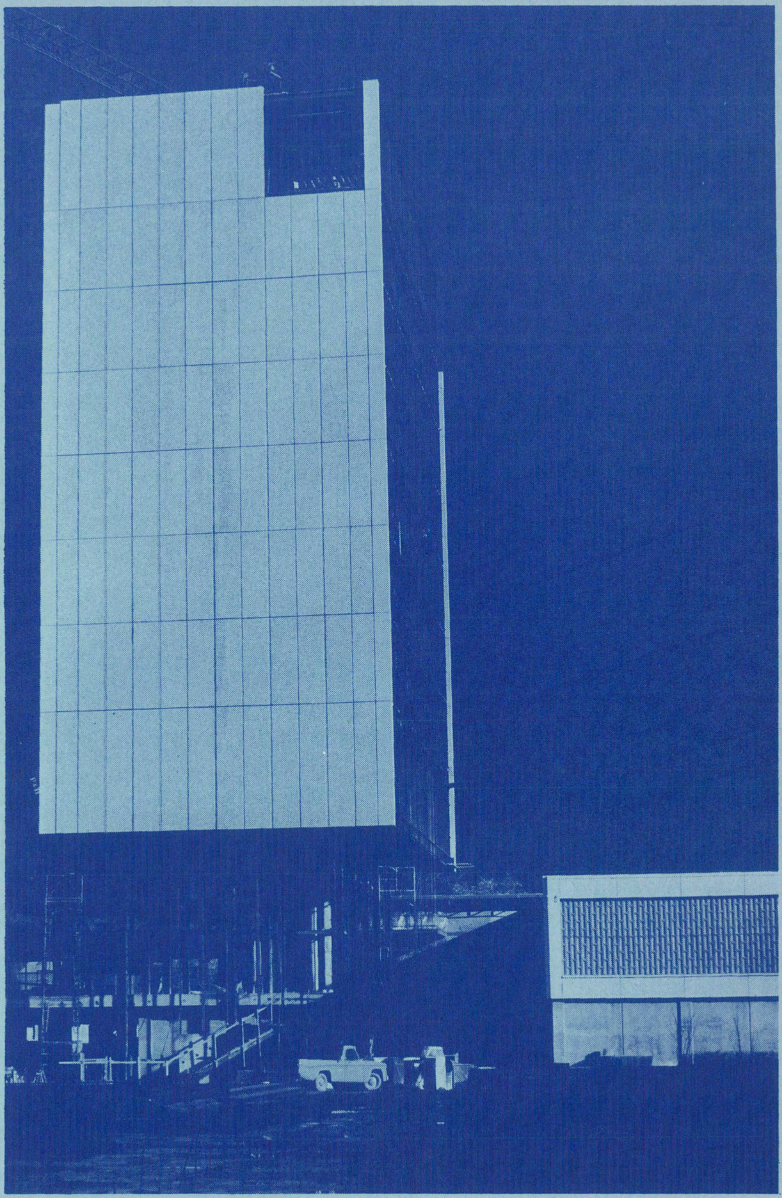
ENGINEERING IMPLICATIONS AND GEOLOGY HALL OF JUSTICE EXCAVATION SALT LAKE CITY, UTAH



Utah Geological and Mineralogical Survey

Special Studies 11

UTAH GEOLOGICAL AND MINERALOGICAL SURVEY

103 Civil Engineering Building
University of Utah
Salt Lake City, Utah 84112

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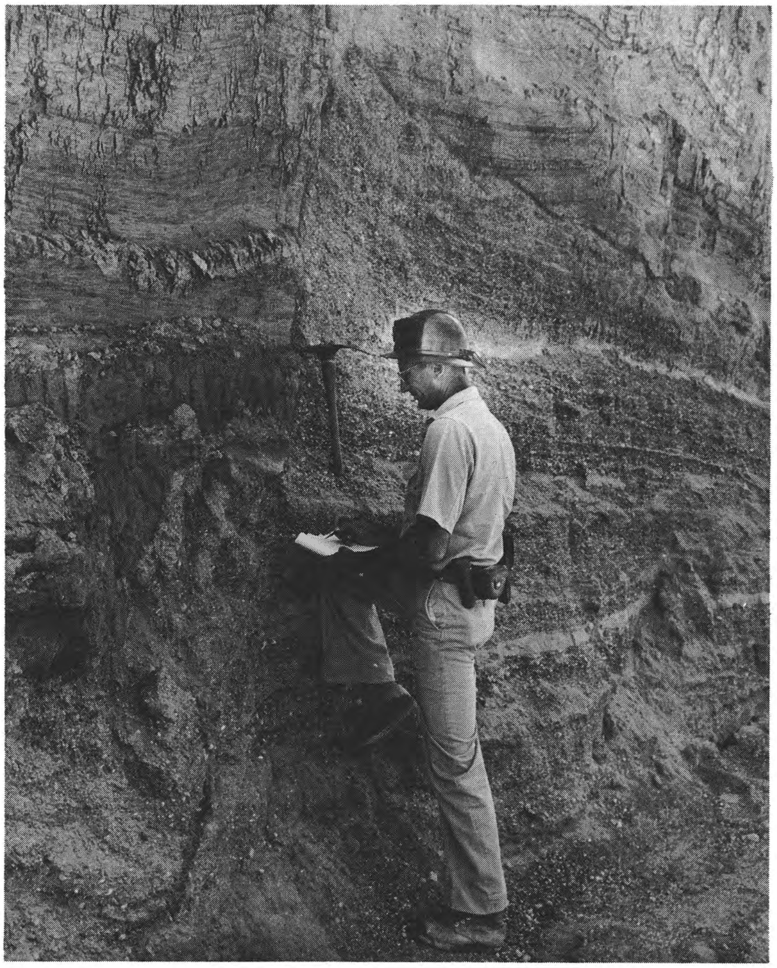
DIRECTORS:

William P. Hewitt, 1961-
Arthur L. Crawford, 1949-1961

ENGINEERING IMPLICATIONS AND GEOLOGY HALL OF JUSTICE EXCAVATION SALT LAKE CITY, UTAH

by J. C. Osmond
W. P. Hewitt
Richard Van Horn



Hall of Justice Excavation, Salt Lake City, Utah Sept. 14, 1963.

(This and cover photograph courtesy Salt Lake Tribune.)

Utah Geological and Mineralogical Survey
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The College of Mines and Mineral Industries
University of Utah, Salt Lake City, Utah

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TABLE OF CONTENTS

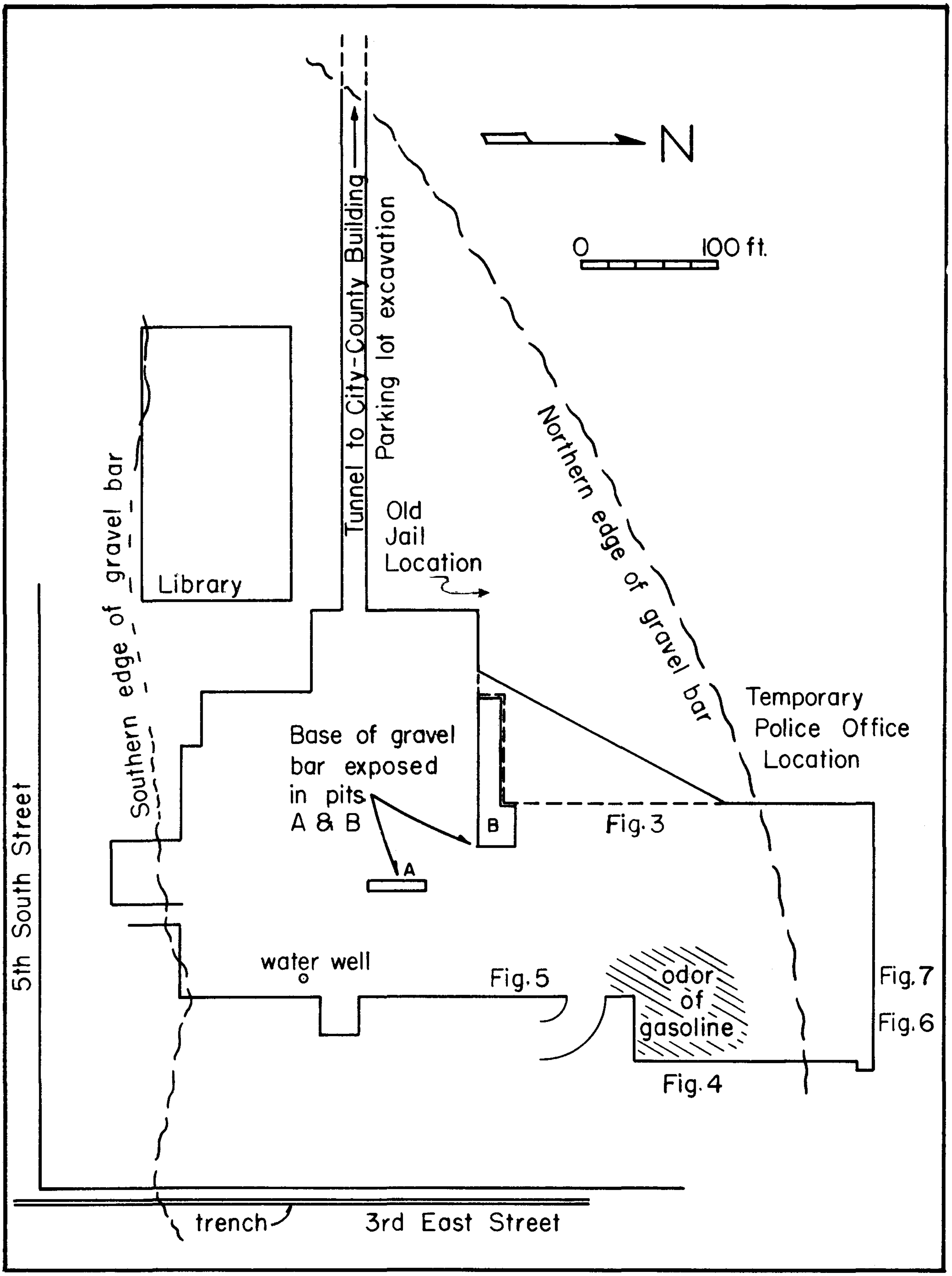
LIST OF ILLUSTRATIONS

FOREWORD

In downtown Salt Lake City between Second and Third East Streets and Fourth and Fifth South Streets, construction on a complex of public buildings was commenced in 1963. Special Studies 11 contains two papers describing conditions observed within the excavation for the Hall of Justice Building in the eastern portion of the block.

The first paper, "Engineering and Structural Geology" by J. C. Osmond and W. P. Hewitt, describes a range and complexity of geologic problems which, though seldom considered, confront all who build in Salt Lake City. Exhibited in one city block, these include the great and rapid variability of sedimentary facies; the problems of seismic activity and the resulting damage to be anticipated; the question of water tables and attendant surface subsidence when reservoirs are pumped; and the man-made problem of wasted gasoline that has accumulated in near-surface geologic traps beneath a metropolitan area.

The second paper, "Pleistocene and Recent Stratigraphy" by Richard Van Horn, deals with the stratigraphy of the sediments exposed in the excavation and describes an interesting stratigraphic section of late Wisconsin and Recent deposits which indicates the possibility of two lake cycles during Alpine time and two lake cycles during Bonneville time. The Bonneville Formation, and an erosional unconformity between the Alpine and Bonneville Formations, can be recognized as low as 4,242 feet above sea level. Soils formed on the Bonneville Formation and overlying terrestrial deposits are of post-Bonneville Formation and post-Lake Bonneville age.



Location Sketch, Based on Figure 1.

