GEOLOGIC MAPPING OF THE VISTA AND STEAMBOAT 7 ½-MINUTE QUADRANGLES, NEVADA

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ABSTRACT

This investigation used information derived from 3 techniques: 1) standard geologic mapping, 2) interpretation of low sun-angle photography and 3) trenching of fault scarps. The products of these techniques are information on the physical properties of the geologic units, verification on the location of faults and determination of age of last movement along selected faults by trenching. Trenching fault scarps provides additional information on 1) the spacial relation of the fault scarp to the fault trace, 2) the subsurface expression of the shear (zone), and 3) stratigraphic relationships as they will aid in recency of movement interpretations.

This study represents the first phase of a two-phased program dealing with the delineation of potential hazards associated with earthquake activity. The results of the investigation are anticipatory to the second phase of the research program which directly addresses earthquake hazards associated with the suspected response of the geologic units to seismic loading. The geologic maps published as a product of this research will provide the needed baseline information for the earthquake hazard maps, which are the primary product of this program.

INTRODUCTION

This investigation used information derived from 3 techniques: 1) standard geologic mapping, 2) interpretation of low sun-angle photography, and 3) trenching of fault scarps. Geologic mapping will be presented at 1:24,000. This scale has been found to be a suitable scale for delineation of the unconsolidated Quaternary units. Approximately 50 line miles of low sun-angle photography was flown over the northern half of the Vista Quadrangle specifically for this program. The remaining portion of the Vista Quadrangle and the entire Steamboat Quadrangle had been covered by low sun-angle photography flown by the Nevada Bureau of Mines and Geology. Interpretation of this photography provided information on the subtle expression of faults which cut alluvial material and are often not apparent in conventional aerial photography (Walker and Trexler, 1977). The trenching program was altered from previous earthquake hazard reduction studies. The trenches were dug with large track mounted equipment and the face opposite the working face was stepped back to a 1:1 slope. This strategy of trenching precluded the use of hydraulic shoring which requires funds for rental and man time for emplacement and removal.

By using the techniques described above we are able to provide information on the physical properties of the geologic units, verification on the location of faults and determine the age of last movement along selected faults by trenching. Trenching of fault scarps provides additional information on 1) the spacial relation of the fault scarp to the fault trace, 2) the subsurface expression of the shear (zone), and 3) stratigraphic relationships as they will aid in recency of movement interpretations.

Many of the descriptions of the geologic units have been discussed in the semi-annual report. Those descriptions that are new or were significantly modified by later work are presented in this report.

This study represents the first phase of a two-phased program dealing with the delineation of potential hazards associated with earthquake activity. The results of this investigation are anticipatory to the second phase of the research program which directly addresses earthquake hazards associated with the suspected response of the geologic units to seismic loading. The geologic maps published as a product of this research will provide the needed baseline information for the earthquake hazard maps, which are the primary products of the program.

STRATIGRAPHY

Pre-Tertiary Rocks

Metasedimentary Rocks

Metasedimentary rocks crop out at one locality in the Steamboat Quadrangle and in two localities in the Vista Quadrangle. Near the Castle Peak mine in the central portion of the Steamboat Quadrangle metasedimentary rocks consisting of carbonaceous slate and limestone are exposed. In the Vista Quadrangle metamorphosed sedimentary rocks are exposed both north and south of the Truckee River at Vista (site). Here the metasedimentary rocks consist predominantly of purple slate with minor metaconglomerate containing siliceous and andesitic pebbles. Chert is also found intercalated with the slates in this area.

Metavolcanic Rocks

Metavolcanic rocks are exposed in the southern portion of the Vista Quadrangle on both sides of the Truckee River in Sections 18 and 19 T19N,R20E and as a small circumalluviated outlier north of the river in Section 11. They are predominantly dark-grayish-green rocks irregularly stained with iron and probably represent metamorphic equivalents of basalt and andesite.

The age of the metamorphic rocks is probably Triassic with some being possibly as old as late Paleozoic (Thompson, 1956; Thompson and White, 1964). The Triassic age of the deposits is based on meager floral and faunal remains (Thompson, 1956).

Granodiorite and Related Rocks

Intrusive rocks of granodiorite composition are exposed in 3 areas; 1) along the west front of the Virginia Range, 2) in the Steamboat Hills, and 3) in the northwest portion of the Vista Quadrangle. The granitic rocks range in composition and texture, the most abundant type is granodiorite, which contains approximately 200% more plagioclase than orthoclase. Gradational changes in the amount of hornblende and biotite are the most conspicuous variations in mineralogy and also have been noted by Thompson (1956), and Rogers (1975). Original mineralogical lineations have been modified by faulting in those outcrops in the southern portion of the Steamboat Quadrangle. The age of the granodiorite intrusives is believed to be contemporaneous with the major intrusive episodes in the Sierra Nevada, which are considered to be Cretaceous in age.

Tertiary

Volcanic and Sedimentary Rocks

Volcanic rocks of silicic and intermediate composition were the predominant rocks extruded during the mid- to late-Tertiary. Following the cessation of eruption of intermediate volcanic rocks, erosion and deposition of conglomeratic rocks derived from the intermediate volcanic rocks and deposition of lacustrine deposits of shale, diatomite and ash were common. Description of these rocks and their age relationships have been discussed in detail in the semi-annual report, and further discussion of the physical properties of these rock units is considered redundant.

Late Tertiary Basaltic Andesites

Lousetown Formation

The Lousetown Formation consists of intrusive plugs and flows derived from at least three vents; one approximately 2 miles north-northeast of Castle Peak; the second just east of the Steamboat Quadrangle boundary at the same latitude as Castle Peak and the third located in the Steamboat Hills off the southwest corner of the Steamboat Quadrangle. The flows are gray-green basalt and pyroxene andesite (basaltic andesite), they rest unconformably upon the Kate Peak Formation and the Tertiary sedimentary rocks. Discordance between these units can be as much as 20 degrees but is generally less. A potassium-argon age of 6.9 ± 0.2 m.y. for the lower part of the Lousetown has been reported by Dalrymple and others (1967).

Basaltic Andesite of Spanish Springs Peak

The rocks are black, dull gray or brown on weathered surface. Minor olivine is present but it is partly or entirely altered to iddingsite. Thin well formed platy partings, parallel to the flow direction are common in flows of Spanish Spring Peak basaltic andesites. Many flows are quite vesicular and have undergone surface oxidation which has produced an orange to red coloration.

The flows north of the Truckee River cover approximately 30 percent of the eastern portion of the Vista Quadrangle. The source for these flows is Spanish Springs Peak located 6.5 km (4 mi) north-northeast of the Vista Quadrangle (H. F. Bonham, Jr., personal commun.). Flow directions and thinning of the flows to the south indicate the source for basaltic andesites are from a vent area located to the north. These flows are considered to be age equivalent with flows of the Lousetown Formation.

Quaternary

Introduction

Quaternary units described in the semi-annual report included the Steamboat Hills Rhyolite, hot springs deposits and sedimentary deposits including old alluvial fan deposits and alluvium, Tahoe outwash, alluvial fan deposits, valley fill alluvium, eolian sand and floodplain-lacustrine deposits. Further mapping in the Steamboat Quadrangle and extensive mapping in the Vista Quadrangle, especially in those areas outside of the Truckee Meadows, such as Spanish Springs Valley and the Truckee Canyon provide information on many of the previously described units and several units which were not recognized at the time of the writing of the semi-annual report. All of the Quaternary units discussed in this section are sedimentary deposits, except for the McClelland Peak olivine basalt, which was discovered in several isolated outcrops near the boundary between the Vista and Steamboat Quadrangles in the Truckee River Canyon.

