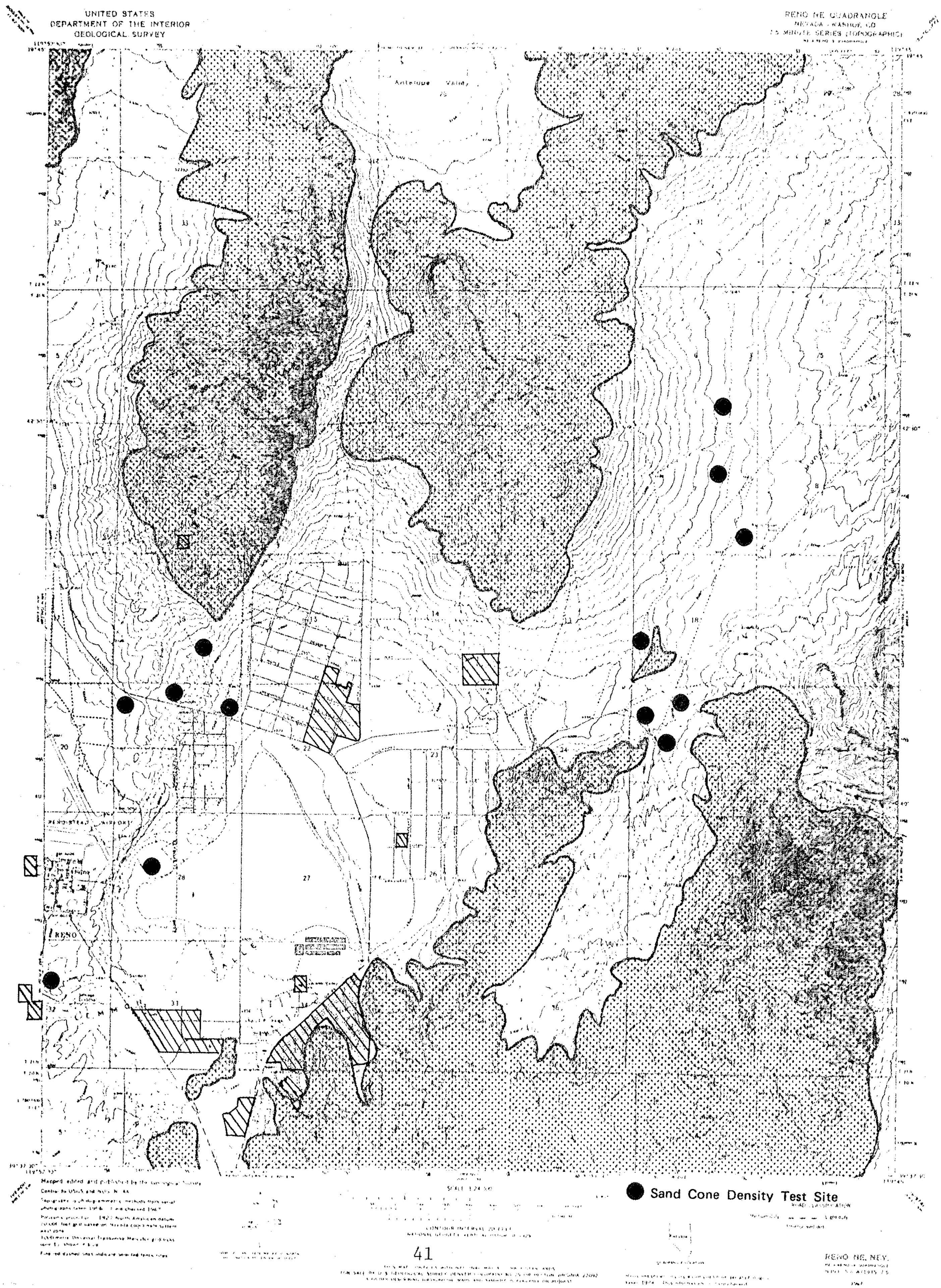
In order to supplement the bulk density data from the consulting reports, 13 sand cone density tests were performed by the author in May 1983. These data have been incorporated into the summary shown in Appendix B and their locations are shown on Figure 5.

Seismic Velocity Measurements

Seismic velocity measurements were taken at 29 locations on 17 geologic units as shown in Figure 6. Locations for seismic measurements were selected on the basis of 1) accessibility, 2) areal extent of the geologic unit, and 3) suspected liquefaction potential in areas of young sandy soils with a high groundwater table. In general, seismic velocities were not measured for bedrock (volcanic, granitic, and metamorphic) units because these areas have the least potential for severe ground shaking and liquefaction due to the strongly indurated or massive nature of the rock units. Seismic velocities were measured for most alluvial units with the exception of those which have limited areal extent (and in most cases, groundwater greater than 10m deep)(Qlf, Qsu, Qcd, Qfgo, Qpg, Qgv, Qbg, QTg), or inaccessible outcrops (Qp (saturated), Qag). Seismic velocities for Qp, Qfp, and Qcd were taken from data collected in the adjacent Reno NW quadrangle (Szecsody, 1983).

Compressional (P) and shear (SH)-wave velocities were recorded in the upper 9m (30 ft) of material by 12 geophones connected to a Nimbus 12-channel enhancement seismograph. At each location, forward and reverse (source at opposite end of geophone string) P-waves and right and left SH-waves were recorded. Comparison of forward and reverse P-wave measurements provided information on the degree of

Figure 5. Locations of Geotechnical Data Sites



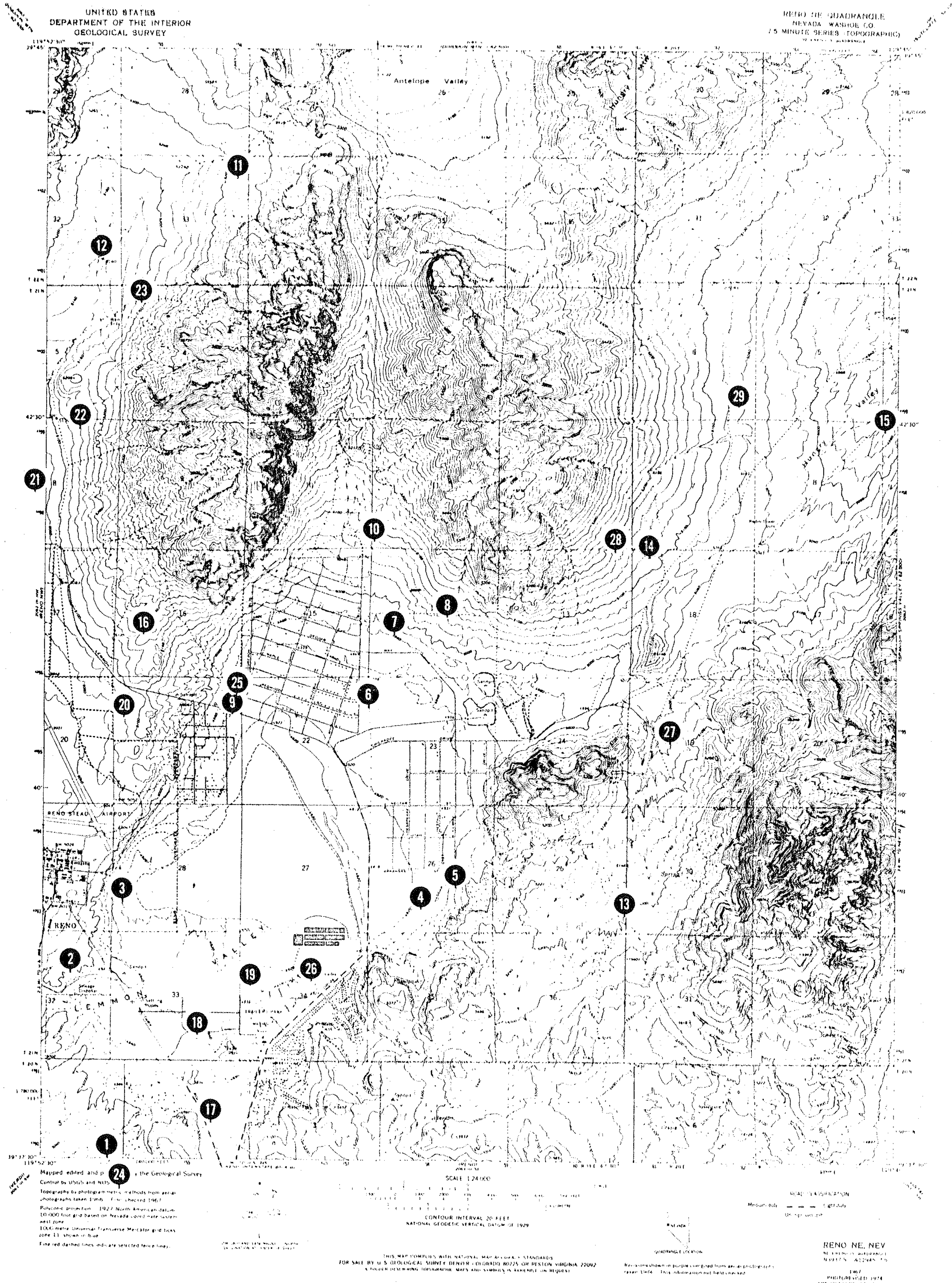


Figure 6. Seismic Velocity Locations

consolidation in the subsurface materials and the attitude and approximate depth of boundary layers (if present).

In order to measure SH-wave velocities, geophones with a horizontal component replace the P-wave phones. Shear waves are induced by striking an aluminum-capped plank which is held firmly in place beneath the front wheels of a truck (Power and Neal, 1976). One end of the plank is struck several times and the travel times are recorded. The opposite end of the plank is then struck an equal number of times. This input energy provides a record with very similar arrival times but opposite in polarity to the record from the opposite end of the plank. The reversal in SH-wave first arrivals is used to insure that shear wave arrivals are not confused with other extraneous wave forms. Figure 7 illustrates the method for obtaining shear waves and choosing first arrivals.

Time-travel plots have been completed for each of the 29 seismic sites shown in Figure 6. Table 1 shows the results for the seismic velocities measured during October 1982, March 1983, and April 1983, in the Reno NE quadrangle. The ratio of the shear wave velocity to the compressional wave velocity (Vs/Vp) is used as an indicator of the reasonability of SH- and P-wave velocities on the basis that Vs/Vp should not exceed approximately 0.7 for all earth materials with Poisson's Ratio less than 0.5 (water) (Knopoff, 1951).

