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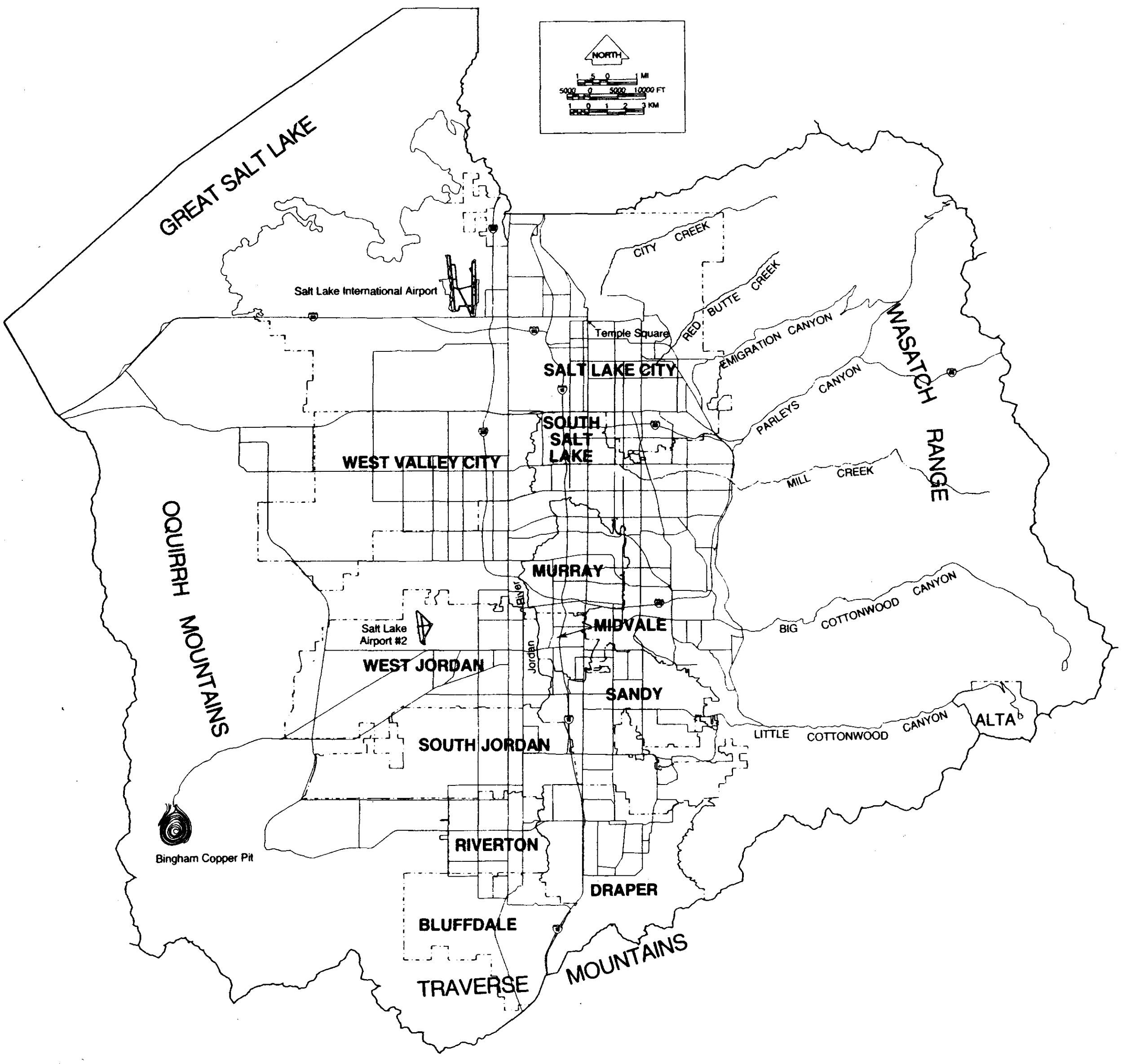

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PALEOSEISMICITY AND EARTHQUAKE HAZARDS EVALUATION OF THE WEST VALLEY FAULT ZONE, SALT LAKE CITY URBAN AREA

ABSTRACT

The West Valley fault zone (WVFZ), previously termed the Jordan Valley fault zone, trends north-northwest through an urbanized area 3 miles southwest of downtown Salt Lake City, Utah. Lying within the Intermountain Seismic Belt and long recognized as the western boundary of a graben forming the Salt Lake Valley, the WVFZ remained obscure while research focused on the more prominent eastern boundary of the graben, the Wasatch fault zone. Evidence from aerial photography, geomorphic mapping, trench exposures, and boring cores indicates that the WVFZ is about 15 km long and 7 km wide, greater than twice the area previously recognized. Distinctly different fault trace patterns distinguish the southern WVFZ as two subparallel east-facing scarps (the Granger fault and the Taylorsville fault), with scarps as high as 6.1 m in late Pleistocene lacustrine sediments. In contrast, the northern WVFZ is characterized by numerous smaller scarps which cover a broader zone, and form a graben and a horst within the valley. In the northern WVFZ, several normal-slip fault scarps displace paleochannels of the Jordan River and other geomorphic features, indicating that a minimum of four separate surface-rupture events post-date littoral and lagoonal deposits in the area associated with Gilbert-age sediments (<12 ka) of Lake Bonneville. At least two of these events formed scarps along the Taylorsville fault. Scarps along the Granger fault, which existed prior to deposition of Gilbert-age sediments, were increased by slip related to at least two post-Gilbert events.

Subsurface data reveals two contrasting styles of deformation along the two main traces of the WVFZ. The Granger fault is characterized by a discrete normal fault plane which juxtaposes the Lake Bonneville Alloformation against sediments of a previous lake cycle, the Cutler Dam Alloformation (Oviatt). Stratigraphic evidence indicates tectonic quiescence during deposition of Lake Bonneville sediments, followed by at least two separate faulting events which produced 5.2-6.7 m of down-to-the-east displacement 12 to13 ka ago. Examination of boring cores suggests

that the top of the Cutler Dam Alloformation was displaced a minimum of 12.8-14.3 m since 60 (± 20) ka ago and the top of the Little Valley Alloformation (McCoy) was displaced a minimum of 17.4-18.9 m since140 (±10) ka. In contrast, near-surface expression of the Taylorsville fault is characterized by monoclinal flexures that warp Lake Bonneville and younger sediments 1.5 m down-to-the-east, with minor step-faults cutting post-Gilbert playa and deltaic deposits. Interpretation of a high resolution seismic reflection profile across the southern Taylorsville fault suggests it does extend to a depth of at least 0.5 km as a high-angle, east-dipping discontinuity.

The Granger fault is characterized by: 1) a displacement rate of 0.4-0.5 mm/yr and a recurrence interval of 6,500 years for the last 13 ka; 2) a minimum displacement rate of 0.1 mm/yr for the last 60 (±20) ka; 3) a minimum displacement rate of 0.1 mm/yr for the last 140 (±10) ka; and 4) a Quaternary vertical seperation rate of 0.04 mm/yr (using drill-hole data from previous studies). The apparent increase in the displacement rate in the past 13 ka is inconclusive, however, due to insufficient stratigraphic evidence to constrain displacement between paleolake cycles. The Taylorsville fault is characterized by a flexure rate of 0.1-0.2 mm/yr and a recurrence interval of 6,000 years for the last 12 ka. The entire WVFZ is characterized by a displacement rate of 0.5-0.6 mm/yr and a reccurrence interval of 2200 years (6 surface-rupture/flexure events) for the last 13 ka. Local patterns of historical seismicity are generally consistant with regional patterns (shallow background seismicity with focal mechanisms indicating western extension). A west-trending zone of seismicity is somewhat coincident with the WVFZ but is problematic in its association with specific structures. The relationship of the WVFZ to the Wasatch fault zone and the potential independence of the WVFZ as a generator of seismicity in the Salt Lake City urban area remain unresolved.

INTRODUCTION

Purpose, Scope, and Methods

The West Valley fault zone (WVFZ) trends north-northwest through a rapidly urbanizing area located within a few miles of downtown Salt Lake City (Figures 1 and 2). The purposes of this investigation were to 1) assemble and evaluate evidence regarding the potential earthquake hazard of this little-known fault zone; 2) provide information for local government officials, geologists, and engineers to use in planning for future development; and 3) illustrate how paleolake chronology of the Bonneville Basin can be used to interpret fault displacement history. We employed the following methods to accomplish these goals:

1) *Geomorphic mapping* - Fault scarps and other geomorphic features significant to interpreting displacement history were mapped at a 1:24000 scale from field investigations, interpretation of aerial photographs, and topographic maps.

2) *Review of historical seismicity* - An earthquake listing and an epicenter plot, covering the area of known and suspected fault traces, were obtained from the University of Utah Seismograph Stations.

3) *Shallow excavations and drilling* - Six exploratory trenches were excavated and eight borings were drilled to investigate near-surface fault geometry and displacement history. Detailed logs were made and samples taken for environmental interpretation and for amino acid and thermoluminescence dating.

Our observations, interpretations, and conclusions are summarized in the following sections of this report. Particular detail is given to geomorphic and stratigraphic relationships, as they were critical to interpreting fault history. To supplement near-surface information, a previously unpublished seismic reflection profile was provided to us and is included in this report. Previous work regarding the geology of the Salt Lake Valley, especially as it pertains to the deeper geometry of the WVFZ, is summarized below.

Previous Work

The WVFZ lies within the north half of Salt Lake Valley (formerly called Lower Jordan Valley) which is bounded on the east by the Wasatch Range, on the west by the Oquirrh Mountains, on the south by the Traverse Mountains, and on the north by the Great Salt Lake. The region is situated at the boundary separating the Basin and Range Seismotectonic Province to the west from the Middle Rocky Mountains Province to the east. The region is characterized by isolated, linear mountain ranges separated by broad, alluvial-filled valleys. The mountain blocks are commonly bounded by normal faults which display evidence of displacing unconsolidated sediments within the past one hundred thousand years. The late Cenozoic deformation history of the Basin and Range Province indicates that stresses responsible for faulting have been west- to southwest-trending horizontal extension (Zoback, 1983).

The Salt Lake Valley has long been recognized as a structural graben based on data from seismic refraction surveys, geologic mapping, drill-holes and gravity surveys (Cook and Berg, 1961; Arnow and Mattick, 1968; Zoback, 1983). The Salt Lake City segment of the well-known Wasatch fault zone forms the eastern boundary of the graben with the western boundary of the graben being less well-defined. Eardley and Haas (1936) interpreted the valley as a single, elongated fault-block basin with valley sediments dipping and thickening to the east. More recent interpretations of gravity and seismic refraction data suggest that the graben is segmented by an east-trending gravity nose that separates a deeper southern basin from a narrower northern basin containing shallow downdropped blocks (Zoback, 1983). Gravity surveys, possible ground-water temperature anomalies, and drill-hole data indicate that the gravity nose correspnds with a shallow bedrock pediment which extends eastward from the Oquirrh Mountains into the northern half of the valley and is fault-bounded to the east by the WVFZ (Cook and Berg, 1961; Marine and Price, 1964; Klauk, 1984).

Two east-facing scarps located in sediments within the northern half of the Salt Lake Valley were first interpreted as faults by Marsell and Threet (1960). They show these two main fault scarps of the WVFZ as subparallel and trending northwest on their geologic map of Salt Lake County. Cook and Berg (1961) found a steep gravity gradient coincident with these scarps and a gravity minimum to the east corresponding to a thick section of valley fill. Marine and Price (1964) located a zone of higher groundwater temperature in the vicinity of the scarps and attributed it to upwelling along faults. They named the scarps the Taylorsville fault and Granger fault, and collectively called them the Jordan Valley fault zone (Figure 1). Based on drill-hole data, Marine and Price suggested a minimum displacement of 229 meters down to the east across the entire fault zone. They also suggested that the Jordan Valley fault zone, together with the East Bench fault, formed an inner graben within the Salt Lake Valley. The East Bench fault is a west dipping normal fault and is a splay of the Salt Lake City segment of the Wasatch fault zone (Scott and Shroba, 1985). The name "Jordan Valley" is not an officially recognized geographic name in Utah; therefore, we propose the name "West Valley fault zone" (WVFZ) for the fault traces in the central northern half of Salt Lake valley because of their proximity to West Valley City. The individual fault names of Granger and Taylorsville were based on the names of communities through which they pass (Marine and Price, 1964) and are retained here.

Although the Granger fault was exposed in construction excavations in 1979, the WVFZ remained obscure and unstudied. Van Horn (1979) did not show it on his surficial geologic map of the Salt Lake City South Quadrangle. His map was prepared prior to the 1979 excavations, and he attributed the scarps to differential erosion of distinct stratigraphic units (Van Horn, 1986, personal communication). The WVFZ was accidentally omitted from Davis' (1983) compilation map of the geology of the Central Wasatch Front (Davis, 1986, personal communication).

The following sections of this report pertain to the surface expression of the faults, details of their surface rupture history based on subsurface data, a review of historical seismicity, and an interpretation of the significance of our findings.

Pleistocene and Holocene Depositional History

Since the Late Tertiary, numerous prehistoric lakes have inundated the Salt Lake valley and a large amount of sediment has been shed from the surrounding mountains, resulting in a thick accumulation of valley fill (Slentz, 1955). Of particular importance to interpreting recent fault history is the depositional history of the three most recent major lake cycles. Therefore, a brief overview of the history of these lake cycles follows.

Previous studies indicate that the last deep-lake cycle of Lake Bonneville (the Bonneville cycle) first inundated the terrain of the WVFZ about 26 ka ago (Currey and Oviatt, 1985; Scott and others, 1983). These studies also indicate that this lake completely covered the known area of the WVFZ during its history of oscillations and stillstands until approximately13 ka ago. Thus, the WVFZ was inundated during the catastrophic Bonneville Flood which resulted in an abrupt drop of lake level of about 108 meters (355 feet). The sudden drop occurred about 15 ka ago and exposed thousands of square kilometers of lake sediments to ersosion above the Provo Shoreline, at an average altitude of 1463 meters (4800 feet) in the Salt Lake Valley. Subsequent to Provo Shoreline development, a lake regression left most of the valley floor (terrain above the Gilbert Shoreline) subaerially exposed after 12 to 13 ka ago. Recent stratigraphic studies, including unpublished radiocarbon dates from deposits associated with the Gilbert Shoreline, indicate that the Gilbert Shoreline is younger than 12 ka old but probably older than the Pleistocene-Holocene boundary (10 ka). In addition, altitudes of all known Holocene highstands are lower than the Gilbert Shoreline (Currey, current research funded by NASA).

Sediments of a major lake cycle preceeding Lake Bonneville were identified in Hansel Valley (McCalpin, 1986) and in the Bear River delta (Oviatt and others, 1985). The Cutler Dam Alloformation has been proposed as the formal name for these sediments, with the name Fielding Geosol for the buried soil formed on these deposits (Oviatt, 1986, personal communication). From mapping and stratigraphic studies, McCalpin and Oviatt independently determined a maximum altitude of 1341 meters (4400 feet) for this intermediate lake cycle. The area of the WVFZ lies below this altitude and was most probably inundated by the lake of the Cutler Dam cycle. Currently, chronology of the Cutler Dam cycle is not as well constrained as that of the Lake Bonneville cycle. Radiocarbon dates and amino acid-ratio correlations indicate that the Cutler Dam Alloformation pre-dates the Lake Bonneville Alloformation and post-dates the Little Vallley Alloformation (Oviatt, 1986, personal communication). Thermoluminescence dates for the Cutler Dam Alloformation range from 58 to 82 ka (McCalpin, 1986).

Deposits of a lake cycle older than the Cutler Dam Cycle were identified in Little Valley (Scott and others, 1983) and in Hansel Valley (McCalpin, 1986). The formal name Little Valley Alloformation has been proposed for these deposits (McCoy, in press). Thermoluminescence dating of the Little Valley Alloformation yielded an age of 138 ka (McCalpin, 1986). These deposits are exposed at altitudes as great as 1494 meters (4900 feet) (Scott and others, 1983), indicating that the area of the WVFZ was inundated by this older lake.

SURFACE EXPRESSION OF FAULTS

Surface expression of the West Valley fault zone prior to major urbanization is documented on a 1923 plane-table topographic map and on stereoscopic aerial photographs taken in 1937 and 1946. Part of the 1923 map showing the topographic expression of the fault zone is reproduced as Figure 3. For comparative purposes, the same area from the 1975 topographic map is shown on Figure 4.

Fault traces trend north-northwest and cover an area approximately 15 km long and 7 km wide. The WVFZ consists of two distinct patterns of fault traces. South of about 2100 South Street the fault zone is characterized by two main east-facing scarps, the Taylorsville fault and Granger fault. These two subparallel scarps are as long as 9 km and are spaced 1 to 2 km apart. They are also subparallel to the East Bench fault, located 7 to 9 km to the east (Figure 2). North of 2100 South Street, the WVFZ splays into numerous smaller traces marked by scarps spread over a broader zone, as much as 7 km wide. These scarps form a graben, which encompasses the Salt Lake City Airport, and a horst located east of the airport (Figure 2). Previous models of detailed gravity surveys transect part of this area and also indicate a horst is located in this area (Klauk, 1984). Alluvial fill east of the horst within a graben bounded on the east by the Warm Springs fault of the Salt Lake City segment of the Wasatch fault zone is interpreted to be as thick as 1 km, suggesting these faults extend to at least this depth (Klauk, 1984).

Urbanization in the Salt Lake valley has modified or destroyed much of the topographic evidence of the WVFZ. Therefore, a 1923 plane-table map, along with 1937 and 1946 aerial photographs were examined in order to supplement current information. For comparison, the same section of the WVFZ is shown on both the 1923 plane-table map and a 1975 topographic map (Figures 3 and 4). As estimated from the 1923 map (Figure 3) and as indicated by Marine and Price (1964), the Granger scarp ranged from 4.6 to 6.1 meters high. The maximum scarp hieght was (and is) near the intersection of 4100 South Street and 2700 West Street (Figure 5). Estimated heights for other scarps of the WVFZ range from 1.5 to 3.0 meters. Extensive urban modification of topography excluded the use of scarp profiling as a technique to help quantify fault displacement history for the WVFZ.

Five closed topographic depressions are still preserved on the down-dropped sides of both the Taylorsville and Granger faults, suggesting local back-tilting of the ground suface adjacent to the scarps. The largest depression is occupied by a small playa, Decker Lake, on the east side of the Taylorsville fault (Figures 3,4, and 6). Interpretation of aerial photographs and examination of stratigraphic exposures in roadcuts allowed the identification of a lunette that developed leeward (north) of Decker Lake (Figure 6). This lunette appears to be cut on its west limb by the Taylorsville scarp, indicating that at least two separate surface-rupture events have occured along the Taylorsville fault (one creating the depression in which the playa and lunette initially formed and another displacing the lunette). A radiocarbon date on charcoal collected from an A-horizon developed on the lunette indicates that the charcoal is modern (Currey, current research funded by NASA) and, therefore, does not provide a constraint on the timing of these events. Evidence for two surface rupture events is also indicated farther north where aerial photographs show a shorter fault scarp truncating the northen end of the longer Taylorsville scarp (Figure 6).

Further detailed examination of aerial photographs reveals geomorphic information which proved to be useful for constraining both slip direction and timing of fault activity in the northern half of the WVFZ. The displacement history of the WVFZ as interpreted from key morphostratigraphic relationships is summarized in Table 1. These morphostratigraphic features and relationships are illustrated on Figures 6 and 6a. Deposits of an extensive system of distributary paleochannels have been displaced by numerous traces of the WVFZ (Figures 6 and 6a). These paleochannels of the Jordan River provide piercing points which indicate normal-slip along all of the faults. Scarps cutting paleochannels appear to be as high as 2 meters.

Deposits associated with the Gilbert Shoreline were also identified on aerial photographs. Apparently, distal portions of an east-trending spit at an altitude of approximately 1296 meters did not extend as far east as the Granger scarp but formed a barrier which allowed a back lagoon to develop. Deposits of a west-trending spit are not displaced by the Granger fault but appear to be deposited against a pre-existing scarp (Figure 6 and 6a). Paleochannel form, paleocurrent direction, and cross-cutting relationships indicate that some of the Jordan River paleochannels pre-date Gilbert littoral and lagoonal deposits while others post-date Gilbert deposits. In addition, some of the paleochannels appear to have been displaced by different traces during various stages of development, some after they were abandoned and some while still active. The latter case is indicated by apparently new channels and a subaqueous fan forming as a result of channel deflection by the scarps (Figure 6a). This evidence suggests that at least two separate surface-rupture events created small scarps north of the Gilbert Shoreline after the main Granger fault scarp was formed but prior to the last two events on the Taylorsville fault.

In summary, crosscutting relationships of scarps, paleochannels, and other geomorphic features chronicle a detailed displacement history for the northern WVFZ since the late Pleistocene. This includes: 1) displacement along the Granger fault prior to formation of the the Gilbert Shoreline (prior to 12 ka ago); 2) a minimum of 4 separate surface-rupture events post-dating the Gilbert Shoreline and creating numerous small scarps less than 2 meters high (at least two of these events affected displacement on the Taylorsville fault); and 3) all geomorphic evidence indicates that faults are normal-slip.

SUBSURFACE EXPRESSION OF FAULTS

Previous studies indicate that the WVFZ penetrates to at least a moderate depth and has been acive since earliest Pleistocene (Cook and Berg, 1961; Marine and Price, 1964). Based on the depth to Tertiary sediments in drill-holes, Marine and Price (1964) suggested a minimum displacement of 229 meters down-to-the-east across the entire WVFZ. The drill-holes were located far enough from the faults so as to be out of the zone of local deformation, however, their estimation did not account for a probable east-dipping unconformity at the Tertiary-Quaternary boundary. Slentz (1955) noted this angular unconformity and measured a 3° eastward slope for pediments developed on Pliocene deposits. Assuming that the attitude of the unconformity is parallel on both sides of the fault and dips 3° uniformly to the east, orthographic construction suggests a minimum vertical separation of 64 meters down-to-the-east across the WVFZ. This results in a minimum Quaternary vertical separation rate of 0.03 mm/yr. Similar constructions using recent drill-hole information (Case, 1985) suggest a vertical separation of 77 meters for the Granger fault alone. This is also based on the depth to Pliocene deposits and suggests an average Quaternary vertical separation rate of O.04 mm/yr for the Granger fault. Caution must be used when interpreting drillers logs. Many workers have noted the difficulty of using drill-hole logs alone to correlate stratigraphy at depth in the valley. This is due to abrupt facies changes and problems in distinguishing different units with similar lithologies (Marine, 1960; Slentz, 1955). However, it does appear that the WVFZ extends to a minimum depth of 229 meters and has been active since at least the beginning of the Quaternary.

To investigate the more recent displacement hisory of the WVFZ, six exploratory trenches were excavated at three sites. Two of these sites were along the Taylorsville fault and one was along the Granger fault. Urbanization imposed severe limitations on site selection and human modification of the ground surface was evident at all of the sites. Shallow trenching observations were supplemented by samples obtained from 10 borings drilled on the Granger fault to depths ranging from 22.5 to 58 feet. Logs of these borings are tabulated in the Appendix. Eight borings were drilled at the Department of Transportation (DOT) site (discussed below) and two borings were drilled at 3166 South 3200 West, approximately 3.6 km north of the DOT site.

Taylorsville fault

The suspected trace of the Taylorsville fault was trenched at two locations along the southern part of its trace. The two locations are in the area of the southernmost closed depression and in the area of the best preserved scarp shown on Figure 4. The southernmost closed depression is approximately 2 miles south-southeast of Decker Lake on the northwest corner of 4100 South Street and Redwood Road (1700 West). Two trenches were excavated at this southern site, as sketched on Figure 7. A log of the materials and features encountered in the northern trench is presented on Figure 8.

Two trenches were excavated at the northern site in Pioneer Industrial Park about one-half mile north of 2100 South Street (Figure 9). Two trenches were excavated at this site, as sketched on Figure 9. A log of the materials and features encountered in the southern trench is presented on Figure 10. The maximum depths of the trenches were limited by the presence of shallow ground water at both the southern and northern sites.