Previous studies in the Truckee Canyon by Birkeland (in Wahrhaftig and others, 1965, and Birkeland, 1968) defining the relationship between glacial outwash deposits and deposits of Lake Lahontan have been modified as a result of this study. Special care was made to use lithostratigraphic relationships as well as soil development and not to rely solely on soil-stratigraphic relationships as employed by Birkeland (1968).

McClelland Peak Olivine Basalt

Isolated flow remnants of the McClelland Peak olivine basalt are found at the confluence of the Truckee River and Long Valley Creek in the extreme south-eastern portion of the Vista Quadrangle. The basalt is black and contains small conspicuous, clear, yellow to green olivine phenocrysts set in an aphanitic groundmass. Locally flows weather reddish-brown and small augite crystals give the surface a peculiar sheen. Columnar jointing is common and large talus piles are common at the base of flows.

The remnants of McClelland Peak olivine basalt are considered to be part of an intracanyon flow that extended down Long Valley Creek into the Truckee River Canyon (Thompson, 1956). Potassium-argon age dating by Doell and others (1966) indicates an age of 1.14 ± 0.04 m.y. for a small remnant of McClelland Peak basalt near Silver City. Outcrops in Long Valley Creek and the Truckee River Canyon are considered to be of similar age.

Old Pediment deposits (Qpo)

The oldest Quaternary units in the Vista quadrangle are small remnants of erosional surfaces confined to the flanks of Spanish Springs Valley. The surfaces are thinly veneered with brown muddy sandy granule gravel that is non-indurated below the soil zone and poorly sorted.

Soils on the deposits have argillic horizons and siliceous duripans (Soil Conservation Service, 1979) suggestive of pre-Sangamon age. The pediment deposits are considered pre-Illinoian since they are at higher topographic positions than old alluvial fan deposits (Qfo) that grade into Donner Lake outwash.

Donner Lake Outwash (Qdo)

Glacial outwash deposits associated with Donner Lake glaciation are exposed in northern Truckee Meadows and at Mustang. In Truckee Meadows exposure of the deposits is limited, but at Mustang they comprise a relatively extensive terrace of low relief. The deposits are gradational into old alluvial fans (Qfo) on the flanks of adjacent mountains.

Donner Lake and Tahoe outwash deposits were originally studied by Birkeland (in Wahrhaftig and others, 1965; and in Birkeland, 1968) who attributed their existence to large-scale flooding of the Truckee River during glacial periods. Bingler (1976) has also described these gravels in the Reno Quadrangle.

In Truckee Meadows the sediments consist of light brown sandy pebble and cobble gravels that are moderately indurated, unsorted and massive and outcrop at an elevation of about 4,440 feet (1,353 m). Gravels are subangular to round and they contain few boulders, with the boulders being less than 0.6 m diameter. Boulder counts yield basalt 58%, andesite 27%, metamorphic rocks 11% and rhyolite 4%. Cobble-pebble counts (combined) yield basalt 80%, andesite 10%, metamorphic rocks 9% and rhyolite 1%.

At Mustang the sediments are dark yellowish brown sandy large pebble and cobble gravels that are non-indurated, unsorted, moderately eroded and occur at an elevation of 4,390 feet (1,338 m). These deposits differ from Tahoe outwash at this locality in that they contain fewer boulders, none of which are greater than 0.6 m diameter, whereas Tahoe outwash contains boulders of up to 4 m diameter. Gravel clasts in Donner Lake outwash at this locality vary from angular to round, with the boulders being composed of basalt 68%, rhyolite 19%, plutonics 9% and andesite 4%. Combined pebble-cobble counts yield basalt 70%, rhyolite 10%, andesite 8%, altered andesite 7% and metamorphic rocks 5%.

Donner Lake outwash is overlain by soils with argillic horizons and petrocalcic-siliceous duripans. They are considered Illinoian age (Bingler, 1976; Birkeland, 1968).

Old alluvial fan deposits of Spanish Springs Valley and Truckee Meadows (Qfo)

Old alluvial fans and bajadas are situated on the flanks of Spanish Springs Valley in the Vista Quadrangle and Truckee Meadows in the Vista and Steamboat Quadrangles. They are moderately eroded, locally pedimented and locally veneered with eolian sand.

The deposits consist of light yellowish brown to grayish brown sandy pebble and cobble gravel and gravelly muddy medium to coarse sand. They are non-indurated, unsorted to poorly sorted and massive. Soils on the deposits contain argillic B horizons and siliceous duripans. The sediments are considered Illinoian age because they are gradational with Illinoian Donner Lake outwash.

Old alluvium of Spanish Springs Valley (Qao)

Old valley-fill alluvium is present in Spanish Springs Valley in the northern part of the Vista quadrangle. The alluvium forms a moderately eroded flat terrace that is being dissected by streams in the valley.

The deposits consist of yellowish brown slightly gravelly medium to coarse sand and gravelly muddy coarse sand containing lenses of muddy very fine sand. They are non-indurated, moderately to well sorted and thick bedded to massive.

Soils on the deposits have argillic horizons and silceous duripans. The sediments grade into old alluvial fans (Qfo) of Illinoian age, and therefore they are also considered Illinoian age.

Tahoe Outwash Deposits (Qto)

Glacial outwash deposits associated with Tahoe glaciation are exposed throughout Truckee Meadows and at Mustang. The deposits form an extensive low-gradient terrace in Truckee Meadows, but only remain as a dissected terrace remnant at Mustang. East of Mustang outwash terraces are present but are confined to the narrow Truckee River Canyon.

Tahoe outwash deposits have been studied by Birkeland (in Wahrhaftig and others, 1965; and in Birkeland, 1968) and Bingler (1976) who has described these deposits in the Reno quadrangle.

In the Truckee Meadows the deposits consist of yellowish brown to grayish brown non-indurated, sandy medium to large pebble gravel interbedded with lenses of slightly gravelly muddy fine to coarse sand (McKinney, unpubl. data). Gravel clasts are subangular to round and composed of andesite 63%, rhyolite tuff 13%, plutonic rocks 11%, metamorphic rocks 9% and basalt 4%. They are exposed at elevations of approximately 4,400 feet (1,341 m), and are overlain by Holocene deposits.

At Mustang the deposits overlie weathered bedrock and consist of yellowish brown bouldery sandy pebble and cobble gravels that are non to weakly indurated, unsorted and massive. Large boulders are present that range from 1-4 m in diameter and are composed totally of basalt, probably locally derived. Boulders less than 1 m in diameter are composed of basalt 66%, andesite 15%, plutonic rocks 15% and metamorphic rocks 3%. Cobble and pebble gravels consist of basalt 76%, andesite 9%, altered andesite 5%, plutonic rocks 4%, metamorphic rocks 4% and rhyolite 2%. Bingler (1976) reports that the deposits in Truckee Meadows are 65 to 100 m thick, but at Mustang the gravels are only 3 m thick. To the east, at Patrick, however, the deposits are at least 7 m thick.

Tahoe outwash deposits are overlain by argillic soils containing columnar structure and clay skins. These soils indicate a Wisconsinan age for the deposits, which, when combined with the fact that they are older than Lake Lahontan [Eetza(?)] units, suggests that they are of early Wisconsinan age. Birkeland (1968) erroneously inferred them to be the same age as Eetza sediments (see section on Lake Lahontan units below).