Studies have shown that geologic materials having a low shear-wave velocity generally have a larger response to earthquake shaking (Seed and Schnabel, 1972). On this basis, the SH-wave velocities in Table 1 indicate that the Holocene windblown sand (Qws), sheetwash/stream alluvium (Qa), and possibily the alluvial fan deposits (Qfg) as well as late Pleistocene forebeach (Qfb) and lake (Ql) deposits may be more responsive to earthquake shaking than other geologic units in Reno NE with greater shear-wave velocities. However, in order to categorize the geologic units into shaking categories for the purpose of earthquake hazards mapping,

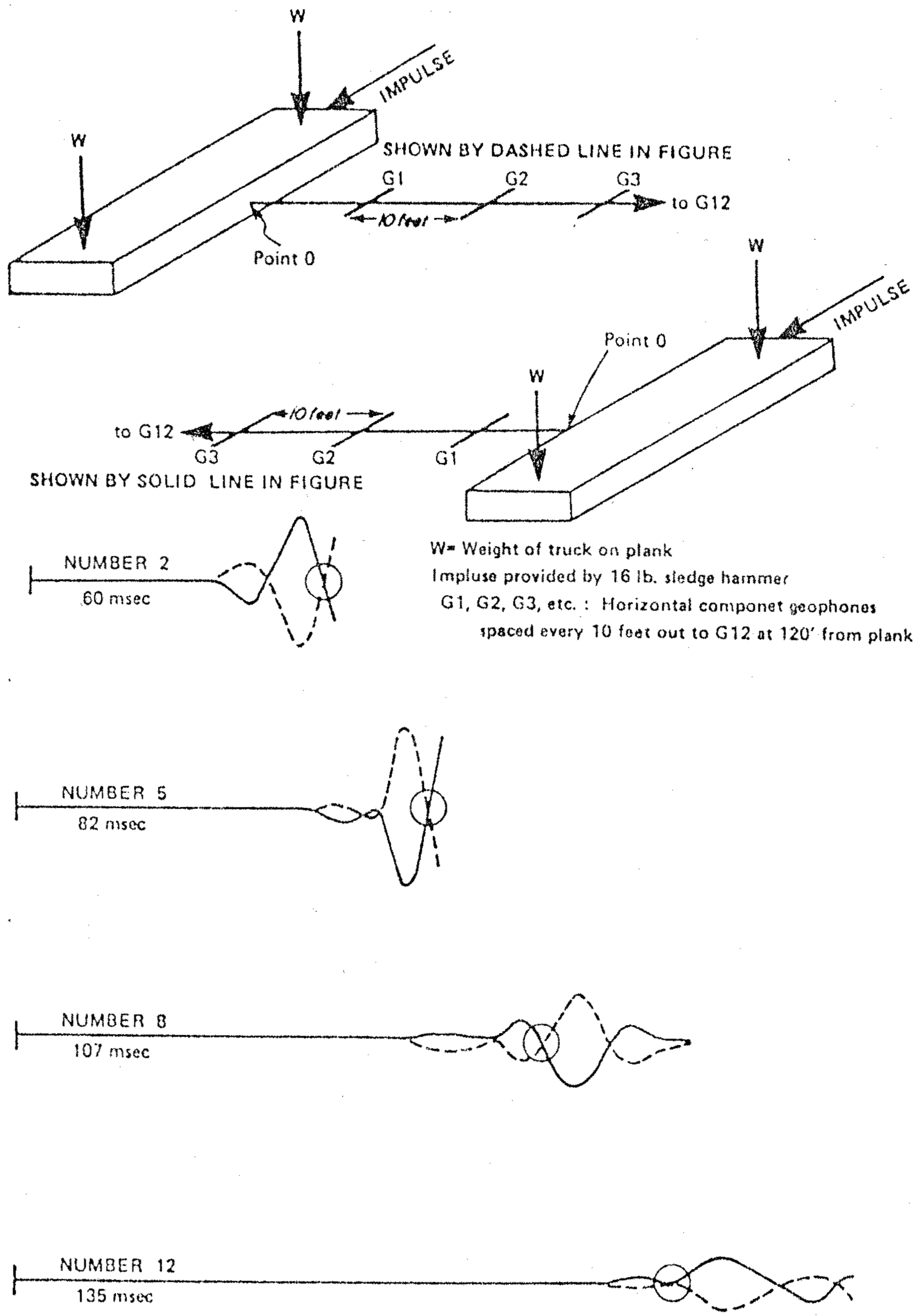


Figure 7. SH - wave source orientations and first arrivals.

Seismic Velocity Data (ft/sec)
Reno NE 7 1/2-minute Quadrangle
TABLE 1

Geol. Unit	Loc. No.*	Vp for	Vp rev	Vp avg	Comments	Vs	Vs/Vp
Qws	8	1053	—	1053	Poor records	+527	.50
Qa	5	1111	1154	1133		833	.74
	26	1111	1111	1111		581	.52
Qa/QTs	12	1000/2069	1333/2222	1167/2146	Thin Qa over Qts	+584/1250	.50/.58
Qfg	22	1200	1200	1200	Vp_{avg}=2556 below 4-5 m deep	794	.66
Qfg/Mzqm	11	1250/2813	1333/3500	1292/3157	Qfg=1+m thick over deeply weathered Mzqm	+646/1363	.50/.43
Qpa	17	1429	1250	1340	Vp_{avg}=2692 below 2 m deep	1000	.75
	18	1333	1111	1222		820	.67
	19	1250	1053	1152		698	.61
Qfp	21	1154	1143	1149	Vs measured=1087, too high	—	—
Ql	3	1136	1212	1174	Saturated approx. 0.1 m below surface	513	.44
	4	1142	1142	1142		448	.39
Qfb	6	1111	1250	1181		+591	.50
Qb	7	1220	1351	1286	Beach and windblown sand	698	.54
Qas	9	—	—	—	Poor records	—	—
	25	1250	1316	1283	QTs at 1-2 m deep with Vp_{avg}=2248	851	.66
Qgs	23	1200	1154	1177	Below approx. 4 m, Vp_{avg}=3640	800	.68
	29	2059	2174	2117		1186	.56
Qva	13	3913	4706	4310		2381	.55
	27	2857	2308	2583	Upper 3 m Vp_{avg}=1152	1818	.70
Qpf	24	2069	2174	2122		1184	.56
Qoa	10	2174	2143	2159			
	28	2581	2340	2461	Thin Qfg over Qoa	1176	.48
QTs	1	1667	2308	1988	Thin Qpf over QTs	1212	.61
	2	2000	1852	1926	Thin Qas over QTs	1230	.64
	14	1765	1250	1508	Thin Qfg over airfall tuff of QTs	968	.64
	15	2222	2963	2593		1053	.41
	16	1750	1852	1801	Thin Qpg over QTs	1129	.63
	20	2286	2143	2215	Thin Qas over QTs	1304	.59

* See Figure 6 for locations
+ 591=Vs calculated at 1/2 Vp

the depth to groundwater and rigidity products must be considered, in addition to shear-wave velocities.

Depth to Groundwater

Information on groundwater depth is useful in evaluating the liquefaction potential of alluvial materials. In general, alluvial deposits in which the groundwater table is within 3m (10 ft) of the surface may be subject to possible severe liquefaction. Liquefaction is also possible where the depth to groundwater is less than 10m (33 ft). For the purpose of delineating liquefaction potential, depths to groundwater have been contoured in 10-ft (3m) intervals up to 30 ft (approximately 10m).

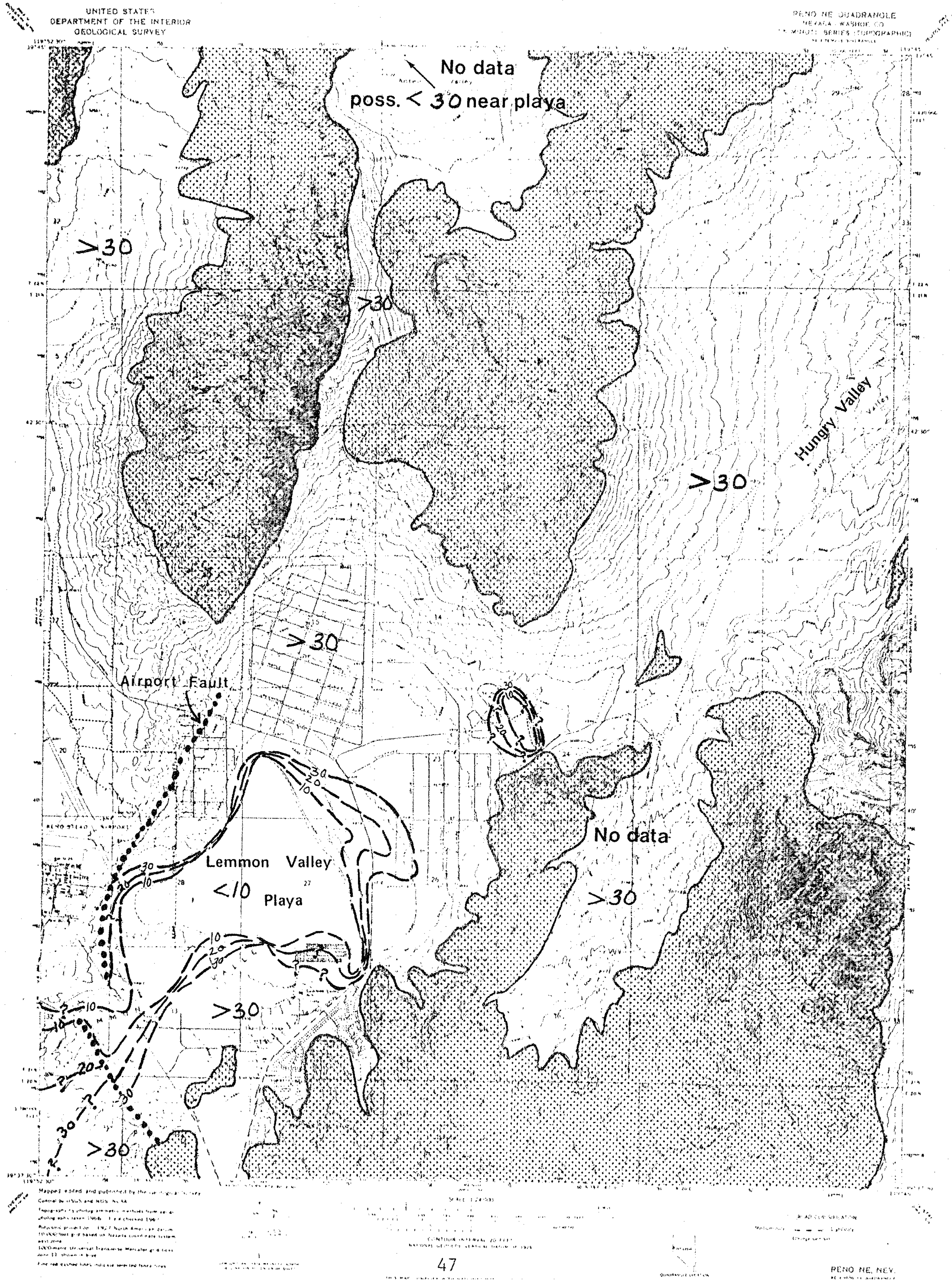
Data on depths to groundwater have been compiled largely from groundwater table elevation measurements made by the Washoe County Regional Planning Commission during the spring and summer of 1982. These data are confined to the inhabited areas surrounding Lemmon Valley playa. Data for the remainder of the quadrangle is sparse to nonexistent. Isolated livestock wells in Hungry Valley and north of Stead were measured during the course of this study by NBMG personnel to get some idea of the depth to water in these areas. Figure 8 shows the approximate depth to groundwater in Reno NE quadrangle.