No evidence of a discrete fault trace was discovered in either trench at the southern site and only relatively minor discontinuous fault traces were found at the northern site. Numerous small-scale faults and abundant evidence of liquefaction were found in interbedded sand and clay exposed at both sites. A monoclinal fold in the sediments was exposed in the trenches at both sites at appropriate positions to represent the Taylorsville fault along its surface expression. However, at both sites scarp morphologies were modified by human disturbance. The scarp at the southern site appears completely anthropogenic (Figure 8). The scarp at the northen site was first graded, then accentuated by excavation and backfilling of a canal (Figure 10). The disturbance at the northern site is local since the same scarp offsets paleochannels to the north and south of the trench site (Figures 6 and 6a). The strata exposed at the northern trench site were offset 5 feet down-to-the-east, similar to the topographic relief across the scarp.

Detrital ostracodes with discontinuous coatings of marl were found in some of the fine sand beds at the southern site. The presence of reworked ostracods suggests that these sediments are younger than the Bonneville Flood which occurred about 15 ka ago (Currey and Oviatt, 1985). The position of the southern site at elevation 4260 feet was last covered by lake water approximately 12 ka ago (Currey and Oviatt, 1985).

The sediments exposed at the northern site consisted of organic-rich silt overlain by deltaic fine sand and clay, overlain by calcareous clay, and capped by eolian sand and silt. The calcareous clay appears polygenetic; a motled texture, prismatic structure, clay films and peds developed within this layer suggest that it may have been deposited initially in a playa environment. Subsequent subaerial exposure then permitted formation of a Bk horizon on this layer, which was already enriched with carbonate. Dissolution and reprecipitation of salts, particularly near the deformation zone, partially distorted this layer and the overlying sand and silt.

The position of the northern site at elevation 4235 is below the Gilbert Shoreline, which probably was occupied by the earliest post-Bonneville lake cycle about 10.5 ka ago (Currey and Oviatt, 1985). The Gilbert Shoreline was occupied following a substantial decline to the lowest post-Bonneville lake stage by about 11 ka ago. A soil horizon formed on the deltaic sediments at the northern site after the Gilbert Shoreline was abandoned; consequently, soil formation and faulting occurred within the past 10 ka.

The origin of the clean sand layer is enigmatic (Figure 10). The layer appears bedded, but it is highly convoluted. It appears to be within the sandy silt layer and not offset. Excavation of shallow soil pits indicate that the layer is localized along the foot of the scarp for a distance of at least 100 feet. The possibility seems remote that this clean sand was injected by earthquake forces to such a shallow depth without breaking through to the ground surface. However, the sand layer does not appear to be depositional in nature because the underlying units are offset the same amount as the amplitude of the topographic scarp. Careful examination revealed no definitive evidence that this layer or the overlying sandy silt were fill deposits. Nonetheless, man-induced processes cannot be eliminated from consideration of the origin of the sand because of the proximity of the canal and its unorthodox character.

A high-resolution seismic reflection profile was run across the trace of the Taylorsville fault by the U.S. Geological Survey in the summer of 1984 at a location along 4700 South Street (Harding, 1985, personal communication). The migrated profile is shown on Figure 11. A preliminary interpretation of this previously unpublished profile was provided by Harding. A zone of disturbed reflectors approximately 2000 feet wide is shown on this profile. A prominent east-dipping reflector appears to truncate a number of less prominent west-dipping reflectors. The prominent east-dipping reflector is traceable to a depth of about 1700 feet and is interpreted to represent the Taylorsville fault.

<u>Granger Fault</u>

The Granger fault was trenched at the Department of Transportation (DOT) facility on the east side of 2700 West Street at about 4500 South at an elevation of about 4300 feet and drilled at the DOT site and at a site approximately 3.6 km to the north at 3166 South 3200 West at an elevation of about 4250 feet. The DOT site was selected because it was between two locations where the fault had been exposed in 1979 and 1980. Two trenches and eight borings were excavated at this site at locations shown on Figure 12 (six borings, 4-1 through 4-6, are shown on Figure 12; borings 4-1a and 4-3a were also drilled at this site adjacent to borings 4-1 and 4-3, respectively). Logs of materials and features exposed in the trenches are shown on Figures 13 and 14. Logs of materials encountered in the borings are tabulated in the Appendix; borings 4-4 and 4-5 are considered representative of the general conditions at the DOT site and are presented graphically as Figures 15 and 16. The site at 3166 South 3200 West was selected because the scarp was pronounced and it was adjacent to a prominent closed depression.

The Granger fault was exposed in both trenches at the DOT site, where it was expressed as a prominent, discrete and planar trace. At this site it strikes N 19° W (341° AZM) and dips about 64° NE. Caving of uncemented sand and gravel at a depth of about 13 feet prevented safe excavation deeper than about 15 feet, even with hydraulic trench shoring. In each trench, sediments exposed on the east side of the fault were completely different from those exposed on the west side. Drag folds in the exposed strata indicate normal slip on the Granger fault (Figures 13 and 14). This sense of displacement is also indicated by the topographic expression of the fault and conforms to what is expected in an environment of extensional stress such as exists along the Wasatch Front (Zoback, 1983).

Sediments exposed in the trenches on the down-dropped side of the Granger fault comprised a nearly complete sequence of the last cycle of Lake Bonneville. As shown on the trench logs (Figures 13 and 14), a weak argillic soil developed on alluvial silty and gravelly sand was exposed at the bottom of the trench. This geosol consisted of reddish-brown (5YR4/4) incipient clay films on sand grains and gravel clasts. It was truncated and overlain by imbricated and well-rounded gravel which we interpret to represent transgressive beach deposits of the last cycle of Lake Bonneville; at the elevation of this site the transgression probably occurred about 26 ka ago (Currey and Oviatt, 1985).

The transgressive beach gravel grades upward into sandy gravel, silty sand, sandy silt, slity clay, and marl, respectively. We interpret the marl exposed in these trenches to be equivalent to the White Marl of Gilbert (1890). The fine-grained sediments on the east side of the Granger fault in the trenches contain abundant ostracodes chiefly of genus *Limnocythere* and *Candona* (Forester, 1986, written communication).

An abrupt transition occurs between the marl and an overlying unit of silty marl. This transition is marked by ostracodee coquina up to 1 inch thick. We interpret this coquina to stratigraphically represent the Bonneville Flood dated at about 15 ka (Currey and Oviatt, 1985). The rapid dropping of the level of the lake would have exposed to erosion a substantial area of previous lake bottom with abundant ostracodes. These exposed ostracodes would have behaved hydrodynamically as fine sand grains and would be expected to be concentrated at selected locations within the basin below the elevation of the Provo Shoreline (4800 feet). This ostracode coquina layer appears to represent a time line analagous to volcanic ash layers in other parts of the western United States.

The silty marl overlying the ostracode coquina layer contains a well-developed modern argillic B soil horizon. The trench site is located in the bottom of a borrow pit and the soil profile has been truncated by grading operations but the presence of the soil suggests that grading removed only a small amount of material at this location.

The sediments exposed on the west side of the Granger fault are older than those on the east side. These sediments consist of interbedded fine sand and clay that are devoid of macroscopic fossils. Sections of the fine sand are ripple laminated, suggesting a shallow water environment. The clay layers contain virtually no sand and are interpreted to represent an environment of water at least 50 feet deep. Therefore, these sediments probably were deposited in a lacustrine environment with a fluctuating water level or with strong bottom currents.

The stratigraphic position of these non-fossiliferous lake deposits at an elevation below 4400 feet strongly suggests that they were deposited in the lake that occupied the basin during the period 58 ka to 82 ka ago (Cutler Dam cycle) (McCalpin, 1986; Oviatt and others, 1985). Samples of inorganic and non-calcareous silty sediment of these deposits were collected for thermoluminescence (TL) dating to permit verification of our interpretation. The results of the TL analyses are summarized in Table 2. The time period in which these pre-Bonneville deep water sediments appear to have been deposited probably is correlative with deep-sea Oxygen Isotope Stage 4 (Shackelton and Opdyke, 1973). These sediments probably represent the "Hansel Valley Cycle" [informal name] of McCalpin (1986) and the Cutler Dam Alloformation of Oviatt and others (in press).

Total offset of sediments of any age across the Granger fault could not be determined by trench exposures because trench depths were limited and the area had been previously graded. To provide information of paleoseismic significance, the information derived from trench exposures was supplemented by drilling eight borings to depths ranging from 22.5 to 58 feet at locations shown on Figure 12. A five-foot long, 3-inch diameter Central Mine Equipment (CME) sampler was used to obtain nearly continuous cores of the subsurface materials. A 1.75-inch diameter Standard Penetration Test sampler was used where gravel prevented penetration of the CME sampler. A Dames & Moore Type-U sampler (2.4-inch inside diameter) was used to obtain samples for thermoluminescence and amino acid dating. Logs of materials encountered in the borings are presented in the Appendix; two of these borings are presented graphically on Figures 15 and 16. Boring 4-4 (Figure 15) is representative of the sediments on the foot wall of the Granger fault. Boring 4-5 (Figure 16) is representative of the sediments on the hanging wall. An interpretive chronostratigraphic diagram of the boring data is shown on Figure 17.

Cores recovered from Boring 4-4 revealed Lake Bonneville sediments on the upthrown side of the Granger fault (Figure 15). These sediments were unconformably overlying silty sandy alluvial deposits which were overlying the same Cutler Dam Alloformation deposits exposed in the trench excavations. The 7-foot thick alluvial deposit bears a weakly developed geosol and appears to be the same unit exposed at the base of Trench 4B on the downdropped side of the Granger fault (Figure 14).

A similar stratigraphic sequence was encountered in Boring 4-5 on the downdropped side of the fault (Figure 16). Geometric and stratigraphic constraints limit offset of the alluvial deposits and overlying Lake Bonneville sediments from 17 to 22 feet.

Cores recovered from Borings 4-1 and 4-1A, also on the upthrown side of the fault, contained a geosol underlying Cutler Dam Alloformation deposits. The geosol consisted of dark reddish brown clay films on a gravelly sand with an underlying weak Bk horizon. This geosol graded downward into a 10-foot thick sequence consisting of ripple laminated fine sand which in turn graded downward into a marl with abundant ostracodes. The marl graded into a silty fine sand which coarsened downward.

We interpret this 10-foot thick sequence to represent the transgressive-regressive deposits of an older deep lake cycle. Preliminary identification of ostracodes extracted from the marl include species of *Candona* and *Limnocythere* that indicate on open lake environment (Forester, 1986, written communication). The nature and stratigraphic position of these sediments at this elevation suggest they are deposits of the Little Valley Cycle of Scott and others (1983). Laboratory results of amino-acid dating of ostracodes and thermoluminescence dating of inorganic silt are presented in Table 2. Stratigraphic position of the samples from what we interpret to be the Little Valley Alloformation require unreasonably large relative temperature depressions to reconcile the ostracode amino acid ratios to an age of about 140 ka, which we believe to be the correct age of the deposit. Reasonable temperature depressions combined with isoleucine epimerization kinetics suggest an age in the range of 45 - 80 ka (McCoy, 1987, written communication) which appears to be incompatible with stratigraphic observations.

Cores from the downdropped side of the Granger fault contained a deposit of sandy clay overlying the soil developed on the Lake Bonneville sediments. This sandy clay was carbonate-rich and contained reworked ostracodes. It had a maximum thickness of about 4.5 feet and thinned to the east. We interpret the sandy clay to represent a wedge of colluvial material shed from the fault scarp created in the Bonneville Alloformation deposits; the carbonate probably indicates an intermittent pond, or playa, environment similar to that currently existing at Decker Lake. We believe that the intermittent pond probably occupied a tectonically-created topographic depression.

The stratigraphy of the sediments under the alluvial deposits on the downdropped side of the Granger fault is complex. Close to the fault (Boring 4-2), colluvial deposits intercalated with playa deposits were found under the alluvial deposits. A minimum of two separate colluvial wedges could be identified within this 25-foot thick colluvial sequence. We believe that Boring 4-2 penetrated the fault plane below these colluvial deposits.

Subsurface data developed from Borings 4-6 and 4-3 to the east of Boring 4-2 indicate that the colluvial deposits under the alluvial deposits thin rapidly to the east. Within a distance of 100 feet from Boring 4-2 to Boring 4-6, the colluvial sediments thin from 25 to 4 feet in thickness. This relatively abrupt thinning may suggest the possible presence of a discrete graben bounded by one or more antithetic faults located between Boring 4-2 and Boring 4-6.

Cutler Dam Alloformation deposits apparently were encountered on the downdropped side of the Granger fault in Borings 4-6, 4-3 and 4-3A. Thermoluminescence dating of samples of the Cutler Dam Alloformation from Boring 4-3A on the downdropped side of the fault and from Trench 4-A on the upthrown side are inconsistent with each other, as shown in Table 2. Nonetheless, we are quite confident in our stratigraphic interpretation. The offset of the Cutler Dam Alloformation deposits appears to be the same as the offset of the overlying alluvial deposits and Bonneville Alloformation.

Cores from Boring 4-3A revealed a 15-foot thick section of colluvial deposits underlying Cutler Dam Alloformation sediments. This colluvial material varied from poorly-sorted silty sand to gravel in a calcareous clay matrix. It contained intercalated alluvial deposits consisting of 0.5- to 2-foot thick clean sand and gravel zones. Boring 4-3A terminated in this colluvial material at a depth of 52.5 feet and deep lake sediments of the Little Valley Alloformation were not encountered.

Exposures southwest of the trench site corroborate subsurface data from borings. The relative positions of the borings and exposures are shown on Figure 12. A natural exposure located within 2000 feet to the southwest of the trench site reveals a complete sequence of Lake Bonneville deposits with a well-developed soil formed in the upper part. The Bonneville Alloformation overlies a weakly- to moderately-developed geosol formed on sandy and gravelly sediments which could represent regressive deposits from the Cutler Dam cycle lake.
A man-made exposure, also within 2000 feet to the southwest of the trench site as shown on Figure 12, reveals the base of the Lake Bonneville sediments overlying the geosol. The geosol is formed on sandy and gravelly materials that grade downward into tufa-cemented, well-rounded gravel which we interpret to represent Cutler Dam Alloformation deposits. Below the Cutler Dam Alloformation sediments is a very well-developed geosol and sediments that appear to represent deposits of an even older lake, possibly equivalent to the Little Valley deep-lake cycle . The very well-developed geosol could represent the valley-bottom expression of the Dimple Dell geosol as interpreted by Scott (1980) which would represent formation during oxygen isotope chron 5 of the deep sea record (Shackleton and Opdyke, 1973).

HISTORICAL SEISMICITY

The WVFZ is located within the Intermountain Seismic Belt, a north-trending zone of seismicity that is characterized by relatively frequent moderate- to large-magnitude earthquakes with shallow focal depths (Smith and Sbar, 1974). In their evaluation of seismicity in the Wastach Front area, Arabasz and others (1980) noted 1) a diffuse, but locally intense, pattern of seismicity parallel to and straddling the Wasatch fault zone; 2) difficulty in associating scattered seismicity west and east of the Wastach fault zone with recognized major active faults; 3) a predominance of normal faulting with primarily west-trending extension indicated by earthquake first-motions; 4) shallow hypocentral depths (nearly 100 percent < 20 km, statistical bimodal distribution clustered in the depth ranges of 1 - 3 km and 7 - 9 km); and 5) only one known historic surface-rupture event (Hansel Valley earthquake of 1934, M_L 6.6, 0.5-m scarp).

Locations of epicenters for earthquakes of local magnitude (M_L) ≥ 1.5 which occurred within the area of the West Valley fault zone from July, 1962 (the date in which reliable seismographs were installed along the Wasatch Front) to December,1985 are shown on Figure 18. The seismic network was expanded significantly in 1974. Location errors for post-1974 events are estimated to be less than 1 km; pre-1974 events have estimated location errors ranging from 0.8 km to 2.5 km. Almost all of the 33 epicenters shown on Figure 18 are clustered in a west-trending zone about 13 km long and 8 km wide. The latitude of this zone is approximately centered on the WVFZ, but the east end of the zone is approximately the WVFZ. No epicenters were located east of the WVFZ, within the graben formed by the Taylorsville fault and the East Bench fault.

The largest earthquake in the WVFZ area was the M_L 5.1 Magna earthquake of 1962, located about 8 km west of the Granger fault on about 2100 South Street. The next largest earthquake was M_L 4.3 in October, 1983, and located less than 0.5 km wast of a scarp north of the Granger fault. Estimated hypocentral depths are shallow, ranging from 1.2 to 11.5 km with a mean of 5.9 km and standard deviation of 3.2 km (Pechmann and Thorbjarnardottir, 1985). Estimated vertical errors of depths for these events range from 0.6 to 4.0 km; the shallow depths are not well constrained and Pechmann and Thorbjarnardottir (1985) suggest a range of 4 to 11 km the the M_L 4.3 event.

Three previously developed fault-plane solutions are shown on Figure 18 and indicate west-trending extension but cannot be associated with specific structures. The nodal planes for the M_L 4.3 earthquake strike about N 5° W (355° AZM) and dipping either steeply (≈ 80°) to the east or gently (≈ 15°) to the west (Pechmann and Thorbjarnardottir, 1985). It appears that this event could be associated with an east-dipping plane of the WVFZ, a west-dipping listric Wasatch fault plane, or a buried, older structure. The possible range of depths, nodal plane orientations, and geometries of structures in this area do not permit further resolution of this question.

In summary, seismicity in the vicinity of the WVFZ can be characterized by 1) a west-trending zone of seismicity approximately coincident with the WVFZ but problematic in its association with specific active faults; 2) normal faulting earthquakes with west-trending extension; and 3) shallow (< 12 km) hypocentral depths. Thus, it appears that siesmicity patterns in the vicinity of the WVFZ are generally consistent with regional patterns and that current data on historical siesmicity do not permit unequivocal resolution of the question regarding the ability of the WVFZ to generate earthquakes.

DISCUSSION

Earthquake hazards represented by the West Valley fault zone consist of the primary aspects of strong ground motion, surface rupture and tectonic deformation and secondary aspects generated by the primary aspects (such as liquefaction and landsliding in susceptible materials). Surface rupture on the WVFZ could represent an urban hazard even if it were to occur in sympathetic response to a major earthquake on the near-by Wasatch fault zone. Strong ground motion is clearly a significant hazard along the entire urban area of the Wasatch Front. The issue related to the seismogenic independence of the WVFZ remains uncertain. In some respects, the WVFZ appears to be a significant antithetic fault zone bounding a major graben on the downdropped side of the Wasatch fault zone, and should, therefore, be expected to move only in response to earthquakes generated by the Salt Lake City segment of the Wasatch fault zone. However, the complicated history of displacement events on the two principal traces of the WVFZ displayed on Table 1 and Figure 6a suggests that the traces of the WVFZ operate independently of each other. In addition, the displacement history of the Salt Lake City segment of the Wastach fault zone is not known well enough to permit unequivocal comparison of individual displacement events. Consequently, this issue cannot be resolved at this time.

The earthquake hazard evaluation of the WVFZ described below is presented with the potentially conservative assumption that the fault zone is seismogenic. Conventional methods of quantifying earthquake hazards of fault zones consists of computing average recurrence intervals and slip rates from the number of displacement events since deposition of the displaced sediments. Earthquake magnitudes may be estimated from fault dimensions and the amounts of displacement expected during individual surface rupture events.

Number of Events and Average Recurrence Intervals

The data collected to this point clearly indicate that both principal traces of the WVFZ have ruptured the ground surface during Holocene time (the past 10 ka). The minimum number of events estimated for the WVFZ at individual sites is summarized on Table 3. A minimum of two surface rupture events (presumably earthquake-producing events rather than sympathetic surface ruptures on the WVFZ due to an earthquake event on the Wasatch fault zone) have occurred on the Taylorsville fault in the past 12 ka: one forming a 1.2- to 1.5-m high scarp and a second truncating that scarp. Thus, 2 events in 12 ka results in an average recurrence interval of about 6000 years.

A minimum of two earthquakes of sufficient magnitude to cause surface rupture (probably $ML \geq 6.5$) have caused 17 to 22 feet (5.2 to 6.7 m) of offset in Lake Bonneville sediments within about the last 13 ka on the Granger fault at the DOT site. The evidence for these two events comes from Boring 4-5 (Figure 15) which shows calcareous playa deposits buried by scarp-generated colluvium. Our interpretation of these observations is that the first scarp-forming event created the topographic depression to permit the playa to form and the second event permitted it to become buried by colluvium. Thus, 2 events in 13 ka results in an average recurrence interval of 6500 years. However, to the north of the DOT site, as shown on Figure 6a and described in Table 1, geomorphic evidence suggests at least 3 additional scarp forming events on the Granger fault. Thus, 5 events in the past 13 ka results in an average recurrence interval of 2600 years.

The displacement across the entire WVFZ (1.2 to 1.5 m on the Taylorsville fault and 5.2 to 6.7 m on the Granger fault) in the past 13 ka appears to have occurred in 6 or 7 events, which would result in an average recurrence interval of 1800 to 2200 years.

The displacement history of the Granger fault over the past approximately 140 ka was developed from trench exposures at and boring cores from the DOT site. Key elements of this history are shown on Figure 19 and details of displacements of morphostratigraphic features are presented in Table 1. Careful examination of the stratigraphy of the deposits of the Bonneville Alloformation adjacent to the Granger fault exposed in the trenches at the DOT site revealed an apparently uniform and continuous sequence with no evidence of a lake-bottom equivalent of a colluvial wedge which would suggest interruption of the lake bottom by a fault rupture event. Also, the top and base of the Bonneville Alloformation were offset the same amount (5.2 to 6.7 m). We interpret this stratigraphy to indicate tectonic quiescence on the Granger fault during the Lake Bonneville cycle, from about 26 ka to 13 ka ago. This 13 ka-year period of apparent quiescence may be significant in understanding the importance of Lake Bonneville on "reservoir-induced seismicity" along the Wasatch Front.

Borings on the downdropped side of the Granger fault encountered colluvial deposits underlying and apparently overlying sediments of the Cutler Dam Alloformation. No equivalent deposits were identified on the upthrown side of the fault, either in borings or natural exposures. This distribution of colluvial deposits suggests that a minimum of 7.6 m of offset occurred on the Granger fault prior to deposition of the overlying alluvial and Lake Bonneville sediments (26 ka ago) but after deposition of the Cutler Dam sediments. The number of events responsible for this amount of offset is unknown, but we suspect that more than two surface rupture events created this offset. The number of events could be five or six if each displacement event produced a uniform 1.2 to 1.5 m of displacement.

The colluvial deposits underlying sediments of the Cutler Dam Alloformation on the downdropped side of the Granger fault suggest a minimum of 4.6 m of displacement after the deposition of Little Valley Alloformation (140±10 ka ago) but prior to the Cutler Dam Cycle transgression (60±20 ka ago). From these interpretations, a minimum cumulative offset of 17.4 to 18.9 m has occurred on the Granger fault at the DOT site in the last 140 ka. If average surface displacement events were 1.2 to 1.5 m, then the cumulative offset should require 11 to 16 events. The incremental offset of 4.6 m appears to have occurred in the 80±30 ka period between Little Valley and Cutler Dam time. At 1.2 to 1.5 m per displacement event, this would require 3 or 4 events.

Possible colluvial wedges incorporated into deep-water deposits of lakes which occupied the basin during Cutler Dam and Little Valley time are unlikely to be detected by borings.

Therefore, the evidence needed to distinguish individual scarp-forming events in the middle of the valley may be impossible to find. Additionally, offset amounts were estimated from thicknesses of colluvial deposits presumed to have formed at the foot of a scarp. Thus, the reported offsets for pre-Lake Bonneville materials are minimum values.

<u>Average Slip Rates</u>

Average slip rates for several scenarios were calculated for the Taylorsville fault, the Granger fault and the WVFZ as a whole. These values were calculated by dividing the range of displacement values discerned from geomorphic evaluations, trench logs, and boring samples by the time interval represented by the displaced horizons. The values are summarized in Table 3. The Taylorsville fault exhibits 1.2 to 1.5 m of flexure-offset of post-Gilbert (< 12 ka) deltaic sediments. The resulting slip rate for this fault is 0.1 to 0.2 mm/yr, as shown in Table 3.

