STUDY OF EARTHQUAKE RECURRENCE INTERVALS on the WASATCH FAULT, UTAH

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December 10, 1975

Contract No. 14-08-0001-14567

U.S. Geological Survey
345 Middlefield Road
Menlo Park
California 94025

Attention: Dr. Jack F. Evernden
Program Manager

Regarding: STUDY OF
EARTHQUAKE RECURRENCE INTERVALS
ON THE
WASATCH FAULT, UTAH

Gentlemen:

Attached are five copies of our final technical report covering a study that is oriented toward developing criteria by which recurrence intervals of moderate to large earthquakes along the Wasatch Fault may be determined from geologic evidence, and toward locating specific areas in which further detailed field study is most likely to yield information regarding the recurrence of surface faulting.

The two tasks of this study, selection of localities for field investigation, and reconnaissance geologic study, have resulted in identifying six localities along the Wasatch Fault that appear optimum to study in detail, and also resulted in general observations of importance when considering geologic data to estimate recurrence of earthquakes.

This study represents an important step toward identifying earthquake-related hazards in close proximity to a major population concentration. The Wasatch Fault is very likely to yield much more data regarding active normal-slip faulting when detailed surficial and subsurficial investigations are pursued.

Thank you for the opportunity to work with personnel of the U.S. Geological Survey on this extremely important project, and for the interest and encouragement that this project has received.

Very truly yours,

Lloyd S. Cluff
Principal Engineering Geologist

LSC:jfm
Enclosure

STUDY OF
EARTHQUAKE RECURRENCE INTERVALS ON
THE WASATCH FAULT, UTAH.

FINAL TECHNICAL REPORT

1975

Sponsored by the

U. S. Geological Survey

Contract No. 14-08-0001-14567

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Consulting Engineers, Geologists, and Environmental Scientists
San Francisco, California

TITLE PAGE

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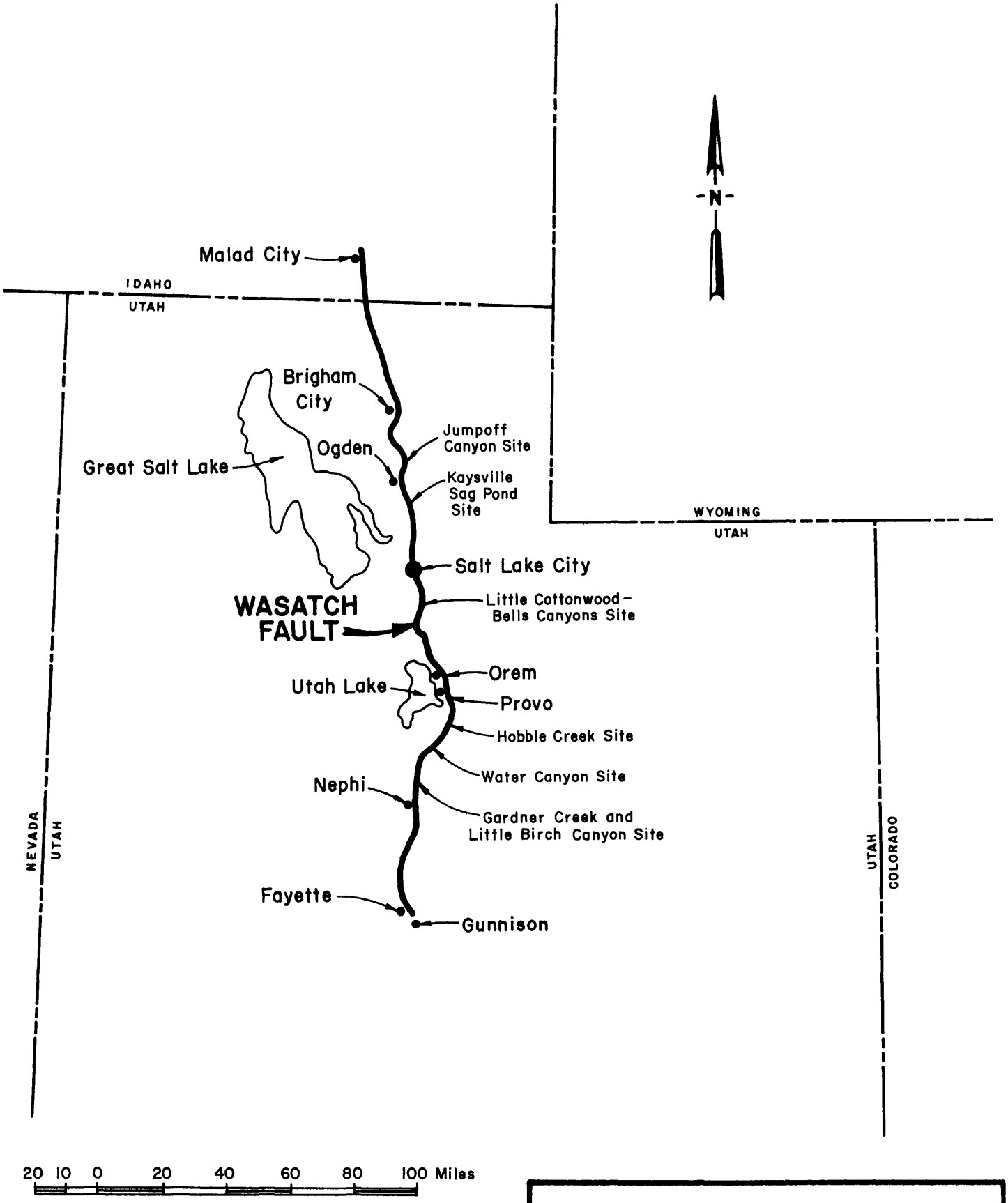
INTRODUCTION

Recurrence intervals of moderate to large earthquakes along the Wasatch fault have been estimated from historical seismicity but not from the late Quaternary geologic record. The Wasatch fault offers a unique opportunity to collect data regarding recurrence of surface faulting because it displaces, by varying amounts, many late Quaternary deposits. The fault displacements could be dated by evaluating the relationships of the displaced strata to the partially dated stratigraphy of the Lake Bonneville area and by carbon-14 dates on materials younger than the Alpine Formation (less than 25,000 years old).