The groundwater depth contours surrounding the small playa northeast of Lemmon Valley playa are conjectural. No depth-to-groundwater data is available for this area; however, standing water in this playa, as well as Lemmon Valley playa, indicates high groundwater tables exist in these areas, at least on a seasonal basis. To indicate this fact, groundwater contours (10, 20, 30 ft) have been somewhat arbitrarily drawn around the small playa. Similarly, the small playa in Antelope Valley which extends just inside the northern edge of the quadrangle, also may have a seasonally high groundwater table associated with runoff accumulating in the playa.

Groundwater contours in the extreme southwest corner of the area are shown

Figure 8.

APPROXIMATE DEPTH TO GROUNDWATER (in feet)



as questionable because they have been extrapolated into Reno NE from data in Reno NW quadrangle. On the upthrown side of the northwest-trending fault (see Figure 8) in the area, the groundwater table is believed to be confined to the Quaternary-Tertiary sediments (QTs) where it is greater than 3m (10 ft) deep.

Comparing Figure 8 with the geologic map of Reno NE quadrangle (this report), it is apparent that the water table is within 10 ft (3m) of the surface in the Holocene playa deposits (Qp), as well as some areas of the Holocene sheetwash/ stream alluvium (Qa), clay dunes (Qcd), and late Pleistocene lake deposits (Ql). These units, as well as some areas of Holocene undifferentiated sand (Qsu), alluvial fan deposits (Qpa), and late Pleistocene beach bar sands (Qb) are within the area encompassed by the 30-foot (approx. 10m) contours in Figure 8. However, depth to groundwater (as an indicator of saturation) is not the only criteria needed to evaluate the liquefaction potential of these units. Grain size, sorting, rigidity product, penetration resistance, density, and degree of induration must also be taken into account. For this reason, the reader is referred to the section "Potential for Ground Shaking During Earthquakes" in this paper for a detailed discussion of liquefaction potential in Reno NE quadrangle.

Rigidity Product

To categorize geologic units into probable (suspected) shaking response groups, the rigidity products are computed. A product of the near-surface shear-wave (SH) velocity and the bulk density (ρ), the rigidity product (RP) is a dimensionless number which is useful in determining the relative responses of geologic units to seismic shaking. The values used to calculate the rigidity products for the Reno NE quadrangle are presented in Table 2.

The geologic units having low rigidity products are the relatively young (late Pleistocene to Holocene), unconsolidated deposits including the playa (Qp) and sheetwash/stream channel (Qa) sediments, clay dunes (Qcd), and the lake (Ql) and forebeach (Qfb) deposits. The undifferentiated sand (Qsu) and windblown sand

RIGIDITY PRODUCTS AND SHAKING CATEGORIES—RENO NE
TABLE 2

Geologic Unit	Shear Wave Velocity (ft/sec) Vs mean	Bulk Density (g/cc) ρ mean	Rigidity Product Vs mean × ρ mean	Shaking Category Depth to Groundwater < 3m	< 10m	> 10m	Remarks
Qlf	–	–	–			V	GWT > 10m, unknown rigidity
Qp	[1]642	[1]1.09	[1]700	I			
Qsu	–	–	–		II		Probable low rigidity, GWT possibly < 10m
Qws	[2]527	–	–			V	Degree of shaking in Qws dependent on shaking category of underlying material
Qa	707	1.50	1061	I	II	II	
Qfg	794	1.88	1493		II	III	
Qpa	839	1.45	1217		II	III	
Qfp	[1]928	[1]1.81	1680			III	Qfp may have seasonally high GWT
Qcd	[1]714	1.22	871	I	II	II	Possible severe shaking where groundwater is < 10m deep due to low rigidity and granular nature of deposit
Ql	481	1.43	688	I	II	II	
Qfb	[2]591	1.47	869			II	
Qb	698	1.77	1235		II	III	
Qfgo	–	–	–			V	No seismic/density data; GWT > 10m. Shaking category III where Qfgo forms alluvial fans along mountain front
Qas	851	1.69	1438			III	Shown as category III where GWT < 10m because thin Qas overlies dense, locally cemented QTs. GWT in QTs
Qgs	993	1.68	1668			III	
Qva	2100	1.49	3129			III	
Qpg	–	–	–			III	Dense, cemented gravels, GWT > 10m
Qpf	1184	[1]1.73	2048		III	III	Shown as category III where GWT < 10m because thin Qpf overlies dense, locally cemented QTs. GWT in QTs
Qgv	–	–	–			III	
Qoa	1117	[1]1.74	1944			III	Variable severity of shaking where Qoa overlies shallow Mzgd and Mzqm
Qag	–	–	–			III	Overlies QTs
Qbv	–	–	–			V	Overlies Hartford Hill Rhyolite
Qbg	–	–	–			III	Overlies QTs
QTs	1164	1.42	1653		III	III	Density value for unconsolidated QTs: QTs moderately well consolidated or cemented locally
QTg	–	–	–			III	
Tk	[3]4320	[4]2.8	12096			IV	
Tp	–	–	–			IV	
Ta	–	–	[5]6900			IV	
Ths/Thn Thp/Thc	[5]2375	[5]2.3	5463			IV	
Mzqm	1363	[5]2.3	3135			V	Deeply weathered locally; converted to grus
Mzgd/Mzfg	[5]2450	[5]2.7	6615			IV	
Mzv	–	–	[5]10,800			IV	

[1]Data from Reno NW quadrangle (Szecsody, 1983)
[2]Vs calculated at ½ Vp
[3]Data from Steamboat quadrangle (Trexler and Nichol, 1981)
[4]Clark, S. P., 1966, in "Handbook of Physical Constants", rev. ed. GSA Memoir 97.
[5]Data from Reno quadrangle (Bell, Trexler, and Bell, 1978).

(Qws) are also considered to be in the low RP category because of their unconsolidated nature and Holocene age. Rigidity products for these units range from 688 to 1061. In general, these geologic units occur in low-lying, basinal areas where the depth to groundwater is often less that 3m (10 ft).

Rigidity products from 1217 (Qpa) to 1680 (Qpf) characterize those geologic units with moderate rigidity. Included in this category are Holocene alluvial fan (Qfg) and floodplain (Qfp) deposits and alluvium derived from Peavine fan (Qpa); late Pleistocene beach bar sands (Qb); mid- to late Pleistocene alluvium of Stead Airport (Qas) and granitic alluvial fan deposits (Qgs), and unconsolidated Quaternary-Tertiary sediments (QTs). Although no data were available, older alluvium (Qfgo) is also considered to have moderate rigidity based on age (indicative of degree of consolidation) and field observations.

The moderately high rigidity category includes mid-Pleistocene volcanic alluvium (Qva) and early Pleistocene alluvial fan deposits of Peavine Mountain (Qpf) and old alluvium (Qoa) with rigidity products from 1944 (Qoa) to 3129 (Qva). Most of the other early Pleistocene alluvial units are also considered to have moderately high rigidity on the basis of their gravelly texture (Qpg, Qgv, Qag, Qbv, Qbg, QTg) and in many cases, cemented or moderately consolidated nature. Quaternary-Tertiary basin-fill sediments (QTs) may have moderately high rigidity locally where they are cemented and/or moderately well consolidated.

Bedrock shear-wave velocities (with the exception of Mzqm) and densities have been inferred from data on similar bedrock types in the Reno (Bell, Trexler, and Bell, 1978) and Steamboat (Trexler and Nichol, 1981) quadrangles. The bedrock units exhibit a wide range of rigidity products from 3135 for deeply weathered quartz monzonite (Mzqm) to over 12,000 for the Kate Peak volcanics (Tk). It should be noted that the rigidity product for Mzqm may vary considerably from deeply weathered areas (3135) to fresh outcrops (possibly 6000-12,000).

Map Explanation

Potential for Ground Shaking During Earthquakes

Geologic units in Reno NE quadrangle have been grouped into 5 categories based on 1) rigidity products as indicators of the severity of shaking, and 2) depth to groundwater, indicative of saturation and possible suseptibility to liquefaction. In addition, controlling factors such as penetration resistance, grain size and sorting, degree of induration, and weathering were considered in an attempt to further define the appropriate shaking category for each unit. Rigidity products, depths to groundwater, and the resultant shaking categories are shown in Table 2 and discussed below. The reader is referred to the "Earthquake Hazards Map of Reno NE Quadrangle" (this report) for use in conjunction with the following text.

Category I: Units in this category have the potential for 1) the greatest severity of shaking based on low rigidity product values (688-1061) and 2) possible severe liquefaction because the groundwater table is less than 3m deep. Playa (Qp), sheetwash/stream channel (Qa), clay dune(Qcd), and lake (Ql) deposits are in this category. These unconsolidated sediments are located primarily in the southwest quater of the quadrangle and locally along ephemeral and perennial streams. They are Holocene to late Pleistocene deposits and are considered to be particularly susceptible to severe shaking based on their low shear-wave velocities (481-714 ft/sec), youthful age, and modes of deposition (particularly lacustrine and windblown (Qcd) which suggest very loose, uncompacted deposits). Of these four units, Qp and Qa are considered to be susceptible to possible severe liquefaction where they are composed of well sorted, fine-grained sands. However, liquefaction should not be precluded for the other units which may include fine-grained sands in the shallow subsurface.

Category II: Included in this category are units with the potential for moderate to possibly severe shaking and possible liquefaction. Low rigidity deposits where the depth to groundwater is greater than 3m (Qsu, Qa. Qcd, Ql, Qfb) and moderate rigidity deposits where depth to groundwater is less than 10m (Qb, Qfg, Qpa) are in this category. The unconsolidated, low rigidity deposits may be subject to severe shaking, whereas the remaining units in this category have the potential for moderate severity of shaking. With the exception of Qfg and Qpa, which are gravelly in nature, and Qfb (groundwater table > 10m deep), the remaining units may be subject to liquefaction due to their fine-grained, sandy (in some cases, locally sandy) texture.

Category III: This category includes deposits which may be subject to moderate severity of shaking; however, on the basis of depth to groundwater, cementation, or consolidation of deposits, liquefaction is unlikely. Unconsolidated to moderately consolidated or cemented deposits of moderate to moderately high rigidity where the depth to groundwater is greater than 10m (Qfg, Qpa, Qfp, Qb, Qfgo, Qgs, Qva, Qpg, Qgv, Qoa, Qag, Qbg, QTg), moderately consolidated or cemented deposits where the depth to groundwater is greater than 3m (QTs), and thin, unconsolidated deposits overlying QTs where groundwater is 3m to 10m deep in QTs (Qas, Qpf) are included in this category.