Lake Lahontan Units

Remnants of lacustrine units associated with Pleistocene Lake Lahontan are exposed in the Truckee River Canyon near Mustang in the southwestern part of the Vista quadrangle at an elevation of 4,346 feet (1,325 m). The sediments are relatively thin and are only locally present at Mustang, but they become progressively more areally extensive to the east in the Spanish Springs Valley and Wadsworth quadrangles. East of Patrick the sediments thicken abruptly.

Morrison (1964) has described in detail Lahontan lacustrine and subaerial units in the Carson Desert and in the Wadsworth area (in Wahrhaftig and others, 1965). Briefly, Morrison (1964) found that during early Lake Lahontan time (35,000-75,000 BP) the lake reached a maximum elevation of 4,380 feet (1,335 m), receded to about 4,100 feet (1,250 m), and then rose again to 4,340 feet (1,323 m). During this lake interval coarse lake sediments (beach gravels) were deposited at elevations about 4,100 feet (1,250 m) and sands, silts, and clays were deposited below this elevation. Collectively these deposits are named the Eetza Formation. During middle Lake Lahontan time (25,000-35,000 BP) the lake was intermittently dry and shallow; lake level was below 4,000 feet (1,220 m). During this recessional phase alluvial sediment was deposited and a distinct soil developed: the sediments are named the Wyemaha Formation and the soil developed on them is called the Churchill soil. The Churchill soil is typically recognized as a Haplargid by soil taxonomic terminology (Bell and Pease, 1979). Following Wyemaha deposition and Churchill soil dvelopment (within the last 25,000 years), the lake rose to 4,370 feet (1,332 m) and then permanently receded to elevations below 4,200 feet (1,280 m). During this last lake maximum fine-grained sediments (sands, silts and clays) of the early Sehoo Formation were deposited. During mid and late Sehoo time the dendritic tufa and upper members were deposited. Morrison's work is still considered very accurate and to date has not been significantly revised. In fact, more recent work confirms the number and time of high stands inferred by Morrison for upper and post-Lake Lahontan intervals (Benson, 1978; Born, 1972), although some of the ages of units and stratigraphic details of Lake Lahontan sedimentation have been modified (Davis, 1978).

Near Mustang the Lake Lahontan sediments have been studied by several authors who have attempted to correlate them with formations of the Lake Lahontan Group in the Lahontan basin. However, none of these workers agree as to which stratigraphic unit the sediments belong. Birkeland (<u>in</u> Wahrhaftig and others, 1965; and Birkeland, 1968) was the first to describe them, and he interpreted them as being part of the Eetza Formation deposited during one of the early lake high stands. Birkeland's work relied heavily on soil-stratigraphy, and he did not use a sedimentologic approach to the problem (such as using lithologic criteria). Also, east of Mustang he apparently failed to recognize post-Churchill soils on Lahontan deposits or else mistakenly identified them as eroded Churchill soils, and concluded that all sediments between Mustang and Clark belonged to the Eetza Formation. Hawley (1969) pointed out that Birkeland's (1968) interpretation has not been "universally" accepted by workers familiar with the Lake Lahontan deposits near Mustang and predicted that some of those deposits may actually be of Sehoo rather than Eetza age.

As part of the present investigation a detailed study was undertaken to determine whether the Lake Lahontan deposits exposed near Mustang belong to the Sehoo or Eetza Formations. The first phase of this study involved careful examination of Lake Lahontan sediments in areas where fairly complete and previously described stratigraphic sections were exposed that are near the sediments in question in the Truckee River Canyon. The Wadsworth amphitheater (S15,T21N,R24E) and a railroad cut (S31,T22N,R24E) were chosen as the best exposures of Lahontan stratigraphy based on previous work by Morrison (in Wahrhaftig and others, 1965). In comparing nearshore sand facies of the Eetza Formation with similar Sehoo facies at these localities it was found that the Eetza Formation contains many complete gastropod fossils averaging 6 mm in diameter, in contrast to the Sehoo Formation which contains very few shells, most of which are only about 1 mm in diameter. In the amphitheater, Sehoo clays were found to be very friable and unconsolidated and could easily be crushed with one hand, but many beds of Eetza clays were much more indurated and could barely be broken with two hands. The Wyemaha Formation stands out as a dark band of oxidized alluvial gravels between Sehoo and Eetza deposits, with the presence of Churchill soil being diagnostic. Other distinctive features noted by Morrison (1964) include an abundance of tufa and the presence of gastropod and pelecypod shells in the Sehoo Formation, and the general absence of tufa and pelecypod shells in the Eetza Formation. Of these criteria, it was decided that the difference in induration of the clays may be of most value because the clays would be present more often than tufa or fossils. Tufa or fossils would be diagnostic when present, but their absence would not be as meaningful. Of course, if the Wyemaha Formation could be recognized, it could be used as a diagnostic marker unit.

The second phase of the study was an attempt to trace the sediments from the Wadsworth exposures westward into the Truckee River Canyon toward Mustang by utilizing the diagnostic criteria described above along with physical sedimentological features, such as types of beddings, which could be used as a method of determining sedimentary environments (deltaic facies, deep lacustrine facies, etc.). At Mustang, the sediments consist of pale brown silt and clay with interbedded fine sand. They are non to weakly indurated well sorted, laminated to thin-bedded and slightly to moderately eroded. Bedding is rippled and contorted, and suggests sedimentation in a deltaic environment. Soils on the units contain argillic B horizons with strong columnar and weak angular blocky structure. Soils were used as an aid in determining the age of the units.

By utilizing these diagnostic criteria, several conclusions were reached:

1. The Wyemaha Formation is tentatively identified in several places between Gilpin and Clark along U.S. Interstate 80 (see Figs. 1 and 2). Unconsolidated Sehoo deposits overlie it, and the Churchill soil is present in the exposure west of Orchard.
2. Moderate to deep lacustrine Sehoo units are present as far west as Patrick at elevations up to about 4,370 feet (1,332 m) and as low as the Truckee River. These deposits are confidentially identified. They are horizontally laminated sands, silts and clays that are unconsolidated and overlain by cambic soils.
3. Between Clark and Patrick, all lacustrine sediments belong to a Sehoo deltaic facies (which has convolute, contorted and rippled bedding) that is unconsolidated and bears cambic soils. West of Patrick, all Lahontan units thin rapidly.
4. The abundance of Sehoo deltaic deposits at Patrick and the absence of them west of Patrick suggests that the Truckee River delta during the time of the last Sehoo lake was located at Patrick. If any Sehoo deposition occurred west of Patrick it must have been very minor. This suggests that the sediments at Mustang are of