SECTION I:
ENGINEERING AND STRUCTURAL GEOLOGY

by J. C. Osmond[1] *and W. P. Hewitt*[2]

INTRODUCTION

The area of this study is a Salt Lake City block, due east of the City and County Building, which is bounded by Second and Third East Streets and by Fourth and Fifth South Streets. Throughout 1963 the new City and County Public Library Building was in construction in the southwest corner of the block, while the old County Jail and the temporary police headquarters were filling their public obligations and occupying their original positions immediately adjacent to the Hall of Justice excavation. In the mid-1800's the area was the site of pioneer homes; and prior to 1856, City Creek flowed within three blocks of it and "cat-tail" swamps occupied adjacent sloughs (personal communication, Ray E. Marsell).

The ground surface is essentially flat, sloping about six feet to the southwest in a distance of roughly 900 feet. Thence it loses another 47 feet of elevation, in the 14-mile interval to Great Salt Lake (1963 lake level), but in the opposite direction, the land rises quickly to the north and east for possibly $\frac{1}{2}$ mile, then abruptly for another 1.8 miles to the flank of the Wasatch Mountains where the highest terraces of Lake Bonneville are clearly etched some 940 feet above the area in question.

Geologically, the area lies on the floor of ancient Lake Bonneville, and occurs on the lowermost slopes of the City Creek alluvial fan which has been built on the floor of the ancient lake. Perhaps of equal importance, although falling within a section of Salt Lake City from which there are no observed displacements, it lies close to projected extensions of the Hot Springs Fault to the northwest and the East Bench Fault to the southeast.

THE EXCAVATION

Based on tape and compass surveys, Figure 1 portrays in plan view the outline of the excavation as it existed when construction began. Surrounding the outline is a series of cross-sections which represent geologic detail as exposed in the excavation's vertical walls. Each section, drawn with its base adjacent to the excavation outline, is located by Arabic numerals which appear at the surface end lines and which are repeated, within circles, on the excavation plan. Thus, section 1-2 is a vertical view through ① - ② , whereas 23-24 and 3-4 are vertical views of the excavation walls that temporarily existed from ㉓ - ㉔ and ③ - ④ . In each case the sections are related to a common elevation: 4,262 feet as read from architects' plan based on the Salt Lake City datum, but 4,235.12 feet above sea-level as determined by the Coast and Geodetic Survey.

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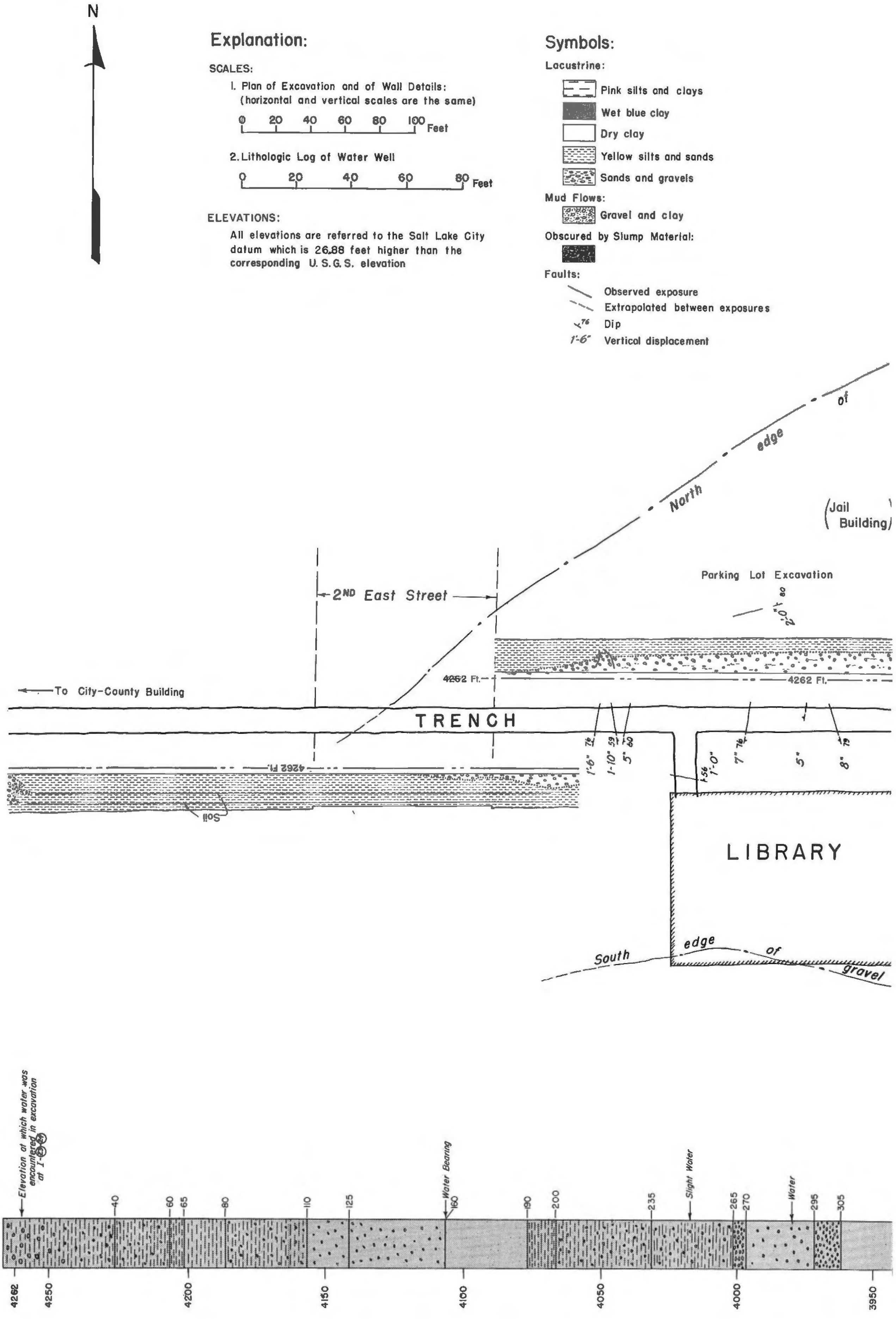
1. Consulting Geologist, Intermountain Assoc. Petroleum Geologists.
2. Director, Utah Geological and Mineralogical Survey


N
Explanation:
SCALES:
1. Plan of Excavation and of Wall Details:
(horizontal and vertical scales are the same)
0 20 40 60 80 100 Feet
2. Lithologic Log of Water Well
0 20 40 60 80 Feet
ELEVATIONS:
All elevations are referred to the Salt Lake City datum which is 26.88 feet higher than the corresponding U. S. G. S. elevation
Symbols:
Lacustrine:
Pink silts and clays
Wet blue clay
Dry clay
Yellow silts and sands
Sands and gravels
Mud Flows:
Gravel and clay
Obscured by Slump Material:
Faults:
Observed exposure
Extrapolated between exposures
76 Dip
1'-6" Vertical displacement
North edge of
(Jail Building)
Parking Lot Excavation
2ND East Street
4262 Ft.
To City-County Building
TRENCH
LIBRARY
Soil
South edge of gravel
Elevation at which water was encountered in excavation
Water Bearing
Slight Water
Water
40 60 65 80 110 125 160 190 200 235 265 270 295 305
4262 4250 4200 4150 4100 4050 4000 3950

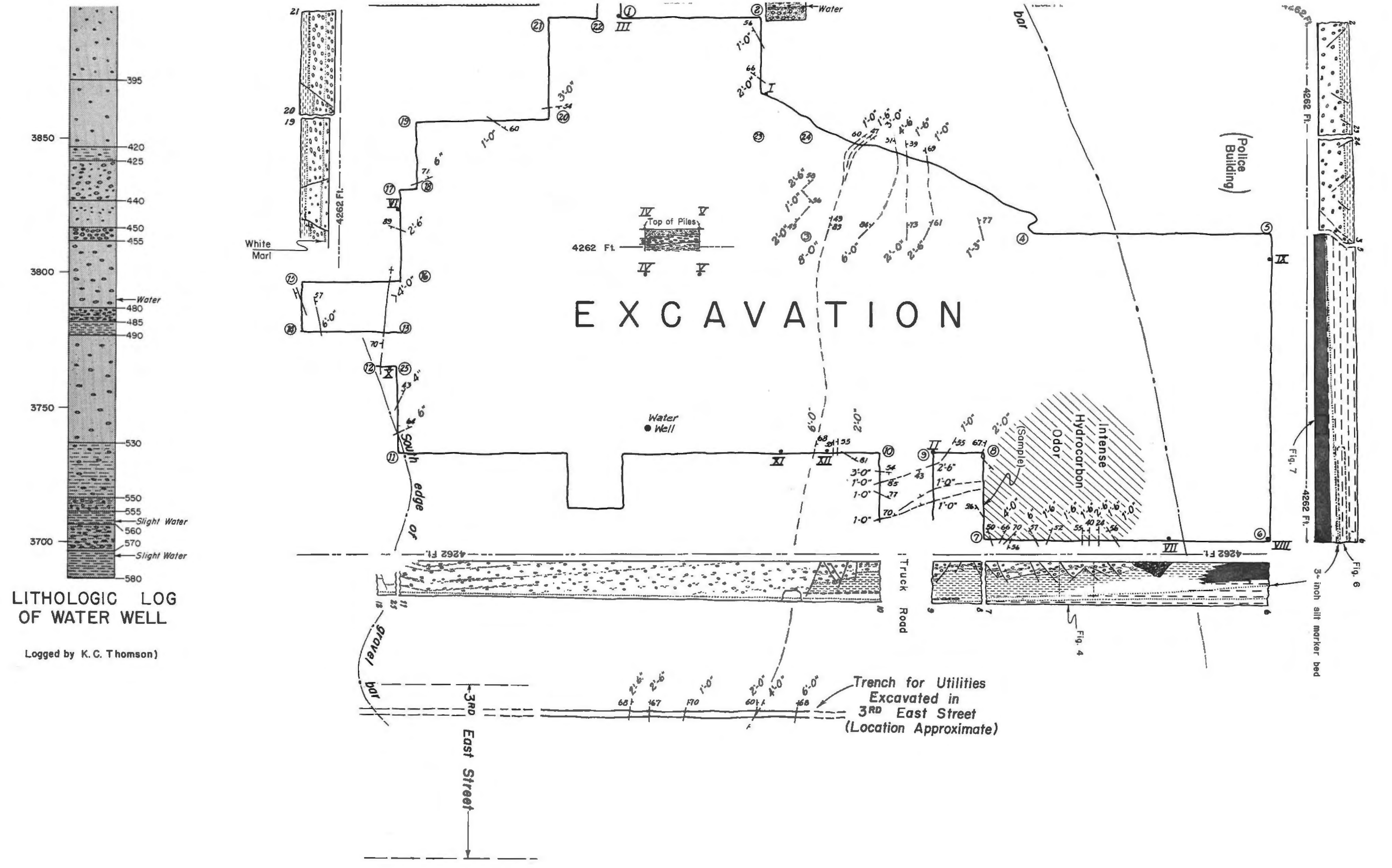


Figure 1. Hall of Justice excavation outline and geologic details.