The Quaternary-Tertiary sediments have been included in this category because in most of the outcrops noted, QTs was often moderately well consolidated to cemented. The higher mean value for penetration resistance of QTs compared to that of the unconsolidated alluvial units (see Appendix B) supports this observation. Therefore, QTs is believed to be generally more resistant to shaking than it's moderate rigidity product implies. Since the density measurements used to determine the rigidity product of QTs were taken on unconsolidated material, this RP (1653) should probably be used to represent the characteristics of unconsolidated QTs only.

It should also be noted here that the groundwater table in Qfp may be seasonally high (< 10m) when excessive runoff collects in the low-lying areas occupied by Qfp. At these times, Qfp may be subject to liquefaction.

Category IV: Included in this category are bedrock units which are considered least susceptible to ground shaking on the basis of high rigidity products (5463-12,096, where known) and the massive nature of the units. Mesozoic metavolcanics (Mzv) and granitics (Mzfg, Mzgd), and Tertiary volcanics (Thc, Thp, Thn, Ths, Ta, Tp, Tk) are all in Category IV.

Category V: Units in this category have a potential for variable severity of shaking. Included in this category are landfill (Qlf) of unknown rigidity overlying bedrock; thin deposits of windblown sand (Qws) overlying alluvial and bedrock units; boulder alluvium (Qbv) overlying Hartford Hill Rhyolite; old alluvial deposits (Qfgo, Qoa) overlying shallow Mzgd and Mzqm; and quartz monzonite (Mzqm) which varies in degree and depth of weathering.

The response of each of these geologic units to earthquake shaking should vary depending on the thickness of the deposit over bedrock, degree of saturation, and the rigidity product contrast. The rigidity product contrast is the difference in RP between an overlying and underlying layer. The potential for amplification of seismic waves increases as the rigidity product contrast increases, if other parameters (i.e., thickness) are constant (Lajoie and Helley, 1975). It is possible then, that the alluvial units listed above (moderate to moderately high RP) may experience a greater severity of shaking where they overlie shallow bedrock (high RP). Similarly, in the areas of deeply weathered quartz monzonite (Mzqm), the weathered material (0.3-10+ m thick) atop massive bedrock may be subject to a greater severity of shaking as a result of seismic wave amplification in response to the RP contrast between the weathered material and competent bedrock below.

Potential for Surface Rupture

Delineation of Faults

Faults in the Reno NE quadrangle were delineated on the basis of geologic mapping by the author in 1982-83. Fault traces were originally mapped on 1:12,000-scale, low sun-angle photographs and later transferred to a 1:24,000 topographic base. A Quaternary fault map of the Reno 1° X 2° sheet (Bell, 1981) provided general information on ages of faulting within the Reno NE quadrangle, and Bell's original, 1:40,000-scale, low-sun angle photographs were useful in delineating some of the larger scale faults and lineaments.

Recency of Fault Movement

Ages of faulting were determined on the basis of geologic relationships, trenching data, geomorphology of the scarps (degree of dissection, slope), and soil stratigraphy. Bell and Pease (1980) have described a method by which the age of faulting can be estimated in the Reno-Carson City area by examining the soils which mantle the faulted alluvial surfaces. Four major soil-stratigraphic units can be recognized based on the work by Morrison (1964) and Birkeland (1968): Toyeh-interval (post-Tioga) Soil; Churchill-interval (post-Tahoe) Soil; Cocoon-interval (post-Donner Lake) Soil; and Humboldt Valley-interval (post-Hobart) Soil. Table 3 shows the age and characteristic pedologic type associated with each soil-stratigraphic unit.

Criteria for recognition of these key soils are given by Bell and Pease (1980) as follows:

"In the Reno-Carson City area (Table 3) the relict Toyeh-interval Soil typically displays a non-clayey B horizon about 30 cm thick (Camborthids or Haploxerolls; the relict Churchill-interval Soil typically displays a textural clay B horizon about 30 cm thick (Haplargids and Argixerolls); the relict Cocoon-interval Soil typically exhibits a thick (30-100 cm) textural clay B horizon commonly underlain by a siliceous duripan or calcic or petrocalcic horizon (Argixerolls, duric Argixerolls, Haplargids, duric Paleargids, and Durargids); and the relict Humboldt Valley-interval Soil typically exhibits Great Groups and Subgroups similar to those of the Cocoon-interval except that they are generally thicker and better differentiated. For example, on some pre-Illinoian surfaces argillic B horizons and duripans, each in excess of 2 m thick, may be encountered."

TABLE 3

Key Soil-Stratigraphic Units

Reno-Carson City area
(from Bell and Pease, 1980)

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

Bell and Pease also note that regional pedologic studies in western Nevada have demonstrated that there has been no appreciable argillic[1)] horizon

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1) Argillic soils are defined (U.S. Soil Conservation Service, 1975) as having an illuvial (B) horizon with at least 3% more clay than the eluvial (A) horizon,

development since the last high stand of Lake Lahontan about 12,000 years ago. Thus, soils which stratigraphically overlie the last high stand of the lake are entisols or cambic soils. Any surface which is underlain by an argillic horizon is late Wisconsinan or older and soils with a duripan are Sangamon age or older. An exception to this rule-of-thumb is the occurrence of sodium-rich soils (natragids) which can develop argillic horizons in less than 6000 years (Bell and Pease, 1980).

Using the soil-stratigraphic relationships outlined in Table 3, recency of fault movement categories were constructed by Bell and Pease (1980) for the Carson City area (Table 4). These categories are applicable to the Reno area as well. They are defined solely on the basis of the youngest soil observed to be displaced and the nature of the soil on the fault scarp.

Test pits and trenching in Reno NE quadrangle provided useful soil-stratigraphic information which could be interpreted according to Table 4. However, where such data were unavailable, criteria from Table 4 were used in conjunction with the U.S. Soil Conservation Service soil map (1974) to determine an approximate age of last fault movement.

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1) (cont.) if the eluvial horizon has less than 15% total clay. If the argillic horizon is loamy or clayey, it should be at least 7.5 cm thick.

Entisols are defined as having little or no diagnostic pedogenic horizon development, and they typically display A-C profiles.

Cambic soils are defined as having an altered B horizon that shows movement or aggregation of soil particles (generally reduction or removal of iron oxides and leaching of carbonates). The base of the horizon must be at least 25 cm below the surface.

TABLE 4. Recency of Fault Movement Categories

Reno-Carson City area
(from Bell and Pease, 1980)

Age of youngest displacement (yrs.)	Soil-Stratigraphic Evidence
< 2000-3000	Entisol displaced
< 5000-12,000	Toyeh-interval Soil displaced
12,000-35,000	Churchill-interval Soil displaced; scarp overlain by Holocene (Toyeh-interval) soil
35,000-100,000	Cocoon-interval Soil displaced; scarp overlain by Churchill-interval Soil
100,000-500,000	Humboldt Valley-interval Soil (or older soils) displaced; scarp overlain by Cocoon-interval Soil

Age of Youngest Fault Displacement

Faulting in the Reno NE quadrangle is divided into three categories based on apparent age of most recent fault movement. The youngest faulting in the quadrangle appears to have occurred from mid- to late Pleistocene, approximately 35,000 to 100,000 years ago. Faults in this category have relatively distinct, dissected scarps which are overlain by undisturbed xerollic Haplargid soils, considered equivalent to Churchill soils (approx. 35,000 years old; see Table 3).

The second category, early to mid-Pleistocene (100,000 to 1.8 million years), includes faults which displace Late Tertiary to early Quaternary alluvial and basin-fill deposits. Haploxerollic Durargids, xerollic Durargids, duric Haplargids, and durargidic Argixerolls, all considered to be Cocoon-interval Soils (approx. 100,000 years old); see Table 3), overlie the fault scarps which are moderately to deeply dissected.

The remaining faults have been categorized as indeterminate. These faults are predominately those of probable pre-Pleistocene age which cut Mesozoic and Tertiary bedrock and bedrock-alluvial faults of probable pre-Plesitocene to possible late Pleistocene age.

Mid- to late Pleistocene

Early in this study it appeared that Holocene movement had occurred on the fault in the northeast corner of T.21N., R.19E., Sec. 21.. Aerial photos taken prior to development of the area showed possible offset of the late Pleistocene to Holocene lake deposits. In order to determine the recency of faulting on this fault, two trenches were excavated across the extension of the fault, north of Lemmon Valley Road (Figure 9).

Trenches 1 and 2 were placed perpendicular to the trend of the scarp and excavated to approximately 2.5 m deep. The scarp heights and slopes were 2.4 m, 13.6% and 1.5 m, 11% at Trenches 1 and 2, respectively. Both trenches were carefully measured and logged. Soil units and parent material were described using Soil Conservation Service terminology (Soil Conservation Service, 1975). Logs of the trenches and respective soil descriptions are shown in Figures 10 and 11.

Each of the trenches showed a Churchill-interval Soil (35,000 years old; xerollic Haplargid) over parent alluvial fan deposits (C horizon). Soil profiles and parent material exposed in both trenches were very similar in color, texture, and thickness. No offset was noted in the Churchill soil which blanketed both upthrown and downthrown sides of the fault as well as the scarp. In fact, the only evidence for possible faulting was a zone of fractures and fissure fillings cutting the parent material in both trenches and the possible offset (0.3 m) of a relatively continuous sand lense in Trench 1. In Trench 2, the sand lense on the upthrown side pinches out at the fissure zone and is not