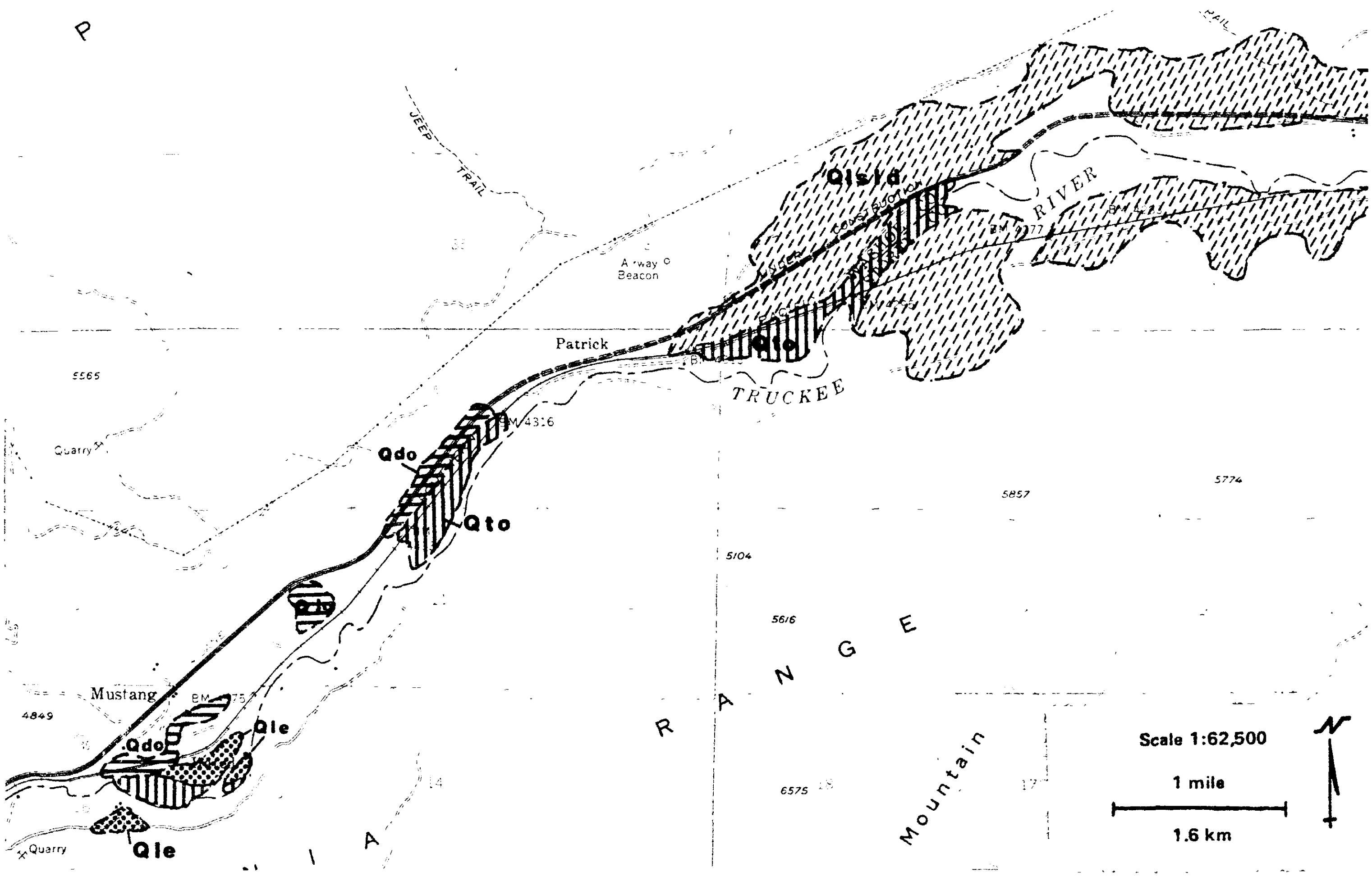

Figure 1. Geology map based on airphoto interpretation showing distribution of Lahontan deposits and outwash. Qlsld = Deltaic facies of the lower member of the Sehoo Fm.; Qle = Eetza (?) Fm., deltaic facies; Qto = Tahoe outwash; Qdo = Donner Lake outwash.

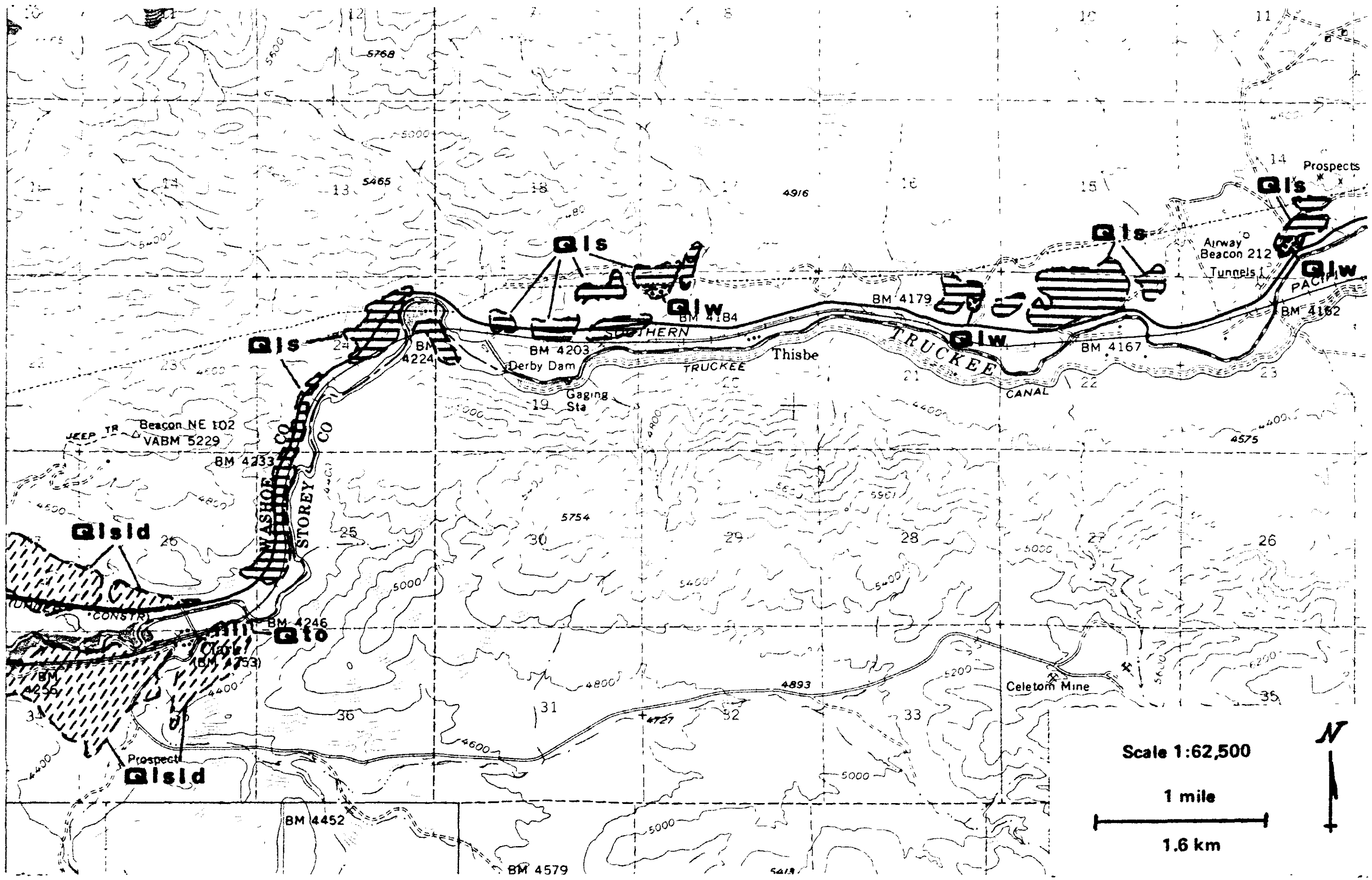

Figure 2. Geology map (modified from Rose, 1969) showing distribution of Lahontan units and outwash. Qlsld = Deltaic facies of the lower member of the Sehoo Fm.; Qls = Sehoo Fm. undifferentiated, mostly moderate to deep lacustrine facies; Qlw = Wyemaha Fm.; Qto = Tahoe outwash.