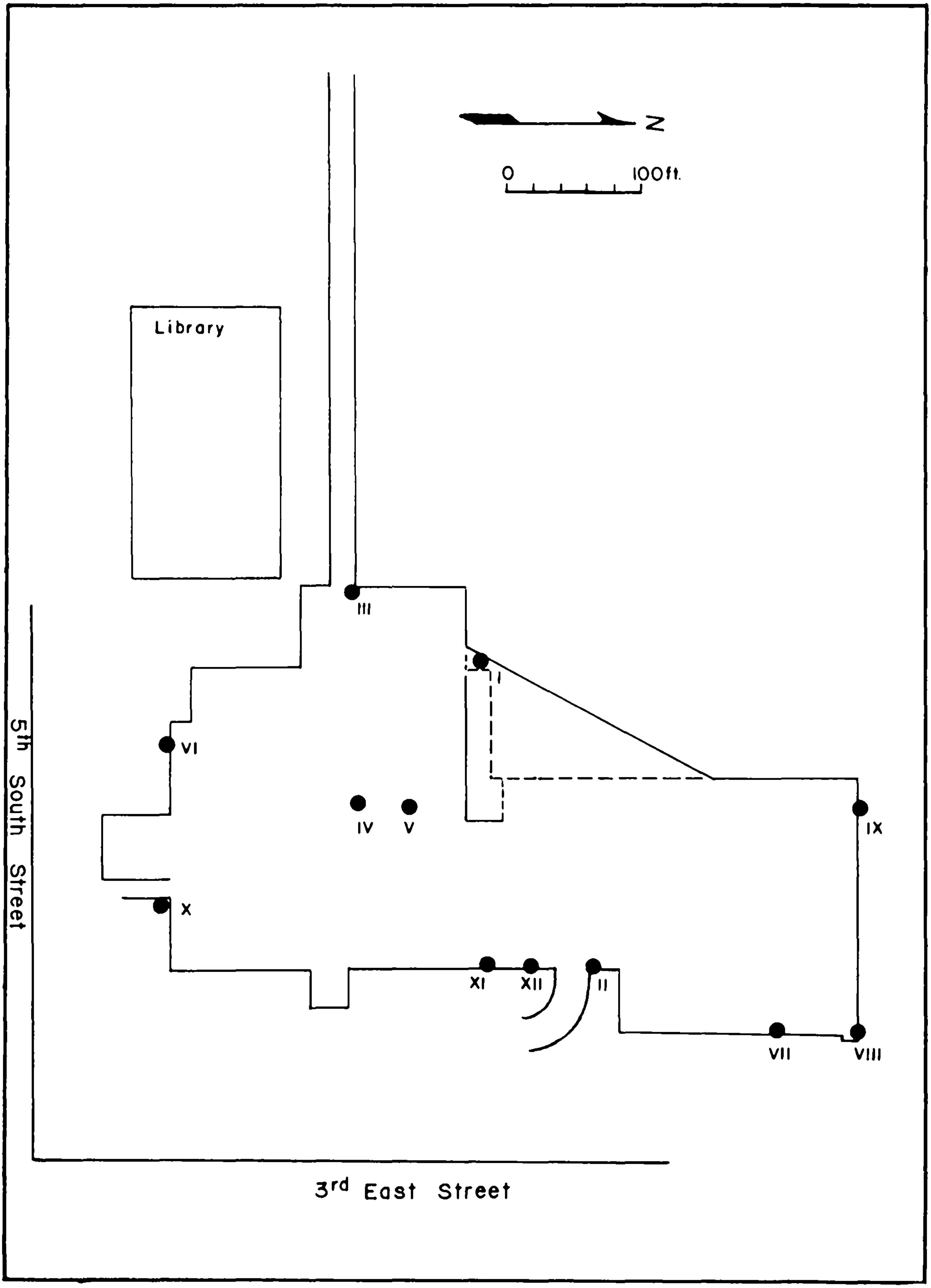


Figure 2a. Index to measured sections shown in Figure 2b.

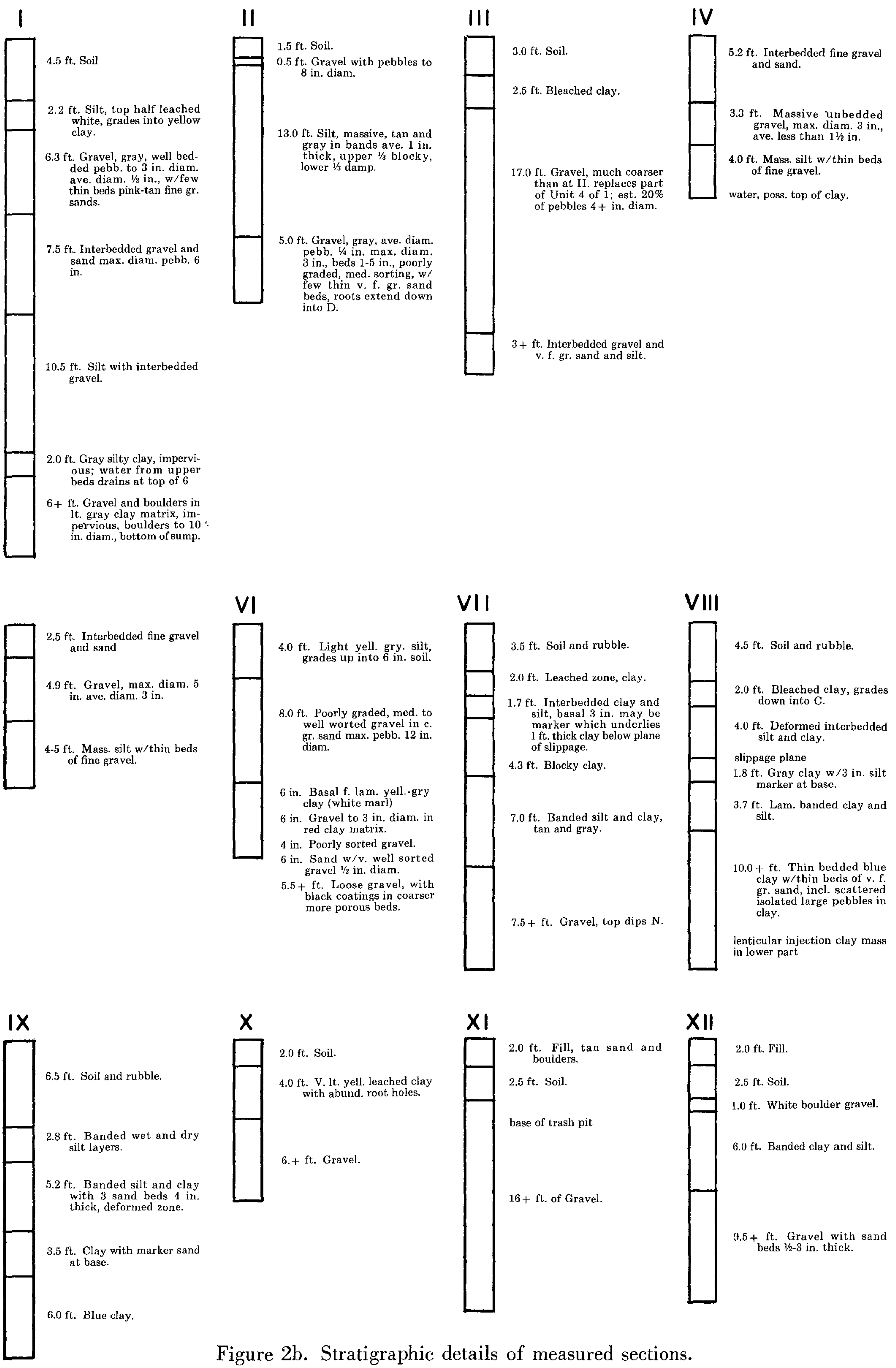


Figure 2b. Stratigraphic details of measured sections.

Associated with the outline is a series of dots, identified by Roman numerals I through XII, which represent location points for measured sections described in detail in Figure 2. Also shown is the location for a water well for which geologic detail is shown in columnar section in the lower portion of Figure 1, the plan view of one section of a utilities trench excavated on Third East Street, and the generalized outline of the City and County Library that concurrently was under construction.

Sediments

All material exposed is gravel, sand, silt, clay and various mixtures of these semi-consolidated sediments. In the south half of the pit, sands and gravels occur essentially from the surface down, except in the extreme south portion where they are overlain by silts. From the center northward, they occur at progressively lower elevations and are overlain by tan silts, clays, and varve-like mixtures of the two. In the extreme north wall, from ⑤ to ⑥, blue clay in the bottom of the pit is overlain by intercalated clays and silts. Both are water saturated and are overlain by a dry pinkish silt. From the center westward, gravels again occur at progressively lower elevations, and west of Second East Street in the deep trench that leads to the City and County Building silts or clays occupy the entire cut except at the extreme west end of the trench where silts and clays give way abruptly but irregularly to gravels.

In the east wall from XII through ⑧, at depths of 2 to 5.5 feet, a thin gravel layer discontinuously overlies silts; and from XI to ⑪, there are surficial deposits, several feet thick, some of which resemble waterlain gravelly sediments, but all of which overlie a layer of man-deposited "debris" composed of coal and broken stones.

Soils

From the surface downward for several feet a well-developed soil has formed on all types of sediments, except on the disturbed near-surface material in the east wall. Indeed, in the west portion of the trench two soils are clearly exposed and their carbonaceous "A-horizons" are indicated on the longitudinal section of the trench.

FAULTS

The contact between the underlying sand and gravel and the overlying silt has been sliced repeatedly by faults with individual vertical displacements ranging from a few inches to eight feet (Fig. 3). They occur throughout the excavation, but are most numerous within a west trending zone that was

Figure 3. Photograph of faults in the west wall from (3) - (4) .

well exposed in three places: a 175-foot length of the east wall, roughly from XII through II through VII; a 110-foot length of the former west wall from points (3) through (4) ; and a 50-foot length of the actual west wall between (24) and (4) . These areas contain a swarm of westerly trending faults that is terminated on the south by a northerly dipping, westerly trending displacement that drops the sand and gravel some six to eight feet to the north. Although there are numerous prominent displacements within the swarm, there appears to be no overall displacement across the entire zone. The faults occur in contrafacing pairs, or groups. The contact is dropped by some, is raised by others. Some produce grabens, others horsts. Such movements are illustrated in section 3-4 of the west wall, and are suggested by the 100 feet of geologic detail shown for the utilities trench on Third East Street. In contrast, geologic detail from XI-VIII on the east wall shows a succession of northward-dropping faults with a total displacement of possibly sixteen feet followed by a chaotic jumble of numerous closely spaced south-dipping slices that "restore" the contact to its normal projected position.

Whereas the general trend of the fault swarm is roughly westerly, it is intersected by northerly trending faults with individual displacement of 1 to 3 feet. These again are contrafacing and produce no overall displacement. They are particularly prominent in the east edge of the excavation as exposed in the walls of the truck road.