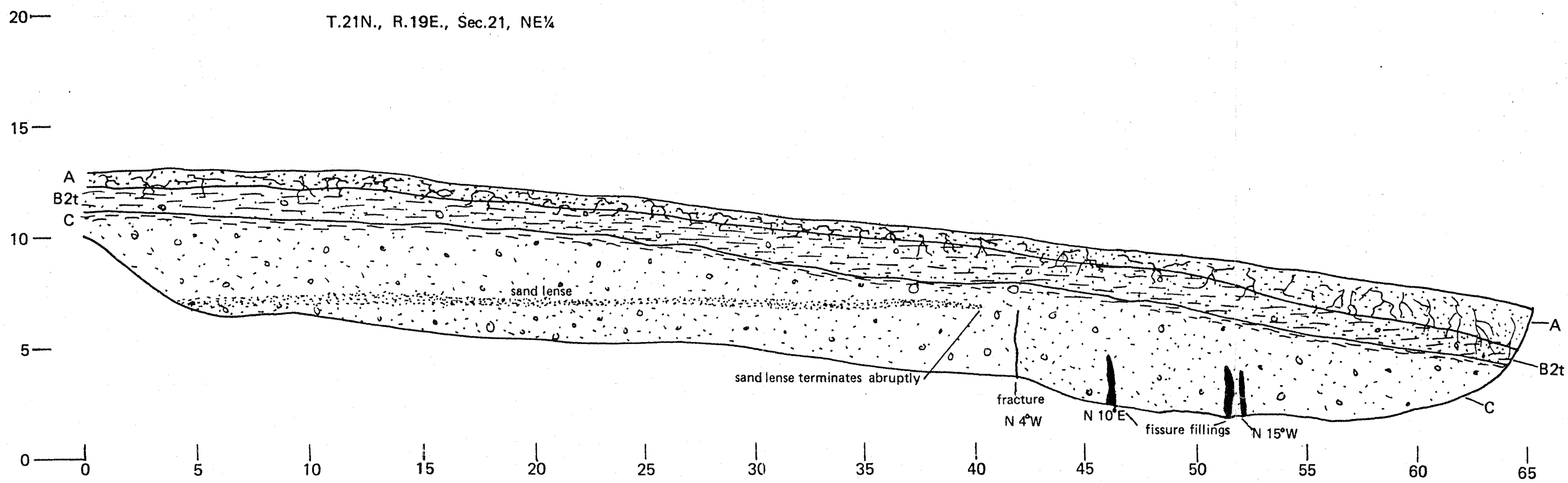
Figure 9. Trench Locations in Reno NE

Figure 11 TRENCH 2 RENO NE QUADRANGLE

WEST North Wall EAST

Trend of Trench - East-West

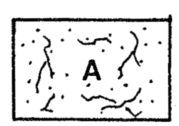
T.21N., R.19E., Sec.21, NE¼



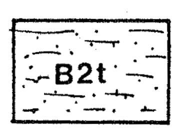
G.C. Szecsody

Horizontal and Vertical Scales 1" = 5'

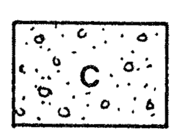
TRENCH 2 - EXPLANATION



A soil horizon - Loamy sand, pale brown (10 YR 6/3, dry) to yellowish brown (10 YR 5/4, moist). Structureless, single grain, loose, nonsticky, nonplastic; fine to coarse roots common; abrupt, smooth to wavy boundary with B2t. Thin surficial cover of gravelly coarse sand, pale brown (10 YR 6/3, dry).



B2t soil horizon - Sandy clay loam to sandy clay, slightly gravelly, light yellowish brown (10 YR 6/4, dry) to dark yellowish brown (10 YR 4/4, moist). Very hard, sticky, plastic; strong, fine to medium, prismatic to angular blocky structure; many moderately thick clay films on ped faces; few fine roots. Clear to gradual, wavy boundary with C.



C soil horizon - **Unaltered parent material** - Coarse sand to sandy loam, slightly gravelly, very pale brown (10 YR 7/3, dry). Hard to slightly hard near base of trench, nonsticky, nonplastic near base of trench to slightly sticky, slightly plastic near boundary with B2t; moderate, medium, subangular blocky structure near B2t grading to massive, structureless near base of trench; few thin clay films on ped faces in upper 3-6 inches of horizon; fine roots, common to few; calcium carbonate as root casts and minor cement. Lense of loose, coarse sand terminates abruptly near the zone of fractures and fissure fillings (loose, brown loamy sand) noted near eastern end of trench.

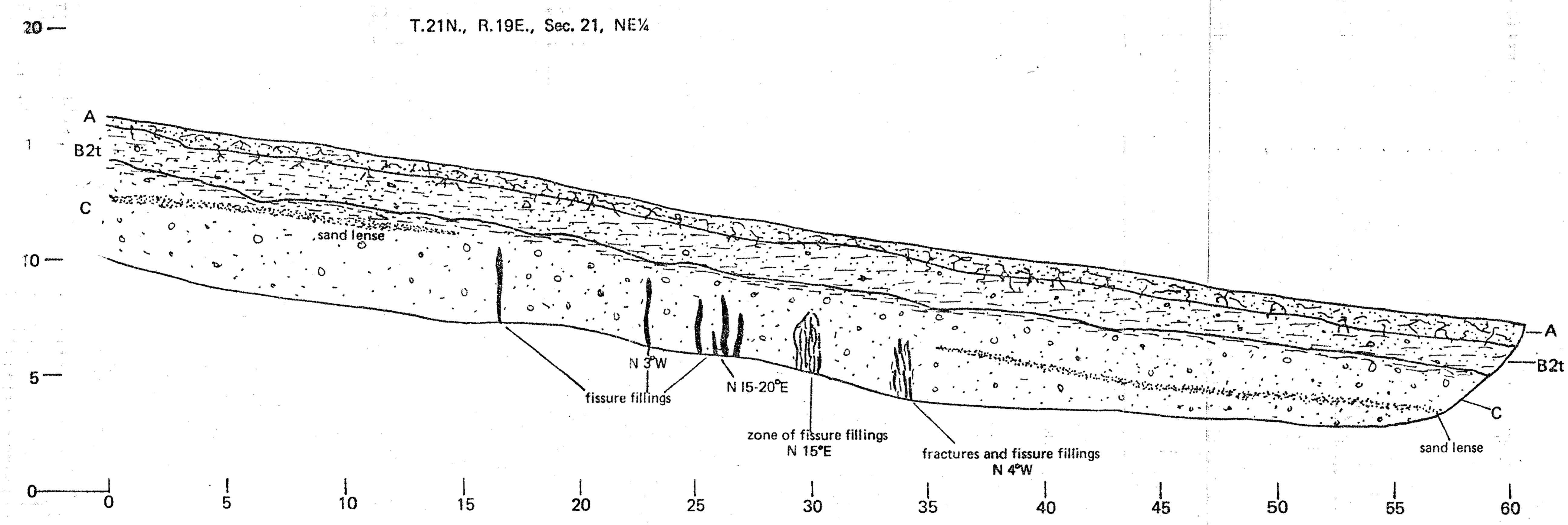
Figure 10

TRENCH 1 RENO NE QUADRANGLE

North Wall

Trend of Trench - N 74°W

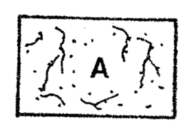
T.21N., R.19E., Sec. 21, NE¼



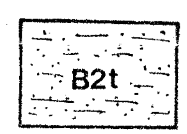
Horizontal and Vertical Scales 1" = 5'

G.C. Szecsody

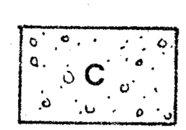
TRENCH 1 - EXPLANATION



A soil horizon - Loamy sand, brown (10 YR 5/3, dry) to dark brown (10 YR 4/3, moist). Structureless, single grain, loose, nonsticky, nonplastic; fine to medium roots common; abrupt, smooth boundary with B2t. Thin surficial cover of gravelly, coarse sand, pale brown (10 YR 6/3, dry).



B2t soil horizon - Sandy clay loam to sandy clay, slightly gravelly, light yellowish brown (10 YR 6/4, dry) to dark yellowish brown (10 YR 4/4, moist). Very hard, sticky, plastic; strong, medium prismatic to medium angular blocky structure; many thick clay films on ped faces; few fine roots. Diffuse to gradual, wavy boundary with C.



C soil horizon - **Unaltered parent material** - Gravelly loamy sand to sandy loam, light yellowish brown (10 YR 6/4, dry). Slightly hard to very hard near boundary with B2t, nonsticky and nonplastic near base of trench to slightly sticky and slightly plastic near boundary with B2t; weak to moderate, medium, subangular blocky structure near B2t grading to massive, structureless near base of trench; few thin clay films on ped faces in upper 3-6 inches of horizon; fine roots common to few; calcium carbonate as root casts and minor cement in lower part of horizon. Lenses of loose, coarse sand terminate abruptly near the zone of fractures and associated fissure fillings (loose, brown loamy sand) noted in the central part of the trench.

exposed on the downthrown trench wall. Thus, it is not clear whether this lense is faulted (downdropped below the base of the trench) or naturally pinches out.

From the trench exposures it is apparent that multiple movements may have formed the present scarp. Multiple movements are suggested by the discrepancy between the apparent offset in Trench 1 (approx. 0.3 m on the sand lense) and the scarp height (1.5-2.4 m). The most recent movement is probably responsible for the 0.3 m of offset, with the remainder of the scarp height attributable to earlier movements.

Trench exposures also confirm that most recent faulting of the parent or C-horizon alluvium took place prior to the formation of the Churchill-interval Soil on the scarp (i.e., prior to 35,000 years ago). Since the soil formed on these alluvial fan deposits is equivalent to that formed on Tahoe outwash in the Reno area, this alluvium was probably deposited contemporaneously with Tahoe outwash approximately 60,000 years ago. Therefore, the age of last fault movement is considered to have occurred post-60,000 years and prior to soil development at 35,000 years ago (mid- to late Pleistocene). Faulting was prior to deposition of the lake deposits (Ql) and thus, what originally appeared to be offset of Ql is now interpreted as a groundwater effect along the fault trace beneath the lake sediments.

The small scale faults associated with the trenched fault exhibit similar soils and morphology to the trenched fault, and they are labeled mid- to late Pleistocene in age also.

Early to mid-Pleistocene

The majority of alluvial faults appear to have had their most recent movement in early to mid-Pleistocene, such as the Airport Fault, so named by Harrill (1973). This scarp probably moved many times in the past as evidenced by it's 6 m to more than 18 m high scarp; however, good exposures of soils and strata along the scarp indicate that the most recent movement occurred in early Pleistocene.

Along the Airport Fault scarp, near the southeastern end of the Reno-Stead Airport runway, an outcrop of cemented pediment gravels (Qpg) overlying Quaternary-Tertiary sediments (QTs), is exposed in a wash cut. At this location, the early Pleistocene pediment gravels are faulted, tilted (strike-N 12-20° E, dip- 9-15° NW), and well exposed on the upthrown side of an apparently high-angle fault zone which truncates these well bedded gravels and sands. On the downthrown side of the fault zone, poorly bedded, coarse sands and gravels overlying QTs dip nearly parallel to the current land surface of the fault scarp. An undisturbed Cocoon-interval Soil has formed over Qpg and the fault scarp forming a duripan in the gravels and sandy gravels on both sides of the fault. The Cocoon-interval Soil overlying the scarp indicates that faulting took place prior to 100,000 years ago, early to mid-Pleistocene, since the most recent movement displaces early Pleistocene Qpg.

Faults in the southwest corner of the quadrangle displace 1-2 m.y. old alluvial fan deposits of Peavine Mountain (Qpf) and Quaternary-Tertiary sediments (QTs). The soils formed on the surfaces of these deposits and on the fault scarp are probably Cocoon-interval Soils (thick Argixerolls and Durargids) and indicate that faulting occurred in early to mid-Pleistocene .