The Granger fault at the DOT site exhibits 5.2 to 6.7 m displacement of the top of the Bonneville Alloformation sediments (13 ka old), resulting in an average slip rate of 0.4 to 0.5 mm/yr. The minimum total offset of the top of the Cutler Dam Alloformation (60±20 ka) is 12.8 to 14.3 m, which results in a slip rate ranging of ~~0.02~~ 0.2 to ~~0.04~~ 0.4 mm/yr. The minimum total offset of the top the the Little Valley Alloformation (140±10 ka) is 17.4 to 18.9 m, which results in an average slip rate of ~~0.01~~ 0.1 mm/yr.

A slip rate of 0.1 to 0.3 mm/yr is calculated on the basis of the 6.1 to 9.1 m difference in displacement between the Bonneville Alloformation and the Cutler Dam Alloformation over a time interval of about 47±20 ka. A minimum slip rate of 0.03 to 0.1 mm/yr is calculated on the basis of the 3.1 to 6.1 m difference in displacement between the Cutler Dam Alloformation and the Little Valley Alloformation over a time interval of about 80±30 ka.

The pre-Bonneville range of slip rates is approximately an order of magnitude less than the slip rates for the post-Bonneville interval. Despite the equivocal character of age determinations from the faulted sediments, we are confident of our stratigraphic interpretation correlating faulted sediments along the WVFZ with those found at similar altitudes elsewhere in the basin. Our stratigraphic interpretation is supported by the paleoecological interpretation based on ostracode fauna (Forester, 1986, written communication). It is on this stratigrahic interpretation that we base our conclusion that considerable temporal variations in slip rate occurred along the WVFZ in the past 140 ka. This temporal variation is illustrated in the diagram presented on Figure 20. The slip rate on the WVFZ appears to have approximately doubled between deep-lake cycles in the basin. The slip rates for the WVFZ are less that those for any segment of the Wasatch fault, as shown in Table 3 *.

Earthquake Magnitudes

The Wasatch fault is considered capable of generating earthquakes as large as Ms 7.5 (Schwartz and Coppersmith, 1984). Because of the relatively short length of the traces comprising the WVFZ (overall length of 10 km for the Taylorsville fault and 11 to 16 km for the Granger fault), a maximum earthquake smaller than that for the 32-km long Salt Lake City segment of the Wasatch fault seems to be reasonable. As shown on Table 4, we have calculated earthquake magnitudes using eleven different methods for four cases representing the range of possible fault geometries. We used 1.2 to 1.5 m as the range of surface rupture displacements, 10 km for the lengths of Taylorsville fault and 16 km for the Granger fault, and 4 to 12 km as the range of focal depths. Earthquake magnitudes summarized in Table 4 are based on statistical regressions among magnitude, surface rupture displacement, surface rupture length, fault width (down-dip length of fault plane involved in movement), and seismic moment. References for the individual methods used are listed in the table.

The magnitude values range from 5.8 to 7.0, with an average value of 6.7 Most of the magnitude values are surface wave magnitudes; however, several are unspecified Richter magnitudes and several are moment magnitudes. The threshold magnitude of surface rupture events is commonly taken as about 6.5. The flexure-displacement event observed on the Taylorsville fault (Figure 10) suggests that the magnitude of the earthquake responsible for this was only slightly larger than the threshold for surface rupture. Thus, the calculated range of magnitudes for the WVFZ appears to be reasonable.

Conclusions

One dramatic result of this study is the documentation of variable slip rate with time on the West Valley fault zone. The marked difference in average slip rate based on pre- and post-Bonneville stratigraphy suggests that the presence of Lake Bonneville may have had a significant influence on the rate of strain release and earthquake frequency. Loading of the earth's crust under the Bonneville Basin during the high stand of Lake Bonneville resulted in isostatic depression and could have generated compressive stresses that tended to retard strain release in the extensional tectonic setting of the region. Unloading of the crust due to lowering of Lake Bonneville resulted in isostatic rebound and could have promoted strain release in the extensional setting of the region.

The results of our evaluation summarized in this report clearly indicate that the West Valley fault zone demonstrates evidence of multiple late Pleistocene and Holocene movements and must be considered as an active fault zone in reducing earthquake hazards along the Wasatch Front. The relation of the West Valley fault zone to the more major Wasatch fault zone remains unclear. The size and number of offsets along the Granger fault, the size of the scarp at the north end of the Taylorsville fault, the locations of earthquake epicenters in the central part of the Salt Lake Valley, and the distribution of newly-recognized traces of faults with evidence of Holocene displacements strongly suggest that the West Valley fault zone is a seismogenic structure that operates independently of the Wasatch fault zone. However, possible sympathetic adjustments on the West Valley fault zone resulting from major earthquakes on the Wasatch fault cannot be ignored. Earthquake magnitudes calculated for the West Valley fault zone range from 5.8 to 7.0, but we believe that a value of 6.5 to 6.7 is most reasonable based on the flexural features and the generally shallow focal depths for most earthquakes in the region.

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Table 1. Summary of scarp-forming events, features of morphostratigraphic significance, and key geomorphic relationships pertaining to the West Valley fault zone in the vicinity of Decker Lake. Notations refer to features shown on Figure 6a. * indicates probable earthquake event.

FAULT ACTIVITY	MORPHO-STRATIGRAPHY		KEY RELATIONSHIPS
* * Two displacement events along Granger fault scarp (fs1 on Figure 6a)		LATE PLEISTOCENE (post Bonneville)	Stratigraphic evidence at the DOT site indicates that 2 surface-rupture events produced 5.2-6.7 m of displacement in the last 13 ka. Geomorphic evidence to the north suggests all displacement is younger than 12 ka.
	Pre-Gilbert paleo-channel system developed (pc1a, pc1b, and pc1c on Figure 6a)		These deltaic channels were graded to a transgressing lake level. Sections of the system are overlain by Gilbert sediments. To the south, the Granger fault scarp appears to have partly controlled the location of pc1a.
	Gilbert Littoral and Lagoonal sediments deposited		These deposits are younger than12 ka based on unpublished radiocarbon dates superceding those published by Miller (1980) and do not appear to be displaced by the Granger fault. Sediment supplied by the paleo-Jordan River system formed a west-trending spit which terminated against the Granger fault scarp. Distal portions of an east-trending spit do not extend as far east as the fault scarp.
	Paleochannel 2 - 2a developed (pc2 and pc2a)		Paleochannel 2 crosscuts pc1b. Paleo-channel system 2 was graded to a re-gressing lake.
* One displacement event (fs2)			This scarp deflected pc2 while it was active, causing pc2b to form and pc2a to be abandoned.
	Paleochannel seg-ments 2b cut (pc2b) and 2a abandoned (pc2a).		The channel still occupied pc2 but turned to the northeast upon reaching scarp 2.
* One displacement event (fs3).			This scarp deflected pc2 while it was active. This second deflection of pc2 caused a small subaqueous fan to form.
	Small subaqueous fan deposited.		This feature formed near the base of scarp 3 and was graded to a lake with an approximate altitude of 1,291 m.

(Continued)

Table 1. (Continued)

FAULT ACTIVITY	MORPHO-STRATIGRAPHY	AGE	KEY RELATIONSHIPS
		HOLOCENE	The Pleistocene-Holocene boundary can be partly constrained as probably post-dating the Gilbert regression. Evidence throughout the lake basin suggests a probable Holocene high-stand at an altitude of 1,287 m.
* One or two (?) displacement events (fs4). The Taylorsville fault scarp also formed about this time (fs5) (same or separate events?)			This scarp displaced pc2 after the channel was abandoned. This scarp displaced pc1a, pc1b, and pc2 after they were all abandoned.
	Decker Playa and lunette formed.		These features formed in a topographic depression at the base of the Taylorsville fault scarp.
* One or two (?) displacement events (fs6) and possible displacement of lunette along Taylorsville fault scarp (same or separate events?)			This scarp truncates the northern end of the Taylorsville fault scarp. Lunette sediments appear displaced by this scarp.

Table 2. Summary of thermoluminescence and amino acid age estimates for sediments displaced by the Granger fault at the DOT site. Thermoluminescence dating was done by Alpha Analytic, Inc., Coral Gables, FL; Amino acid racemization was done by University of Massachusetts, Amherst, MA.

Thermoluminescence Dates

Laboratory Number	Age (yr)	Material	Stratigraphic Position
Alpha-2849	90,000±5,000 134,000±8,000	Lacustrine silty sand	Cutler Dam Alloformation in foot wall of Granger fault
Alpha-2850	36,800±6,000	Lacustrine silty sand	Cutler Dam Alloformation in hanging wall of Granger fault
Alpha-2851	85,000±5,000 198,000±15,000	Lacustrine silty sand	Little Valley Alloformation in foot wall of Granger fault
Alpha-2852	49,000±3,500 88,000±8,000	Colluvial silty sand	Below Cutler Dam Alloformation in hanging wall of Granger fault

Amino Acid Estimates

Laboratory Number	Alloisolucine / Isolucine	Ostracode Genus	Estimated Age (yr)	Stratigraphic Position
AGL503A	0.13±0.01	*Candona*	45,000-80,000	Little Valley Alloformation
AGL503B	0.13±0.01	*Limnocythere*	45,000-80,000	Little Valley Alloformation
AGL507	0.05	*C.* and *L.*	25,000-35,000	Bonneville Alloformation

Table 3. Average recurrence intervals and slip rates for the West Valley fault zone (WVFZ) and selected segments of the Wasatch fault zone.

FAULT ZONE	SEGMENT	SITE	AVERAGE RECURRENCE (yr)[Events]	INTERVAL REP-RESENTED	MOST RECENT EVENT	AVERAGE SLIP RATE (mm/yr)	REFERENCE
WVFZ	Taylorsville	Salt Lake City	6000 [2 events]	<12 ka	< 12 ka	0.1-0.2 [a]	This report
WVFZ	Granger	West Valley City	6500 [2 events]	13 ka	< 13 ka	0.4-0.5 [b]	This report
	Granger	(WVC)	2600 [5 events]	13 ka	< 13 ka	0.4-0.5 [c]	This report
	Granger	(WVC)	--	60±20 ka	--	.2-0.4 ~~0.02-0.04~~ [d]	This report
	Granger	(WVC)	--	140±10 ka	--	0.1 ~~0.01~~ [e]	This report
	Granger	(WVC)	--	47±20 ka	--	0.1-0.3 [f]	This report
	Granger	(WVC)	--	80±30 ka	--	0.03-0.1 [g]	This report
WVFZ	Entire zone	--	1800-2200 [6-7 events]	13 ka	< 12 ka	0.5-0.6 [h]	This report
WVFZ (1980)	Granger	--	4000-8000	16 ka	--	0.19-0.38 [i]	Doser & Smith
Wasatch	Salt Lake City	Little Cottonwood Canyon	2400-3000 [2 events]	19±2 ka	--	0.76+.6-.2 [j]	Schwartz and Coppersmith (1984)
Wasatch	Ogden	Kaysville	2000 [2 events]	1580± 150 yr	< 500 yr	1.3+.5-.2 [k]	Schwartz and Coppersmith (1984)
Wasatch	Provo	Hobble Creek	1700-2600 [6-7 events]	13.5 ka	>1000 yr	0.85-1.0 [l]	Schwartz and Coppersmith (1984)
Wasatch	Nephi	North Creek	1700-2700 [3 events]	4580 yr	300-500 yr	1.27-1.36 [m]	Schwartz and Coppersmith (1984)

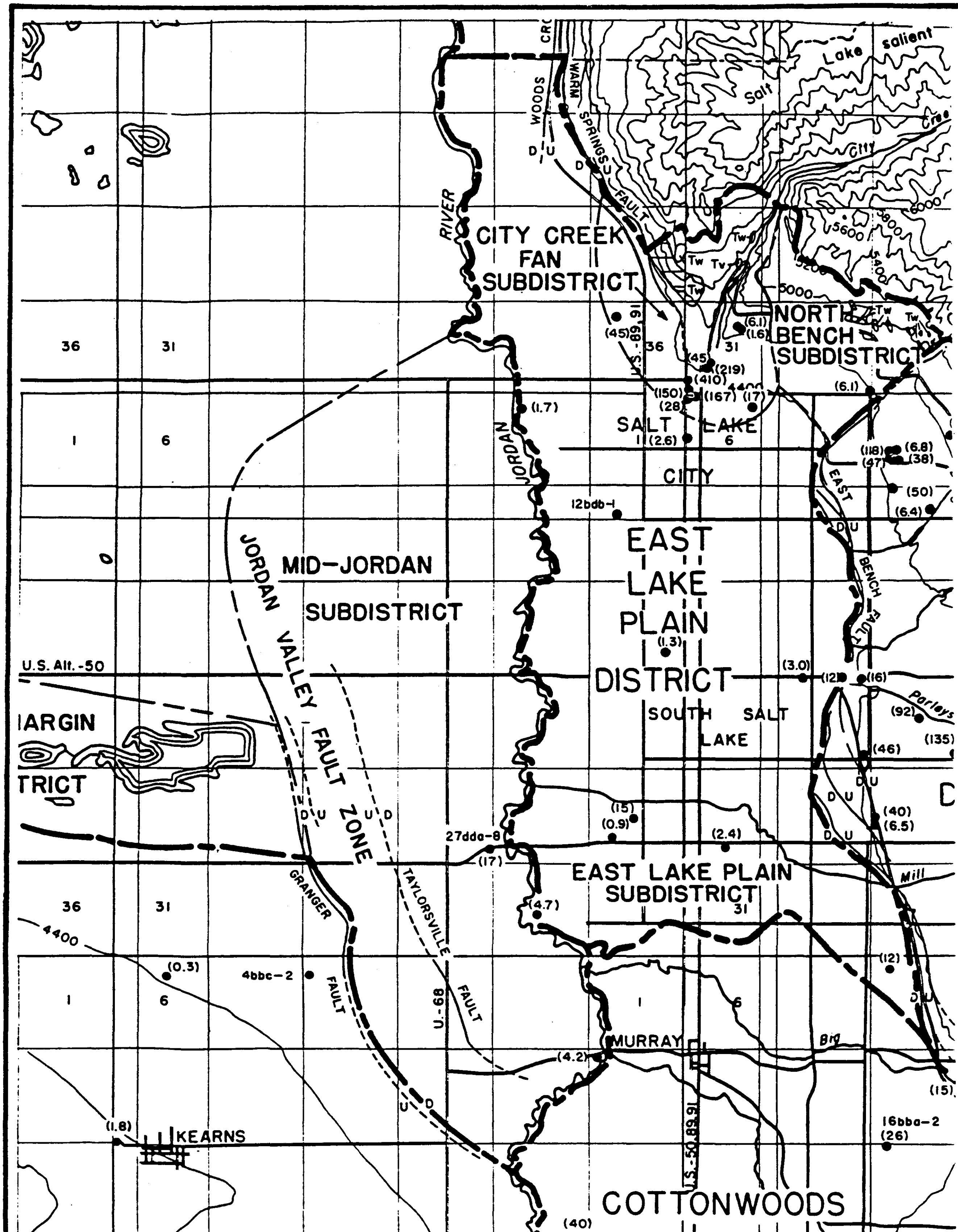
Notes: (a) Based on 1.2-1.5 m flexure-displacement of post-Gilbert sediments (<12 ka).
(b) Based on 5.2-6.7 m vertical displacement of top of Bonneville Alloformation (13 ka), minimum of 2 events at DOT site.
(c) Based on evidence for 5 events combining DOT site and morphostratigraphic evidence from Figure 6a, Table 1.
(d) Based on 12.8-14.3 m minimum displacement of Cutler Dam Alloformation (60±20 ka).
(e) Based on 17.4-18.9 m minimum displacement of Little Valley Alloformation (140±10 ka).
(f) Based on 6.1-9.1 m displacement difference between Bonneville and Cutler Dam Alloformations.
(g) Based on 3.1-6.1 m displacement difference between Cutler Dam and Little Valley Alloformations.
(h) Based on combination of (a) and (b) above to represent entire WVFZ cumulative displacement in last 13 ka.
(i) Based on 3-6 m displacement of 16 ka-old deposits.
(j) Based on 14.5 m net vertical displacement of Bells Canyon till (19±2 ka).
(k) Based on 10-11 m net vertical displacement of alluvial fan (8±2 ka).
(l) Based on 11.5-13.5 m pf post-Provo net vertical displacement (13.5 ka).
(m) Based on 7±0.5 m net vertical displacement of alluvial fan (4580 yr).

Table 4. Relations between fault parameters and estimated magnitudes of earthquakes generated by the West Valley fault zone in the past 13 ka. Four cases are presented for fault geometries which appear to be reasonable to represent the range of possible magnitudes. Cases 1 and 2 use lengths (L) which represent the Taylorsville fault; Case 1 uses the the width (W) associated with the minimum focal depth and smaller amount of surface displacement (D), while Case 2 uses the width associated with the likely maximum focal depth and larger amount of surface displacement. (Width is computed as the down-dip dimension along the fault plane assuming a dip of approximately 60° and focal depths of 4 km and 12 km). Cases 3 and 4 represent the Granger fault; Case 3 uses the smaller width and displacement values, while Case 4 uses the larger values.

Magnitude † Relation	**Regression †† Equation** (and Reference)	**Case 1** (L=10 km, W=4.5 km, D=1.2 m)	**Case 2** (L=10 km, W=14 km, D=1.5 m)	**Case 3** (L=16 km, W=4.5 km, D=1.2 m)	**Case 4** (L=16 km, W=14 km, D=1.5 m)
1. Magnitude-Displacement	Ms = 6.81 + 0.741 log D (Bonilla and others, 1984)	6.9	6.9	6.9	6.9
2. Magnitude-Displacement	Ms = 6.93 + 0.665 log D (Bonilla and others, 1984)	7.0	7.0	7.0	7.0
3. Magnitude-Length	Ms = 5.17 + 1.237 log L (Bonilla and others, 1984)	6.4	6.4	6.7	6.7
4. Magnitude-Length	Ms = 6.02 + 0.729 log L (Bonilla and others, 1984)	6.7	6.7	6.8	6.8
5. Magnitude-Length x Displacement	Ms = 6.22 + 0.492 log LD (Bonilla and others, 1984)	6.8	6.8	6.9	6.9
6. Magnitude-Length x Width	Ms = 4.96 + 0.823 log LW (Bonilla and others, 1984)	6.3	6.7	6.5	6.9
7. Magnitude-Length x Width x Displacement	Ms = 5.65 + 0.514 log LWD (Bonilla and others, 1984)	6.5	6.8	6.7	6.9
8. Magnitude-Length x Displacement	M = 4.55 + 0.53 log lD (Slemmons, 1977)	6.7	6.8	6.8	6.9
9. Magnitude-Length x Displacement Squared	M = 5.57 + 0.30 log lD^2 (Slemmons, 1977)	6.8	6.9	6.9	6.9
10. Magnitude-Seismic Moment	Mw = 0.667 log Mo - 10.7 (Hanks and Kanamori, 1979)	6.1	6.5	6.3	6.7
11. Magnitude-Source Area	M = 4.15 + log A (Wyss, 1979)	5.8	6.3	6.0	6.5

† Magnitude relations from Bonilla and others (1984) represent ordinary least squares regressions of the following data sets: Relation 1, normal and normal-oblique events; Relation 2, plate interior events; Relation 3, western North America events; Relation 4, plate interior events; Relations 5, 6, and 7, all events of M>6.

†† The abbreviations used are: Ms, surface wave magnitude; M, unspecified Richter magnitude; Mw, moment magnitude; Mo, seismic moment (Mo = μlwd, where μ is modulus of rigidity (generally taken to be 3.3 E+11 dynes cm^{-2} for crustal rocks), lw is the area of fault over which movement occurs in cm^2, and d is the average displacement of the fault in cm); D, surface displacement in m; L, surface rupture length in km; W, down-dip dimension of fault over which movement occurs (width) in km; l, surface rupture length in m; A, area of fault plane over which movement occurs in km^2.

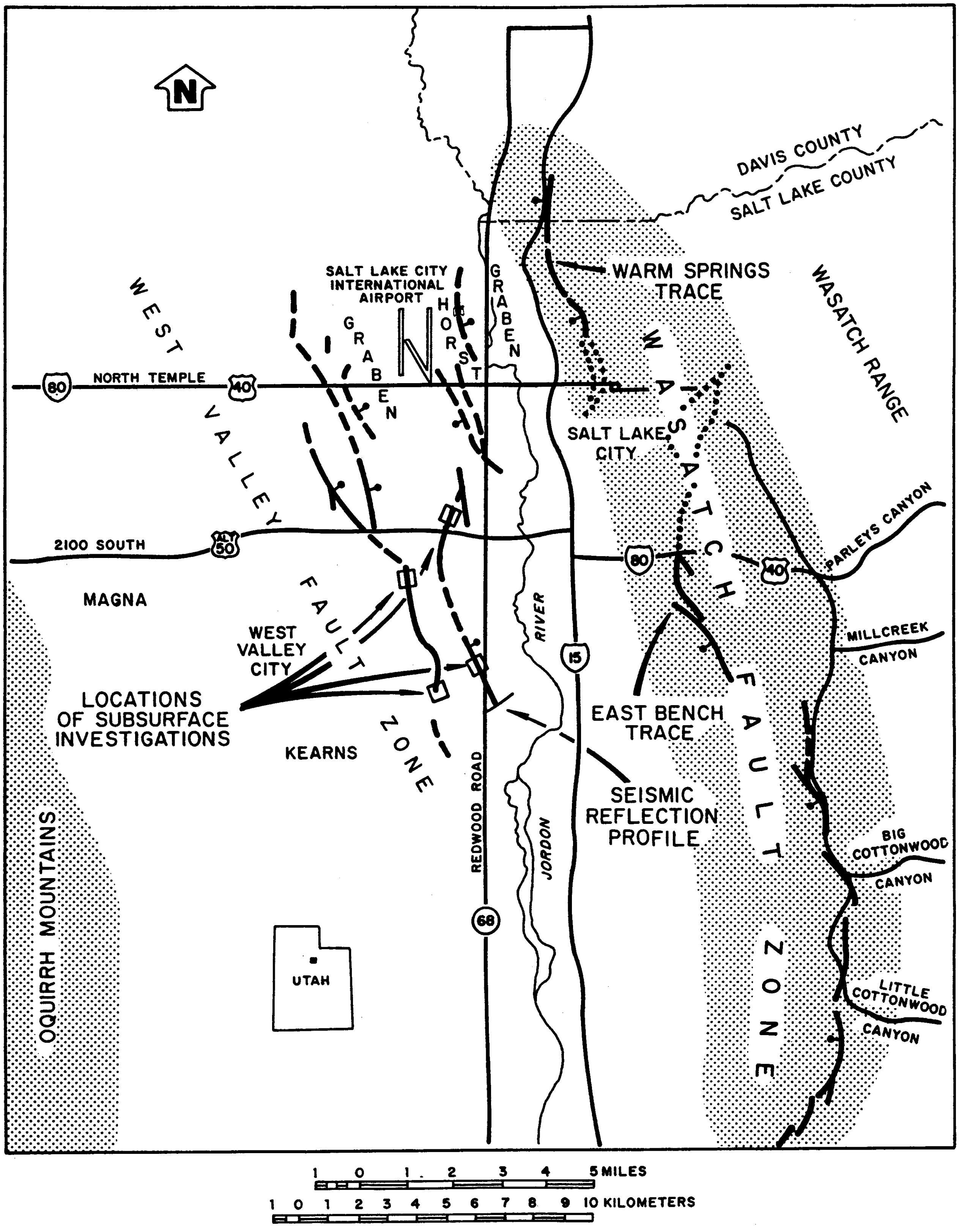


JORDAN VALLEY FAULT ZONE OF MARINE AND PRICE (1964)