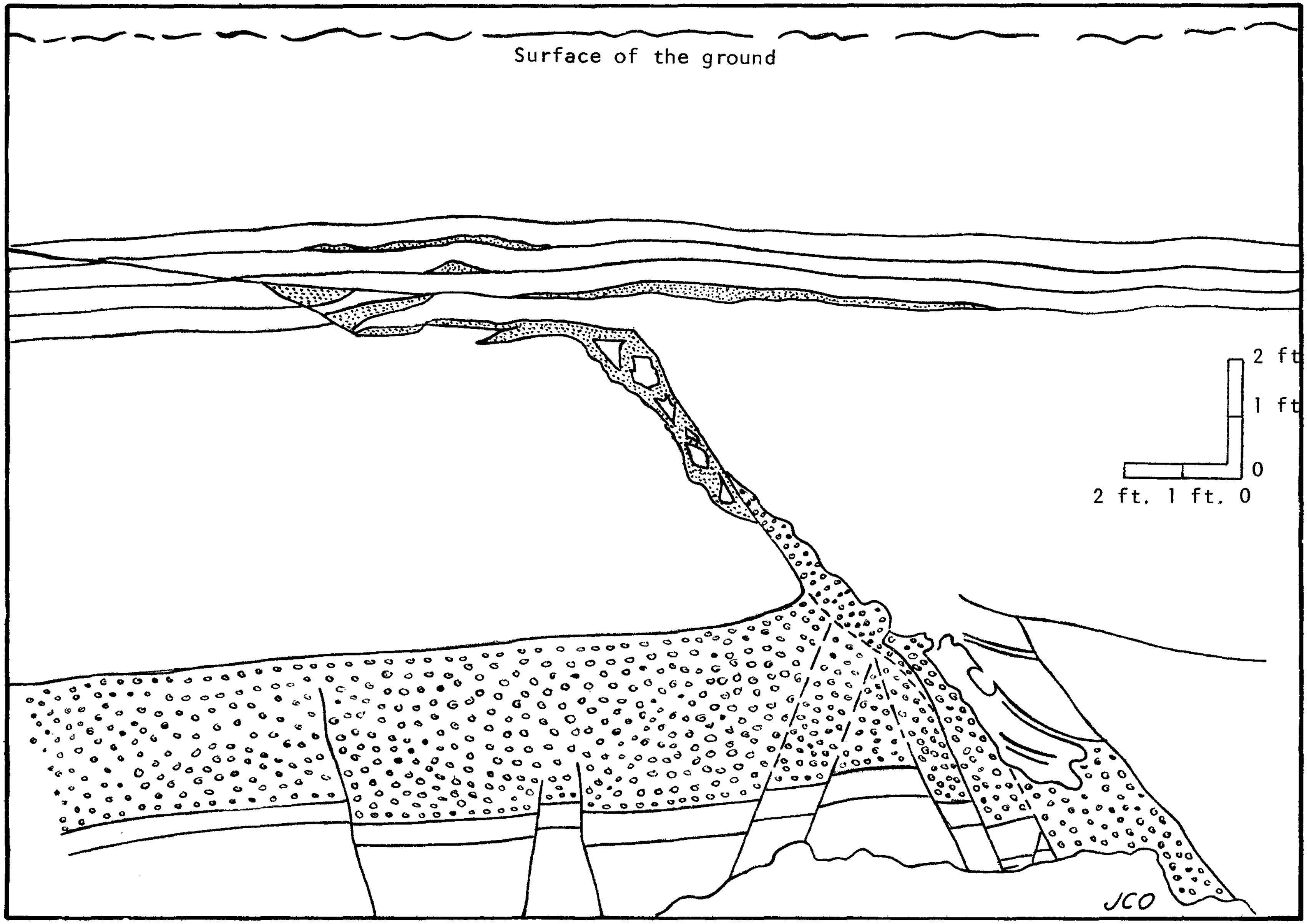


Figure 4. Sketch of faulting on east wall of the excavation at Location 40-50 feet north of (7) . Note upward flow of gravel and sand along main fault plane and lateral injection of sand between clayey siltstone beds as dip of fault decrease near the surface of the ground.

Faults occur in other parts of the excavation, particularly along the south wall, but not in a concentrated swarm. Some trend westerly, others northerly. Their vertical displacements range from a few inches to as much as six feet, and their more prominent members form small grabens. In the northwest corner of the Library excavation, possibly 200 feet southwest of corner ②, there was an exposure of a northerly trending fault with an apparent horizontal displacement of possibly 10 feet.

With the exception of the prominent displacement marking the south edge of the westerly trending fault swarm, it is difficult to project individual faults more than a few tens of feet. They seem to die out; new ones appear to spring up; and even those that are traced with apparent confidence within a few feet exhibit wide variations in strike and dip. The entire area resembles a plate that has been shattered.

As the faults are traced upward they become lost in the soil; but strata adjacent to the fault planes exhibit drag effect; silt and sand have been injected along the disturbed zones (Fig. 4); and pebbles within the zones have been rotated parallel to the plane of movement. None of the faults produces a scarp in the present surface.

Age

North of the City-County Library in an excavation for an underground parking lot, a prominent 2-foot fault slices both underlying gravel and overlying silty clays. In the latter, displacement is marked by an abrupt color change from pinkish silts to yellowish silts along the projected dip of the fault plane. It is the opinion of Mr. Van Horn that soils of Bonneville and Altithermal age have been developed in these silts and that this fault slices both of them. If so, the faulting is younger than 5,000 years.

Displacements have not been confined to a single period of faulting. In addition to faults which cut the contact between sand and gravel with overlying silt, there are displacements which antedate silt deposition. These occur on the east wall in the vicinity of measured section XII (Fig. 5). There is also a suggestion of relatively recent faulting. Thus, the near-surface gravel at XII, if projected north, across the truck road, to ⑨, should lie 4 feet lower than its actual position at ⑨. On present evidence there is no way to estimate the elapsed time between these displacements, or precisely when they occurred. If the surficial gravels have been displaced, it was within the last few hundred years, whereas the oldest movement, dating from occupancy of the valley by Lake Bonneville, may exceed 30,000 years.

Figure 5. Photograph of pre-silt displacement in east wall at measured section XII.

Origin

Faults exposed in the walls of the excavation could have resulted from any of several causes.

1. They could be directly related to faults in the bedrock, but their east-west trend does not favor this possibility.

2. They could have been formed by shaking of the unconsolidated sediments during local earthquakes. Possibly in the past when severe earthquakes shook the valley, the gravel acted as a rigid and almost uncompactable unit, thus localizing the readjustment of the overlying unconsolidated materials.

3. They may have been caused during the normal process of compaction of the unconsolidated underlying sediments, particularly clays or peats, as the water level in Lake Bonneville fell from several hundred feet above the deposits to below the level of the present surface. The water well in the southeast corner of the pit encountered underlying clays at various depths, but no peat.

It seems probable that the faults were caused by the triggering effect of earthquakes on unconsolidated deposits which had become unstable as their environment changed from lacustrine to subaerial. The detail from XII through VII suggests fault-triggered landslide failure and, on a small scale, resembles the destructive Turnagain Heights landslides that were developed by the March 27, 1964, Alaskan earthquake at Anchorage.

GRAVEL BAR

Description

Within the excavation the gravel deposit trends easterly and has a width of 450 feet. The northern edge was exposed in the main excavation and in the tunnel leading to the old City and County Building. The southern edge, close to the south wall of this excavation as well as that for the Library building, was also exposed in a trench dug in Second East Street. As exposed in pits dug below the general level of the floor of the excavation, the gravel has a maximum thickness of 24 feet, and its top is overlain by the present soil.

The crest of the deposit, about 50 feet north of the southern edge, reflects the asymmetry of the deposit which is further emphasized by the dip of bedding surfaces within the gravel, size distribution, and the degree of sorting. Northward from the crest, bedding surfaces dip 5^{o} and increase to 10^{o} near the north edge. South of the crest, dips are up to 20^{o}. The coarsest material (up to 8 inches in diameter) is in the central part and occurs from within 30 feet of the southern edge northward for about 170 feet. Sorting is best on the southern edge where distinct beds appear, but elsewhere the deposit is poorly sorted.

Intermittently throughout the gravel there are streaks of iron oxide discoloration that appear to be water-deposited. Associated with them are discontinuous streaks of a soft black material that coats the bottom and side of gravel fragments. Somewhat sooty in appearance, it has been interpreted variously as carbonaceous material or as a manganese oxide. A spectrographic analysis by Harold K. Bradford indicates that silicon, manganese, and magnesium are its major constituents.

Origin

The deposit is interpreted as a gravel bar that was deposited by off-shore currents in Lake Bonneville. Abundant specimens of Nugget Sandstone indicate a source feeding northward, possibly from Red Butte Canyon. Although its east-northeast trend, almost at a right angle to the northwest strike of the surface contours appears anomalous, there is no valid relationship between conditions at the time of gravel deposition and actual surface contours.

Silts and Clays

The north flank of the bar is overlain by silts and clays which were deposited in quiet waters, possibly in a lagoon or back-bay environment that lay between the bar and the eastern shore of the lake. Northward the gravel bar is overlain by blue clay. The geologic detail shown in the wall sections that accompany Figure 1 has been greatly simplified and only the water-saturated blue clay is shown. Whereas an x-ray spectrograph of material collected

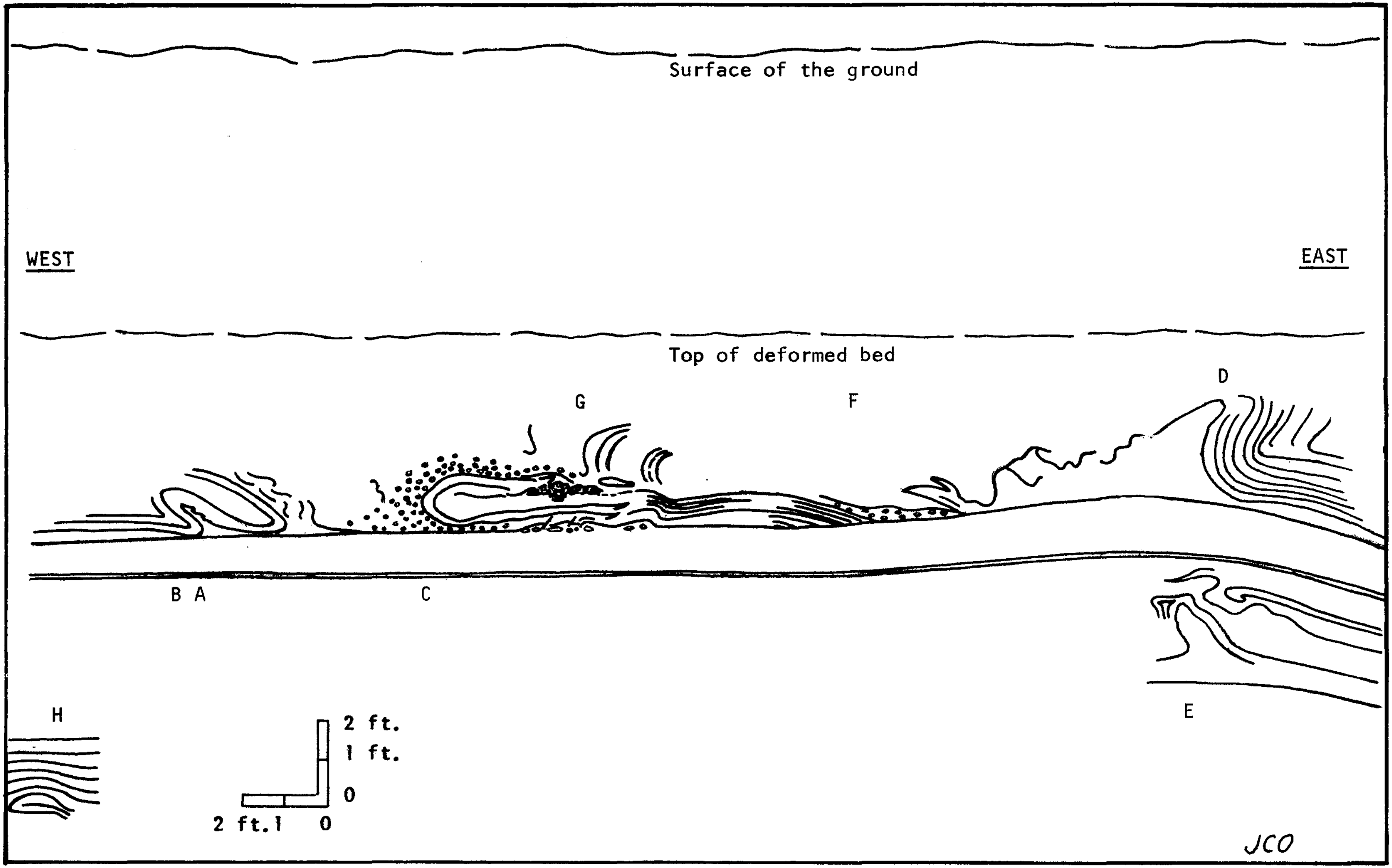


Figure 6. Sketch of deformed siltstone and gravel overlying clay bed in north wall of the excavation. The zone of deformation is 4 feet thick, and the top is 6.5 feet below the surface. Strike of axes: A=N20W; B=N15W; C=N27W; D=N30E; E=N80W; G=N45E.

from the bottom of the pit failed to reveal a clay mineral but indicated fine-grained quartz, calcite, and potassium (?) feldspar (a composition suggestive of a relatively fresh rock, possibly a volcanic glass), an adjusted analysis from bulk x-ray determination of drier materials, somewhat yellowish and collected some 80 feet to the south and 15 feet higher, recorded montmorillonite 41%, quartz 37%, calcite 9%, kaolin 8%, dolomite 5%(Jerry Odekirk, Analyst).