Eetza age, but does not completely preclude the possibility that they are actually Sehoo, since they are of the same deltaic origin as those at Patrick.

5. The deposits at Mustang are tentatively regarded as Eetza Formation for three reasons. First, the induration of the clays is similar to Eetza clays seen in the Wadsworth amphitheater; second, the soils at Mustang are much stronger (argillic) than those on Sehoo deposits (cambic) elsewhere in Truckee River Canyon; and third, the apparent absence of Sehoo deposition west of Patrick suggests that the sediments at Mustang are of Eetza age.

6. Although the sediments at Mustang are tentatively considered Eetza, there remains some conflicting evidence. First, the sediments at Mustang are of the same facies as those at Patrick; second, the Sehoo lake should have obliterated Eetza deposits and the relict soil at Mustang due to the high energy flow of the Truckee River; third, in the Carson Desert all of the Eetza Formation above 4,200 feet (1,280 m) is gravel rather than sand, silt and clay; and fourth, all Eetza deposits seen in the Truckee River Canyon east of Mustang are at a maximum elevation of 4,280 feet (1,305 m) which is about 65 feet (20 m) lower than the elevation of the sediments at Mustang. In addition, the deposits at Mustang should have been permanently exposed following the last high stand of the Sehoo lake, thus allowing a soil to form over about a 15,000 year period, which could look similar to the Churchill soil but would have formed at a much later time (0-15,000 years BP as compared to 12,000-35,000 years BP).

Alluvial fan deposits of Spanish Springs Valley and Truckee Meadows (Qf)

Alluvial fans and bajadas flank Spanish Springs Valley in the Vista quadrangle and Truckee Meadows in the Vista and Steamboat quadrangles. They are moderately eroded.

The sediments consist of light yellowish brown to strong brown muddy sandy granule to pebble gravel, gravelly very coarse sand and gravelly muddy medium to coarse sand. They are non to moderately indurated, poorly to well sorted and laminated and crossbedded to massive.

Soils on the deposits contain argillic horizons and they are considered late Pleistocene (Wisconsinan) age.

Alluvial fan deposits of Truckee River Canyon (Qft)

Alluvial fan and bajada sediments have been deposited along the Truckee River in the Vista Quadrangle. The fans are slightly eroded, and have been dissected by the river.

Lithologically, the deposits consist of light yellowish brown and yellowish brown muddy sandy small to medium pebble gravel and gravelly muddy medium to coarse sand. They are non-indurated, unsorted and thick bedded to massive.

The deposits are overlain by cambic soils and are early to middle Holocene age.

Alluvium of Spanish Springs Valley and Truckee Meadows (Qa)

In Spanish Springs Valley and Truckee Meadows are slightly eroded deposits of valley-fill alluvium that are being dissected by active drainages.

The deposits consist of very pale brown to brown muddy very fine to medium sand, fine to medium sand and sandy mud with thinly interbedded sandy pebble gravel. They are non-indurated, well sorted and laminated to thickly bedded.

Soils overlying the sediments have cambic horizons; and the sediments are of early to middle Holocene age.

Floodplain and lake deposits (Qfl)

Floodplain deposits occur throughout parts of the Vista and Steamboat Quadrangles in Truckee Meadows as an undissected terrace of low relief. The deposits have been studied by McKinney (Unpubl. data) and Bingler (1976) who carbon-dated them at 2,130 ± 165 years BP. In the Helms gravel pit they overlie Tahoe outwash.

The sediments consist of pale yellowish brown to light gray very fine sandy mud and silt with minor interbedded fine to medium sand locally containing lenses of peat up to 2 feet thick and organic-rich beds. They are non-indurated, well sorted and thin to medium bedded (McKinney, Unpubl. data).

The sediments contain thin soils and are of late Holocene age.

Eolian Sand (Qe)

Dunes of eolian sand are present locally throughout the Vista Quadrangle. The sand is yellowish brown to pale brown very fine to medium sand; non-indurated, well sorted and non-eroded. For the most part, soils on the sand lack pedogenic horizons (Entisols) but on some of the deposits A-C profiles are recognizable. The dunes are late Holocene age.

Mainstream gravel (Qmg)

Sand and gravel have been deposited on the active Truckee River floodplain. The sediments are the result of flooding along the the river, some of which has occurred during historic time (Bingler, 1976).

STRUCTURE

Regional tectonic regimes impacting the Steamboat Quadrangle and the Vista Quadrangle are: 1) the Sierra Nevada frontal fault system, 2) Basin and Range type normal faulting, and 3) the Olinghouse fault zone. A fourth type of structural orientation is also apparent which occurs where components of both the Sierra Nevada and east-northeast zones, such as the Olinghouse fault zone interact with one another (Trexler, 1979). Where east-northeast zones intersect the Sierra Nevada front the manner of faulting is one of en echelon faults with small vertical offsets which combine to equal a total displacement of several thousands feet.

In the Steamboat Quadrangle faulting appears to have components of two of the major styles of deformation, Sierra Nevada and Basin and Range. Along the front of the Virginia Range in sections 34, 35 and 36 T19N,R20E and sections 1, 2 and 3 of T18N,R20E the combined effects of the Basin and Range and the Olinghouse trends are apparent. Here the range front exhibits the saw-tooth appearance that has been noted previously at regional scales as well as local scales (Bell and Trexler, 1979). This saw-tooth appearance in the range front is caused by orthogonal sets of faults which have had movement continuously for some period of time, with each having similar rates of occurrence and magnitudes of displacement. This equilibrium in opposite sets of stress has been maintained since post-Kate Peak Formation time or less than 12 m.y. (Silberman and McKee, 1972). Based on the present mapping both trends offset alluvial fan deposits (Qf) of similar age and therefore a distinction between which trend had the most recent activity cannot be made. Both trends are common in the northwest and north-central portions of the Steamboat Quadrangle.

In the Huffaker Hills along the western border of the quadrangle northeast trends are the only fault orientation apparent in the bedrock. These northeast trends are also found immediately south of the Huffaker Hills where faults with similar trends have offset Donner Lake outwash (Qdo). The combined effect of the northwest and northeast trends is to cause a marked perturbation in the range front trend east of the Huffaker Hills. It appears that the conjugate effects of the northwest-northeast trending faults are operative in the northern portion of the Steamboat Quadrangle while the southern portion is characterized by faulting that is more consistent with the typical Basin and Range north-northeast trends.

The youngest age that can be attributed to faulting in the bedrock areas of the Virginia Range is post-Lousetown ($\approx$ 7 m.y., Dalrymple and others, 1967). There does not appear to be any structural control to the alteration of the Alta and Kate Peak Formations.

In the Steamboat Hot Springs area in the southeast corner of the quadrangle faulting along a northerly trend is suspected to be the controlling factor for the hot spring location. The determination of the age of the faulting is difficult since siliceous sinter is continuously deposited.

Trenching of two fault segments in the Steamboat Quadrangle, which cut alluvium, provided information on the age of last movement. Based on soil development both faults are no younger than pre-Sangamon (early- to middle-Pleistocene). The method of age determination and a detailed discussion of the results of trenching are discussed in the next section of this report.