Ref: Marine and Price, 1964

Dames & Moore

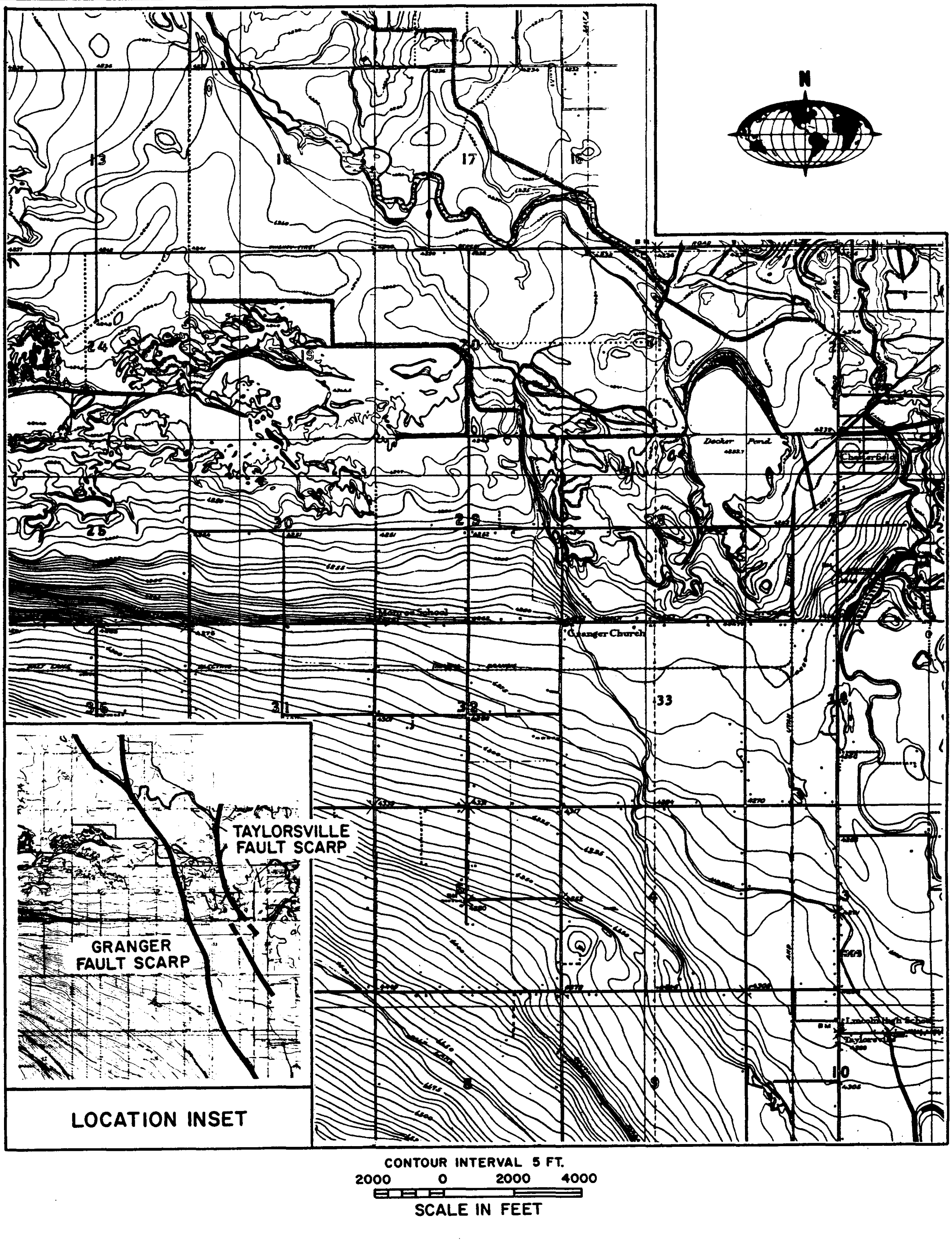
FIGURE 1



DISTRIBUTION OF TRACES
WEST VALLEY FAULT ZONE

Dames & Moore

FIGURE 2

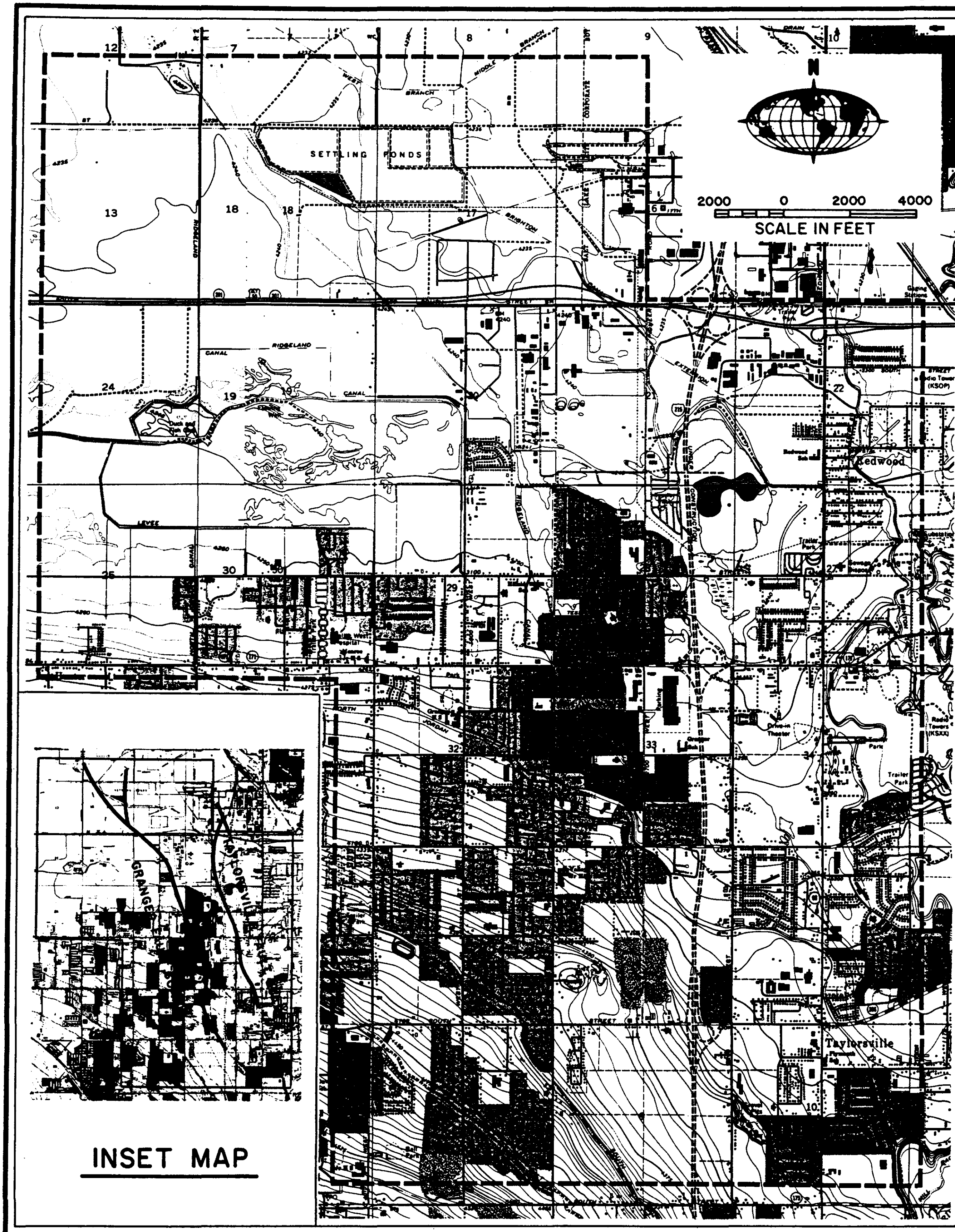


PART OF 1923 TOPOGRAPHIC MAP

REFERENCE
U.S.G.S. TOPOGRAPHIC MAP OF A PORTION OF SALT LAKE COUNTY (1923).

Dames & Moore

FIGURE 3



PART OF 1975 PHOTOREVISED TOPOGRAPHIC MAP

REFERENCE
U. S. G. S. QUADRANGLES ENTITLED "MAGNA, UTAH" (1952) PHOTOREVISED 1975 AND "SALT LAKE CITY SOUTH, UTAH" (1963) PHOTOREVISED 1975.

Dames & Moore

FIGURE 4

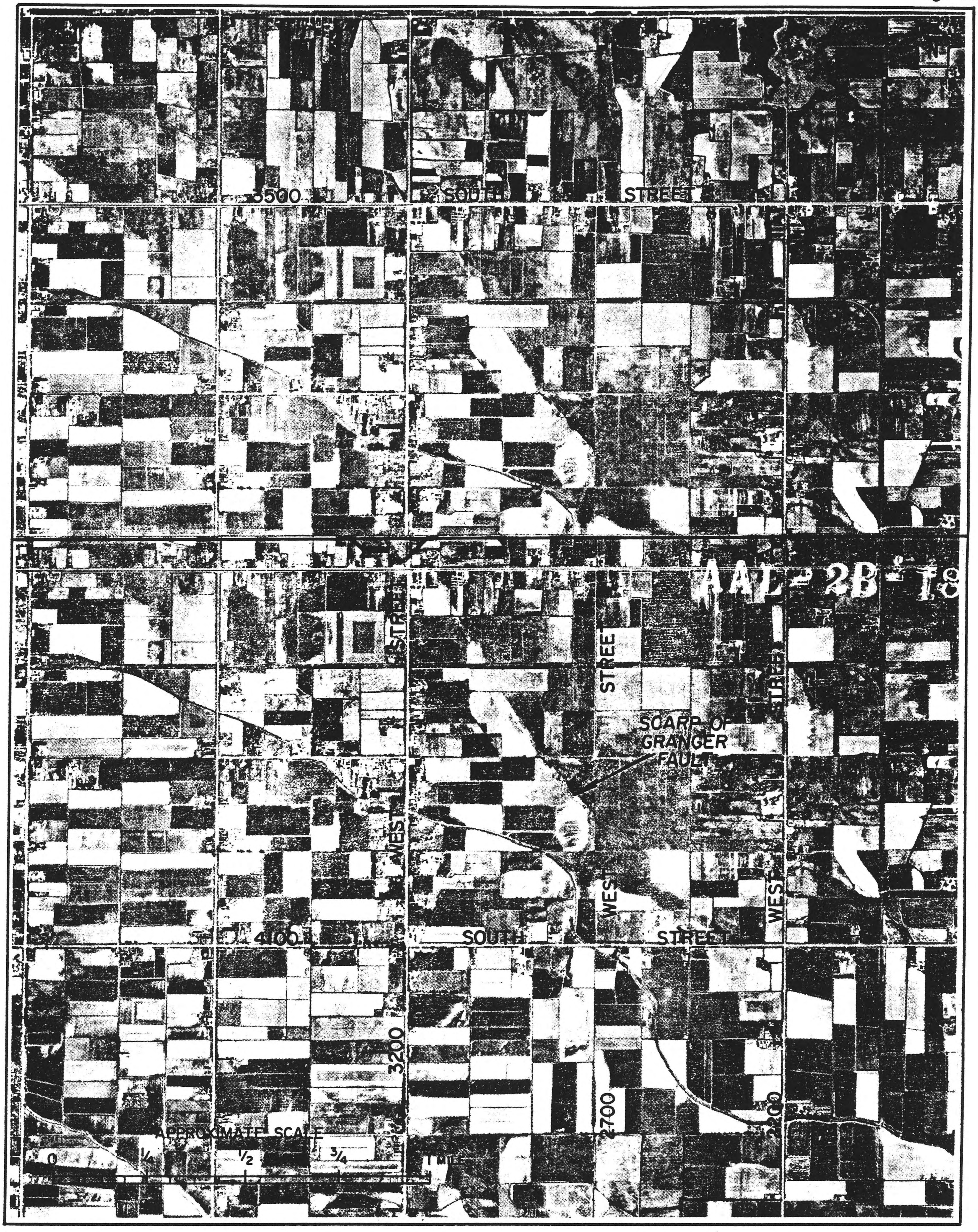


FIGURE 5. STEREOSCOPIC PAIR OF AERIAL PHOTOGRAPHS TAKEN AUGUST 17, 1946, SHOWING SCARP OF GRANGER FAULT NEAR 4100 SOUTH AND 2700 WEST STREETS — FRAMES AAL—2B—17 AND 18.

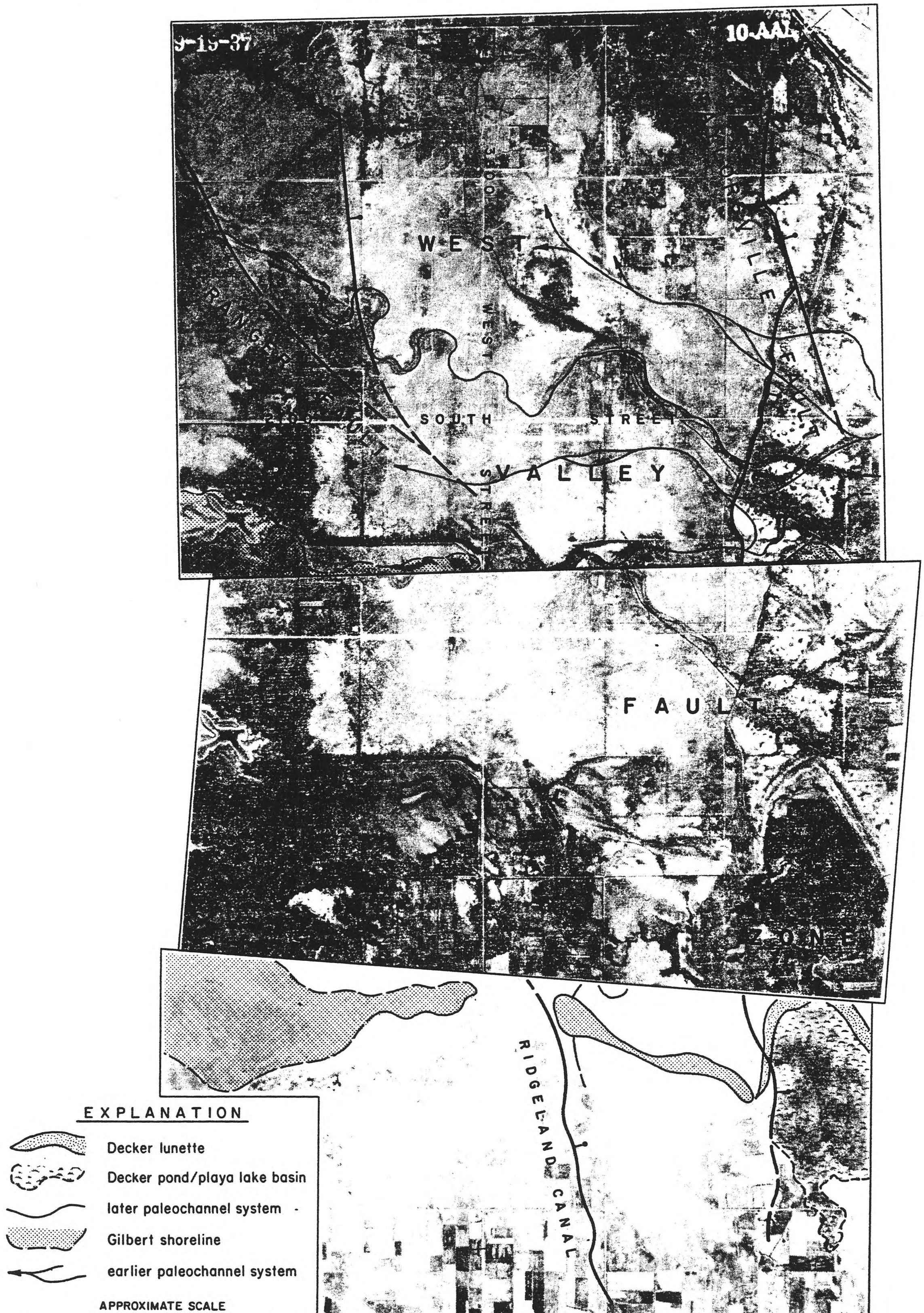


FIGURE 6. STEREOSCOPIC TRIPLET OF AERIAL PHOTOGRAPHS TAKEN SEPTEMBER 19, 1937, SHOWING WEST VALLEY FAULT ZONE NEAR 2100 SOUTH AND 3600 WEST — FRAMES 10—AAL—2—22, 23 AND 24.

Dames & Moore

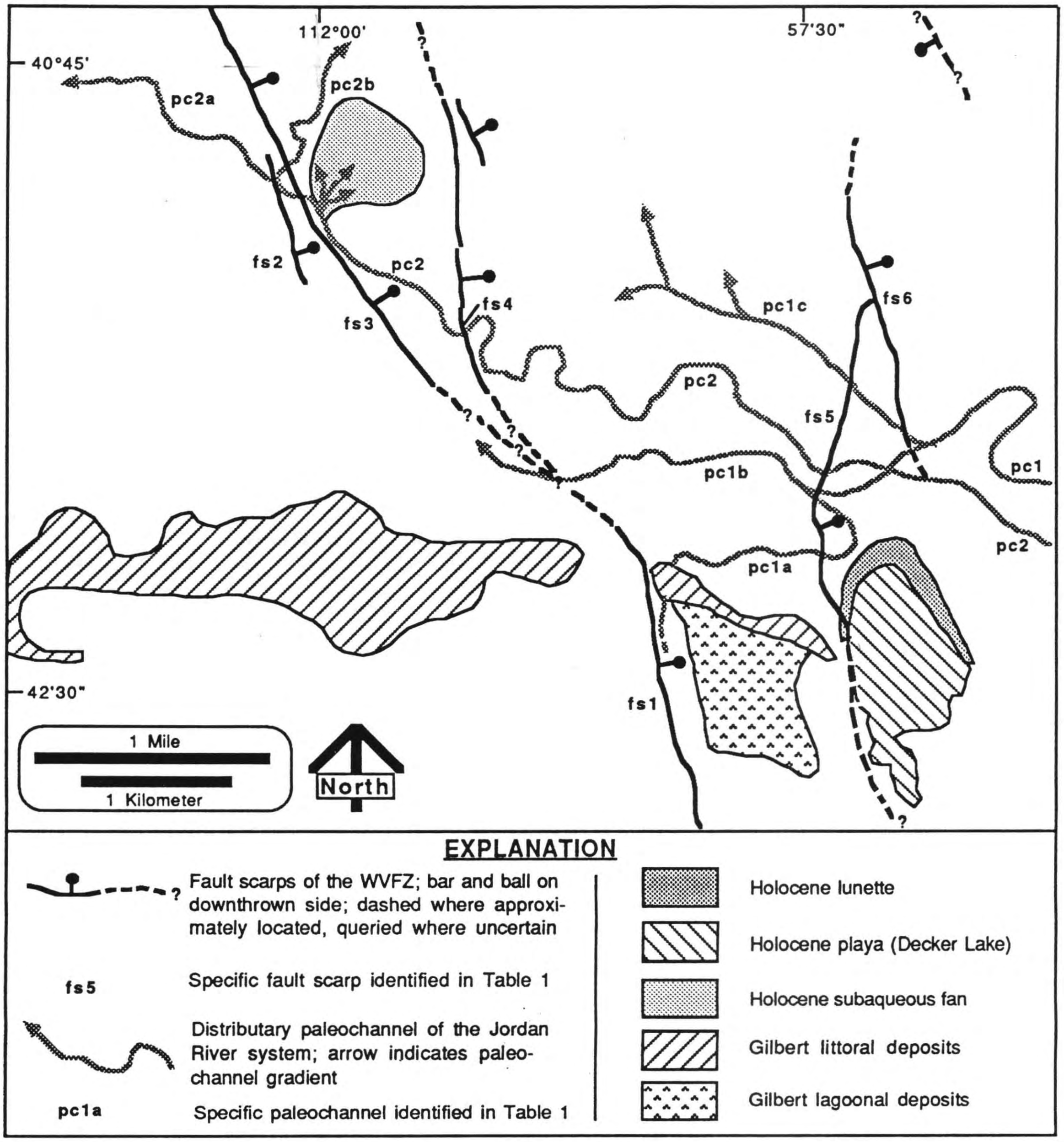
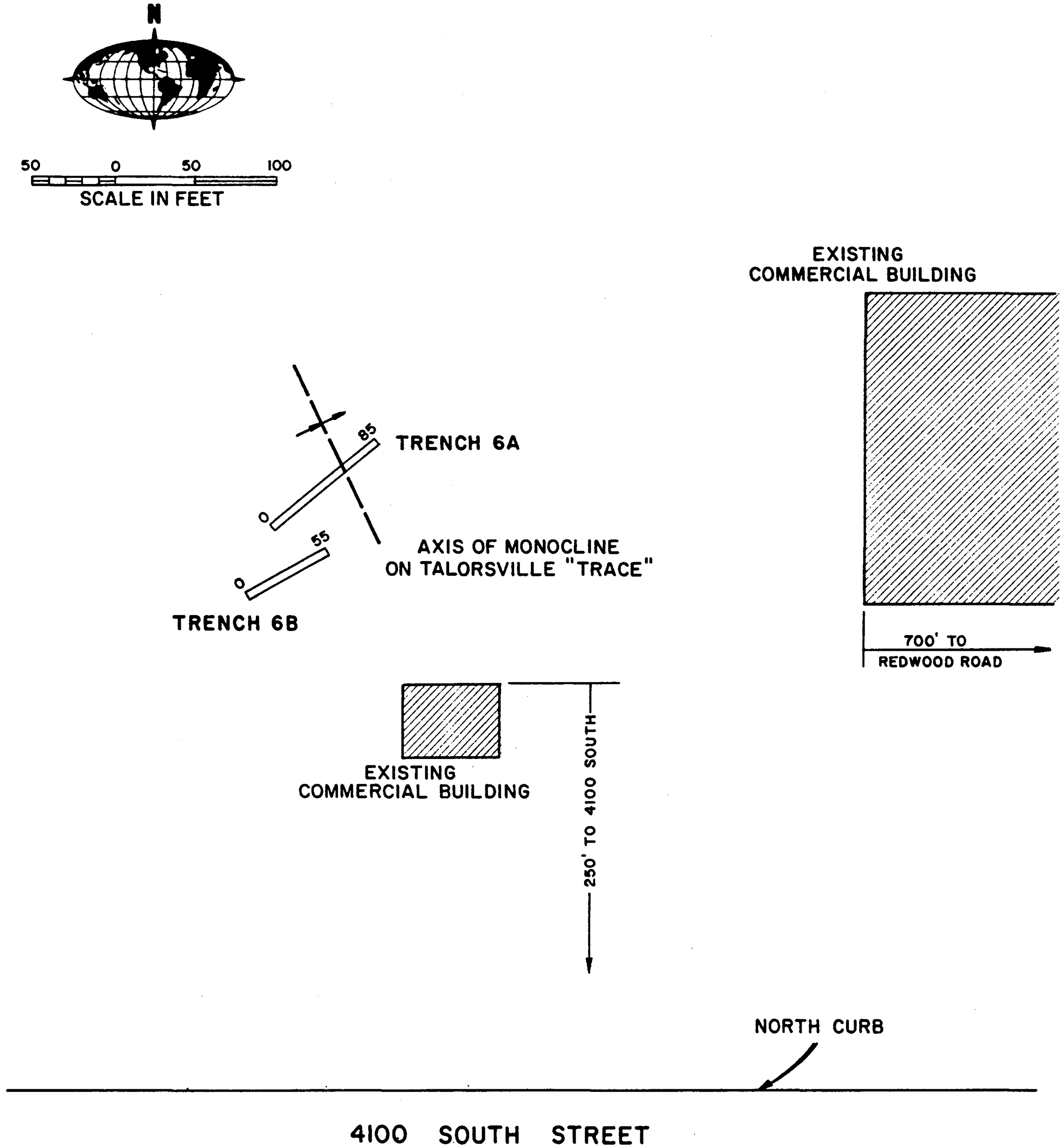


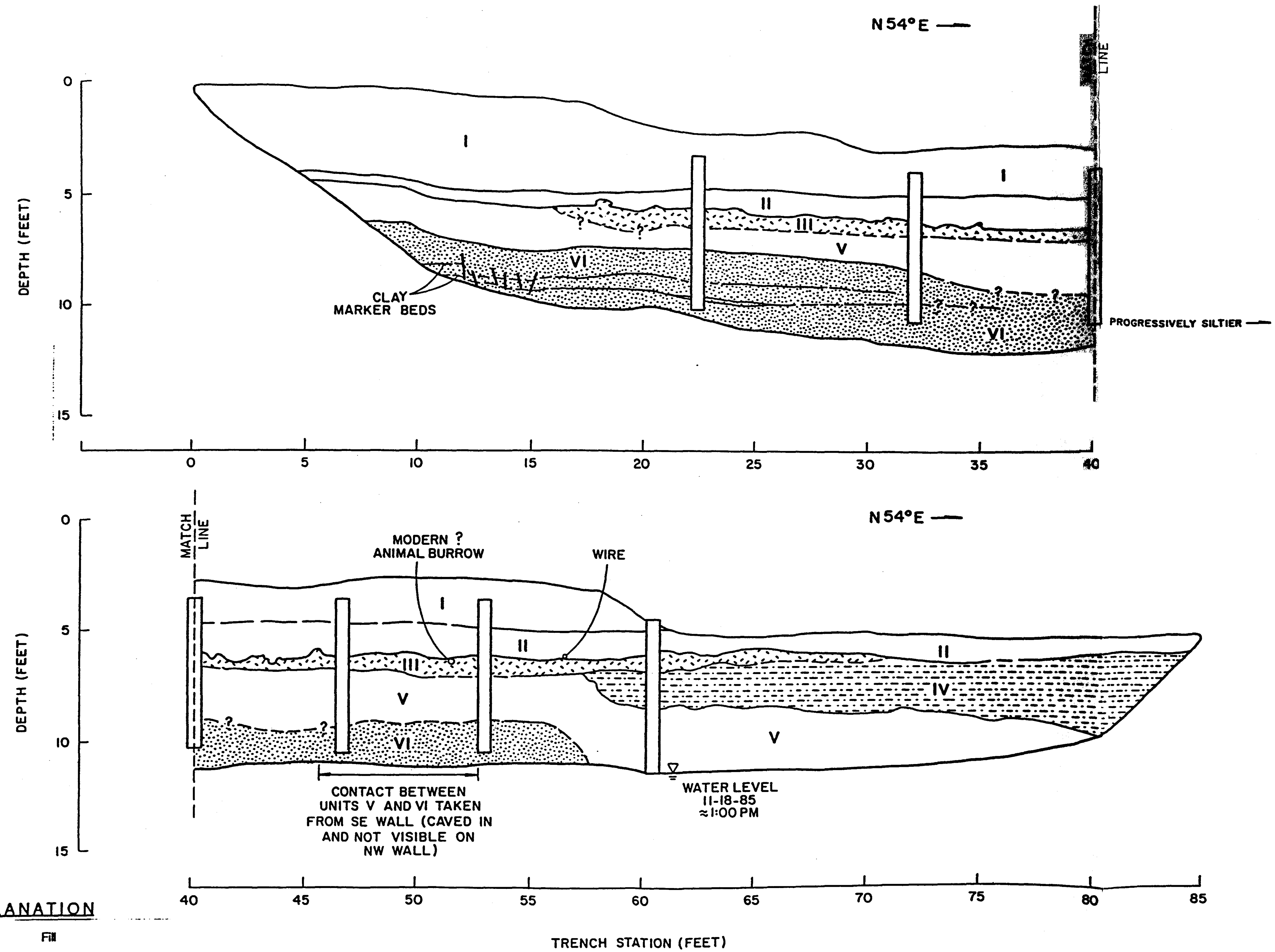
Figure 6a. Map showing relationships of morphostratigraphic features in the northern WVFZ. Refer to table 1 and text for explanation of relationships and resulting interpretation of displacement history.