The prominent fault in the northeast corner of Reno NE quadrangle displaces deposits of old alluvium (Qoa) of early Pleistocene age, and the scarp is moderately dissected. The southern half of the fault scarp is blanketed by undisturbed deposits of mid- to possibly late Pleistocene granitic alluvial fan deposits (Qgs). Along the northern half of the fault, the scarp is overlain by Cocoon-interval Soils (Durargids), and thus, the age of most recent movement on the fault appears to be post-Qoa and pre-Cocoon soil (100,000 years) or early to mid-Pleistocene.

Other faults with possible early to mid-Pleistocne movement displace early Pleistocene deposits (Qbg, Qag) overlying QTs (T.21N., R.19E., Sec. 5; T.21N., R.20E., Sec. 21). Although more recent movement cannot be precluded on these faults, the weathered morphology of the scarps confirms to the author that these faults have probably not moved since early to mid-Pleistocene.

Indeterminate

This category includes bedrock faults of probable pre-Pleistocene age which cut Mesozoic granodiorite and quartz monzonite, and Tertiary volcanics of the Hartford Hill Rhyolite, and the Alta and Kate Peak Formations. Also included in this category are bedrock-alluvial faults which separate the mountainous highlands from the surrounding basins. These faults have been moderately to deeply dissected and in most cases, covered by younger alluvial deposits of Holocene to mid-Pleistocene age. The relatively youthful age of deposits overlying these faults could indicate that they have moved as recently as Holocene; however, the total lack of evidence for Holocene movement elsewhere in the quadrangle and the dissection and apparent retreat of some of the scarps (mountain fronts), makes this unlikely. Instead, movement on the bedrock-alluvial faults is believed to be pre-Pleistocene to possibily as recent as late Pleistocene (35,000 years ago); however, more recent movements cannot be precluded for faults in this category.

Three faults which cut Mzgd and extend into QTs have been included in this category (T.21N., R.19E., Sec. 9,16; T.21N., R20E., Sec. 20). For these faults, the most recent movement is post-QTS, which can range from Late Tertiary to present. (No Pleistocene or younger deposits, which could give an upper age limit for faulting, overlie these faults). However, the weathering of the fault scarps suggests that they probably have not moved in Holocene time, and they are considered to be of probable early to mid-Pleistocene age by the author.

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*GRAIN SIZE ANALYSES

APPENDIX A

Unit	Sample No.	[1]Median Diameter (ø)	[2]Mean Diameter (ø)	[3]Sorting σ_I	[4]% gravel/sand/mud	[5]Sorting Term	Textural Term (Folk, 1954)
Qws	46-D-A	+1.2	+1.3	1.2	<1/96/3.2	poorly sorted	sand
Qa	1A	-0.8	-0.8	2.0	46/53/<1	poorly to very poorly sorted	sandy pebble gravel
Qa	42A	+0.5	+0.6	2.3	23/70/7.6	very poorly sorted	granular sand
Qa	N56B	+2.6	+2.6	1.2	<1/87/12.6	poorly sorted	muddy sand
Qa	79A	+0.8	+1.1	1.7	8/85/6.9	poorly sorted	granular sand
Qfg	104A	+1.2	+1.3	1.9	11/81/8.1	poorly sorted	granular sand
Qfg	142A	+1.2	+1.3	1.8	10/81/7.9	poorly sorted	granular sand
Qpa	36A	+1.7	+1.8	1.4	<1/93/6	poorly sorted	sand
Qpa	38A	+1.2	+1.2	2.1	15/75/10.2	very poorly sorted	pebbly muddy sand
Qb	51A	+1.7	+1.9	1.7	2/85/13.1	poorly sorted	muddy sand
Qb	222A	+1.6	+1.7	1.0	0/97/2.7	moderately to poorly sorted	sand
Qfb	52A	+1.3	+1.4	2.1	12/76/12	very poorly sorted	granular muddy sand
Qfb	217A	+2.1	+1.6	1.7	8/86/6.4	poorly sorted	granular sand
Qfgo	145A	+1.5	+1.5	1.9	8/83/9.7	poorly sorted	granular sand
Qfgo	145A	+1.4	+1.4	1.9	9/82/8.6	poorly sorted	pebbly sand
Qfgo	151A	+0.5	+0.7	2.8	28/59/12.6	very poorly sorted	pebbly muddy sand
Qfgo	151A	+0.6	+0.9	2.6	25/61/14	very poorly sorted	pebbly muddy sand
Qas	28A	+0.8	+0.9	1.9	14/80/6.5	poorly sorted	pebbly sand
Qas	63A	+0.7	+0.9	2.2	18/72/9.7	very poorly sorted	pebbly muddy sand
Qas	65A	+0.7	+0.8	2.5	24/66/10.2	very poorly sorted	pebbly muddy sand
Qas	141A	+1.3	+1.3	1.8	8/84/7.9	poorly sorted	pebbly sand
Qgs	167A	+1.4	+1.4	2.0	11/80/9.2	poorly to very poorly sorted	granular sand
Qgs	178A	+1.2	+1.3	1.9	13/80/7.8	poorly sorted	granular sand
Qvs	127A	+0.8	+0.9	2.4	20/69/10.9	very poorly sorted	pebbly muddy sand
Qpg	46-B-A	+0.5	+0.1	2.8	30/63/6.8	very poorly sorted	gravelly sand
Qpf	35A	-1.7	-1.4	1.95	60/40/1.1	poorly sorted	sandy pebble gravel
Qpf	35B	+0.1	+0.2	2.8	38/52/9.9	very poorly sorted	muddy sandy pebble gravel
Qoa	N56A	+1.8	+1.8	1.7	6/86/8.7	poorly sorted	pebbly sand
Qoa	182A	+0.8	+0.7	2.3	20/74/6.1	very poorly sorted	gravelly sand
Qbg	143A	+1.4	+1.3	2.5	16/73/10.9	very poorly sorted	bouldery muddy sand
QTs	46-A-A	+1.5	+1.4	1.4	5/92/3.4	poorly sorted	sand (anomalous-sand-size aggregates of mud)

*Using system of Folk and Ward (1957)

ø = $^{-}\log_2$ diameter (mm) (i.e., ø of 4 mm diameter gravel = -2)

1. Median diameter = ϕ_{50}
2. Mean diameter = $\frac{\phi_{16} + \phi_{50} + \phi_{84}}{3}$
3. Sorting $\sigma_I = \frac{\phi_{84}-\phi_{16}}{4} + \frac{\phi_{95}-\phi_5}{6.6}$
4. Gravel = <-1ø (includes gravel, cobbles, boulders
   Sand = -1ø to 4ø
   Mud = >4ø
5. Sorting term

Sorting term	σ_I
very well sorted	<0.35
well sorted	0.35-0.50
moderately sorted	0.50-1.0
poorly sorted	1.0-2.0
very poorly sorted	2.0-4.0
extremely poorly sorted	>4.0

SUMMARY OF GEOTECHNICAL DATA—RENO NE
APPENDIX B

	Seismic Velocity (ft/sec)						Bulk Density (pcf)				Standard Penetration Resistance (blows/ft)			Depth to Groundwater (ft)		
Geologic Unit	No. of measurements	Vp range	Vp mean	No. of measurements	Vs range	Vs mean	No. of measurements	ρ range	ρ mean	g/cc	No. of measurements	Range	Mean	No. of measurements	Range	Remarks
Qws	1	–	1053	1	–	[1]527	–	–	–	–	–	–	–	–	–	GWT (groundwater table) > 30′ in Qws
Qa	6	1000–1333	1137	2	581–833	707	8	70–109	93.7	1.50	70	5–49	20.4	30	≥ 10	GWT < 30′ in Qa near playa lakes
Qfg	4	1200–1333	1246	1	–	794	[3]5	104–123	117	1.88	61	3–85	25.1	40	> 6	GWT generally > 30′ in Qfg
Qpa	6	1053–1429	1238	3	698–1000	839	3	82–104	90.4	1.45	100	2–63	20.8	43	> 10	GWT generally > 30′ in Qpa
Qfp	2	*1143–1154	1149	1	–	–	–	–	–	–	–	–	–	–	–	Seasonally high GWT locally
Qcd	–	–	–	–	–	–	[2]1	–	76.4	1.22	–	–	–	–	–	GWT generally 10–30′ deep in Qcd
Ql	4	1136–1212	1158	2	448–513	481	5	81–97	89.4	1.43	3	14–26	20.3	22	12 > GWT < 20	GWT generally < 30′ in Ql; > 30′ north and northeast of Lake Lemmon
Qfb	2	*1111–1250	1181	1	–	[1]591	5	82.9–101	92.0	1.47	–	–	–	11	> 12	GWT > 30′ in Qfb
Qb	2	*1220–1351	1286	1	–	698	2	110–112	111	1.77	–	–	–	8	> 17	GWT generally > 30′ in Qb
Qas	2	*1250–1316	1283	1	–	851	[2]3	102–107	106	1.69	–	–	–	–	–	GWT generally > 30′ in Qas
Qgs	4	1154–2174	1647	2	800–1186	993	[2]3	99–110	105	1.68	–	–	–	1	59	GWT > 30′ in Qgs
Qva	4	2308–4706	3446	2	1818–2381	2100	[2]3	84–97	93	1.49	–	–	–	–	–	GWT probably > 30′ deep in Qva
Qpf	2	*2069–2174	2122	1	–	1184	–	–	–	–	–	–	–	–	–	GWT generally > 30′ in Qpf
Qoa	4	2143–2581	2310	2	1058–1176	1117	–	–	–	–	–	–	–	–	–	GWT > 30′ in Qoa
QTs	14	1250–2963	2025	7	968–1304	1164	[4]2	84.2–92.9	88.5	1.42	29	11–60	31.6	3	6	GWT generally > 30′ in QTs
Mzqm	2	2813–3500	3157	1	–	1363	–	–	–	–	–	–	–	–	–	Often deeply weathered

*Forward and reverse measurements at a single site.
[1]Vs calculated at ½ Vp
[2]Sand cone densities by NBMG, May 1983
[3]Includes sand cone density data by NBMG, May 1983
[4]Sand cone densities on unconsolidated QTs only