In summary, faulting in the southern portion of the Steamboat Quadrangle has a north to north-northeasterly orientation. Trends of Quaternary age faulting, as well as faulting in the bedrock areas of the Virginia Range have a component which trends northeasterly. Northwest trends occur as range bounding faults and as bedrock faults in the Virginia Range.

Faulting in the Vista Quadrangle has components of the Sierra Nevada front and the Olinghouse fault zone. Northeast and east-northeast fault trends are the most predominant type in the Vista Quadrangle. These easterly trends are associated with the Olinghouse fault which has had historic surface rupture along an east-northeast trending segment 14 km (9 mi) east of the Vista Quadrangle. The total length of the zone is 23 km (14 mi) and 3.65 m (12 ft) of left-slip offset occurred as a result of the December 27, 1969 earthquake which had a magnitude of 6.7 (Sanders and Slemmons, 1979).

Four faults enter the Vista Quadrangle from the east and have trends similar to the Olinghouse fault zone. Slemmons (1979) believes that these faults are part of a larger northeast trending zone that includes faults and folds in the Truckee, Verdi and Reno areas. The deformation includes the Pliocene - Quaternary synclinal like downwarp in the Verdi-Reno area which has an east-west axis. This zone terminates and transposes to the west the Sierra Nevada front. The zone is considered seismically active with surface rupture occurring during the 1966 Truckee earthquake which had a magnitude of 6.

Several other faults in the hills north of Reno and Sparks exhibit similar northeast trends. North of Sparks in sections 23-26, 3 faults have northeast trends and one has an east-west orientation.

The fault which bounds Spanish Springs Valley on the west offsets alluvial fan deposits (Qf) which are probably Wisconsinan in age at the northern boundary of the quadrangle. Age of this fault to the south appears to be older since it is covered by fan material of Wisconsinan age.

In summary, northeast trending faults are the predominant trend in the Vista Quadrangle. The morphology of the scarps suggests a relative young age, although deposits of Quaternary age have not been offset. Northeast trending faults outside of the Vista Quadrangle to the west and east have had historic siesmicity accompanied with ground rupture. North-northeast trending faults which bound Spanish Spring Valley on the west are Sierra Nevada front type faults and exhibit movement as late as mid-Pleistocene.

TRENCHING

Three trenches were dug across two faults along the western front of the Virginia Range in the Steamboat Quadrangle. Trenching was performed with a large track mounted backhoe rather than a conventional rubber tired back hoe (fig. 3). The use of this type of equipment allowed for excavation of a much wider trench. The north face of the trench was vertical while the south face was stepped back to form a 1 to 1 slope. By using this type of trench design and excavating to maximum depths of 3 m (10 ft), nominally 2 m (6 ft), the use of hydraulic speed shoring to prevent caving was unnecessary.

Trenches 1 and 2 were located in the Hidden Valley area (S23,T19N,R20E) of the Steamboat Quadrangle (fig. 4). They were placed across the trace of a fault which exhibited a scarp in alluvial fan deposits which were thought to be of a relatively young age.

Trench 1 was 30 m (110 ft) in length and reached a maximum depth of 3 m (10 ft). Exposures in the trench wall indicated an A soil horizon ranging from 15-25 cm (6-10 in) containing eolian sand. The boundary between horizon A and the lower B_{2t} is abrupt and smooth. The underlying B_{2t} soil horizon is a clay loam to sandy clay. It has a strong angular blocky, weak prismatic texture. The boundary between this horizon and B_3 is abrupt and smooth to wavy. The B_3 horizon is a loam having a weak angular blocky texture and being slightly sticky and non-plastic. The boundary with lower Csica horizon is diffuse to gradational.

The lowermost development of soil (Csica) is characterized by a coating of silica and calicum carbonate on gravel clasts in gravelly alluvium and a strong well cemented duripan and coatings on clasts and ped surfaces. Boundary with alluvium below is diffuse.

The alluvium can be differentiated into five distinct mappable units. These are shown on Figure 5 and range from sandy small pebble gravel (Unit 2)

Figure 3. Photograph of track mounted backhoe excavating trench in the Hidden Valley area of the Truckee Meadows.

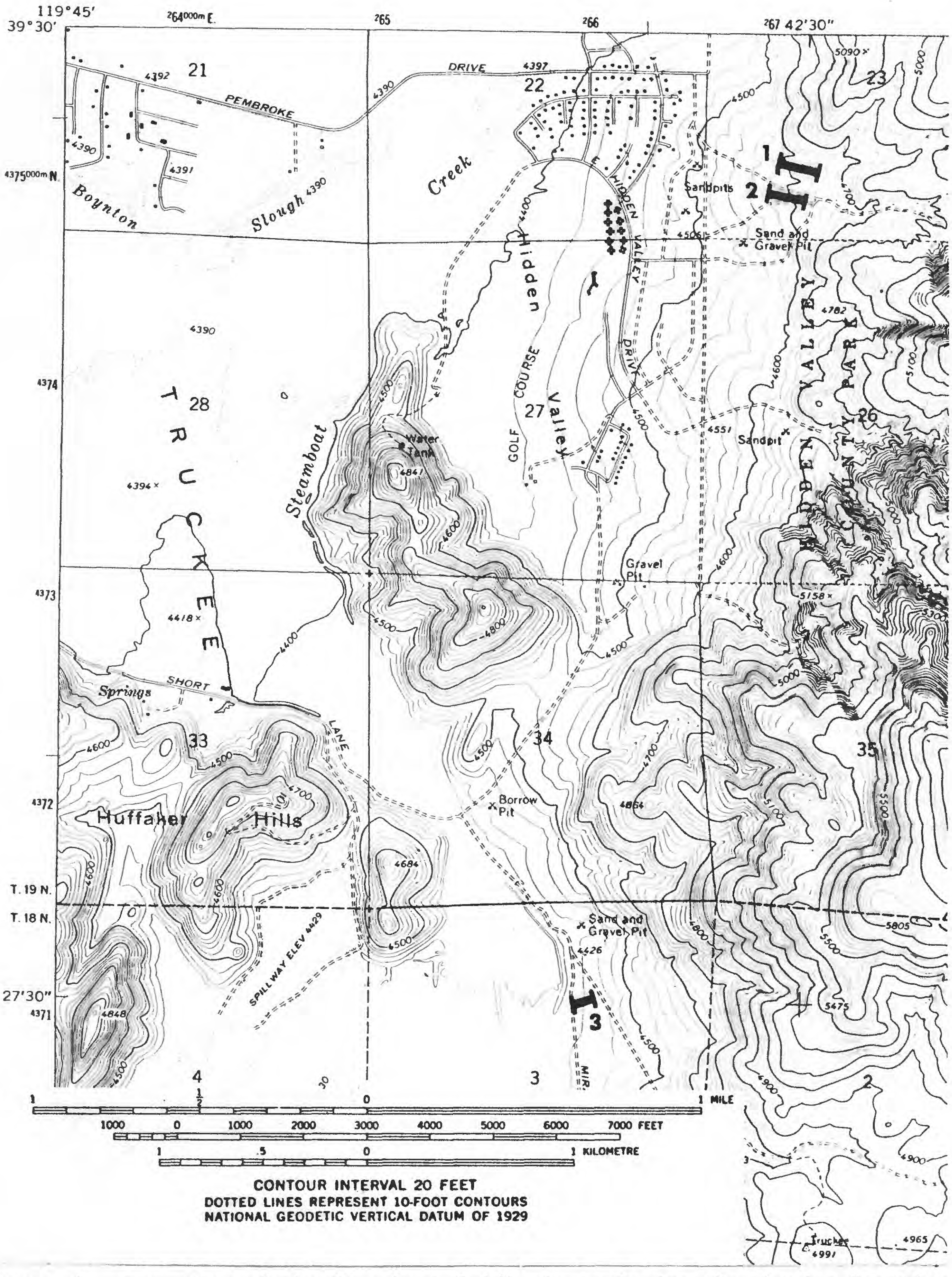

Figure 4. A portion of the Steamboat 7 1/2-minute Quadrangle showing location of trenches.