LOCATION OF TRENCHES 6A & 6B
ON TAYLORSVILLE FAULT
S 1/2, SE 1/4, SW 1/4, SECTION 34
TOWNSHIP 1 SOUTH, RANGE 1 WEST, S.L.B. & M.

Dames & Moore

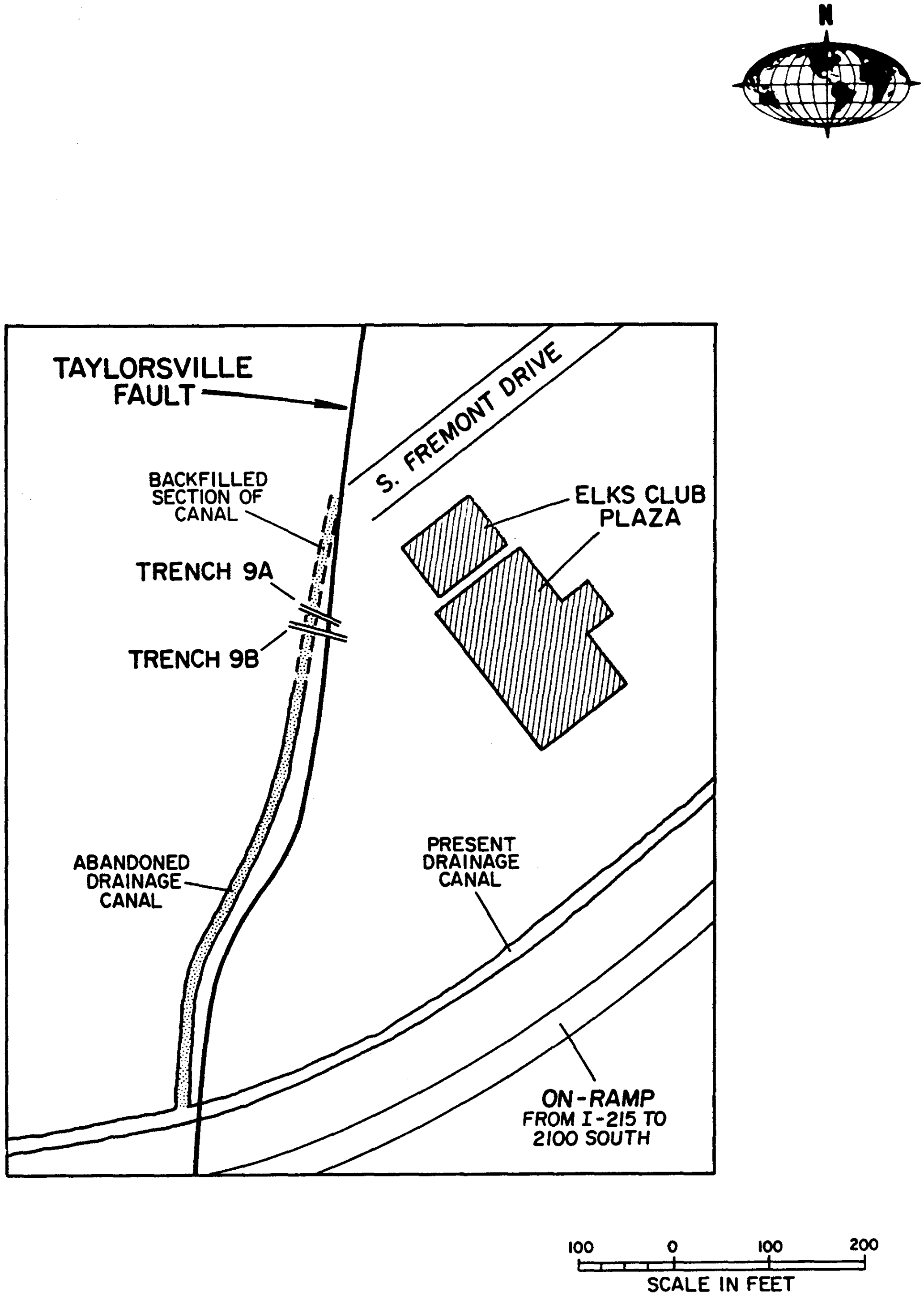
FIGURE 7



EXPLANATION

	I	Fill
	II	Fill, wire at base
OXYGEN ISOTOPE STAGE 1	III	Calcareous clayey playa deposit (?) or pedocalcic horizon (?)
	IV	Colluvial wedge (?) deposit
BONNEVILLE CYCLE OXYGEN ISOTOPE STAGE 2	V	Lacustrine silty clay
	VI	Lacustrine sand to silty sand with occasional detrital ostracods

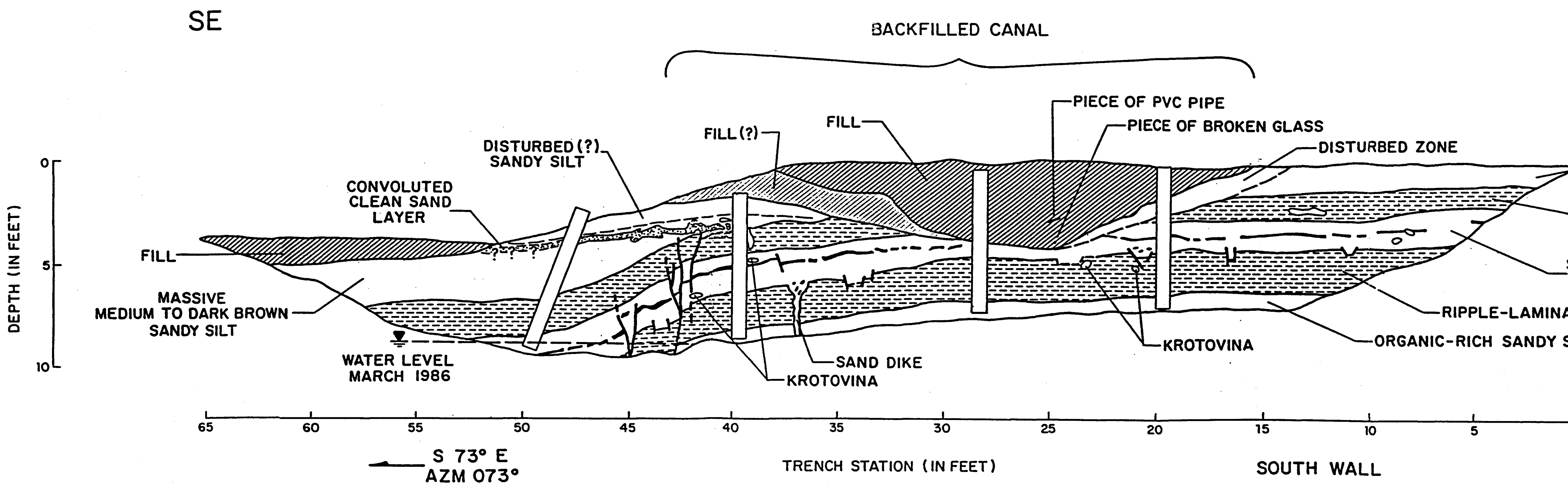
LOG OF TRENCH 6A
TAYLORSVILLE FAULT, WEST VALLEY FAULT ZONE, UTAH



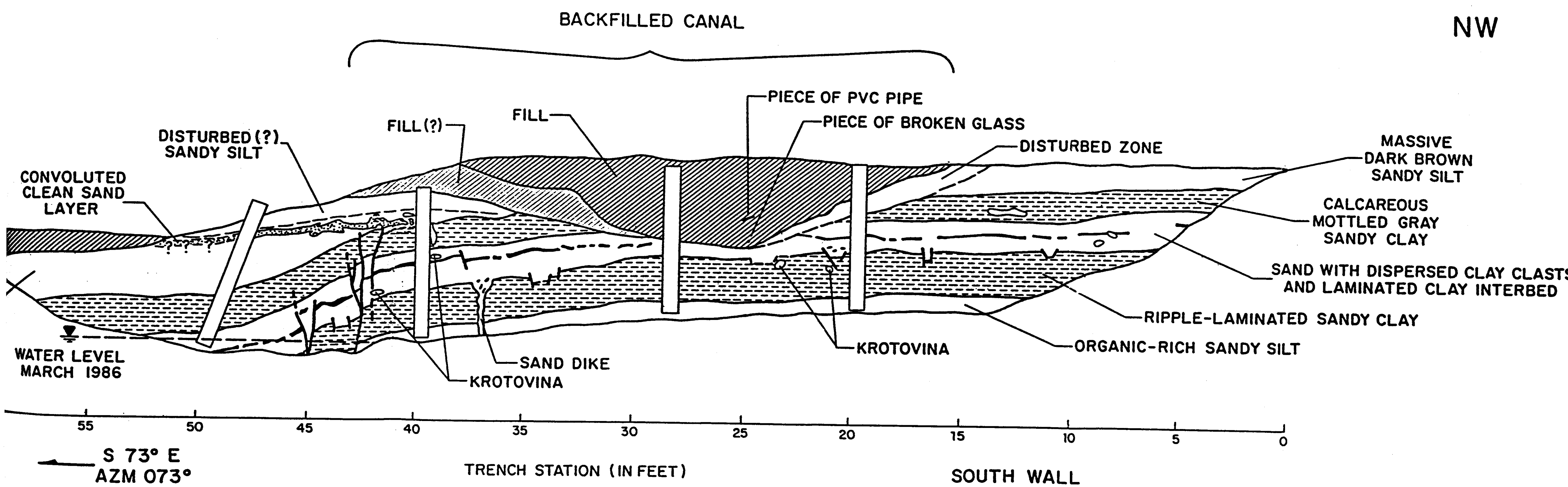
LOCATION OF TRENCHES 9A AND 9B ON TAYLORSVILLE FAULT

Dames & Moore

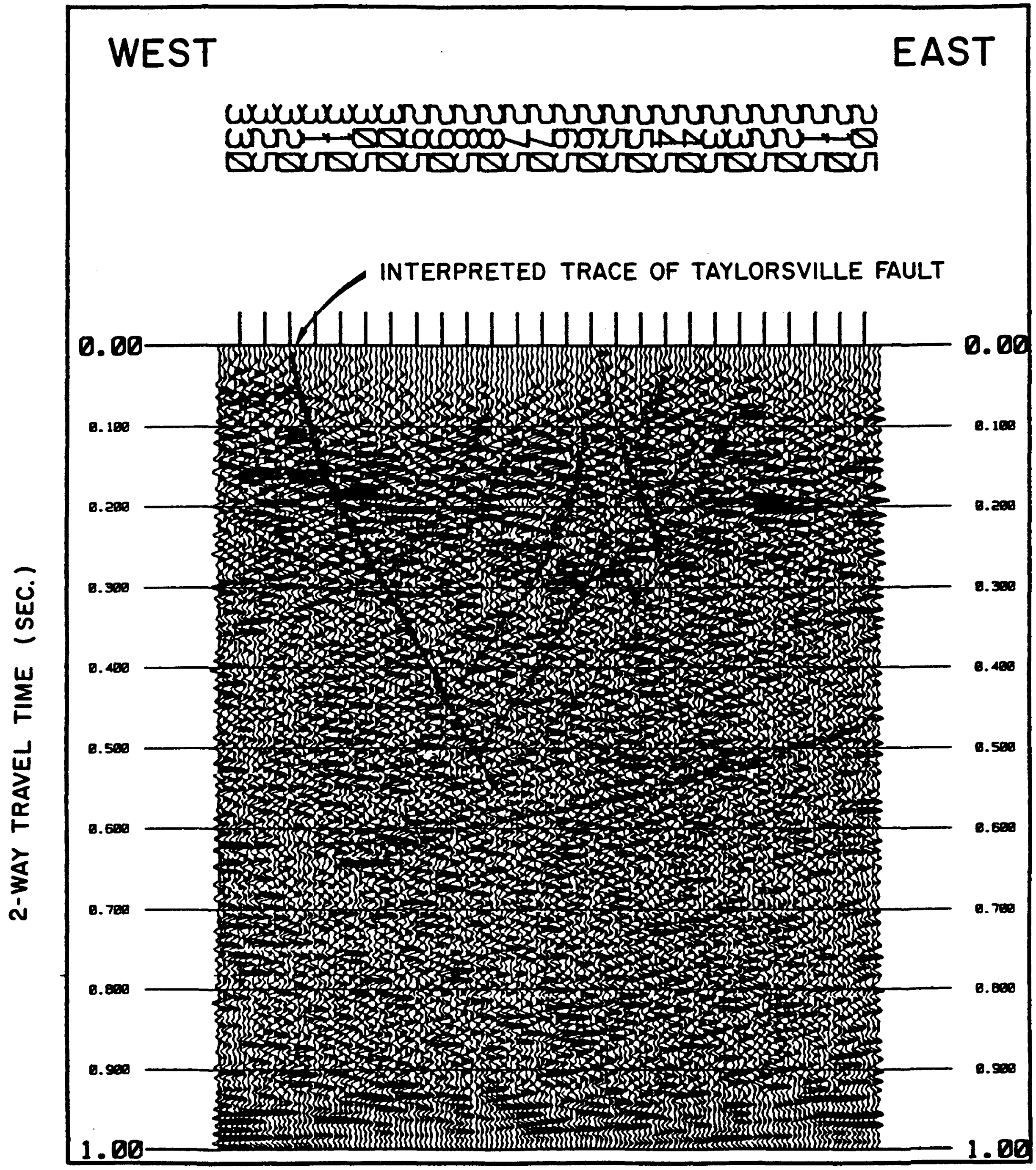
FIGURE 9



LOG OF TRENCH 9B (1836 SOUTH FREMONT DRIVE)
TAYLORSVILLE FAULT, WEST VALLEY FAULT ZONE, UTAH



LOG OF TRENCH 9B (1836 SOUTH FREMONT DRIVE)
TAYLORSVILLE FAULT, WEST VALLEY FAULT ZONE, UTAH

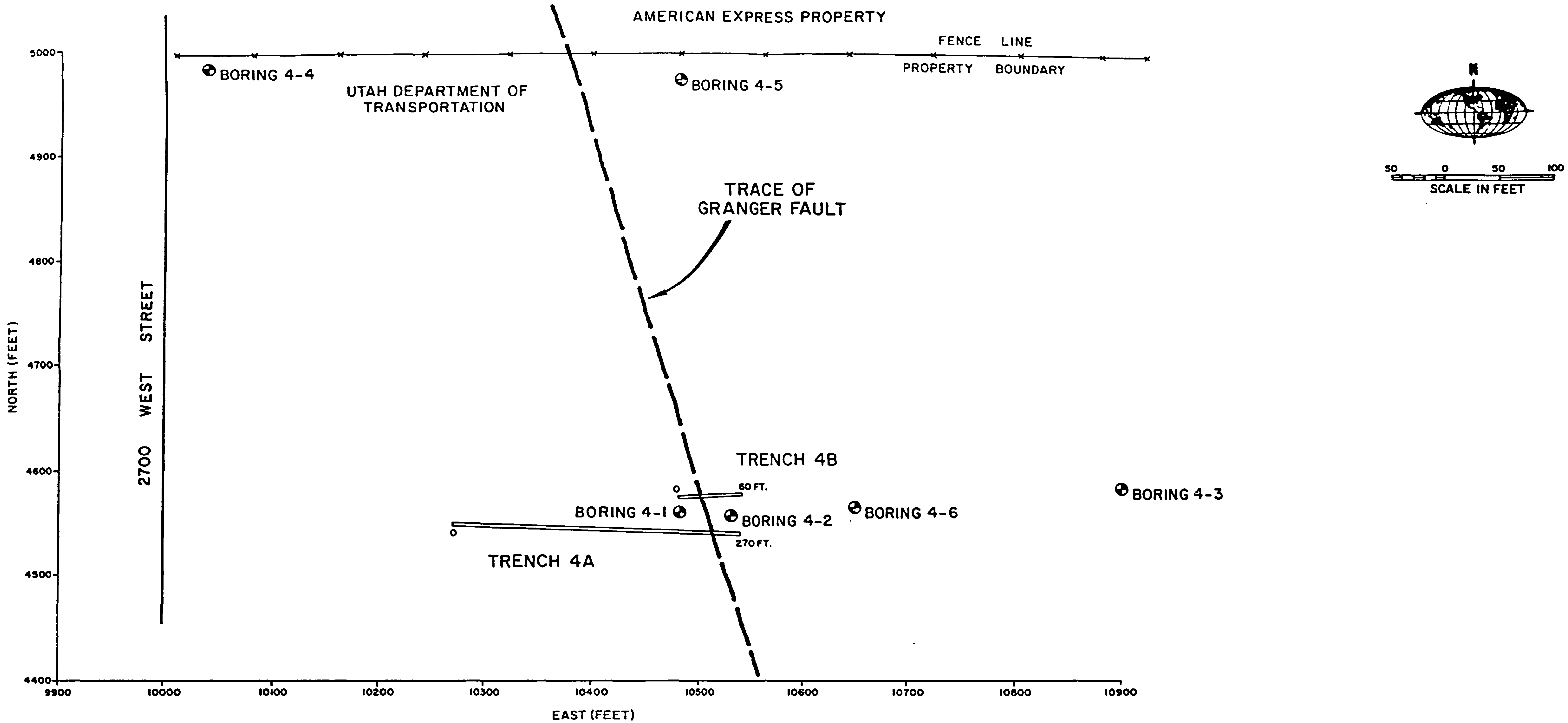


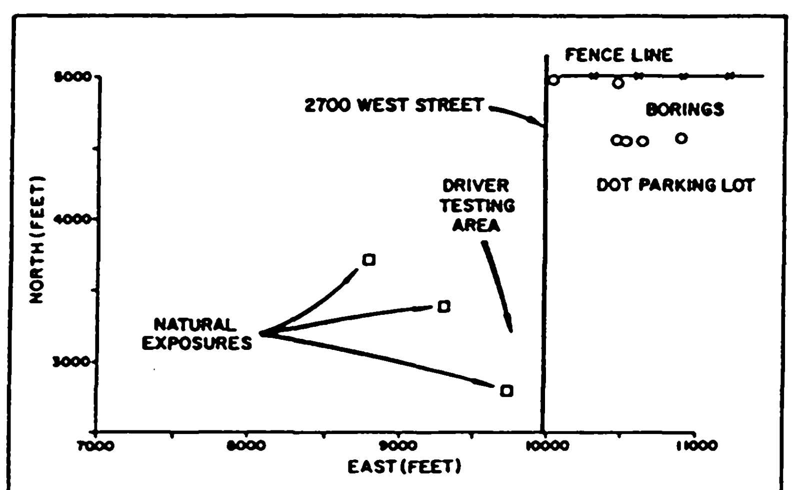
SEISMIC REFLECTION PROFILE ALONG UTAH HIGHWAY 226

PROVIDED BY S. HARDING, U.S.G.S., DENVER.

DAMES & MOORE

FIGURE 11





BORING AND EXPOSURE LOCATIONS
(NEAR GRANGER FAULT AT DOT SITE)

LOCATION OF
TRENCHES 4A & 4B
ON GRANGER FAULT
N1/2, NW1/4, SE1/4, SECTION 4
TOWNSHIP 2 SOUTH, RANGE 1 WEST
S.L.B. & M.