Erosion

Whereas the silts overlying the north flank of the bar appear to rest conformably on the gravel, both the crest of the bar and its south edge show evidence of pre-silt, post-gravel erosion. Thus, along the crest there is angular discordance between the stratification of the silt and that of the underlying gravel, and along the south edge in the vicinity of measured section VI there is a thin horizon of white marl which terminates abruptly against truncated south-dipping bedding planes within the gravel. In the ensuing chapter by Richard Van Horn, this white marl assumes considerable importance in deciphering the history of Lake Bonneville.

Underlying Sediments

Sediments beneath the gravel bar were exposed in the floor of the excavation (I - (23) - (24)). There the underlying material is two feet of gray clay with six feet of gray matrix containing cobbles and boulders. These may be mudflow deposits.

Small Scale Deformation On Shoreward Flank of Bar

Figures 4, 6 and 7 show soft-rock deformation in beds overlying the north flank of the gravel bar. The locations of the figured areas are shown on Figure 1.

Figure 6 is a sketch of contorted, overfolded and dismembered clayey silts with interbedded thin layers of sand and gravel. A prominent marker bed of very fine-grain tan sands $1\frac{1}{2}$ inches thick occurs just above the letters B, A and C in the sketch. This layer is overlain by 14 inches of light gray silty clay, the upper surface of which is the main slippage plane.

The deformed zone is 4 feet thick, and the top is 6.5 feet below the surface. The trends of the axes of the folds range from N15W to N80W and from N30E to N48E as described in the explanation of Figure 6. The directions of the fold axes indicate that the folding could have been caused by gravity sliding down the initial northerly dip and off the higher part of the gravel bar. Possibly the slumping was triggered by earthquakes which caused the deformation of the unconsolidated sediments made unstable by lowered water level in the lake.

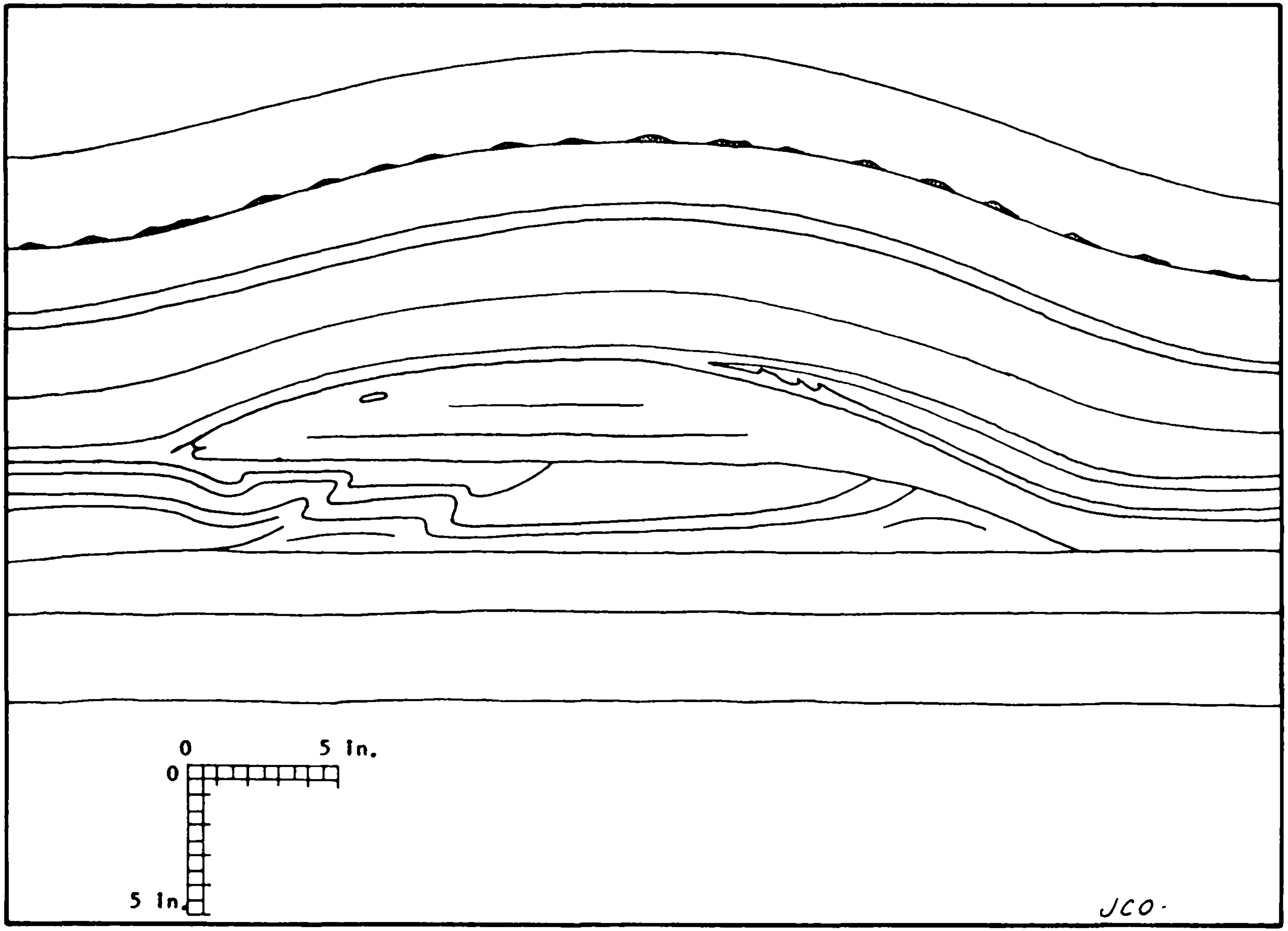


Figure 7. Sketch of overturned and overthrust fold in clay at north end of the excavation. Note small sand ridges of ripple marks arched over the lenticular, concretion-like mass of clay.

Figure 7 is a detail sketch of fold "H" which occurs in the clay below the marker sand. Fold "E" also occurs below the marker. Fold "H" was of particular interest because it resembled a lenticular concretion at first glance. However, one of the overlying bedding surfaces in the clay carries small ripple marks of sand and was arched over the fold, which indicates the concretion was injected into place after burial under more than 1 foot of clay.

Figure 4 shows a detail of the faulting overlying the gravel bar. Gravel moved upward along the fault plane about 2 feet, and sand moved upward several feet and was injected laterally along bedding surfaces in the overlying clay. The fault plane was deflected from 53° in the lower part of the exposure to 10° four feet below the surface and could be traced to within $1\frac{1}{2}$ feet of the surface.

WATER

Prior to excavation, as judged from records in test borings, the top of the water table occurred from 9-18 feet beneath the surface, and was not only uneven but beneath the Hall of Justice it lay some 9 feet higher than beneath the Library which is immediately to the southwest. During excavation for the Library the higher water to the north was released and the excavation flooded (Fig. 8, S.L. Trib.). During a 6-month period prior to excavating for the Hall of Justice, pumping in the Library excavation lowered the water table to a depth of 16-20 feet. While excavating for the Hall of Justice, sands and gravels beneath the water table yielded abundant water freely and waterlogged clays and interbedded clays and silts seeped water along every interbedded silty layer.

Approximately at point (23), a sump extended some 16 feet beneath the general bottom level of the excavation. In its walls, as shown in detail in measured section I, sands and gravels exist to a depth of 30 feet beneath the surface, where they are underlain by a 2-foot bed of impervious gray silty clay which in turn overlies an impervious mixture of boulders, up to 10 inches in diameter, in a gray clay matrix. At this impervious contact, roughly at the 4,258-foot elevation (Salt Lake City datum), water issued in great volumes and small caves, several feet high and equally deep, washed out of the sands and gravels immediately above the contact. The flow slacked off after about three days and the overlying sands and gravels were then water-free, but the clays and silts in the north portion of the excavation remained waterlogged. In efforts to dewater these clays, wells were sunk and pumped prior to setting reinforced concrete piles, but with little or no success in drying the clays. In the water well drilled 190-200 feet southeast of the sump, water was not reported at the gray clay depth. The driller, however, reported water at depths of 160, 248, 287, 477, 558 and 573 feet, but the well was never tested.

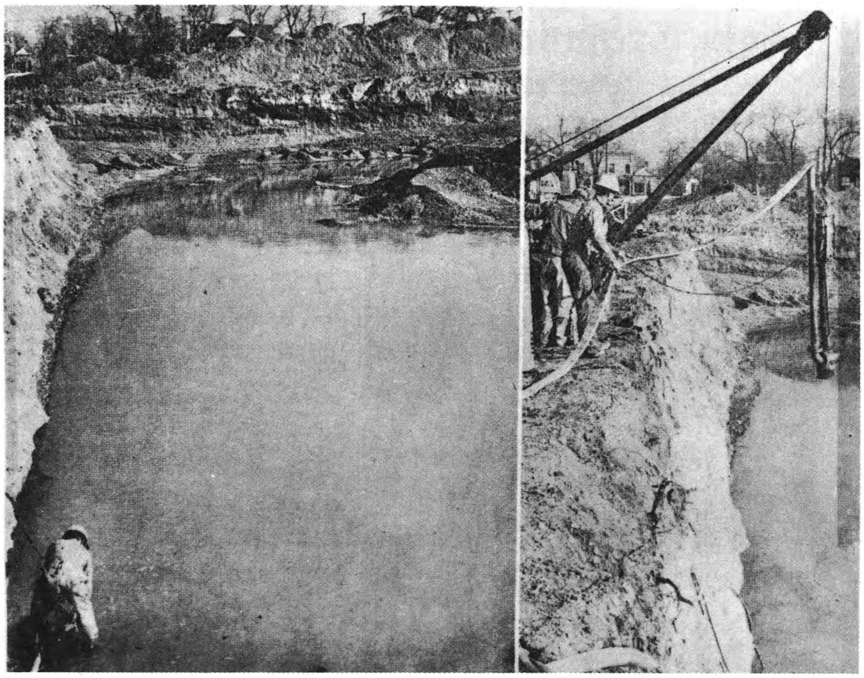


Figure 8. Flooded excavation for City-County Library.
(Salt Lake Tribune, January 9, 1963.)

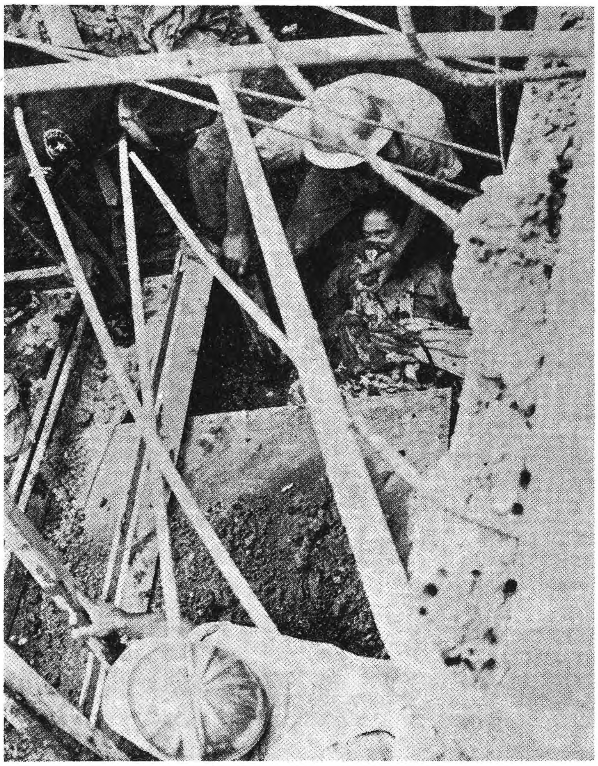


Figure 9. Accident in the trench leading to the
City and County Building.
(Salt Lake Tribune, October 8, 1963.)