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FIGURE 5

HIDDEN VALLEY SITE
TRENCH 1, LOG OF NORTH WALL
T19N,R20E SW½ SECTION 23
SCALE 1 in. = 5 ft.

[A] A soil horizon—Eolian fine sand. Brown (10YR 5/3), single grain, non-sticky, non-plastic. Boundary to B_{2t} is abrupt and smooth.

[B_{2t}] B_{2t} soil horizon—Clay loam to sandy clay. Brown to dark (7.5YR 4/4) brown (moist color), strong angular blocky (1" peds), weak prismatic (2" peds), sticky, plastic. Boundary to B_3 is abrupt and smooth to wavy.

[B_3] B_3 soil horizon—Loam light yellowish brown (10YR 6/4, m), massive to weak angular blocky (1" peds), slightly sticky, non-plastic. Boundary to Csica is diffuse.

[Csica] Csica soil horizon—In gravelly alluvium = coatings on gravel clasts with no cementation. Mostly *duric*. In clayey alluvium = strong, and well cemented duripan, coatings on clasts and ped surfaces, non-sticky, non-plastic, light yellowish brown (10YR 6/4, m). Boundary to alluvium is diffuse.

1. Sandy small to large cobble gravel—yellowish brown (10YR 5/4), massive, unsorted, non-indurated.
2. Sandy small pebble gravel—brown (10YR 5/3), poorly to moderately sorted, non-indurated, graded bedding.
3. Sandy medium large cobble gravel—yellowish brown (10YR 5/4), unsorted, non-indurated, massive. Contains some 1–2 foot boulders.
4. Sandy large pebble and small cobble gravel—brown (10YR 5/3), poorly sorted, non-indurated. Occurs as local lenses.
5. Muddy large pebble gravel—brown (7.5YR 5/4), unsorted, non-indurated.

Fault descriptions:

Main fault zone is apparent as a 1–2 foot wide disturbed zone containing a mixture of alluvial debris from geologic units 1–3. Brown (10YR 5/4), loose, unconsolidated, roots in fractures. Main fault trace = N15E70W. Offset = 6 feet, which occurred in one movement. Other fracture at 55 feet trends N40E70W but has no offset.

Fault age—Csica soil horizon is *not* displaced and have Csica in fault zone also. Thus faulting is pre-soil, and therefore, is slightly pre-Sangamon in age (probably about Mid-Pleistocene).

through large pebble and small cobble gravel (Unit 4) to a sandy small to large cobble gravel, some boulders as large as .3-.6 m (1-2 ft) in diameter. The alluvial units range from unsorted to poorly sorted and are all non-indurated.

The main zone of displacement was encountered between stations 60 and 65 in Figure 5. This zone consisted of a .3-.6 m (1-2 ft) wide disturbed area containing a mixture of alluvial debris from alluvial units 1 through 3. Abundant roots were apparent in the disturbed zone. Total offset measurable in the fault trace was 2 m (6 ft) and the orientation was N15E and dipping to the west at 70°.

The age of the fault is considered to be pre-Sanyomon because the faulting is pre-soil and the Csica Horizon is not displaced. This data would indicate a probable mid-Pleistocene age of last movement.

Trench 2 was located 130 m (420 ft) south of the location of Trench 1 and indicates a marked difference in the style of deformation and tends to indicate the most southerly extension on surface rupture along this segment of the frontal fault. The differences observed in Trench 1 and Trench 2 are shown by comparing Figures 5 and 6. The disturbance by faulting is limited to alluvial units devoid of soil development.

Soil development consists of an A horizon composed of a non-sticky, non-plastic clayey silt. The boundary between the A horizon and the subjacent B_{2t} is gradual to smooth. The B_{2t} horizon consists of a clay loam having a massive to weak subangular-subrounded blocky texture. The contact with the B_3 soil below is gradual and smooth to wavy. Soil development in the B_3 horizon consists of a slightly plastic, slightly sticky massive sandy loam. This grades abruptly to alluvium below along a smooth wavy boundary.

The alluvium units consist of 3 major units and a lense of Unit 1A which is a sandy small to medium cobble gravel. The superjacent unit is a sandy small cobble gravel which is poorly sorted, non-indurated and becomes a moderately

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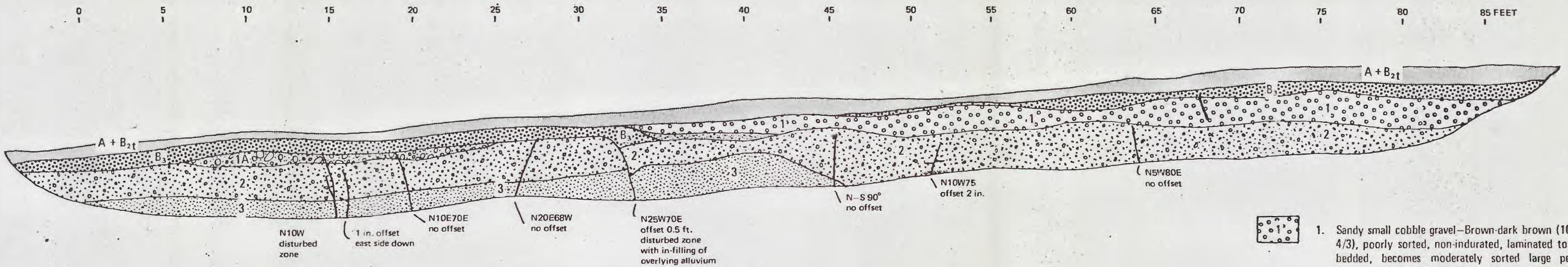

FIGURE 6

HIDDEN VALLEY SITE
TRENCH 2
T19N,R20E, SW¼ SECTION 3
SCALE 1 in. = 5 ft.

A — A soil horizon—Loam—dark yellowish brown (10YR 4/4), non-sticky, non-plastic, massive. Boundary to B_{2t} gradual, smooth.

B_{2t} — B_{2t} soil horizon—Clay loam—dark yellowish brown (10YR 4/4), massive to weak subangular-subrounded blocky (0.5–2" peds), sticky, plastic. Boundary to B_3 gradual and smooth to wavy.

B_3 — B_3 soil horizon—Sandy loam—brown, massive, slightly sticky, slightly plastic. Boundary to alluvium abrupt and smooth to wavy.

1. Sandy small cobble gravel—Brown-dark brown (10 YR 4/3), poorly sorted, non-indurated, laminated to thin bedded, becomes moderately sorted large pebble gravel upwards; contains lenses of well sorted slightly gravelly medium to coarse sand at base.

1A. Sandy small to medium cobble gravel—Brown (10YR 5/3), unsorted, non-indurated.