Dames & Moore

FIGURE 12

EXPLANATION

I	Fill
II	Pink clayey sand in fault zone
III	Green-gray sandy clay with cobbles in fault zone

BONNEVILLE CYCLE
OXYGEN ISOTOPE STAGE 2

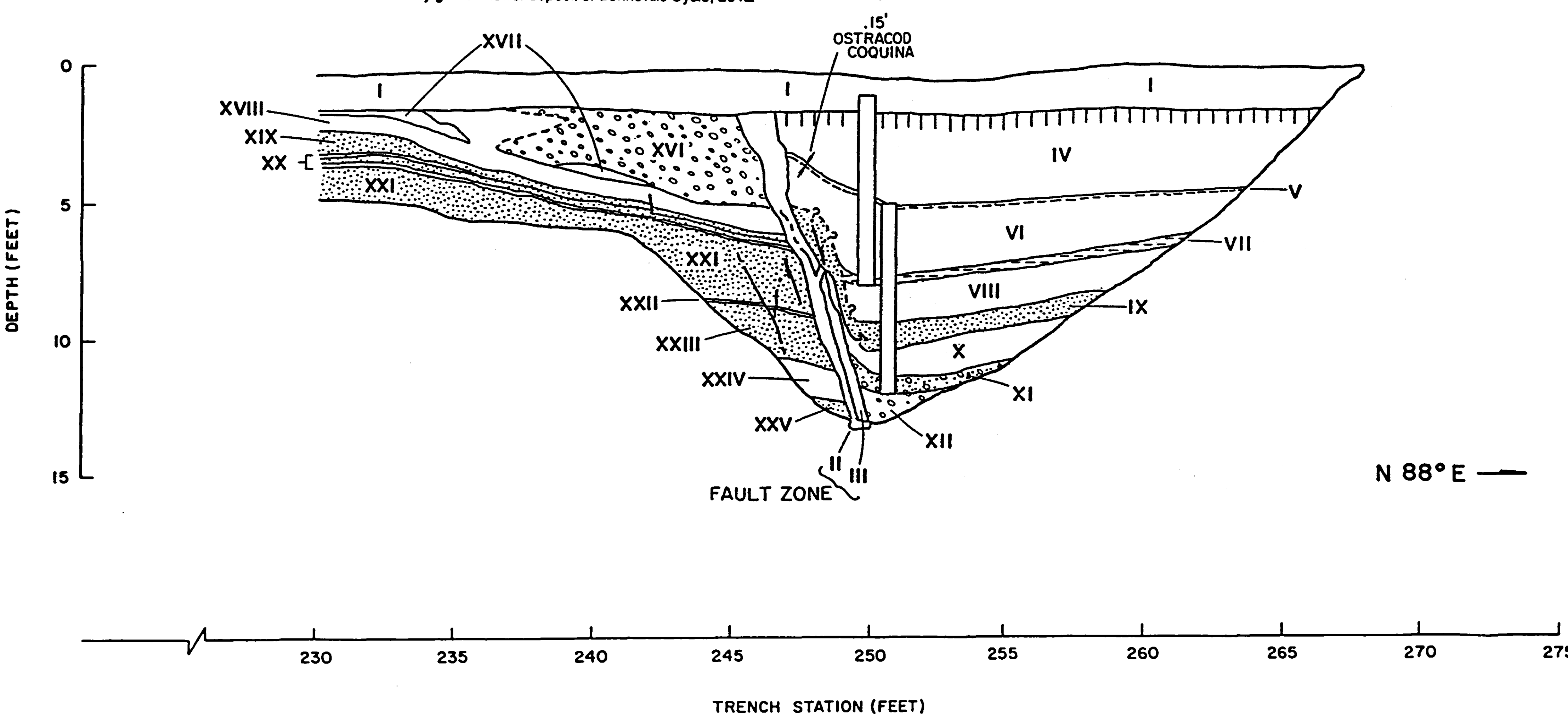
IV	Oxidized silty marl with drop stones - upper deposit of Bonneville Cycle, 15 - 12 ka
V	Ostracod coquina - may represent the Bonneville Flood, 15 ka
VI	Unoxidized silty marl, common ostracods - deep water lacustrine deposit
VII	Green-gray clay, common ostracods - deep water lacustrine deposit
VIII	Green-gray very fine sandy clay - moderately deep water lacustrine deposit
IX	Interbedded fine sand and silty clay - fluctuating shallow and deep lacustrine deposit
X	Yellow-orange silty fine sand - shallow water lacustrine deposit
XI	Brown well-rounded cobbles and silty gravel - transgressive beach deposit
XII	Brown clean pebbly gravel - transgressive beach deposit
XIII	Brown silty sand - interbeach deposit
XIV	Brown clean sandy gravel - lower deposit of Bonneville Cycle, 26 ka

OXYGEN ISOTOPE STAGE 3

XV	Sandy gravel with weak argillic horizon - alluvial deposit
XVI	Sandy gravel - channel deposit or alluvial deposit

HANSEL VALLEY CYCLE
OXYGEN ISOTOPE STAGE 4

XVII	Interbedded sandy clay and fine sand - fluctuating shallow and deep lacustrine deposit
XVIII	Laminated gray clay - deep water lacustrine deposit
XIX	Medium to fine sand - shallow water lacustrine deposit
XX	Silty clay with sand interbeds - lacustrine deposit
XXI	Silty sand with thin beds of clay - fluctuating shallow and deep water lacustrine deposit
XXII	Sandy clay marker bed - lacustrine deposit
XXIII	Interbedded silty clay and fine sand - lacustrine deposit
XXIV	Clay with thin fine sand partings - lacustrine deposit
XXV	Fine sand - lacustrine deposit

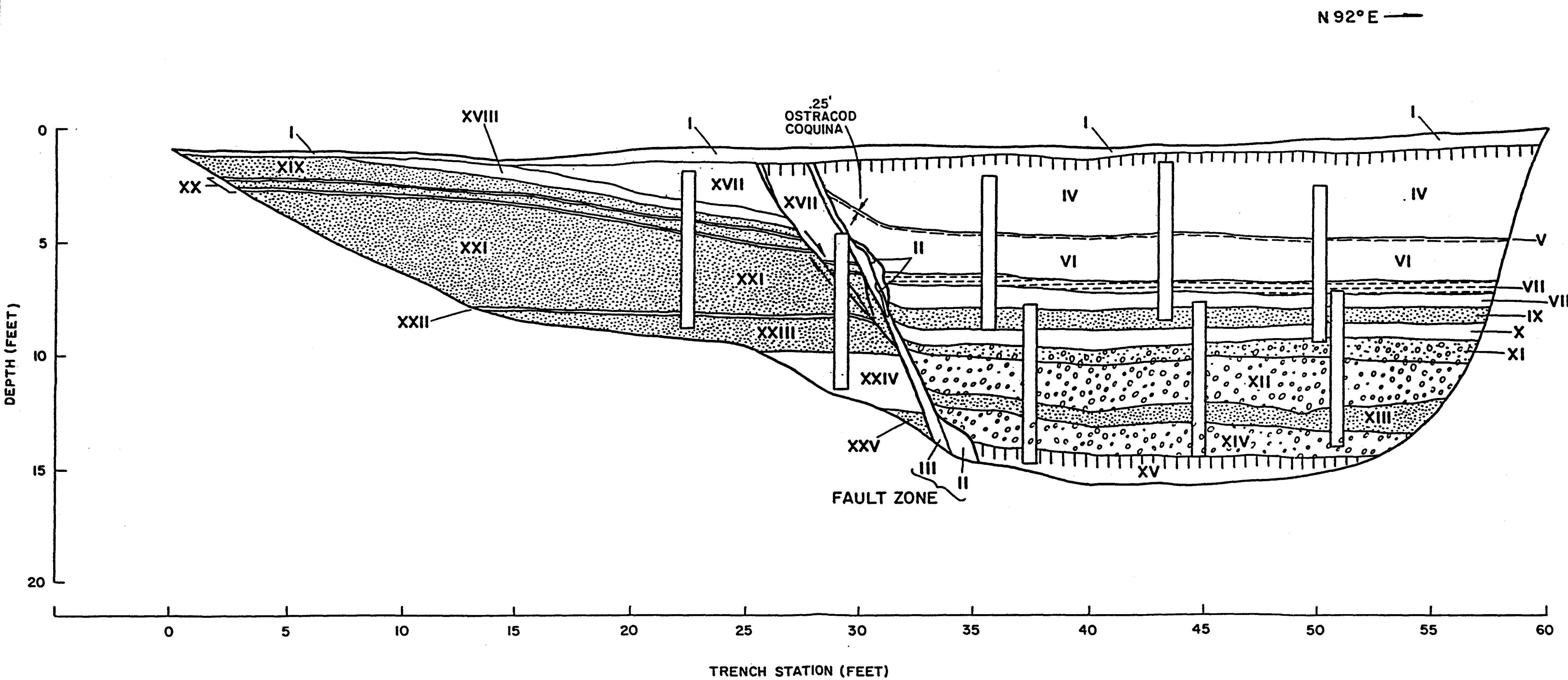


LOG OF TRENCH 4A (UTAH DEPT. OF TRANSPORTATION SITE)
GRANGER FAULT, WEST VALLEY FAULT ZONE, UTAH

NOTE
EASTERN SECTION OF LOG FROM 230' TO 267'.

Dames & Moore

FIGURE 13



LOG OF TRENCH 4B (UTAH DEPT. OF TRANSPORTATION SITE)
GRANGER FAULT, WEST VALLEY FAULT ZONE, UTAH

NOTE – EXPLANATION ON FIGURE 10.

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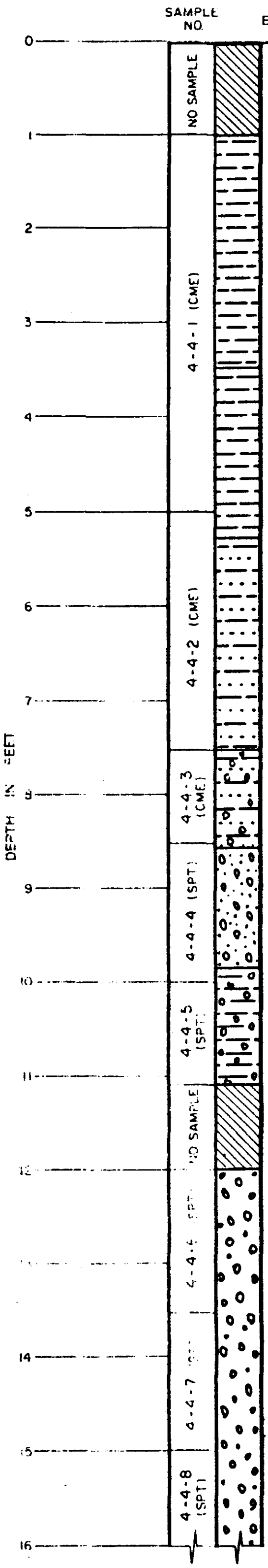
FIGURE 14

BORING 4-4

ELEVATION 4316'



NO SAMPLE

REDDISH BROWN SILTY CLAY (IV) WITH WHITE VERY FINE SAND PARTINGS, OSTRACODS, SOME WHITE CALCAREOUS MOTTLING, BLOCKY TEXTURE, ROOTS AND ROOT TUBES THROUGHOUT

GREENISH GRAY CLAY (V THRU VIII) WITH VERY FINE TO FINE SAND PARTINGS CONTAINING ABUNDANT OSTRACODS, LAMINATED TO THINLY BEDDED, OCCASIONAL WELL - ROUNDED WEATHERED PEBBLES

WHITE TO PINKISH TAN CLAYEY SILTS AND SANDS (IX AND X), RIPPLE LAMINATED, FINING UPWARDS FROM FINE SAND TO VERY FINE SAND TO SILTY CLAY

GRAY TO DARK BROWN CLAYEY SAND WITH GRAVEL (XI), VERY POORLY SORTED

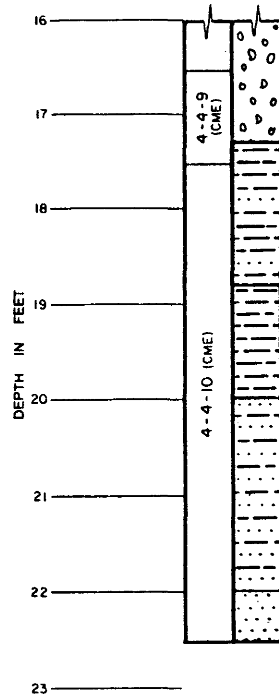
GRAY SANDY GRAVELS (XII AND XIV) MATRIX SUPPORTED, WELL ROUNDED, CALCAREOUS COATED QUARTZITE PEBBLES AND MEDIUM TO COARSE SAND

PINKISH BROWN CLAYEY GRAVELS (XV) MATRIX SUPPORTED, WELL ROUNDED, CALCAREOUS COATED PEBBLES AND MEDIUM TO COARSE SAND

NO SAMPLE

TAN GRAVELS (XVII) MATRIX SUPPORTED FINE TO COARSE GRAVELS, CLASTS, PREDOMINANTLY QUARTZITE, OFTEN WEATHERED AND CALCAREOUS COATED - MATRIX VARIES FROM SILT TO MEDIUM SAND

BORING 4-4 (CONTINUED)



TAN CLAYEY SILT TO FINE SAND, RIPPLE LAMINATED, COARSENING UPWARD FROM SILT TO VERY FINE SAND TO FINE SAND

MOTTLED GRAY SILTY CLAY (XVIII) WITH VERY FINE SAND PARTINGS, NO OSTRACODS

GRAY INTERBEDDED SILTY CLAY AND SILTY VERY FINE SAND (XVII TO XVIII), CLAY IS LAMINATED, SAND IS RIPPLE - LAMINATED, OVERALL FINING UPWARD, .05 TO 2.5 INCH THICK BEDS

YELLOWISH TAN FINE SAND (XIX), CROSS-BEDDED QUARTZ - RICH MODERATELY SORTED

BORING COMPLETED AT 22.5 FEET ON 12-12-85.

GROUND WATER WAS NOT ENCOUNTERED.

NOTE

CME INDICATES 3 INCH DIAMETER CONTINUOUS SAMPLE

SPT INDICATES 1.75 INCH DIAMETER SAMPLER DRIVER USING STANDARD PENETRATION TEST METHOD

EXPLANATION

	I	Fill
	II	Pink clayey sand in fault zone
	III	Green-gray sandy clay with cobbles in fault zone
BONNEVILLE CYCLE OXYGEN ISOTOPE STAGE 2	IV	Oxidized silty marl with drop stones - upper deposit of Bonneville Cycle, 15 - 12 ka
	V	Ostracod coquina - may represent the Bonneville Flood, 15 ka
	VI	Unoxidized silty marl, common ostracods - deep water lacustrine deposit
	VII	Green-gray clay, common ostracods - deep water lacustrine deposit
	VIII	Green-gray very fine sandy clay - moderately deep water lacustrine deposit
	IX	Interbedded fine sand and silty clay - fluctuating shallow and deep lacustrine deposit
	X	Yellow-orange silty fine sand - shallow water lacustrine deposit
	XI	Brown well-rounded cobbles and silty gravel - transgressive beach deposit
	XII	Brown clean pebbly gravel - transgressive beach deposit
	XIII	Brown silty sand - interbeach deposit
	XIV	Brown clean sandy gravel - lower deposit of Bonneville Cycle, 26 ka
OXYGEN ISOTOPE STAGE 3	XV	Sandy gravel with weak argillic horizon - alluvial deposit
	XVI	Sandy gravel - channel deposit or alluvial deposit
HANSEL VALLEY CYCLE OXYGEN ISOTOPE STAGE 4	XVII	Interbedded sandy clay and fine sand - fluctuating shallow and deep lacustrine deposit
	XVIII	Laminated gray clay - deep water lacustrine deposit
	XIX	Medium to fine sand - shallow water lacustrine deposit
	XX	Silty clay with sand interbeds - lacustrine deposit
	XXI	Silty sand with thin beds of clay - fluctuating shallow and deep water lacustrine deposit
	XXII	Sandy clay marker bed - lacustrine deposit
	XXIII	Interbedded silty clay and fine sand - lacustrine deposit
	XXIV	Clay with thin fine sand partings - lacustrine deposit
	XXV	Fine sand - lacustrine deposit

LOG OF BORING 4-4 ON UPTHROWN SIDE OF GRANGER FAULT

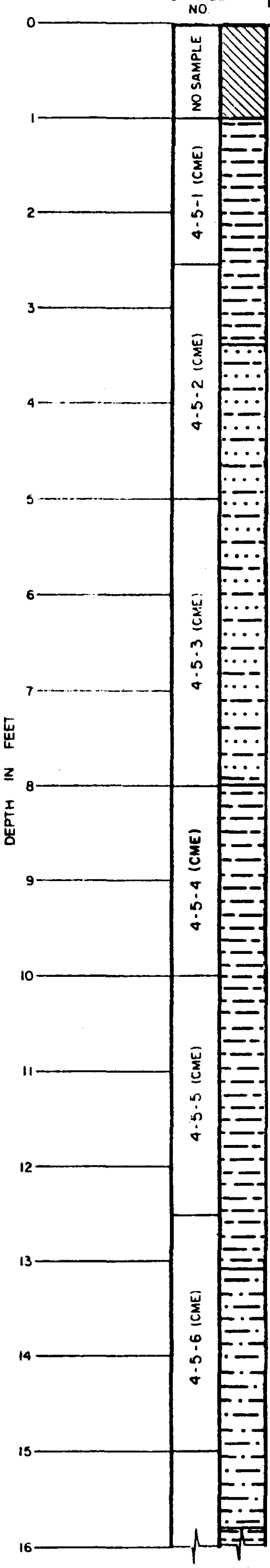
Dames & Moore

FIGURE 15

BORING 4-5

SAMPLE NO. ELEVATION 4304'

DEPTH IN FEET



NO SAMPLE

DARK BROWN SILTY CLAY (1)
TAN MOTTLING

TAN INTERBEDDED VERY FINE TO FINE SAND AND SILTY CLAY, THINLY BEDDED WITH KROTOVINA, REWORKED OSTRACODS, WHITE CALCAREOUS MOTTLING OF CLAYS, CLAYS VARY FROM PINKISH BROWN TO BUFF TO GRAY

LIGHT PINKISH BROWN SILTY CLAY (IV) WITH TAN TO WHITE FINE AND VERY FINE SAND PARTINGS, OSTRACODS, MODERN ROOTS, WHITE CALCAREOUS MOTTLING, BLOCKY TEXTURE

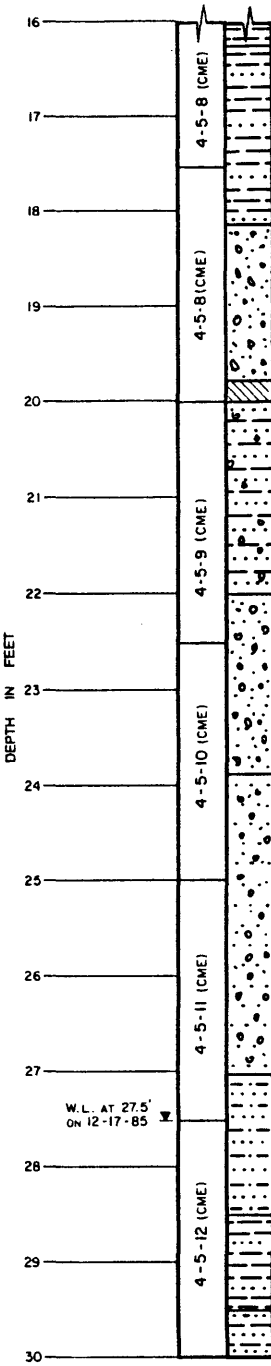
BECOMES LESS BLOCKY AND DARKER IN COLOR

GREENISH GRAY SANDY CLAY (V AND VI) WITH LIMONITIC STAINING ALONG VERY FINE TO FINE SAND PARTINGS, MODERN ROOTS IN UPPER AREA SECTION

BLUISH GREEN CLAY (VII)

BORING 4-5 (CONTINUED)

DEPTH IN FEET



INTERBEDDED GREENISH GRAY CLAY AND TAN CLAYEY VERY FINE TO FINE SAND (VIII THRU X) WITH LAMINATIONS AND NO OSTRACODS

FINE TO COARSE SANDY GRAVELS (XII THRU XIV), WELL ROUNDED QUARTZITE CLASTS IN VARIABLE, CLEAN SANDY MATRIX

NO SAMPLE

GRAY TO PINKISH BROWN CLAYEY, PEBBLY SAND, VERY POORLY SORTED WITH WELL ROUNDED CALCAREOUS COATED COBBLES, HIGHLY VARIABLE

DARK REDDISH BROWN PEBBLY SAND VERY POORLY SORTED IN SILTY MATRIX

DARK BROWN CLAYEY, SANDY GRAVELS, WELL ROUNDED PEBBLES AND COBBLES OF QUARTZITE, SOME WITH CALCAREOUS COATING IN A CLAYEY SAND MATRIX WITH WHITE CLACAREOUS MOTTLING

GRAY SILTY FINE TO MEDIUM SAND, APPARENT CROSS BEDS

LIGHT GRAY CLAY WITH YELLOWISH TAN FINE SAND PARTINGS

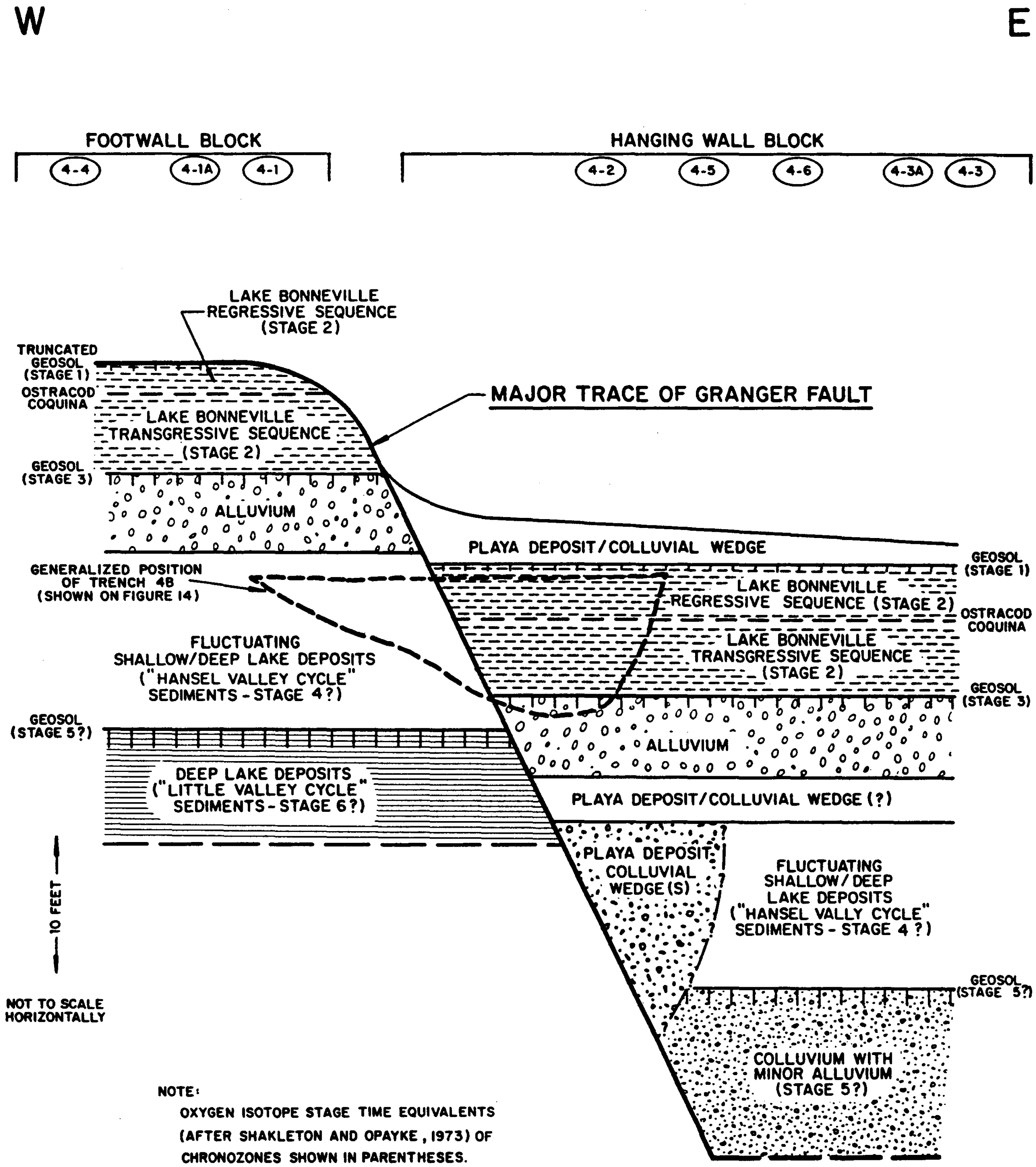
GRAY CLAYEY FINE SAND

BORING COMPLETED AT 30.0 FEET ON 12-17-85.