After completion of the sump in the fall of 1963, drains were placed at Salt Lake elevation 4,272 and 4,264. These have been pumped uninterruptedly, but without a record of pumping rates. On April 27, 1964, they were delivering together 50 gallons a minute, while a drain in the northwest corner was contributing 8 gallons a minute.

BEHAVIOR OF THE SEDIMENTS

The outstanding characteristic of these sediments is an extreme variability of constructional properties, both horizontally and vertically. This precludes the projection of test data for more than a few feet beyond individual test holes. The variability, well illustrated during the driving of friction piles, was such that support conditions changed radically within distances of 20 feet, and is considered a direct consequence of the geologic environments under which the sediments were deposited.

Within the walls of the pit, where dry, the sand and gravels remained firm, even in vertical faces approaching 30 feet in height. But where wet, and particularly where they were subjected to a fluctuating water table, possibly caused by variations in pumping rate, they lost their cohesion and slumped, which weakened the overlying silts and in the deep trench leading to the City-County Building the walls failed with nearly fatal consequences (Fig. 9, S.L. Trib.). Pertaining to this horizon, data from test borings are summarized as follows:

> Medium dense to dense, density varies from 97-130 pounds per cubic foot; moisture content above water table ranges from 9 to 12%, below water table from 27 to 29%; 3,000 pounds per square foot unconfined compressive strength.

In the north end of the excavation the water-saturated clays, particularly in the vicinity of the vertical drains, failed in great blocks that separated from the overlying clayey mass, possibly along silt partings, and slumped vertically. Data from test borings in this material are summarized thus:

> Hard; density 95-102 pounds per cubic foot; moisture content, 26-32%; 555-2,000 pounds per square foot unconfined compressive strength; liquid limit, 46-49; plastic index, 13-25.

In the northwest corner immediately south of (5), instability in the wall necessitated I-beams being driven parallel to the face. Pine planks and two-by-fours were laced behind the beams as a lagging to hold the face, but pore pressure within the clays and interbedded silts caused them to move outward toward the pit. Six months after the initial exposure of the clay bank, the lagging was bulging and snapping. Although both blue clay and overlying silt were involved in the failure, test-hole data from material overlying the blue clay are as follows:

> Very stiff; average density 102-105 pounds per cubic foot; average moisture content 19-24%; 3,000-4,000 pounds per square foot unconfined compressive strength; liquid limit 43; plastic index 11.

Dewatering has occurred only in the first 30 feet beneath the surface, but removal of the water has produced sufficient surface subsidence to cause the jail, immediately west of the sump, to settle and to require the rehanging of the doors.

HYDROCARBONS

In the northeast portion of the excavation, in the vicinity of points 8-7-VII, the sands were so saturated with a volatile hydrocarbon that the air reeked with the odor of gasoline. Trapped beneath overlying silts and immediately overlying the water table, all the freshly exposed sands emitted the volatiles, although thin carbonaceous seams were particularly rich in them. A sample of freshly exposed sand was collected in a liter polyethylene bottle and the volatiles, collected by displacing entrapped air with a column of rising water, were analyzed by Mr. Mark Griffin of the American Oil Company.

The results, recorded below, were entirely unexpected and raise questions as to origin.

95.8% air
4.1% ethane
0.1% normal butane
No propane
No methane
No carbon monoxide

The presence of natural gas in similar shallow sand and gravel bodies a few miles north of Salt Lake City, and the alleged flowing of a well in the vicinity of Thirteenth South and Fifth East Streets for some three years, suggests a natural gas derivation. But if the volatiles are from such a source, methane should be present. If they are from commercial gasoline, the propane content should exceed that of ethane. Possibly the source of the hydrocarbons was leakage from butane storage, yet the odor of gasoline was unmistakable. This remains an enigma.

As early as 1948, the presence of gasoline was recognized in the sand from this area. According to Mr. W. L. Butler, former Chief Engineer of the Power and Heating Division of Salt Lake City, (personal communication) as a result of complaints that gas was leaking into basements, the City investigated this problem in 1948, 1949 and 1950. The City sank numerous test holes, withdrew gas from various horizons, and traced a westerly trending belt of gasoline contamination as far east as the corner of Eighth East and Fourth South Streets and westerly to the Jordan River. The contamination varied in depth beneath the surface and fluctuated with changes in the water table. It did not come to the surface, but occasionally the odors leaked into storm sewers or the basements of public buildings. As a result of the investigation, it was established that the contaminant was leakage from gasoline storage tanks, and a 60-foot test well was sunk near Fourth West and South Temple Streets. From it 100 barrels of gasoline were pumped in a 2-month period. As a result, the City's Fire Marshall now has the legal right to check any gasoline storage tank within the City.

The 1948-1949-1950 investigation established that different volatiles were drawn from different horizons in the sands; and concluded on the basis of these volatiles that gasoline had been leaking into the zone more than 25 years. Following the 1920's it seems that volatiles of the type encountered in the 1948-1950 investigation were removed from commercial gasoline, but prior to this time they were contained within the gasoline.

The above investigation also established that one area of noticeable contamination was near the site of the former Midwest Meat Market, possibly within the area of hydrocarbon contamination in the Hall of Justice excavation. Not knowing of the 1948-1949-1950 investigations, the authors learned that when the Midwest Meat Market was in business it burned 110 gallons a day of No. 2 stove oil, and the suggestion was raised that there may have been a leakage from this source. Out of business since 1962, the Market left an underground storage tank containing 1,000 gallons of oil (personal communication, Wes Wonnacott, Manager, Phillips 66 Service Station, 204 East Fourth South Street). Measured on April 30, 1964, this tank still had 18 inches of oil which reportedly approximates a 1,000 gallon content. Therefore, this was not a source of contamination, unless leakage occurred above the 1,000-gallon mark.

The authors reasoned that the most probable source for contamination would be somewhere to the east because the hydraulic gradient is from east to west. Of possible significance, in May of 1962 the Texaco Service Station at 502 East Fourth South, two blocks east of the excavation, became aware of a 100 to 150-gallon-a-month leakage. Because of the pressure of the oncoming tourist season this leakage was ignored. But in the summer of 1962 there were two earthquakes. As a result of the second, on September 5th, which had its epicenter on the west edge of the Salt Lake valley against the east flank of the Oquirrh Mountains, these tanks collapsed and 3,500 gallons of gasoline of combined ethyl and standard brands (Sky Chief and Fire Chief respectively) were lost (personal communication from Mr. James E. Young, Manager, Texaco Service Station, 502 East Fourth South Street). Apparently the Texaco station leakage represents the most recent of a large number of leakages that have drained into the area for many years. Even so, the ethane to propane ratio still remains to be explained and Mr. Joseph M. Glassett of the American Oil Company has asked whether the unconsolidated sediments through which the leakage migrated could have acted as a chromatograph. The relationship between type of gas and depth of occurrence obtained during Mr. Butler's investigation suggests there may be merit to the possibility.

The Texaco station, aside from its part in the speculation relating to the hydrocarbons, is of further interest. The collapse of its tanks should be a prime example of one type of disaster that can be anticipated should subsequent major earthquakes strike the valley.

Dr. George Hill of the University of Utah's Department of Fuel Technology suggests that an unusual ethane to propane ratio might be obtained as a result of leakage from a storage tank of liquid petroleum gas (LP gas), and Dr. V. Dean Allred, Director of Analytical Department, Marathon Oil Company, Littleton, Colorado, advises that when demand for propane is high, excess ethane is sometimes added to liquid petroleum gas to obtain the required vapor pressure. If such material had leaked into the sands, carbonaceous matter might absorb it, and it could remain trapped for years (personal communication, Dr. George Hill). Within 2,000 feet of the occurrence there are, or were, nine filling stations, but none has any knowledge of a liquid petroleum gas storage tank. However, if LP gas be the source, contamination might have been from a domestic tank, rather than from commercial operators.

In considering the significance of this peculiar ethane to propane ratio, there remains a possibility that all the hydrocarbons may not have been released from the sands in the polyethylene bottle.

FOSSILS

Shells of ostracods and gastropods were collected by Mr. Van Horn from a prominent layer of white marl 12-14 feet beneath the surface at point VI (Fig. 10). There is a rumor that a skull of a horned animal was collected from the gravels 25 feet beneath the surface of the east wall about opposite the water well. Several fragments of skeletal material have been found in the north part of the pit, but none of them in place. One, found by Mr. P. G. Panos in a pile of blue clay was apparently from that horizon, as stiff blue clay adhered tightly to it. None of the fragments was diagnostic, but according to G. Edward Lewis of the U.S. Geological Survey (written communication, Feb. 12,

1964) the specimen collected by Mr. Panos is the metacarpal bone of a large bovid; it might represent either bison or domestic cattle, but most features suggest Recent bison.

SIGNIFICANCE IN URBAN BUILDING

All the sediments are derived from the neighboring Wasatch Mountains, yet they exhibit rapid variations in both type and structural competency. These variations are a consequence of the environment in which they were deposited.

In the 39 feet exposed, the oldest of the sediments is a stiff unsorted mud-flow. Immediately overlying it, is an off-shore gravel bar that was built by currents in Lake Bonneville. Both it and the underlying mudflow furnish excellent foundation support, but immediately overlying it to the shore-ward side of the old lake is a thick series of silts and clays that possess inferior foundation characteristics. These originally were muds and oozes that settled in quiet lagoons behind open water. In contrast, on the open-water side of the bar, storm waves pounded at it, tore it down, and deposited another series of gravels. Currents eroded the upper surface of the gravel bar, but then calmer waters prevailed, possibly the result of a sudden deepening of water level, and silts blanketed all earlier deposits. The lake withdrew. A soil formed. Silt has been deposited on this soil, but whether it is of lacustrine or terrestrial origin is questionable. On this silt, another soil has formed. Streams cut channels in the exposed silts, as shown in the west end of the trench near the City and County Building, deposited another series of gravels; and, if the evidence in the east wall is correctly read, they have continued to deposit sediments, even since the arrival of the pioneers.

Each sediment was deposited in response to a specific set of energy conditions. These, at any given water level, varied laterally and vertically in response to the depth or shallowness at a particular point, the exposure to wind-generated currents, the quantity and type of incoming sediments, and to climatic variations. Moreover the ancient lake suffered extreme and rapid variations in level, with corresponding energy changes in each change of level. Add to these the energy of streams, consider all the variations, and perhaps it will be understood that the sediments found within this city block can be extrapolated neither shoreward nor lakeward, yet are typical of some of the variations that can be anticipated in any block within the city.

Add to these complexities the jumbled disarray that ensues when incompetent sediments are disturbed by earthquakes and by faults, and an explanation emerges for the extreme variations within this excavation.

The variations in water level and flooding are explained by the erratic distribution of permeable sands and gravels; and by the sudden release, through excavation, of water contained in nearby, semi-isolated, permeable bodies that occur at higher horizons. Except for the most recent stream deposits, all the sediments have lain beneath the lake and even the impermeable clays are water-saturated. Moreover, the porous permeable horizons are recharged each year from snow-melt runoff coming from the Wasatch Mountains. These waters are an integral part of the space occupied by the sediments, and when they are withdrawn the sediments begin to compress and the surface subsides.