2. Sandy large pebble gravel and gravelly coarse sand—Brown to dark brown (10YR 4/3), graded bed sequence of sandy pebble gravel at base fining upward into moderately sorted gravelly coarse sand which then coarsens to unsorted sandy medium-large pebble gravel, laminated, non-indurated, clasts coated with $CaCO_3$ on undersides.

3. Slightly gravelly medium to coarse sand—Yellowish brown, well sorted, non-indurated.

Fault descriptions:

Open fractures and local disturbed zones with in-filling of overlying alluvium that has since weathered to B_3 soil. Disturbed zones evidenced by destruction of bedding (or laminae). Small offsets of sand and pebble lenses of up to 0.5 feet show normal movement with east side downthrown. This is interpreted as the southern most end of this fault.

Fault age—All fractures have been clearly eroded before the soil developed on them. Soil here is a Haplargid, but since the soil on T-1 is Durargid, the age of the fault is pre-Sangamon.

sorted large pebble gravel upwards. The more continuous subjacent unit (2) is a sandy large pebble gravel and gravelly coarse sand. With minor variabilities the unit is laminated, non-indurated and $CaCO_3$ coats clasts on the undersides.

The lowest-most recognizable alluvial unit in Trench 2 is Unit 3 which is composed of slightly gravelly medium to coarse sand which exhibits a well sorted and non-indurated nature.

Visible recognition of the fault zone consists of open fractures and local disturbed zones with infillings of overlying alluvium that has since weathered to B_3 soil. The zones of disturbance associated with faulting are evidenced by destruction of bedding (and/or laminae) and offsets of sand and pebble lenses of up to 15 cm (0.5 ft) indicate normal movement with the east side down thrown. The age of faulting based on soil development is pre-Sangamon. In addition all fractures have been eroded before the soil developed on them.

Trench 3 was placed across a subtle tonal lineation apparent on low sun-angle photography in S3,T18N,R20E. The surface material at this location is young fan deposits of Wisconsinan age. Soil development at this site is a duragid consisting of an A horizon of loamy sand that is loose, non-plastic and in part eolian sand (fig. 7). The boundary between this horizon and the B_{2t} below is a graded smooth boundary. The B_{2t} soil horizon is a clay loam which is slightly hard, sticky and plastic. The boundary with B_3 below is a gradual smooth boundary. Loam of the B_3 horizon is hard, massive slightly sticky and slightly plastic. Its contact with Csica soil horizon below is an abrupt boundary. The Csica soil is a loamy sand, hard to very hard and well cemented. The contact with the underlying alluvium is abrupt and well defined.

The alluvium below the Csica horizon can be differentiated into 3 units. Unit 1 is a slightly gravelly coarse sand which is moderately sorted and moderately indurated. Unit 2 consists of well sorted medium sand which is non-indurated.

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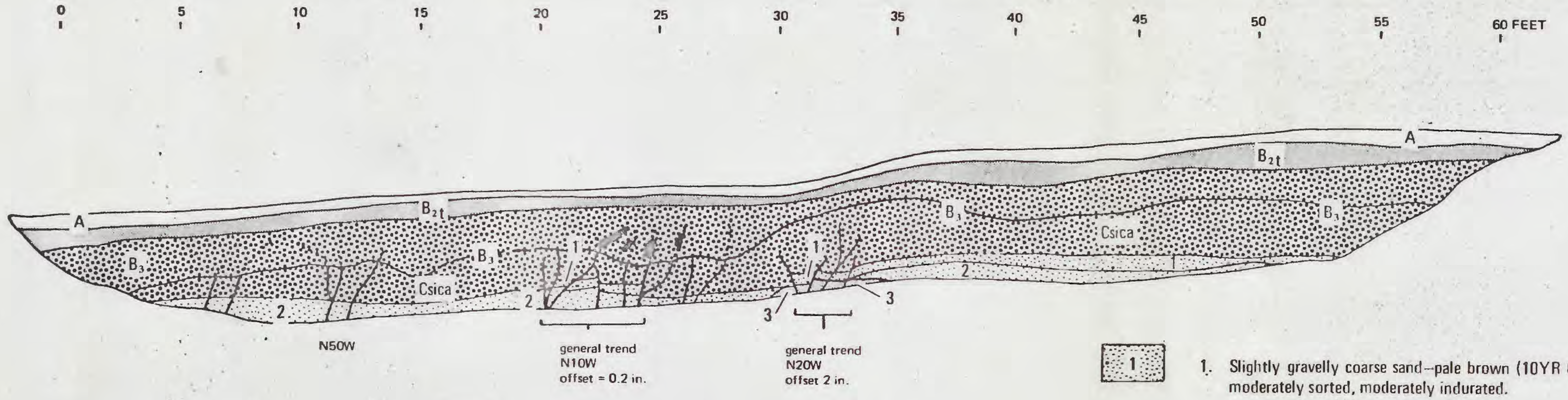

FIGURE 7

TRENCH 3
LOG OF NORTH WALL
T18N,R20E, NW½ SECTION 3
SCALE 1 in. = 5 ft.

A — A soil horizon—Loamy sand—light gray (10YR 7/2, m). Loose to slightly hard, single grain to massive, non-sticky, non-plastic, in part eolian sand. Graded, smooth boundary to B_{2t}.

B_{2t} — B_{2t} soil horizon—Clay loam—strong brown (7.5YR 5/6, moist), slightly hard, sticky, plastic 0.5–2" strong subangular blocky, weak ½" platy at base with weak angular blocky. Gradual, smooth boundary to B_3.

B_3 — B_3 soil horizon—Loam—light yellowish brown (10YR 6/4), hard, massive, slightly sticky, slightly plastic. Abrupt wavy boundary to Csica.

Csica — Csica soil horizon—Loamy sand—pale brown (10YR 1/3), hard to very hard, well cemented, massive, 1 inch laminae and coatings on clasts and grains below laminae. Abrupt contact to underlying alluvium.

Oxided pods—brown-dark brown (7.5YR 4/4), loose, developed in fault zone during faulting.

1. Slightly gravelly coarse sand—pale brown (10YR 6/3), moderately sorted, moderately indurated.

2. Medium sand—light yellowish brown (10YR 6/4), well sorted, non-indurated.

3. Sandy medium-large pebble gravel—pale brown (10YR 6/3), unsorted non-indurated.

Fault descriptions:

Fractures filled with $CaCO_3$ leached down from Csica soil horizon as soil formed. General trend of main zones = N10W85E to N20W50W, with small offsets of 0.2–2 inches forming small graben. Largest offset = 0.8 feet in Unit 1. Oxided pods of loose alluvium have developed along fractures.

Fault age—Fault is pre-soil, with soil being a durargid, and therefore the fault is pre-Sangamon (early to mid-Pleistocene age).

Fault, dotted where weathered in soil

Diffuse soil boundary

The lowermost alluvial unit appeared in the deepest portions of the trench and is a sandy pebble-gravel which is unsorted and non-indurated.

The trend of the faults in the main zone of disturbance ranges from N10W to N20W. The dip of the fissures range from slightly east (85°) to 50° west. Small offsets of .5-5 cm (0.2-2 in) form a graben in the zone of major disturbance. The largest offset observed was 24 cm (.8 ft) in alluvial Unit 1. The age of last movement along any of small faults exposed in the trench is early to mid-Pleistocene (pre-Sangoman). All movement was pre-soil and with the soil being a durargid this indicates the early to mid-Pleistocene age for latest movement.

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