*GRAIN SIZE ANALYSES

APPENDIX A

Unit	Sample No.	[1]Median Diameter (Ø)	[2]Mean Diameter (Ø)	[3]Sorting σ_I	[4]% gravel/sand/mud	[5]Sorting Term	Textural Term (Folk, 1954)
Qws	46-D-A	+1.2	+1.3	1.2	<1/96/3.2	poorly sorted	sand
Qa	1A	-0.8	-0.8	2.0	46/53/<1	poorly to very poorly sorted	sandy pebble gravel
Qa	42A	+0.5	+0.6	2.3	23/70/7.6	very poorly sorted	granular sand
Qa	N56B	+2.6	+2.6	1.2	<1/87/12.6	poorly sorted	muddy sand
Qa	79A	+0.8	+1.1	1.7	8/85/6.9	poorly sorted	granular sand
Qfg	104A	+1.2	+1.3	1.9	11/81/8.1	poorly sorted	granular sand
Qfg	142A	+1.2	+1.3	1.8	10/81/7.9	poorly sorted	granular sand
Qpa	36A	+1.7	+1.8	1.4	<1/93/6	poorly sorted	sand
Qpa	38A	+1.2	+1.2	2.1	15/75/10.2	very poorly sorted	pebbly muddy sand
Qb	51A	+1.7	+1.9	1.7	2/85/13.1	poorly sorted	muddy sand
Qb	222A	+1.6	+1.7	1.0	0/97/2.7	moderately to poorly sorted	sand
Qfb	52A	+1.3	+1.4	2.1	12/76/12	very poorly sorted	granular muddy sand
Qfb	217A	+2.1	+1.6	1.7	8/86/6.4	poorly sorted	granular sand
Qfgo	145A	+1.5	+1.5	1.9	8/83/9.7	poorly sorted	granular sand
Qfgo	145A	+1.4	+1.4	1.9	9/82/8.6	poorly sorted	pebbly sand
Qfgo	151A	+0.5	+0.7	2.8	28/59/12.6	very poorly sorted	pebbly muddy sand
Qfgo	151A	+0.6	+0.9	2.6	25/61/14	very poorly sorted	pebbly muddy sand
Qas	28A	+0.8	+0.9	1.9	14/80/6.5	poorly sorted	pebbly sand
Qas	63A	+0.7	+0.9	2.2	18/72/9.7	very poorly sorted	pebbly muddy sand
Qas	65A	+0.7	+0.8	2.5	24/66/10.2	very poorly sorted	pebbly muddy sand
Qas	141A	+1.3	+1.3	1.8	8/84/7.9	poorly sorted	pebbly sand
Qgs	167A	+1.4	+1.4	2.0	11/80/9.2	poorly to very poorly sorted	granular sand
Qgs	178A	+1.2	+1.3	1.9	13/80/7.8	poorly sorted	granular sand
Qva	127A	+0.8	+0.9	2.4	20/69/10.9	very poorly sorted	pebbly muddy sand
Qpg	46-B-A	+0.5	+0.1	2.8	30/63/6.8	very poorly sorted	gravelly sand
Qpf	35A	-1.7	-1.4	1.95	60/40/1.1	poorly sorted	sandy pebble gravel
Qpf	35B	+0.1	+0.2	2.8	38/52/9.9	very poorly sorted	muddy sandy pebble gravel
Qoa	N56A	+1.8	+1.8	1.7	6/86/8.7	poorly sorted	pebbly sand
Qoa	182A	+0.8	+0.7	2.3	20/74/6.1	very poorly sorted	gravelly sand
Qbg	143A	+1.4	+1.3	2.5	16/73/10.9	very poorly sorted	bouldery muddy sand
QTs	46-A-A	+1.5	+1.4	1.4	5/92/3.4	poorly sorted	sand (anomalous-sand-size aggregates of mud)

*Using system of Folk and Ward (1957)

$\phi = {}^{-}\log_2$ diameter (mm) (i.e., ϕ of 4 mm diameter gravel = -2)

1. Median diameter = ϕ_{50}
2. Mean diameter = $\frac{\phi_{16} + \phi_{50} + \phi_{84}}{3}$
3. Sorting $\sigma_I = \frac{\phi_{84} - \phi_{16}}{4} + \frac{\phi_{95} - \phi_5}{6.6}$
4. Gravel = <-1ϕ (includes gravel, cobbles, boulders
   Sand = -1ϕ to 4ϕ
   Mud = >4ϕ
5. Sorting term

Sorting term	σ_I
very well sorted	<0.35
well sorted	0.35-0.50
moderately sorted	0.50-1.0
poorly sorted	1.0-2.0
very poorly sorted	2.0-4.0
extremely poorly sorted	>4.0

RIGIDITY PRODUCTS AND SHAKING CATEGORIES — MT. ROSE NE
TABLE 5

Geologic Unit	Shear wave Velocity (ft/sec) Vs mean	Density (g/cc) ρ mean	Rigidity Product Vs mean x ρ mean	SHAKING CATEGORY Depth to Groundwater <3m	<10m	>10m	Remarks
Qfl	765	1.36	1040	I			
Qa	717	1.54	1104	I	II		Includes Qa gravel unit. Variable severity of shaking (V) where Qa overlies bedrock in mountain streams.
Qaf	1224	1.47	1799		II	III	Variable severity of shaking (V) where Qaf overlies shallow bedrock in Steamboat Hills.
Qsu	1024	—	—			V	May be saturated at times due to hydrothermal activity; rigidity uncertain.
Qtm	1374	1.95	2679			III	Variable severity of shaking (V) where Qtm overlies shallow bedrock in Carson Range.
Qoa	833	1.65	1374		II	III	Variable severity of shaking (V) where Qoa overlies shallow bedrock in Steamboat Hills.
Qs	700	[1]1.8	1260			III	Low rigidity but groundwater deeper than 10m.
Qmb	—	—	—			IV	
Qd	1367	1.76	2406		III		Moderately high rigidity and penetration resistance; very coarse, bouldery deposit.
Qdm	1066	1.65	1759		II	III	Variable severity of shaking (V) where Qdm overlies shallow bedrock in Carson Range and Steamboat Hills.
Qp	1503	1.66	2495		III	III	Moderately high rigidity, generally underlain by bedrock at 1 meter; groundwater <10 ft deep southwest of Windy Hill (structurally controlled). Variable severity of shaking (V) where Qp overlies shallow bedrock in Carson Range.
Qpf	1692	1.63	2758		III	III	Moderately high rigidity; very coarse gravelly deposit; semi-lithified locally.
Qb	—	—	—			IV	
Qsb	—	—	—			IV	
Qsr	912	—	—			V	Possible hot spring activity locally causing saturation of Qsr; largely porous opal and chalcedony.
Th	1072	[2]1.4	1501		III	III	Low rigidity may be result of low density diatomaceous beds in Th; slightly to semi-lithified. Groundwater <30m deep southwest of Windy Hill (structurally controlled).
Tk	[3]4320	*2.8	12096			IV	
Tk (altered)	—	—	—			V	Hydrothermally altered to depths of 15-30m.
Ta	[4]3254	[2]2.6	8460			IV	
Kgd	[2]2450	[2]2.7	6600			IV	
Pkm	—	—	—			IV	
Landslide deposits	—	—	—			V	Landslides in Qdm, Th, Tk of unknown rigidity.

[1]Data from Reno quadrangle assumed density (Bell, Trexler, and Bell, 1978)
[2]Data from Reno quadrangle (Bell, Trexler, and Bell, 1978)
[3]Data from Steamboat quadrangle (Trexler and Nichol, 1981)
[4]Vs calculated at 1/2 Vp.
*Clark, S.P., 1966, in "Handbook of Physical Constants", rev. ed., GSA Memoir 97.

Seismic Velocity Data (ft/sec)
Reno NW 7 1/2-Minute Quadrangle
Table 4

Geol. Unit	Loc. No.*	Vp for	Vp rev	Vp avg	Comments	Vs	Vs/Vp
Qp	11	1000	964	982	Shallow groundwater table (<3 m deep)	784	.80
	29	1077	1176	1127	Shallow groundwater table (<3 m deep)	500	.44
Qfs	16	1733	1333	1533	Qfs may overlie Ts	960	.63
	21	1714	1652	1683		1147	.68
	24	2063	2143	2103		1163	.55
Qfg	26	2857	2500	2679		1300	.49
Qs	6	1875	1857	1866		1048	.56
	10	1250	1214	1232	Extensive animal burrowing at site	850	.69
	25	1875	1778	1827	Mudcracks at surface	885	.48
Qsw	9	1800	1742	1771	Qsw may overlie Ts	993	.56
	13	1571	1571	1571	Qsw may overlie Ts	744	.47
	15	1818	1500	1659	Qsw may overlie Ts	1119	.67
	17	2500	2500	2500	Qsw may overlie Ts; shallow groundwater table, extensive animal burrowing at site.	825	.33
	19	1440	1583	1512	Qsw may overlie Ts	790	.52
Qcd	2	1098	1142	1120	Shallow groundwater table (<3m deep)	714	.63
Qls	31	2385	2100	2242		1436	.64
Qb	4	1556	1842	1699		1037	.61
Qbu	30	1600	1500	1550	Qbu may overlie Ts	1297	.84
Qfb	3	886	1136	1011	Shallow groundwater table (<3 m deep)	750	.74
	20	1667	1130	1399	Shallow groundwater table (<3 m deep)	622	.44
Ql	23	1220	1290	1255		608	.48
Qd	22	1438	1444	1441		750	.52
Qoa	1	--	--	--	Poor P-wave record.	667	--
	14	1375	1667	1521		821	.54
Qpf	27	2889	2571	2730		1250	.46
	28	3000	2750	2875		1586	.55
Ts	5	1667	1667	1667		879	.53
	7	2625	2667	2646		1100	.42
	8	2860	2820	2840		1500	.53
	12	2222	2856	2539		793	.31
	18	2042	2300	2172		1045	.48
	33	2647	2500	2574	Ts overlies Mzv	1875	.73
Mzgd	32	--	--	--	Fill over Mzgd; test didn't penetrate fill.	--	--

* See Figure 5 for locations.

RIGIDITY PRODUCTS AND SHAKING CATEGORIES — MT. ROSE NE
TABLE 5

Geologic Unit	Shear wave Velocity (ft/sec) Vs mean	Density (g/cc) ρ mean	Rigidity Product Vs mean x ρ mean	SHAKING CATEGORY Depth to Groundwater <3m	<10m	>10m	Remarks
Qfl	765	1.36	1040	I			
Qa	717	1.54	1104	I	II		Includes Qa gravel unit. Variable severity of shaking (V) where Qa overlies bedrock in mountain streams.
Qaf	1224	1.47	1799		II	III	Variable severity of shaking (V) where Qaf overlies shallow bedrock in Steamboat Hills.
Qsu	1024	—	—			V	May be saturated at times due to hydrothermal activity; rigidity uncertain.
Qtm	1374	1.95	2679			III	Variable severity of shaking (V) where Qtm overlies shallow bedrock in Carson Range.
Qoa	833	1.65	1374		II	III	Variable severity of shaking (V) where Qoa overlies shallow bedrock in Steamboat Hills.
Qs	700	[1]1.8	1260			III	Low rigidity but groundwater deeper than 10m.
Qmb	—	—	—			IV	
Qd.	1367	1.76	2406		III		Moderately high rigidity and penetration resistance; very coarse, bouldery deposit.
Qdm	1066	1.65	1759		II	III	Variable severity of shaking (V) where Qdm overlies shallow bedrock in Carson Range and Steamboat Hills.
Qp	1503	1.66	2495		III	III	Moderately high rigidity, generally underlain by bedrock at 1 meter; groundwater <10 ft deep southwest of Windy Hill (structurally controlled). Variable severity of shaking (V) where Qp overlies shallow bedrock in Carson Range.
Qpf	1692	1.63	2758		III	III	Moderately high rigidity; very coarse gravelly deposit; semi-lithified locally.
Qb	—	—	—			IV	
Qsb	—	—	—			IV	
Qsr	912	—	—			V	Possible hot spring activity locally causing saturation of Qsr; largely porous opal and chalcedony.
Th	1072	[2]1.4	1501		III	III	Low rigidity may be result of low density diatomaceous beds in Th; slightly to semi-lithified. Groundwater <30m deep southwest of Windy Hill (structurally controlled).
Tk	[3]4320	*2.8	12096			IV	
Tk (altered)	—	—	—			V	Hydrothermally altered to depths of 15-30m.
Ta	[4]3254	[2]2.6	8460			IV	
Kgd	[2]2450	[2]2.7	6600			IV	
Pkm	—	—	—			IV	
Landslide deposits	—	—	—			V	Landslides in Qdm, Th, Tk of unknown rigidity.