Water exerts pore pressure on the unsupported face of all freshly excavated sediments beneath water table. When the sediments drain, this pore pressure is relieved, but impermeable silts and clays release their water slowly and pore pressure continues to act on unsupported faces long after the excavation has been made, which accounts for the slow but sustained failure of the blue clay.

Waste gasoline rides on the water table, seeps from all parts of the city through permeable water ways until it reaches a base level beyond which it does not travel. As in the gravel bar exposed in this excavation, it collects in porous strata that are blanketed by impermeable sediments. When released through excavation, the volatiles escape; mix with air; and as in underground mines that are poorly ventilated, can accumulate in unexpected places and create explosive hazards.

The indication of seismic activity should alert any designer, for each of the sediments will react in its own way to earthquake waves and each of these individual reactions will be transmitted to overlying structures. Currently we have no data should earth tremors occur, as to seismic accelerations that can be expected within the individual horizons.

With the exception of the volatile hydrocarbons, the constructional problems exhibited in this excavation are common place and differ only in their great variety from those normally anticipated elsewhere. It is only in the failure to recognize this great variety of problems, inherent in the geologic history of the area, that danger arises. As for the hydrocarbons, perhaps they are indicative of problems to be encountered in urban areas elsewhere.

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SECTION 11:
LATE WISCONSIN AND RECENT STRATIGRAPHY IN DOWNTOWN SALT LAKE CITY, UTAH

by Richard Van Horn[1]

INTRODUCTION

An unusual opportunity for reconstructing details of the late Pleistocene and Recent history in part of the Great Salt Lake basin was provided by an excavation in downtown Salt Lake City for the new Hall of Justice Building. Of particular interest is the stratigraphic sequence as well as several folds and faults that disturb the Pleistocene and Recent deposits. The excavation is in the east part of the block between Second and Third East Streets and Fourth and Fifth South Streets and was studied in the early part of September 1963. The geologic units exposed in the vertical walls of the excavation were measured and sketched onto cross section paper. Precise vertical and horizontal control of the excavation was provided by Harold K. Beecher and Associates, supplemented by the author's pace, hand level, and measurements and estimates. Several faults were clearly exposed offsetting the various stratigraphic units in the walls of the excavation and are shown on the accompanying fence diagram (Fig. 10). These faults are discussed in detail in the accompanying paper by Osmond and Hewitt.

STRATIGRAPHY

The stratigraphic nomenclature used in this report is similar to that of Hunt and others (1953). Correlation with their units is based on the presence of a thin white marl, unconformities, and actual and inferred fossil soils.

Eight stratigraphic units were exposed in the excavation. These are, from oldest to youngest, old alluvium, Alpine Formation, post-Alpine Formation clay and gravel, lower part of the Bonneville Formation, intra-Bonneville Formation gravel, upper part of the Bonneville Formation, post-Bonneville alluvium, and later deposits. The Alpine Formation is defined here as the deposits of an unknown number of lake cycles that occurred during Wisconsin time prior to the cycle that initiated deposition of the Bonneville Formation. The Bonneville Formation is composed of the post-Alpine lacustrine deposits on which a moderately developed soil formed. It probably represents two distinct lake cycles. No lake deposits younger than the Bonneville Formation were recognized in the excavation for the Hall of Justice although terrestrial deposits of Recent age are present.

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Old Alluvium

The oldest unit seen, the old alluvium, was exposed in a deep pit near the center of the excavation. Its coarse unsorted nature indicates that it may be an ancient mudflow or alluvial fan. It consists of more than 6 feet of a nearly impervious mixture of bouldery gravel in a light-gray clayey matrix. The old alluvium is overlain by 2-5 feet of silt and silty clay (unit a) of the Alpine Formation.

Alpine Formation

Lacustrine beds of the Alpine Formation include silt and clay (units a and b) deposited in quiet water, and gravel (unit c) that probably was deposited as an offshore bar. Unit a is a gray silty clay that was exposed near the center of the excavation. The top of unit a is slightly irregular and suggests an unconformity. Unit a possibly is equivalent to the interbedded light-gray to grayish-brown silt and silty clay of unit b exposed near the north end of the east side of the excavation. The apparent dip of unit b is about 2° N. The top of unit b is marked by an erosional unconformity that truncates the bedding at sharp angles. A rind of iron oxide 0.1-foot-thick marks the contact between unit b and the overlying gravel.

Both units a and b are overlain by unit c, composed of clean sand and pebble gravel containing a few thin beds of silt. In gross aspect the undifferentiated unit c is poorly sorted although individual beds are well sorted. The pebbles are rounded and are of many lithologic types, including a pale reddish-brown and light-brown banded sandstone probably derived from the Nugget Sandstone of Early Jurassic age. In the central part of the excavation unit c contained cobbles up to 8 inches in diameter. Unit c thins to the north and to the south, but maintains a relatively constant thickness of about 15 feet in a southwesterly direction; it has the shape of an elongate flat-bottomed lens. Beds within unit c dip as much as 10° NW. At the southwest corner of the excavation as much as 2 feet of a silty and oxidized reddish-brown zone (unit d) is developed on unit c.

Post-Alpine Formation Clay and Gravel

The post-Alpine Formation clay and gravel overlies both units c and d of the Alpine Formation and extends most of the way across the south wall of the excavation. It is a south-dipping bed, about 6 inches thick, of reddish-brown, noncalcareous to slightly calcareous clay and small pebbles. The origin of the bed is not clear but it is probably either alluvial or colluvial. This bed and unit d of the Alpine Formation are cut out by a small channel near the southwest corner of the excavation.

Lower Part of Bonneville Formation

The deposits of the lower part of the Bonneville Formation recording the early lake cycle of Bonneville time consist of lacustrine gravel, white marl, silt, and clay. Near the southwest corner of the excavation the post-Alpine Formation clay and gravel is overlain by a south-dipping bed of white, strongly calcareous silt or marl 6 inches thick (unit a of the Bonneville Formation) that contains ostracodes, gastropods, pebbles, and thin clay beds. Unit a drapes down and pinches out in a small channel that cuts out the post-Alpine Formation clay and gravel. In the channel the marl, unit a, interfingers with the lower 6 inches of gravel of unit b of the Bonneville. The overlying gravel of unit b is as much as 7 feet thick and is similar to the gravel (unit c) of the Alpine Formation except that it lacks interbedded silt. Locally as much as 1.5 feet of greenish-gray silty and clayey gravel, unit c, is developed on unit b. Unit b has apparent south dips. The Bonneville gravel does not extend very far into the excavation and it appears to be a much smaller deposit than the Alpine gravel. The Bonneville gravel and the white marl are separated from underlying units by an erosional unconformity. This complex relationship is shown in cross section in the section extending north from the southwest corner of the fence diagram (Fig. 10).

Bonneville and Alpine gravel beds are overlain by beds of lacustrine silt and clay that dip parallel to the slope of the top of the gravel; in the north part of the excavation the silt and clay beds which overlie the Alpine gravel dip north, whereas in the south part of the excavation these beds overlie both the Bonneville and Alpine gravels and dip south.

In the north part of the excavation the Alpine gravel is overlain by a persistent bed of pale-brown massive sandy silt that is 1 to 2 feet thick (unit d of Bonneville Formation). Unit d is overlain by a light-grayish-brown thin-bedded clayey silt as much as 13 feet thick (unit e) that interfingers and grades northward into blocky silty clay (unit f). The clay, as much as 9 feet thick, is medium to bluish gray and contains a sparse ostracode fauna. Units d, e, and f dip 3^{o}–5^{o} N. and are truncated southward by an erosional unconformity.

Intra-Bonneville Formation Gravel

Along the north wall of the excavation unit f of the Bonneville Formation is overlain locally by the intra-Bonneville Formation gravel which consists of thin lenses of very fine grained silty sand, and at one place, shown on Figure 10, of a thin lens of very fine grained gravel. The lenticularity and coarse nature of the thin lens of gravel indicate that it probably is alluvium.

Upper Part of Bonneville Formation

Where the intra-Bonneville Formation gravel is absent, unit f is overlain by a light-grayish-brown thin-bedded silt and clayey silt that contains a sparse ostracode fauna, unit h of the Bonneville Formation. Along the north and east walls the lower 2 feet of unit h is distinctly browner than the overlying and underlying beds. Water seeps from this browner zone along the north wall. Near the northeast corner of the excavation the brown beds have a pinkish-gray silt (unit i). Units h and i dip 3°-5° N. and are truncated southward by an erosional unconformity.

In the south part of the excavation, overlying the Bonneville and Alpine gravels, is as much as 12 feet of greenish- to light-brownish-gray thin-bedded clayey silt (unit g) that resembles unit h and contains a sparse ostracode fauna. The clayey silt has a slight dip to the south, about parallel to the top of the underlying gravel. To the north the clayey silt (unit g) has been truncated by post-Bonneville Formation erosion. Correlation of the Bonneville Formation silt and clay beds between the north and south parts of the excavation is prevented by this erosion which removed the silt and clay beds and the upper parts of Alpine and Bonneville gravels in the central part of the excavation.

Post-Bonneville Formation Soil

The eroded surface that truncates the Alpine and Bonneville Formations has been subjected to soil-forming processes. At a few places where the soil is relatively undisturbed, it is moderately to weakly developed. The soil consists of a humic, weakly calcareous, dark-gray B horizon as much as 1.5 feet thick, underlain by a CCa horizon as much as 2 feet thick. The B horizon has generally been removed by erosion, so that at most places the soil is represented only by the Cca horizon, consisting of a light-gray zone of thin stringers and disseminated spots of calcium carbonate. The Cca horizon occurs in various truncated units of both the Bonneville and Alpine Formations. Where the B horizon has been removed by erosion, the Cca horizon has been enriched by additional calcium carbonate leached from overlying deposits during a later soil-forming interval.

Post-Lake Bonneville Alluvium and Soil

At most places the erosional surface and soil on the Bonneville Formation are unconformably overlain by a fluvial deposit of dark-gray, sandy to clayey, pebbly silt, unit c of the post-Lake Bonneville alluvium. The silt is generally 1 to 3 feet thick and is moderately to strongly calcareous throughout. At one place on the west side of the excavation a narrow, steep-walled channel filled with the silt almost cuts out the underlying Cca horizon of the post-Bonneville Formation soil. A weak soil has developed on unit c and at places there is a poorly defined prismatic structure in the upper part of the soil and a weak zone of calcium carbonate deposition in the lower part. At many places the calcium carbonate extends below the silt and merges with the underlying calcium carbonate zone of the post-Bonneville Formation soil. At these places the lower contact of the dark-gray silt and the bedding in the underlying deposits are obscured by the combined calcium carbonate deposits. This combined zone gives the impression of a single thick Cca horizon and is included in the Cca horizon of the post-Bonneville Formation soil on Figure 10.

The relationship between the two soils was well displayed where the excavation crossed Second East Street (Fig. 10). Here a brown sandy silt (unit a of the post-Lake Bonneville alluvium) intervenes between two dark-gray B soil horizons. The brown silt thins toward the east where the upper part contains thin streaks and tiny spots of calcium carbonate leached from the overlying dark-gray B soil horizon (unit c of the post-Lake Bonneville alluvium). A similar but more strongly enriched zone of calcium carbonate underlies the lower dark-gray soil horizon. At the east end of the exposure, where the brown silt (unit a) is only a few inches thick, the calcium carbonate zone from the upper soil extends through the brown silt and the underlying dark-gray B horizon and into the lower calcium carbonate zone. This abnormally thick calcium carbonate would appear to be part of a single much more strongly developed soil at places where the lower B soil horizon has been removed by erosion. A similar sequence of soils exposed on the west face of the main excavation indicates that the calcium carbonate accumulation in the Cca horizon of the post-Bonneville Formation soil is the combined result of two soil-forming periods. The degree of soil development shown in the soils near Second East Street indicates that the upper soil is probably equivalent to the Altithermal soil, and the lower soil to the post-Bonneville Formation soil.