LOG OF BORING 4-5
ON DOWNTHROWN SIDE OF GRANGER FAULT

Dames & Moore

FIGURE 16

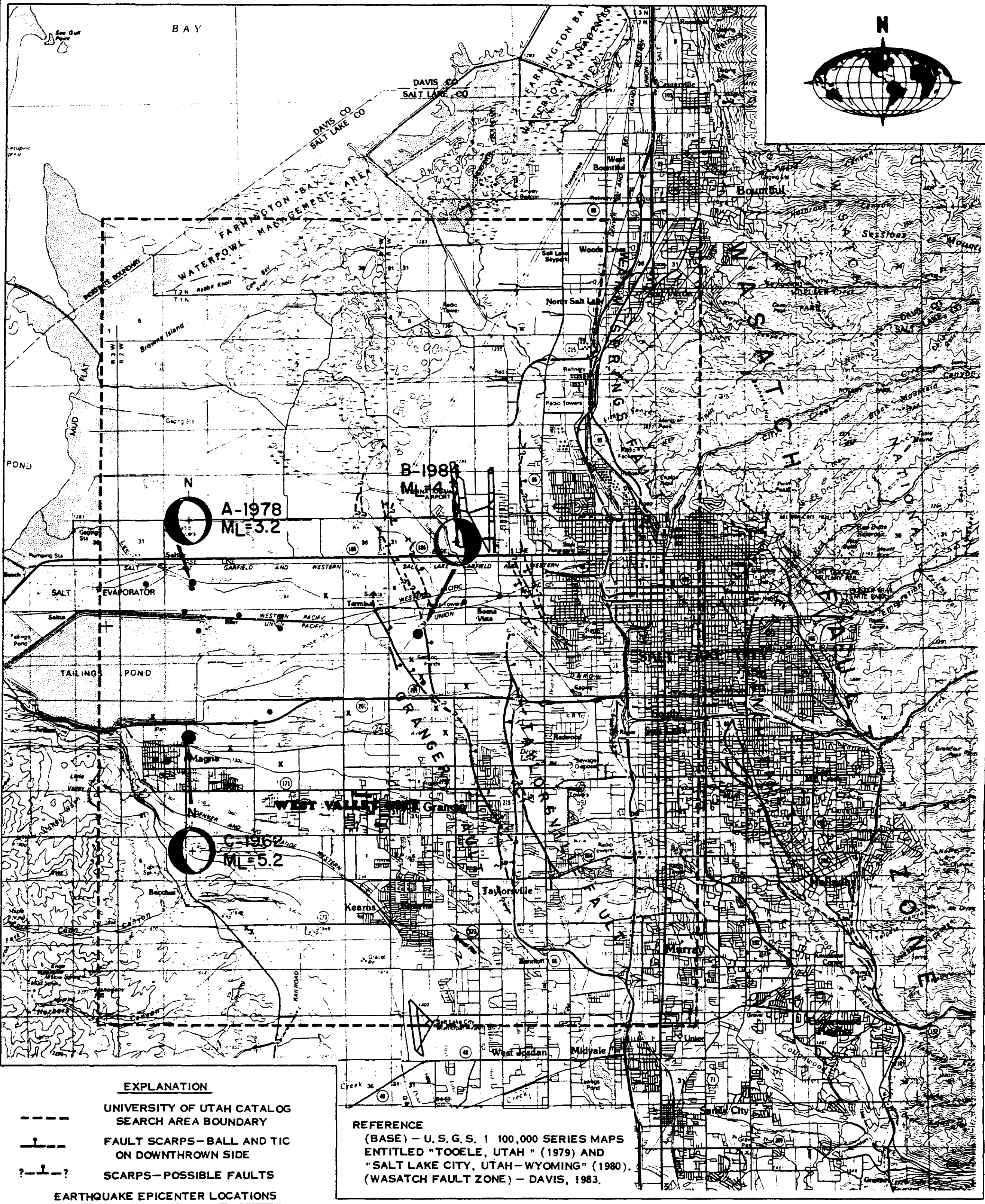


NOTE:
OXYGEN ISOTOPE STAGE TIME EQUIVALENTS (AFTER SHAKLETON AND OPAYKE, 1973) OF CHRONOZONES SHOWN IN PARENTHESES.
4-2 DESIGNATES RELATIVE BORING HOLE POSITIONS.

IDEALIZED CHRONOSTRATIGRAPHY ALONG GRANGER FAULT (4501 SOUTH 2700 WEST)

Dames & Moore

FIGURE 17



EXPLANATION

- ---- UNIVERSITY OF UTAH CATALOG SEARCH AREA BOUNDARY
- FAULT SCARPS—BALL AND TIC ON DOWNTHROWN SIDE
- ?—?—? SCARPS—POSSIBLE FAULTS

EARTHQUAKE EPICENTER LOCATIONS

- M_L 5.0 AND GREATER
- M_L 4.0 TO 5.0
- M_L 3.0 TO 4.0
- M_L 2.0 TO 3.0
- x M_L 1.5 TO 2.0

FAULT-PLANE SOLUTIONS (LOWER HEMISPHERE PROJECTIONS)

N

A-1978
M_L=3.2

COMPRESSIONAL QUADRANTS ARE SHADED, DILATIONAL QUADRANTS ARE UNSHADED.

A—COMPOSITE AFTER ARABASZ, SMITH AND RICHINS (1979)
B—COMPOSITE AFTER PECHMANN AND THORBJARNARDOTTIR (1984)
C—AFTER PAVLIS AND SMITH (1979)

REFERENCE
(BASE) — U. S. G. S. 1 100,000 SERIES MAPS ENTITLED "TOOELE, UTAH" (1979) AND "SALT LAKE CITY, UTAH—WYOMING" (1980).
(WASATCH FAULT ZONE) — DAVIS, 1983.

1 0 1 2 3 4 5 6 7 8 9 KILOMETERS
1 0 1 2 3 4 5 MILES

EARTHQUAKE EPICENTER PLOT
FOR
WEST VALLEY FAULT ZONE
(ALL EVENTS JULY 1962 - DEC. 1985)

Dames & Moore

FIGURE 18

AGE	PALEOLAKE CHRONOLOGY	DISPLACEMENT HISTORY OF GRANGER FAULT
Holocene	Subaerial Exposure	5.2 to 6.7 m displacement (minimum of 2 events)
Pleistocene	Regression 13 ka Bonneville Cycle Transgression 26 ka	No displacement
	Subaerial Exposure	7.6 m minimum displacement
	Cutler Dam Cycle (60±20 ka)	(?)
	Subaerial Exposure	4.6 m minimum displacement
	Little Valley Cycle (140±10 ka)	(?)

Figure 19. Summary of paleolake chronology and displacement history of the Granger fault at the DOT site in Salt Lake Valley. The timing of the Bonneville Cycle transgression and regression are from Currey and Oviatt (1985); the age range of the Cutler Dam Cycle is from Oviatt (1986, personal communication) and McCalpin (1986); the age range of the Little Valley Cycle is from Scott and others (1983) and McCalpin (1986).

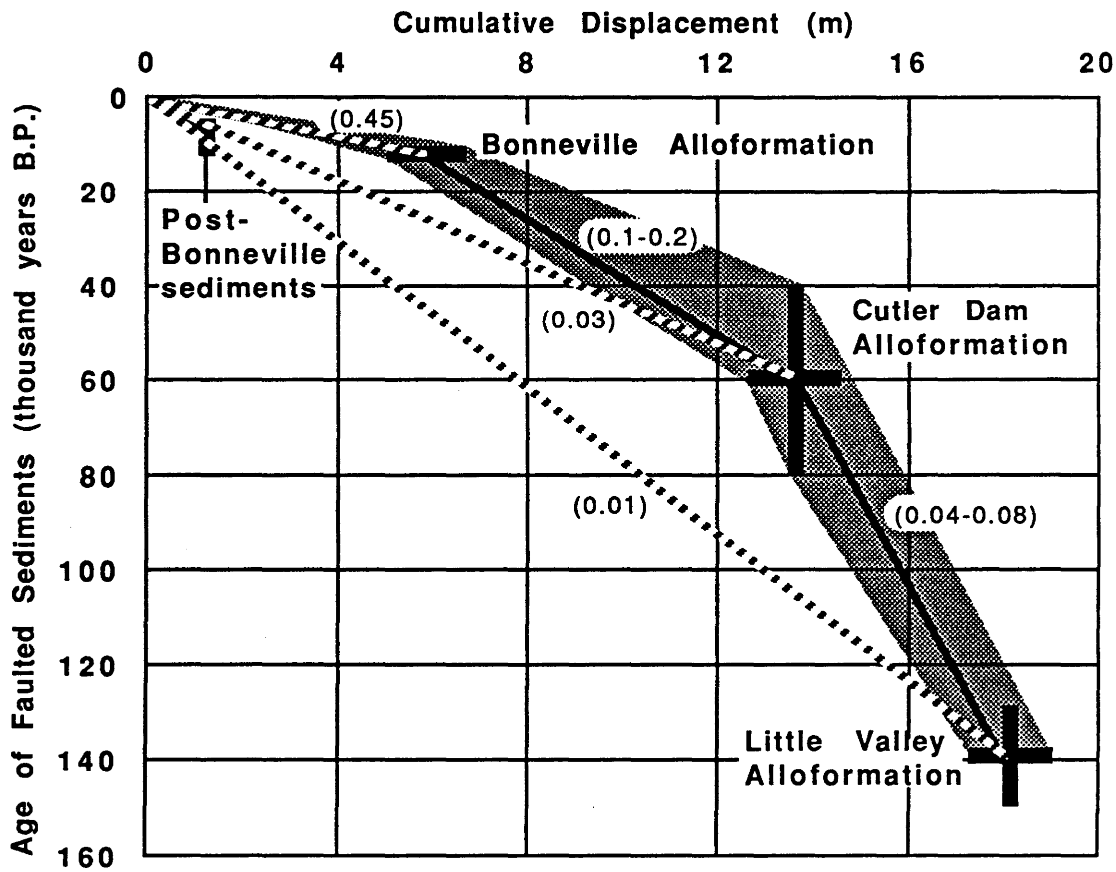


Figure 20. Cumulative displacement on the West Valley fault zone for the past 140 ka. Dotted lines show average slip rates based on displacements of deposits of Little Valley Alloformation (17.4-18.9 m, 140±10 ka, average slip rate 0.01 mm/yr), Cutler Dam Alloformation (12.8-14.3 m, 60±20 ka, average slip rate 0.03±0.01 mm/yr), and Bonneville Alloformation (5.2-6.7 m, 13 ka, average slip rate 0.45±0.05 mm/yr). Solid lines show average incremental slip rates between deposition events; shaded zone encompasses error bars on ages and displacements (heavy vertical and horizontal bars). Post-Bonneville sediments are displaced 1.2-1.5 m and are < 12 ka old, yielding an average slip rate of 0.01 mm/yr. Values for post-Bonneville sediments are from the Taylorsville fault; other data are from the Granger fault.

APPENDIX

LOGS OF BORINGS DRILLED ACROSS THE GRANGER FAULT IN SALT LAKE COUNTY

BORING 3-1

On Upthrown Side of Granger Fault
(NE 1/4 NE 1/4 SE 1/4 S 29 T1S R1W)
Approximate elevation: 4255 feet

0.0 to 1.7 feet	Dark brown clayey silt, modern soil profile with uppermost 0.2 feet plowed
1.7 to 2.6 feet	Light pinkish brown clayey silt with very fine sand, laminated, some thin gray very fine sand interbeds; calcareous mottling, abundant root tubes, platy texture; sand is quartz--rich and well-sorted
2.6 to 7.0 feet	Light gray silty clay, laminated with some very fine sand partings, drop stones, root tubes, calcareous mottling Abundant ostracodes
7.0 to 9.9 feet	Light to dark gray clay with very fine sand interbeds, uppermost 0.6 feet oxidized, distinctly laminated carbonaceous clay with 0.0001 to 0.1 thick well-sorted silty to very fine sand layers, thicker sand layers are cross-bedded, micaceous and quartz-rich, coarsens downward
9.9 to 12.0 feet	Light gray silty very fine sand, coarsens upward, well-sorted, minor organic fragments and two clay laminations near top, occasional well-rounded quartzite pebbles
12.0 to 14.9 feet	Buff sandy clay to silty sand calcareous clay mottling, platy texture, root tubes, bioturbated
14.9 to 17.4 feet	Orangeish to pinkish tan interbedded clay, silt and sand distinctly laminated to thinly bedded, predominantly clay and silt, very well-sorted, very fine to medium micaceous, quartz-rich sand
17.4 to 19.5 feet	Tan very fine to medium sand fines upward, moderately sorted, clean, sub-rounded 65 percent quartz, 25 percent feldspars, 15 percent lithics
19.5 to 21.0 feet	No sample
21.0 to 23.0 feet	Tan and gray medium to very coarse sand with gravel similar to above, fines upward, gravels are rounded quartz and quartzite clasts
23.0 to 28.4 feet	Buff to light pinkish brown silty clay to sandy silt, semi-stratified with faint laminations in sandier horizons and calcareous mottling and platy texture in muddier horizons

BORING 3-1
--continued--

28.4 to 32.5 feet	Interbedded light gray and pink clay and tan to gray very fine sand, 0.1 to 0.4 feet thick laminated silty to sandy clay, 0.05 to 1.1 feet thick silty very fine to medium sand, beds with rare ostracodes, moderately-sorted, sub-angular to sub-rounded, 70-75 percent quartz, 10-15 percent feldspar, 10-15 percent lithics Overall fining upward Poor recovery
32.5 to 33.9 feet	Light pinkish brown clay with very fine sand partings, laminated, abundant ostracodes
33.9 to 35.4 feet	Light gray silty clay with very fine sand partings, mottled with limonitic staining, some ostracodes, occasional drop stones, grades sandier downward
35.4 to 37.7 feet	Mottled light gray clayey to silty very fine sand, faintly laminated, calcareous and limonitic mottling
37.7 to 39.0 feet	Interbedded yellowish tan very fine sand and gray sandy clay and silt, 0.05 to 0.25 feet thick beds, well-sorted, laminated, some calcareous mottling
39.0 to 39.5 feet	Tan to gray very fine to medium sand faintly bedded, well-sorted, sub-rounded, quartz-rich
39.5 to 42.0 feet	No sample
42.0 to 44.5 feet	Same sand as above with some silty clay laminations in lowermost 0.5 feet

Boring completed at 44.5 feet on March 32, 1986.

Ground water was not encountered.

BORING 3-1

Sample Summary

0.0 to 4.5 feet	Sample 3-1-1 (CME)
4.5 to 9.5 feet	Sample 3-1-2 (CME)
9.5 to 14.5 feet	Sample 3-1-3 (CME)
14.5 to 19.5 feet	Sample 3-1-4 (CME)
19.5 to 21.0 feet	No sample
21.0 to 24.5 feet	Sample 3-1-5 (CME)
24.5 to 29.5 feet	Sample 3-1-6 (CME)
29.5 to 34.5 feet	Sample 3-1-7 (CME)
34.5 to 39.5 feet	Sample 3-1-8 (CME)
39.5 to 42.0 feet	No sample
42.0 to 44.5 feet	Sample 3-1-9 (CME)

BORING 3-2

On Downthrown Side of Granger Fault
(NE 1/4 NE 1/4 SE 1/4 S 29 T1S R1W)
Approximate elevation: 4250 feet

0.0 to 1.0 feet	Dark brown very fine sandy silt, modern soil profile, roots, humate staining, platy texture
1.0 to 3.7 feet	Light to medium pinkish brown clayey to silty very fine sand, highly bioturbated (roots, root tubes and krotovina), calcareous mottling
3.7 to 6.5 feet	Light pinkish brown clayey silt with very fine sand, whole ostracodes and fragments throughout, laminated, some roots and root tubes
	Very fine sand partings increase in abundance and thickness
6.5 to 9.3 feet	Interbedded clay and sand, 0.3 to 0.7 feet thick, light pinkish to grayish brown silty clay beds with very fine sand partings and ostracodes, 0.01 to 0.7 feet thick white to orangeish tan laminated silty very fine to fine sand. beds
9.3 to 13.0 feet	Light gray to charcoal brown silty clay with very fine sand partings, distinctly laminated, carbonaceous, ostracodes throughout
	Becomes sandier
13.0 to 20.5 feet	Light to dark gray interlaminated silty clay, silt and very fine sand, distinctly laminated, occasional drop stones, minor ostracodes in some sand beds, some roots and organics
	Highly deformed layer with recumbent folds, convolutions and detachment planes
	Becomes sandier and more carbonaceous
	Deformed layer (?) crenulateld laminations and detachment planes
20.5 to 24.0 feet	Light gray silt to very fine sand, fining upwards with increasing carbonaceous material, faintly bedded, white calcareous mottling and krotovina throughout
	3 inch thick carbonate-rich cemented layer

BORING 3-2
--continued--

24.0 to 25.7 feet	Grayish tan silty medium sand with occasional well-rounded calcareous-coated quartzite gravels and minor reworked odids
	Grades muddier
25.7 to 26.8 feet	Light gray calcareous very fine sandy clay, faintly laminated, intensely calcareous with root tubes
26.8 to 29.0 feet	Buff fine to silty very fine sand, quartzite-rich, appears massive, calcareous mottling increases downward
29.0 to 31.3 feet	Pinkish tan interlaminated fine sand and silt, pink calcareous mottling throughout
31.3 to 32.7 feet	Pinkish tan silty clay, laminated, calcareous mottling, root tubes
32.7 to 36.3 feet	Interbedded pinkish to orangeish tan sand, silt and clay, 0.4 to 2 inches thick silty clay beds, 0.5 to 15 inches thick well-sorted, quartz-rich, micaceous, very fine and fine sand beds, 0.4 to 8 inches thick ripple-laminated silt beds
36.3 to 38.9 feet	Light pinkish tan silty very fine to fine sand ripple-laminated
38.9 to 39.5 feet	Moderately-sorted gray sand silt to very coarse sand
39.5 to 43.0 feet	No sample recovered
43.0 to 44.4 feet	Gray silty sand to gravelly sand 2 to 7 inches thick beds, moderately-sorted silty fine sand to coarse sand with fine gravels
44.4 to 49.7 feet	Gray carbonaceous sandy clay, bioturbated, root tubes, calcareous mottling
	Pinkish tan silt and very fine sand ripple-laminated
49.7 to 51.7 feet	Gray gravelly sand, clean, fine to coarse sand with well-rounded quartzite, fine and medium gravels, fines upward
51.7 to 52.3 feet	Pinkish tán laminated sandy clay

BORING 3-2
--continued--

52.3 to 57.7 feet   No sample recovered, saturated sand

Boring completed at 57.7 feet on March 21, 1986.

Ground water was not encountered.

BORING 3-2

Sample Summary

0.0 to 4.5 feet	Sample 3-2-1 (CME)
4.5 to 9.5 feet	Sample 3-2-2 (CME)
9.5 to 14.5 feet	Sample 3-2-3 (CME)
14.5 to 19.5 feet	Sample 3-2-4 (CME)
19.5 to 24.5 feet	Sample 3-2-5 (CME)
24.5 to 29.5 feet	Sample 3-2-6 (CME)
29.5 to 34.5 feet	Sample 3-2-7 (CME)
34.5 to 39.5 feet	Sample 3-2-8 (CME)
39.5 to 43.0 feet	No sample
43.0 to 44.5 feet	Sample 3-2-9 (CME)
44.5 to 49.5 feet	Sample 3-2-10 (CME)
49.5 to 52.3 feet	Sample 3-2-11 (CME)
52.3 to 57.5 feet	Sample 3-2-12 (CME) No sample

BORING 4-1

On Upthrown Side of Granger Fault
Elevation: 4300 feet

0.0 to 1.0 feet	No sample
1.0 to 1.5 feet	Fill (I)
1.5 to 3.0 feet	Interbedded gray laminated clay, tan silt and fine sand (XVII-XVIII)
3.0 to 8.5 feet	Tan silt and very fine sand (XIX-XXI) micaceous ripple laminated, quartz rich
8.5 to 10.5 feet	Tan silty very fine sand to fine sand with thin clay (XXII-XXIII)
10.5 to 12.0 feet	Gray silty clay with thin silty very fine sand interbeds coarsening upwards (XXIV)
12.0 to 13.0 feet	Light gray to orange fine sand (XXV) well sorted, cross-bedded ?
13.0 to 17.0 feet	Light pinkish brown silty sand with gravels white, weathered, well-rounded quartzite pebbles in a silty sand with calcareous mottling
	Grades into buff to pinkish brown silty very fine sand to sandy silt some well-rounded quartzite pebbles at bottom contact
17.0 to 22.0 feet	Greenish gray clay with silty laminations and very fine sand partings
	Becomes less sandy and contains ostracodes
22.0 to 24.0 feet	Clayey very fine sand to fine sand pinkish to yellow-tan, thinly bedded
24.0 to 25.0 feet	Light tan medium to fine sand moderately sorted, ooid-bearing

Boring completed at 25.0 feet on December 5, 1985.

Ground water encountered at 21.8 feet on December 5, 1985.

BORING 4-1

Sample Summary

0.0 to 1.0 feet	No sample
1.0 to 5.0 feet	Sample 4-1-1 (CME)
5.0 to 10.0 feet	Sample 4-1-2 (CME)
10.0 to 15.0 feet	Sample 4-1-3 (CME/SPT) CME: 10.0 to 13.0 feet SPT: 13.0 to 15.0 feet
15.0 to 20.0 feet	Sample 4-1-4 (CME)
20.0 to 25.0 feet	Sample 4-1-5 (CME)

BORING 4-1A

On Upthrown Side of Granger Fault
Elevation: 4300 feet

0.0 to 12.0 feet	No sample taken
12.0 to 14.0 feet	Gray to tan very fine sand, well-sorted, sub to well-rounded quartz-rich sand, coarsens upward
	Grades siltier and pinker
14.0 to 14.5 feet	No sample
14.5 to 15.2 feet	Dark to pinkish brown calcareous silty very fine sand with gravel, clay films, minor organics, 0 to 5 percent medium gravels of calcareous coated well-rounded quartzite clasts
15.2 to 16.3 feet	Pinkish tan silty very fine sand, well-sorted and ripple laminated
16.3 to 16.6 feet	No sample
16.6 to 18.9 feet	Greenish gray sandy clay, very fine sand partings with drop stones and limonitic staining, ostracodes common
	Becomes less sandy, ostracodes increasing in size and numbers
18.9 to 19.5 feet	No sample
19.5 to 21.3 feet	Very large ostracode
	Grades sandier
21.3 to 21.8 feet	No sample
21.8 to 22.5 feet	Greenish gray to tan clayey very fine sand
22.5 to 23.7 feet	Light pinkish tan silty very fine sand, fining upward
23.7 to 24.7 feet	Reddish brown fine sand, moderately-sorted, ooid-bearing, incipient calcareous cementation
24.7 to 25.3 feet	No sample
25.3 to 26.7 feet	Light pinkish tan to brown sand, variable but fines upward from fine sand to silty very fine sand, ooid-bearing
26.7 to 27.7 feet	No sample

BORING 4-1A
--continued--

27.7 to 29.7 feet	Sandy fine gravel, clast-supported, well-rounded, calcareous coasted gray quartzite and sandstone gravels, 5 to 15 percent sand matrix similar to overlying unit Grades muddier and more calcareous
29.7 to 30.3 feet	No sample
30.3 to 32.3 feet	No sample
32.3 to 32.7 feet	No sample
32.7 to 33.5 feet	No sample
33.5 to 35.3 feet	No sample
35.3 to 37.5 feet	Light pinkish tan silty very fine sand, ripple laminated, some calcareous mottling

Boring completed at 37.5 feet on February 5, 1986.

Ground water was not encountered.