[1]Data from Reno quadrangle assumed density (Bell, Trexler, and Bell, 1978)
[2]Data from Reno quadrangle (Bell, Trexler, and Bell, 1978)
[3]Data from Steamboat quadrangle (Trexler and Nichol, 1981)
[4]Vs calculated at 1/2 Vp.
*Clark, S.P., 1966, in "Handbook of Physical Constants", rev. ed., GSA Memoir 97.

RIGIDITY PRODUCTS AND SHAKING CATEGORIES — RENO NW

TABLE 6

Geologic Unit	Shear wave Velocity (ft/sec) Vs mean	Density (g/cc) ρ mean	Rigidity Product Vs mean x ρ mean	SHAKING CATEGORY Depth to Groundwater <3m	<10m	>10m	Remarks
Qp	642	1.09	700	I			
Qfs	1090	2.06	2245		II	III	
Qfg	1300	2.05	2665			III	High density due to coarse, gravelly nature of unit. Variable severity of shaking where thin deposit of Qfg overlies Mesozoic bedrock.
Qs	928	1.81	1680		II	III	
Qsw	920	1.55	1426		II	III	
Qcd	714	1.55	1107	I			Possible severe shaking where groundwater is <10m (33 ft) deep due to low rigidity and granular nature of deposit.
Qls	1436	—	—			III	Appears moderately well consolidated.
Qb	1037	1.74	1804		II	III	
Qbu	1247	2.16	2802		II	III	Inaccurate velocity and density measurements.
Qfb	686	1.42	974	I	II		North of Silver Lake where groundwater contours are inaccurate, all Qfb is designated as I. Qfb in this area has lower seismic velocity than Qfb at White Lake.
Ql	608	1.97	1198	I	II		
Qd	750	2.02	1515		II		
Qoa	744	1.74	1295		II	III	
Qpf	1418	1.73	2453		III	III	Shown as shaking category III where groundwater is <10m because of the moderately indurated nature of Qpf.
Ts	1199	1.66	1990		II	III	Lithified locally. Variable severity of shaking where isolated deposits of Ts overlie Mesozoic bedrock.
Tk	[1]4320	*2.8	12096			IV	
Tp	—	—	—			IV	
Mzqm	[2]1450	[2]2.3	3300			V	Deeply weatherly locally; converted to grus.
Mzgd	[2]2450	[2]2.7	6600			IV	
Mzqd	—	—	—			IV	
Mzv/Mzs Mzvs	[3]4000	[2]2.7	10800			IV	Bleached and altered locally.

*Clark, S.P., 1966, in "Handbook of Physical Constants", rev. ed., GSA Memoir 97.

[1]Data from Steamboat quadrangle (Trexler and Nichol, 1981).

[2]Data from Reno quadrangle (Bell, Trexler, and Bell, 1978).

[3]Vs calculated at 1/2 Vp.

Geologic Unit	Seismic Velocity (ft/sec)						Bulk Density (lbs/ft)	
	No. of Measurements	Vp range	Vp mean	No. of Measurements	Vs range	Vs mean	No. of Measurements	ρ range
Qp	4	964-1176	1054	2	500-784	642	2	+ 54-82
Qfs	6	1333-2143	1773	3	960-1163	1090	16	++125-139
Qfg	2	*2500-2857	2679	1	—	1300	1	—
Qs	6	1214-1875	1642	3	850-1048	928	1	—
Qsw	10	1440-2500	1875	4	744-1119	920	23	++ 70-131
Qcd	2	*1098-1142	1120	1	—	714	1	—
Qls	2	*2100-2385	2242	1	—	1436	—	—
Qb	2	*1556-1842	1699	1	—	1037	2	+100-118
Qbu	2	*1500-1600	1550	1	—	1297	1	—
Qfb	4	886-1667	1205	2	622-750	686	2	+ 80-98
Ql	2	*1220-1290	1255	1	—	608	2	+104-141
Qd	2	*1438-1444	1441	1	—	750	1	—
Qoa	2	*1375-1667	1521	2	667-821	744	1	—
Qpf	4	2571-3000	2803	2	1250-1586	1418	9	++ 76-127
Ts	12	1667-2860	2406	6	793-1875	1199	31	78-123
Tk	1	—	[1]6590	1	—	[1]4320	—	—

*Forward and reverse measurements at a single site.
[1]Data from Steamboat quadrangle (Trexler and Nichol, 1981).
+Sand cone densities by NBMG, July 1981.
++Includes sand cone density data.
+++Sand cone density sample contained gravel; density erroneously high.

ρ mean	g/cc	Standard Penetration Resistance (blows/ft) No. of Measurements	Range	Mean	Depth to Groundwater (ft) No. of Measurements	Range	Remarks
68	1.09	—	—	—	—	<10	
129	2.06	—	—	—	—	>10	Groundwater table (GWT) generally 10-30' (deep) in Qfs in south half of quadrangle; >30' in north.
++128	2.05	—	—	—	—	>30	
113	1.81	—	—	—	—	>10	GWT <30' in Qs north of Silver Lake; >30' in Cold Spring Valley and northern Lemmon Valley.
+ 97	1.55	132	1-96	17	34	4-13+	GWT generally >30' in Qsw in northern half of quadrangle
+ 97	1.55	—	—	—	—	<10	
—	—	—	—	—	—	>30	
109	1.74	17	20-74	48	—	<30	GWT <30' in Qb near Silver Lake; >30' near airport.
+135	2.16	—	—	—	—	10-30+	Density too high for this type of loose, sandy deposit.
89	1.42	—	—	—	—	<30	GWT <10' in Qfb north of Silver Lake; generally 10-30' elsewhere.
123	1.97	—	—	—	—	<10	GWT 10-20' in Ql north of White Lake.
±126	2.02	—	—	—	—	10-30	
+109	1.74	—	—	—	—	>30	GWT <30' in Qoa south of Silver Lake.
108	1.73	50	9-94	31	36	2-36+	GWT generally >30' deep in Qpf.
104	1.66	276	4-126	40	113	6-41+	Ts is generally unconsolidated; however, some anomalous lithified areas occur locally. This may, in part, account for the wide variation in seismic velocities.
—	[1]2.8	—	—	—	—	—	

Geologic Unit	Seismic Velocity (ft/sec) No. of Measurements	Vp range	Vp mean	No. of Measurements	Vs range	Vs mean	Bulk Density (lbs/ft) No. of Measurements	ρ range
Qfl	4	1037-1368	1200	3	611-846	765	19	51-119
Qa	10	947-2154	1508	5	547-893	717	243	57-139
Qa gravel	—	—	—	—	—	—	8	92-134
Qaf	8	2000-3030	2546	4	950-1444	1224	11	++ 78-120
Qsu	2	*2000-2250	2125	1	—	1024	—	—
Qtm	6	1622-2759	2161	3	1226-1647	1374	2	+113-130
Qoa	4	1250-2353	1662	1	—	833	5	++ 93-118
Qs	3	1000-2000	1450	1	—	700	—	—
Qd	3	2000-2071	2051	2	1304-1429	1367	80	93-135
Qdm	12	1412-2889	1937	6	735-1309	1066	9	+ 64-119
Qp	6	2428-3000	2715	3	1429-1550	1503	34	89-121
Qpf	12	1714-4705	3060	6	1270-2526	1692	33	++ 72-117
Qsr	2	*1043-1143	1093	1	—	912	—	—
Th	4	1786-2963	2235	2	1000-1143	1072	—	—
Tk	1	—	[3] 6590	1	—	[3] 4320	—	—
Ta	4	5000-8667	6507	—	—	[4] 3254	—	—

*Forward and reverse measurements at a single site.
[1] Data from Reno quadrangle, assumed density (Bell, Trexler, and Bell, 1978).
[2] Data from Reno quadrangle (Bell, Trexler, and Bell, 1978).
[3] Data from Steamboat quadrangle (Trexler and Nichol, 1981).
[4] Vs calculated at ½ Vp.
+Sand cone densities by NBMG, July 1981.
++Includes sand cone density data.

DATA — MT. ROSE NE
A

ρ mean	g/cc	Standard Penetration Resistance (blows/ft) No. of Measurements	Range	Mean	Depth to Groundwater (ft) No. of Measurements	Range	Remarks
85	1.36	242	1-86	16	104	3-10+	Groundwater table (GWT) generally <10' (deep).
96	1.54	1004	2-92	20	215	2-30+	GWT generally <10'.
110	1.76	54	23-100	53	59	1-18	GWT generally <10'; extent of this gravel unit within Qa is unknown; Qa gravel included with Qa for mapping purposes.
92	1.47	241	2-85	27	98	7-15+	GWT generally 10'-20'.
—	—	—	—	—	—	—	GWT generally >30', may be <30' locally.
122	1.95	—	—	—	—	—	GWT generally >30'.
103	1.65	13	14-63	43	26	4-8	GWT generally <30'.
—	[1]1.8	—	—	—	—	—	GWT generally >30'.
110	1.76	185	10-91	42	149	7-45+	GWT generally <30'.
103	1.65	12	12-39	27	41	6-12+	GWT generally >30' deep; <30' along streams and at distal ends of Mt. Rose fan.
104	1.66	18	10-50	36	32	>10	GWT generally >30'; <30' southwest of Windy Hill where structurally controlled.
102	1.63	49	14-73	37	73	10-47+	GWT generally >30'.
—	—	—	—	—	—	—	GWT generally >30', may be <30' locally.
—	[2]1.4	—	—	—	—	—	GWT generally >30'; <30' southwest of Windy Hill where structurally controlled.
—	[3]2.8	—	—	—	—	—	GWT generally <30'; large areas of Tk hydrothermally altered.
—	[2]2.6	—	—	—	—	—	GWT generally >30'.