Later Deposits

At one place near the middle of the east face of the excavation about 1 foot of crudely bedded silt and gravel possibly represents an historic flood deposit of City Creek. This deposit, included with "later deposits" on Figure 10, contains many pebbles partly coated with calcium carbonate and skewed at various angles. It overlies the post-Lake Bonneville soil and underlies artificial fill. At most places, however, the later deposits consist of as much as 10 feet of artificial fill that is composed of broken glass, bricks, and rusty metal in a silt matrix.

GEOLOGIC HISTORY

The foregoing information, although meager and isolated from more diagnostic exposures, provides some basis for an interpretation of the early history of Lake Bonneville at lower elevations than have hitherto been possible. The interpretation is also based in part on recent work by R. B. Morrison of the U.S. Geological Survey (oral communication, 1964) in the Little Valley and Little Cottonwood areas north and south of Salt Lake City, from unpublished work by David J. Varnes and Richard Van Horn in the Leamington area 150 miles south of Salt Lake City, and from unpublished work by Van Horn in the Salt Lake City area. The most critical link in the sequence of events as herein constructed is the correlation of the thin calcareous, white silt containing ostracodes and gastropods (unit a of the Bonneville Formation) with the white marl of Gilbert (1890, p. 193) and the Bonneville Formation of Hunt, Varnes, and Thomas (1953, p. 20). If this correlation is valid, then the rest of the deposits are in a stratigraphic sequence similar to that observed elsewhere. The similarity of stratigraphic sequences tends to corroborate the correlation, but of course does not prove it.

The unconformity exposed in the excavation between lacustrine silty clay and gravel (units b and c of the Alpine Formation) is at an altitude of 4,242 feet above sea level; it is at least 15 feet lower if units a and b of the Alpine Formation are correlative. Deposition of the silt and clay beds in a deep-water lake was followed by erosion (presumably subaerial) and then deposition of the lower gravel (unit c) as an offshore bar by west-trending currents in a shallow lake. The foregoing deposits of the Alpine Formation are believed to represent two lake cycles separated by an unconformity. Two similar lake cycles in Alpine time have been recognized in the Leamington area (Varnes and Van Horn, 1961) and in Parleys Canyon of the Salt Lake City area. At these two areas lacustrine silt and clay beds of the Alpine Formation are separated by alluvial gravel deposits. Both localities are much higher topographically than the excavation for the Hall of Justice. From this relation the author would expect to find silt and clay deposits between the Alpine gravel and the Bonneville gravel at the excavation but none were found. It is, of course, possible that silt and clay were deposited in this position and later removed by erosion.

The reddish-brown post-Alpine Formation clay and gravel overlying the Alpine gravel is not in itself a fossil soil but possibly represents the reworking of the noncalcareous B horizon of a well-developed soil. The leached B horizon of a soil is the only plausible source for noncalcareous sediments in the surficial deposits of this area; the reworked material of such a soil may have been introduced into this deposit. The channel that cuts into the Alpine gravel in the southwest corner of the excavation also indicates subaerial erosion and a lake level lower than 4,244 feet above sea level between Alpine and Bonneville time.

As the lake rose from this low level, the white marl (unit a of the Bonneville Formation) was deposited on the lakeward side of the eroded gravel bar of the Alpine Formation (unit c), and then a small gravel bar of the Bonneville Formation (unit b) was built on the lakeward side of the Alpine bar. As the lake rose higher, the silt and clay of the Bonneville Formation (units d, e, and f) were in turn deposited over the two superimposed gravel bars. The sandy silt of unit d is possibly the lagoonal equivalent of the Bonneville bar. The overlying thin-bedded clayey silt (unit 3) becomes finer grained on the north or lagoonal side of the bar as it grades into unit f. The abrupt change to coarser sediments, including the thin gravel lens of the intra-Bonneville Formation gravel, above the thin-bedded silty clay is similar to the poorly displayed disconformity between the two depositional cycles of the Bonneville Formation at Little Valley (Morrison, oral communication, 1964). There is no obvious evidence of erosion at this horizon at the Hall of Justice excavation, but the thin gravel lens is probably terrestrial and no doubt represents a drop of the lake to a low of at least 4,246 feet above sea level during deposition of the Bonneville Formation.

The fine-grained lake sediments above and below the disconformity and the Alpine and Bonneville bar gravels were all subsequently truncated by subaerial erosion. The post-Bonneville Formation soil was formed on the truncated surface. During this erosion and soil formation, the lake was at least as low as 4,255 feet above sea level. Subsequent erosion removed the B horizon of the post-Bonneville Formation soil at most places and the soil is generally represented by a zone of calcium carbonate deposition.

A fluvial sandy to clayey silt that contains a few pebbles and gravel-filled channels was deposited on the post-Bonneville Formation soil. A weak soil, probably the Altithermal soil, was developed on this deposit.

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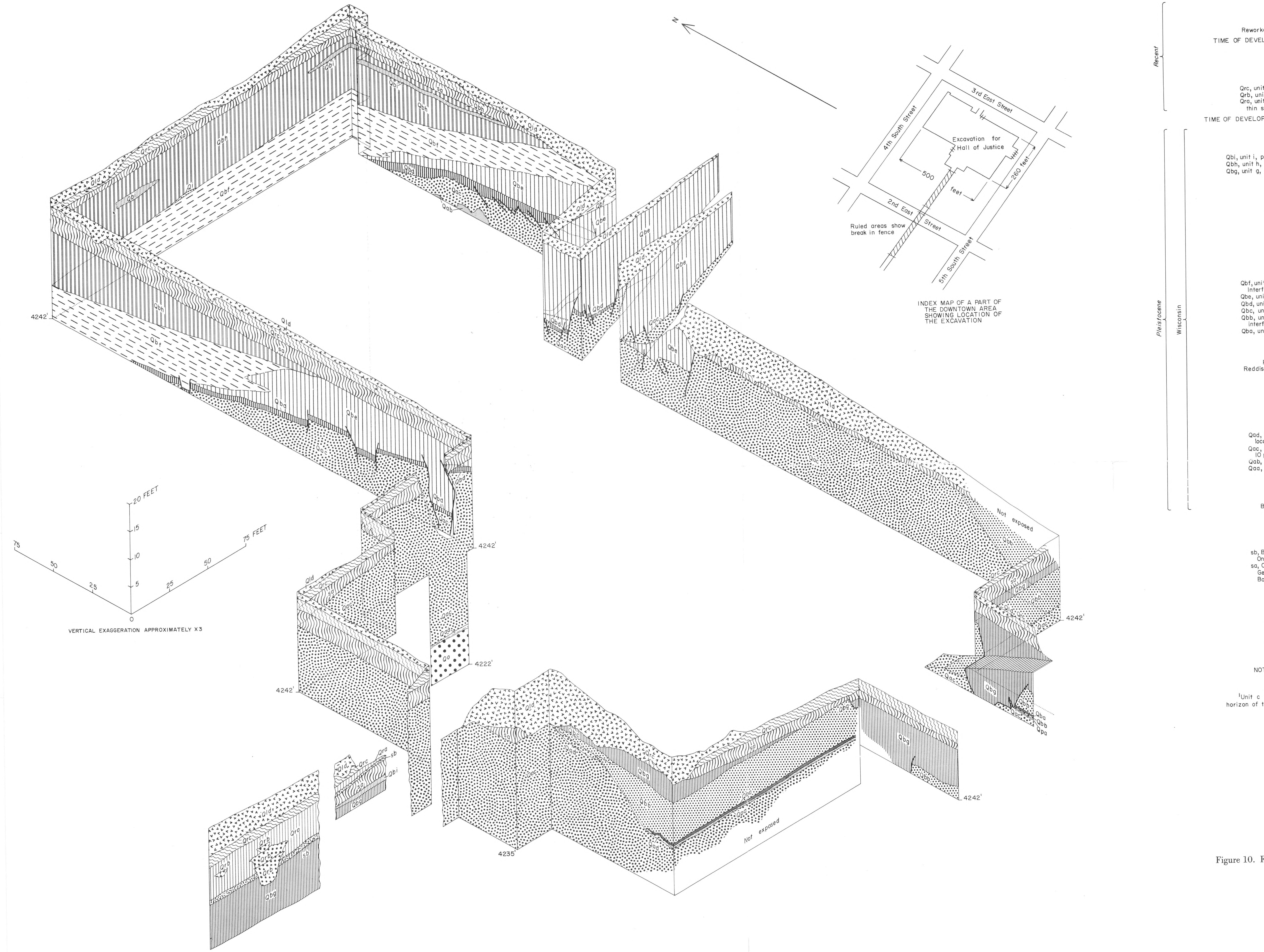

EXPLANATION

Recent

Qld
Later deposits
Reworked silt to gravel, glass, bricks, and metal

TIME OF DEVELOPMENT OF THE POST-LAKE BONNEVILLE SOIL

Qrc / Qrb / Qra
Post-Lake Bonneville alluvium
Qrc, unit c, dark-gray silt[1], prismatic to blocky, humic
Qrb, unit b, very silty pebble gravel
Qra, unit a, light-brown sandy silt. Upper part has very thin streaks and tiny spots of calcium carbonate

TIME OF DEVELOPMENT OF THE POST-BONNEVILLE FORMATION SOIL

Pleistocene — Wisconsin

Qbh / Qbi / Qbg
Upper part of Bonneville Formation
Qbi, unit i, pinkish-gray silt
Qbh, unit h, light-brown to light-gray clayey silt
Qbg, unit g, greenish-gray to light-grayish-brown clayey silt

Qi
Intra-Bonneville Formation gravel
Fine-grained gravel; may be alluvium

Qbf / Qbe / Qbd / Qbc / Qbb / Qba
Lower part of Bonneville Formation
Qbf, unit f, medium- to bluish-gray blocky clay. Interfingers and grades into unit e
Qbe, unit e, light- to light-grayish-brown clayey silt
Qbd, unit d, pale-brown thin-bedded sandy silt
Qbc, unit c, greenish-gray silty and clayey gravel
Qbb, unit b, poorly sorted gravel. Lower 0.5 foot interfingers with underlying unit a
Qba, unit a, white to very light gray marly silt

Qpa
Post-Alpine Formation clay and gravel
Reddish-brown slightly calcareous to noncalcareous clay and gravel; may be alluvium

Qad / Qac / Qab / Qaa
Alpine Formation
Qad, unit d, silty oxidized reddish-brown zone locally developed on upper part of unit c
Qac, unit c, poorly sorted gravel containing about 10 percent of interbedded silt
Qab, unit b, interbedded silt and clayey silt
Qaa, unit a, gray silty clay

Qo
Old alluvium
Bouldery gravel in a light-gray clayey matrix

QUATERNARY

sb / sa
Post-Bonneville Formation soil
sb, B horizon, dark-gray clayey to sandy silt. Only locally preserved
sa, Cca horizon, light-gray strongly calcareous silt. Generally is the combined Cca horizons of the post-Bonneville Formation and post-Lake Bonneville soils

Contact
Dashed where gradational.
Dotted where concealed by one fence

Fault
Dotted where concealed by one fence

NOTE: Altitudes are feet above mean sea level

[1]Unit c of the post-Lake Bonneville alluvium is the B horizon of the post-Lake Bonneville soil developed on alluvium.

Figure 10. FENCE DIAGRAM OF EXCAVATION SITE.