BORING 4-1A

Sample Summary

0.0 to 12.0 feet	No sample
12.0 to 14.0 feet	Samples 4-A1-1 thru 4-1A-4 (SPT "U")
14.0 to 16.3 feet	Samples 4-A1-5 thru 4-A1-7 (SPT "U")
16.3 to 18.9 feet	Samples 4-A1-8 thru 4-A1-11 (SPT "U")
18.9 to 21.3 feet	Samples 4-1A-12 thru 4-1A-14 (SPT "U")
21.3 to 24.7 feet	Samples 4-1A-15 thru 4-1A-20 (SPT "U")
24.7 to 26.7 feet	Samples 4-1A-21 thru 4-1A-23 (SPT "U")
26.7 to 29.7 feet	Samples 4-1A-24 thru 4-1A-27
29.7 to 32.3 feet	Samples 4-1A-28 thru 4-1A-31 (SPT "U")
32.3 to 33.5 feet	Samples 4-1A-32/33 (SPT "U")
33.5 to 37.5 feet	Samples 4-1A-34 thru 4-1A-37 (SPT "U")

BORING 4-2

On Downthrown Side of Granger Fault
Elevation: 4300.6 feet

0.0 to 1.3 feet	No Sample
1.3 to 3.0 feet	Fill (I)
3.0 to 4.5 feet	Reddish brown sandy clay (IV) with white to tan fine sand partings, blocky, some drop stones, some mottling
4.5 to 7.0 feet	Greenish gray clay (V-VIII) with less very fine sand partings than above, limonitic mottling, ostracode
7.0 to 9.0 feet	Thinly bedded gray clays, tan very fine sands and silts (VIII-IX) fining upwards
9.0 to 10.2 feet	Buff fine sand (X) well sorted, quartz rich
10.2 to 11.0 feet	No sample - coarse gravels (?)
11.0 to 13.4 feet	Gray sands and gravels (XI-XIV) well sorted, clean, sub-rounded medium to very coarse sand and well rounded quartzite pebbles (poor sample recovery)
13.4 to 16.5 feet	Brown silty, sandy gravels (XV) clay films (10 yr. 7/2 to 10 yr. 6/3) on coarse to very coarse sand, sub-angular, moderately sorted medium to fine gravels are well rounded, some stratification, calcareous clay in sand and calcareous coatings on pebbles
16.5 to 17.0 feet	No sample
17.0 to 19.3 feet	White coarse to very coarse sand clean, coarsens upwards, sub-angular to sub-rounded
19.3 to 20.0 feet	Mottled gray silty clay with fine sand partings
20.0 to 21.8 feet	Mottled sandy clay and tan silty very fine to fine sand
21.8 to 22.8 feet	Pinkish brown silty sand with gravel
22.8 to 24.1 feet	Gray laminated sandy clay
24.1 to 25.0 feet	No sample - Lost 0.9 feet from bottom of Sample 4-2-10
25.0 to 27.0 feet	Light pinkish brown clayey gravels to clayey sands very poorly sorted calcareous coated sub-angular to rounded pebbles in a highly variable matrix with calcareous, mottling, some stratification

BORING 4-2
--continued--

27.0 to 27.5 feet	No sample
27.5 to 32.0 feet	Same light pinkish brown clayey gravels as above
32.0 to 37.8 feet	Light pinkish brown clayey gravels to clayey sands very poorly sorted calcareous coated sub-angular to rounded pebbles in a highly variable matrix with calcareous, mottling, some stratification
37.8 to 39.0 feet	No sample - too much resistance
39.0 to 41.0 feet	Same light pinkish brown clayey gravels as above
41.0 to 42.0 feet	No sample - too much resistance
42.0 to 43.0 feet	Same light pinkish brown clayey gravels as above
43.0 to 45.0 feet	No sample - too much resistance
45.0 to 46.5 feet	Tan sandy gravels (XVI) moderately to poorly sorted, fine to medium rounded gravels
46.5 to 50.0 feet	No sample - too much resistance
50.0 to 51.0 feet	Silty medium to coarse sand to sandy gravel fines upward
51.0 to 55.0 feet	No sample - too much resistance
55.0 to 55.6 feet	Tan fine sand with thin gray clay interbeds
55.6 to 57.1 feet	Gray sandy clay laminations and limonitic staining
57.1 to 58.0 feet	Tan sand with thin gray clay interbeds fines upward from very coarse to fine sand

Boring completed at 58.0 feet on December 6, 1985.

Ground water encountered at 23.6 feet on December 6, 1985.

BORING 4-2

Sample Summary

0.0 to 1.3 feet	No sample
1.3 to 4.8 feet	Sample 4-2-1 (CME)
4.8 to 10.0 feet	Sample 4-2-2 (CME)
10.0 to 10.2 feet	Sample 4-2-3 (CME)
10.2 to 11.0 feet	No sample
11.0 to 13.0 feet	Sample 4-2-4 (SPT)
13.0 to 15.0 feet	Sample 4-2-5 (CME)
15.0 to 16.5 feet	Sample 4-2-6 (SPT)
16.5 to 17.0 feet	No sample
17.0 to 19.0 feet	Sample 4-2-7 (SPT)
19.0 to 20.0 feet	Sample 4-2-8 (CME)
20.0 to 22.5 feet	Sample 4-2-9 (CME)
22.5 to 24.1 feet	Sample 4-2-10 (CME)
24.1 to 25.0 feet	No sample
25.0 to 27.0 feet	Sample 4-2-11 (SPT)
27.0 to 27.5 feet	No sample
27.5 to 27.9 feet	Sample 4-2-12 (SPT)
27.9 to 30.0 feet	Sample 4-2-13 (CME)
30.0 to 32.5 feet	Sample 4-2-14 (CME)
32.5 to 35.0 feet	Sample 4-2-15 (CME)
35.0 to 37.0 feet	Sample 4-2-16 (CME)
37.0 to 37.8 feet	Sample 4-2-17 (SPT)
37.8 to 39.0 feet	No sample
39.0 to 41.0 feet	Sample 4-2-18 (SPT)

BORING 4-2
Sample Summary
--continued--

41.0 to 42.0 feet	No sample
42.0 to 43.0 feet	Sample 4-2-19 (SPT)
43.0 to 45.0 feet	No sample
45.0 to 46.5 feet	Sample 4-2-20 (SPT)
46.5 to 50.0 feet	No sample
50.0 to 51.0 feet	Sample 4-2-21 (SPT)
51.0 to 55.0 feet	No sample
55.0 to 57.0 feet	Sample 4-2-22 (SPT)
57.0 to 58.0 feet	Sample 4-2-23 (SPT)

BORING 4-3

On Downthrown Side of Granger Fault
Elevation: 4298.7 feet

0.0 to 1.0 feet	No sample
1.0 to 2.5 feet	Gray silty clay with tan very fine sand partings and white calcareous mottling, some ostracodes
2.5 to 8.0 feet	Brown sandy silt with organics (IV A-Horizon)
	Reddish brown silty clay (IV) with white very fine to fine sand partings, root tubes and medium roots
8.0 to 10.4 feet	Greenish gray clay (V-VIII) less silty than above with limonitic staining along sand partings
10.4 to 11.0 feet	Pinkish tan silt and gray silty clay (IX)
11.0 to 13.4 feet	Buff to pinkish brown silty very fine to fine sand (X) ripple laminated, well sorted
13.4 to 17.0 feet	Ooid bearing sand rusty brown to light pinkish brown silty fine to medium sand with some pebbly layers, pebbles are well rounded calcareous coated quartzite clasts, sand is semi-cemented near top, coarsens upward
17.0 to 19.6 feet	Very poorly sorted gravelly sand variable but semi-stratified, clayey very fine to coarse sand with fine and coarse gravels, calcareous mottling
19.6 to 21.4 feet	White very fine to fine sand, quartz rich, well rounded, crossbedded (?), calcareous mottling
21.4 to 24.6 feet	Interbedded mottled gray clay and tan silty very fine sand, 0.2 to 0.5 foot thick laminated clay beds with calcareous nodules and mottling
24.6 to 27.0 feet	Yellow tan very fine sand
27.0 to 30.0 feet	Tan to gray laminated sandy clay with thin sand interbeds, some calcareous nodules in clay and some fine to very coarse lenses in silty very fine sand beds
30.0 to 31.6 feet	Ooid bearing buff medium to very fine sand, coarsens upward, ripple laminated
31.6 to 34.4 feet	Tan very fine sand with laminated gray and tan clay interbeds

BORING 4-3
--continued--

34.4 to 36.6 feet	Tan sand, some ooids, moderately sorted, coarsens up from clayey very fine sand to coarse sand
36.6 to 37.5 feet	Tan sandy gravels, fine and medium sub-rounded gravels with well rounded pebbles

Boring completed at 37.5 feet on December 10, 1985.

Ground water encountered at 20.5 feet on December 10, 1985.

BORING 4-3

Sample Summary

0.0 to 1.0 feet	No sample
1.0 to 5.0 feet	Sample 4-3-1 (CME)
5.0 to 10.0 feet	Sample 4-3-2 (CME)
10.0 to 12.6 feet	Sample 4-3-3 (CME)
12.6 to 15.0 feet	Sample 4-3-4 (CME)
15.0 to 17.0 feet	Sample 4-3-5 (CME)
17.0 to 20.0 feet	Sample 4-3-6 (CME)
20.0 to 22.6 feet	Sample 4-3-7 (CME)
22.6 to 25.0 feet	Sample 4-3-8 (CME)
25.0 to 27.4 feet	Sample 4-3-9 (CME)
27.4 to 30.0 feet	Sample 4-3-10 (CME)
30.0 to 32.6 feet	Sample 4-3-11 (CME)
32.6 to 35.0 feet	Sample 4-3-12 (CME)
35.0 to 37.5 feet	Sample 4-3-13 (CME)

BORING 4-3A

On Downthrown Side of Granger Fault
Elevation: 4299 feet

0.0 to 7.5 feet	No sample taken
7.5 to 8.0 feet	Reddish brown silty clay, root tubes, fine sand partings and abundant ostracodes
8.0 to 8.5 feet	Greenish gray clay
8.5 to 12.7 feet	No sample
12.7 to 13.7 feet	Tan very fine to medium sand, fines upward
13.7 to 14.7 feet	Dark reddish brown sand, moderately-sorted medium to fine sand with clay films
14.7 to 15.3 feet	No sample
15.3 to 16.7 feet	Sandy silt, laminations of gray clay, tan silt and tan very fine sand, coarsens upward, some pink calcareous mottling
16.7 to 17.3 feet	Gray to dark brown sand with gravels, weakly developed soil on clean well-sorted fine sand with occasional well-rounded, calcareous coated pebbles to cobbles, incipient (or partially dissolved)
17.3 to 17.7 feet	No sample
17.7 to 19.7 feet	No sample
19.7 to 20.3 feet	No sample
20.3 to 20.7 feet	No sample
20.7 to 22.3 feet	Interbedded clay and sand, 0.25 to 1.0 feet thick beds of gray silty very fine sand, laminated gray silty clay with calcareous nodules, and tan clay with very fine sand partings
22.3 to 22.7 feet	No sample
22.7 to 23.3 feet	No sample
23.3 to 24.7 feet	Gray to tan silty very fine sand, well-sorted, laminated, micaceous, quartz-rich
24.7 to 25.3 feet	No sample

BORING 4-3A
--continued--

25.3 to 26.7 feet	No sample
26.7 to 27.3 feet	Interbedded gray to tan clay and very fine sand, 0.5 to 2 inches thick beds of laminated clays and micaceous sands
27.3 to 27.7 feet	No sample
27.7 to 29.7 feet	No sample
29.7 to 30.3 feet	No sample
30.3 to 31.0 feet	Ooid-bearing gray fine sand, moderately-sorted, well-rounded, 10 to 15 percent reworked ooids
31.0 to 32.3 feet	Gray to tan silty very fine sand, well-sorted, possibly laminated, minor reworked ooids, slightly fines upward
32.3 to 32.7 feet	No sample
32.7 to 34.7 feet	No sample
34.7 to 35.0 feet	No sample
35.0 to 35.7 feet	Gray gravelly silty sand, poorly-sorted fine to coarse sand with 15 to 20 percent fine quartzite gravels
35.7 to 37.5 feet	No sample
37.5 to 39.7 feet	Dark reddish brown gravelly clayey sand, very poorly-sorted, matrix supported fine gravels to very fine sandy clay, coarsens upward, pink carbonate stringers increasing downward
39.7 to 40.0 feet	No sample
40.0 to 42.2 feet	Pinkish tan to light gray sandy clay, very poorly-sorted, variable 0 to 20 percent fine to medium calcareous coated quartzite gravels, intensely mottled with pink carbonate clay
42.2 to 42.7 feet	No sample
42.7 to 44.7 feet	No sample
44.7 to 46.3 feet	No sample
46.3 to 46.7 feet	2 to 4 inches thick laminated gray sandy clay bed

BORING 4-3A
--continued--

46.7 to 47.3 feet	No sample
47.3 to 47.7 feet	No sample
47.7 to 49.7 feet	Interbedded gray sands and gravels, 0.3 to 2.0 feet thick beds of moderately-sorted, clean fine to coarse sand and matrix-supported, fine to medium, weathered, quartzite gravels in a clayey sand matrix
49.7 to 50.0 feet	No sample
50.0 to 52.5 feet	No sample

Boring completed at 52.5 feet on February 6, 1986.

Ground water was not encountered.

BORING 4-3A

Sample Summary

0.0 to 7.5 feet	No sample
7.5 to 8.5 feet	Samples 4-3A-1 thru 4-3A-2 (SPT "U")
8.5 to 12.7 feet	No sample
12.7 to 14.7 feet	Samples 4-3A-3 thru 4-3A-6 (SPT "U")
14.7 to 17.3 feet	Samples 4-3A-7 thru 4-3A-10 (SPT "U")
17.3 to 19.7 feet	Samples 4-3A-11 thru 4-3A-14 (SPT "U")
19.7 to 22.3 feet	Samples 4-3A-15 thru 4-3A-18 (SPT "U")
22.3 to 24.7 feet	Samples 4-3A-19 thru 4-3A-22 (SPT "U")
24.7 to 27.3 feet	Samples 4-3A-23 thru 4-3A-26 (SPT "U")
27.3 to 29.7 feet	Samples 4-3A-27 thru 4-3A-30 (SPT "U")
29.7 to 32.3 feet	Samples 4-3A-31 thru 4-3A-34 (SPT "U")
32.3 to 34.7 feet	Samples 4-3A-35 thru 4-3A-38 (SPT "U")
34.7 to 35.7 feet	Sample 4-3A-39/40 (SPT "U")
35.7 to 37.5 feet	No sample
37.5 to 39.7 feet	Samples 4-3A-41 thru 4-3A-43 (SPT "U")
39.7 to 42.2 feet	Samples 4-3A-44 thru 4-3A-47 (SPT "U")
42.2 to 44.7 feet	Samples 4-3A-48 thru 4-3A-51 (SPT "U")
44.7 to 46.7 feet	Samples 4-3A-52 thru 4-3A-55 (SPT "U")
46.7 to 49.7 feet	Samples 4-3A-56 thru 4-3A-59 (SPT "U")
49.7 to 52.5 feet	Samples 4-3A-60 thru 4-3A-63 (SPT "U")

BORING 4-4

On Upthrown Side of Granger Fault
Elevation: 4316 feet
(Presented graphically as Figure 15)

0.0 to 1.0 feet	No sample
1.0 to 3.5 feet	Reddish brown silty clay (IV) with white very fine sand partings, ostracodes, some white calcareous mottling, blocky texture, roots and root tubes throughout
3.5 to 5.3 feet	Greenish gray clay (V thru VIII) with very fine to fine sand partings containing abundant ostracodes, laminated to thinly bedded, occasional well-rounded weathered pebbles
5.3 to 7.5 feet	White to pinkish tan clayey silts and sands (IX and X), ripple laminated, fining upwards from fine sand to very fine sand to silty clay
7.5 to 8.5 feet	Gray to dark brown clayey sand with gravel (XI), very poorly sorted
8.5 to 9.8 feet	Gray sandy gravels (XII and XIV) matrix supported, well-rounded, calcareous coated quartzite pebbles and medium to coarse sand
9.8 to 11.1 feet	Pinkish brown clayey gravels (XV) matrix supported, well rounded, calcareous coated pebbles and medium to coarse sand
11.1 to 12.0 feet	No sample
12.0 to 17.3 feet	Tan gravels (XVII) matrix supported fine to coarse gravels, clasts, predominantly quartzite, often weathered and calcareous coated-matrix varies from silt to medium sand
17.3 to 18.8 feet	Tan clayey silt to fine sand, ripple laminated, coarsening upward from silt to very fine sand to fine sand
18.8 to 20.0 feet	Mottled gray silty clay (XVIII) with very fine sand partings, no ostracodes
20.0 to 22.0 feet	Gray interbedded silty clay and silty very fine sand (XVII to XVIII), clay is laminated, sand is ripple-laminated, overall fining upward, 0.05 to 2.5 inch thick beds

BORING 4-4

--continued--

22.0 to 22.5 feet	Yellowish tan fine sand (XIX), cross-bedded quartz rich, moderately sorted

Boring completed at 22.5 feet on December 12, 1985.

Ground water was not encountered.

BORING 4-4

Sample Summary

0.0 to 1.0 feet	No sample
1.0 to 5.0 feet	Sample 4-4-1 (CME)
5.0 to 7.5 feet	Sample 4-4-2 (CME)
7.5 to 8.5 feet	Sample 4-4-3 (CME)
8.5 to 10.0 feet	Sample 4-4-4 (SPT)
10.0 to 11.1 feet	Sample 4-4-5 (SPT)
11.1 to 12.0 feet	No sample
12.0 to 13.5 feet	Sample 4-4-6 (SPT)
13.5 to 15.0 feet	Sample 4-4-7 (SPT)
15.0 to 16.5 feet	Sample 4-4-8 (SPT)
16.5 to 17.5 feet	Sample 4-4-9 (CME)
17.5 to 22.5 feet	Sample 4-4-10 (CME)

BORING 4-5

On Downthrown Side of Granger Fault
Elevation: 4304 feet
(Presented graphically as Figure 16)

0.0 to 1.0 feet	No sample
1.0 to 2.4 feet	Dark reddish brown silty clay (I) tan mottling
2.4 to 8.0 feet	Tan interbedded very fine to fine sand and silty clay, thinly bedded with krotovina, reworked ostracodes, white calcareous mottling of clays, clays vary from pinkish brown to buff to gray
8.0 to 13.1 feet	Light pinkish brown silty clay (IV) with tan to white fine and very fine sand partings, ostracodes, modern roots, white calcareous mottling, blocky texture Becomes less blocky and darker in color
13.1 to 15.8 feet	Greenish gray sandy clay (V and VI) with limonitic staining along very fine to fine sand partings, modern roots in upper area section
15.8 to 16.3 feet	Bluish green clay (VII)
16.3 to 18.1 feet	Interbedded greenish gray clay and tan clayey very fine to fine sand (VIII thru X) with laminations and no ostracodes
18.1 to 19.8 feet	Fine to coarse sandy gravels (XII thru XIV), well rounded quartzite clasts in variable, clean sandy matrix
19.8 to 20.0 feet	No sample
20.0 to 22.0 feet	Gray to pinkish brown clayey, pebbly sand, very poorly sorted with well rounded calcareous coated cobbles, highly variable
22.0 to 23.9 feet	Dark reddish brown pebbly sand very poorly sorted in silty matrix
23.9 to 27.0 feet	Dark brown clayey, sandy gravels, well rounded pebbles and cobbles of quartzite, some with calcareous coating in a clayey sand matrix with white calcareous mottling
27.0 to 28.5 feet	Gray silty fine to medium sand, apparent cross beds

BORING 4-5
--continued--

28.5 to 29.5 feet	Light gray clay with yellowish tan fine sand partings
29.5 to 30.0 feet	Gray clayey fine sand

Boring completed at 30.0 feet on December 17, 1985.

Ground water encountered at 27.5 feet on December 17, 1985.

BORING 4-5

Sample Summary

0.0 to 1.0 feet	No sample
1.0 to 2.5 feet	Sample 4-5-1 (CME)
2.5 to 5.0 feet	Sample 4-5-2 (CME)
5.0 to 8.0 feet	Sample 4-5-3 (CME)
8.0 to 10.0 feet	Sample 4-5-4 (CME)
10.0 to 12.5 feet	Sample 4-5-5 (CME)
12.5 to 15.0 feet	Sample 4-5-6 (CME)
15.0 to 17.5 feet	Sample 4-5-7 (CME)
17.5 to 20.0 feet	Sample 4-5-8 (CME)
20.0 to 22.5 feet	Sample 4-5-9 (CME)
22.5 to 25.0 feet	Sample 4-5-10 (CME)
25.0 to 27.5 feet	Sample 4-5-11 (CME)
27.5 to 30.0 feet	Sample 4-5-12 (CME)

BORING 4-6

On Downthrown Side of Granger Fault
Elevation: 4300.5 feet

0.0 to 1.0 feet	No sample
1.0 to 1.4 feet	Fill
1.4 to 4.2 feet	Reddish brown silty clay (IV) with very fine to fine sand partings containing ostracodes, blocky texture, roots, root tubes and drop stones
4.2 to 5.9 feet	Greenish gray clay (V-VIII) with very fine sand partings and abundant ostracodes
5.9 to 8.0 feet	Buff to pinkish tan clayey silts and very fine sands (IX-X) distinctly ripple laminated, fining upward
8.0 to 10.6 feet	Gray gravels with sand (XI-XII) well rounded fine to medium quartzite clasts with clean sand layers
10.6 to 13.0 feet	Tan silty fine sand (XIII)
	Sandy gravels (XIV-XV?)
	Poor recovery
13.0 to 14.2 feet	Gravelly silty sand, poorly sorted, some light pinkish brown calcareous cement
14.2 to 16.2 feet	Tan gravels with sand, moderately sorted, well rounded, fine to medium gravels, with sandy interbeds
16.2 to 17.0 feet	Mottled gray sandy clay with pink calcareous mottling and some gravel
17.0 to 20.0 feet	Light pinkish brown silty sand with gravels, very poorly sorted, calcareous mottling coarser near bottom contact
20.0 to 21.8 feet	Gray sandy clay, fining upward with limonitic and calcareous mottling
21.8 to 23.8 feet	Tan silty very fine sand, ripple laminations of well sorted very fine sand, silt and clay
23.8 to 25.8 feet	Mottled gray sandy clay, blocky with calcareous nodules near bottom contact

BORING 4-6
--continued--

25.8 to 28.4 feet	Buff silty very fine sand, ripple laminations of well sorted very fine sand, silt and clay
28.4 to 29.6 feet	Gray sandy clay with white calc layer with laminations and limonitic mottling
29.6 to 31.0 feet	Light gray clayey sand with gravels, very poorly sorted and massive
31.0 to 32.0 feet	Pinkish brown sandy gravel, very poorly sorted with muddy matrix
32.0 to 40.0 feet	Sandy gravels, moderately sorted, semi-stratified, clast-supported, well rounded fine and medium gravel, predominantly quartzite clasts with calcareous coating, matrix is silty to very coarse sand

Boring completed at 40.0 feet on December 18, 1985.

Ground water encountered at 20.0 feet on December 18, 1985.

BORING 4-6

Sample Summary

0.0 to 1.0 feet	No sample
1.0 to 5.0 feet	Sample 4-6-1 (CME)
5.0 to 8.0 feet	Sample 4-6-2 (CME)
8.0 to 10.0 feet	Sample 4-6-3 (SPT)
10.0 to 12.0 feet	Sample 4-6-4 (SPT)
12.0 to 13.0 feet	Sample 4-6-5 (SPT)
13.0 to 15.0 feet	Sample 4-6-6 (SPT)
15.0 to 20.0 feet	Sample 4-6-7 (CME)
20.0 to 22.6 feet	Sample 4-6-8 (CME)
22.6 to 25.0 feet	Sample 4-6-9 (CME)
25.0 to 27.4 feet	Sample 4-6-10 (CME)
27.4 to 30.0 feet	Sample 4-6-11 (CME)
30.0 to 32.6 feet	Sample 4-6-12 (CME)
32.6 to 35.0 feet	Sample 4-6-13 (CME)
35.0 to 37.7 feet	Sample 4-6-14 (CME)
37.7 to 40.0 feet	Sample 4-6-15 (CME)

NOTE

CME indicates 3 inch diameter continuous sample

SPT indicates 1.75 inch diameter sampler driver using standard penetration test method

EXPLANATION

I	Fill
II	Pink clayey sand in fault zone
III	Green-gray sandy clay with cobbles in fault zone
IV	Oxidized silty marl with drop stones - upper deposit of Bonneville Cycle, 15 - 12 ka
V	Ostracode coquina - may represent the Bonneville Flood, 15 ka
VI	Unoxidized silty marl, common ostracodes - deep water lacustrine deposit
VII	Green-gray clay, common ostracodes - deep water lacustrine deposit
VIII	Green-gray very fine sandy clay - moderately deep water lacustrine deposit
IX	Interbedded fine sand and silty clay - fluctuating shallow and deep lacustrine deposit
X	Yellow-orange silty fine sand - shallow water lacustrine deposit
XI	Brown well-rounded cobbles and silty gravel - transgressive beach deposit
XII	Brown clean pebbly gravel - transgressive beach deposit
XIII	Brown silty sand - interbeach deposit
XIV	Brown clean sandy gravel - lower deposit of Bonneville Cycle, 26 ka
XV	Sandy gravel with weak argillic horizon - alluvial deposit
XVI	Sandy gravel - channel deposit or alluvial deposit
XVII	Interbedded sandy clay and fine sand - fluctuating shallow and deep lacustrine deposit
XVIII	Laminated gray clay - deep water lacustrine deposit
XIX	Medium to fine sand - shallow water lacustrine deposit
XX	Silty clay with sand interbeds - lacustrine deposit
XXI	Silty sand with thin beds of clay - fluctuating shallow and deep water lacustrine deposit
XXII	Sandy clay marker bed - lacustrine deposit
XXIII	Interbedded silty clay and fine sand - lacustrine deposit
XXIV	Clay with thin fine sand partings - lacustrine deposit
XXV	Fine sand - lacustrine deposit