This investigation was undertaken with two goals in mind: (1) to develop and/or refine field criteria by which recurrence intervals of moderate to large earthquakes (magnitude greater than 6) could be determined for the Wasatch fault zone; and (2) to locate areas where further detailed work has the highest probability of yielding information regarding recurrence of surface faulting.

The Wasatch fault defines the western edge of the Wasatch Range and linearly contiguous ranges for a distance of approximately 200 miles (Figure 1). (Locations referred to and not mapped in this report may be found on U. S. Geological Survey topographic maps of the area.) It is a normal fault dipping 50 to 70° west and has a net vertical displacement of up to about 14,000 feet (Crittenden, 1964). The fault is not one continuous break but a sequence of irregular, generally north-trending en echelon segments, each of which shows varying indications of recency of faulting. In places, the fault swings sharply away from a northerly trend, and elsewhere it appears to die out, only to continue again en echelon to the east or west.

The fault is actually a fault zone hundreds or even thousands of feet wide in which complex surficial fracturing is common. In its largest sense and at depth the fault probably represents a simple, steeply-dipping fracture along which lithospheric extension is occurring (thus the normal, essentially dip-slip, aspect of the fault). However, in the weak sediments and under the low confining pressures near the surface, it often is expressed as a multiplicity of minor features such as discontinuous step



LOCATION MAP OF WASATCH FAULT AND SITES RECOMMENDED FOR FURTHER INVESTIGATION

Project No. G-13187	Figure 1
WOODWARD-CLYDE CONSULTANTS	Page 2

and antithetic faults, sharply branching and rejoining segments, splays, graben, sags, and associated tilted surfaces.

PREVIOUS WORK AND ACKNOWLEDGMENTS

Various reports in recent years (as well as older reports) have noted evidences of the active character of the Wasatch fault (Bissell, 1963; Cluff and others, 1970, 1973; Cook, 1972; Marsell, 1964; Morisawa, 1972; Morrison, 1965a, 1965b; among many) and a few reports have shown that fault displacements are visible in many places in the lacustrine and fluvial sediments, as well as in several places in glacial moraines (Bissell, 1963; Gilbert, 1928; Hunt and others, 1953; Marsell, 1964; Morrison, 1965a; Richmond, 1964). Earthquake recurrence curves have recently been determined for the fault zone based on a statistical study of earthquakes between 1932 and 1961 along the Intermountain Seismic Belt (Smith, 1972). Smith's study suggests that a major event of magnitude 7 could occur approximately every 76 years, despite the fact that no earthquakes greater than magnitude 6.0 have occurred since 1847.

Stratigraphy studies by Bissell (1963), Richmond (1964), and Morrison (1965a, 1965b) provided a basis for the subdivision of Quaternary deposits along the fault. Especially helpful were in-field consultations with Richard Van Horn and M. D. Crittenden, Jr., of the U. S. Geological Survey.

This investigation was conducted by Gary A. Carver and John C. Young. The report was edited by Janet L. Born.

METHOD AND SCOPE

Field work during the summer of 1974 commenced with aerial reconnaissance of the fault zone from its southernmost extent near Gunnison, Utah, northward to the vicinity of Cutler Dam (approximately 15 miles south of the Idaho border). The reconnaissance was made during morning hours when the low angle of the sun enhanced the observation of west-facing scarps. Previous literature regarding the area was used extensively, and vertical (1965) and low-sun-angle (1969) aerial photographs of the area were interpreted. Ground observations were

conducted in the area between Nephi and Brigham City, with areas of concentration mainly near the population centers of Ogden, Salt Lake City, and Provo-Springville. Those areas that showed promise for a maximum yield of information regarding recurrence were then investigated further, with the idea of delineating several localities that would yield high returns from future detailed work. Numerous scarp heights and angles were measured; soil units, stratigraphic units, and artificial cuts (gravel pits, roadcuts, trenches) were examined; and attempts were made to collect fossil organic material that might yield carbon-14 dates. The results of the detailed analyses of the various areas are presented in this report.

GEOLOGIC COMPOSITION OF THE WASATCH FOOTWALL BETWEEN BRIGHAM CITY AND NEPHI

The upthrown side or footwall of the Wasatch fault has resulted in exposure of a great north-south panorama of predominantly sedimentary rock ranging in age from Precambrian to Quaternary. Igneous and metamorphic rocks are also present.

Paleozoic carbonate rock makes up the mountain block between Brigham City and Willard. Southward from Willard to the vicinity of the Weber River are stratigraphic units consisting primarily of Lower Cambrian and upper Precambrian quartzite and argillite. The Farmington Canyon complex of Precambrian gneiss and schist occupies the range between Weber Canyon and Bountiful. Tertiary clastic rocks (mostly conglomerate) cap upturned lower and middle Paleozoic rocks in the Warm Springs Spur between Bountiful and Salt Lake City. East of Salt Lake City, there is a section of east- to northeast-trending Paleozoic and Mesozoic rocks (mostly shelf carbonate and clastic rocks) passing downsection southward into the Precambrian clastic rocks exposed in the escarpment between Mt. Olympus and northern Utah Valley. The quartz monzonite Little Cottonwood Stock intrudes the Precambrian rock between Big Cottonwood Canyon and Corner Creek.

Paleozoic carbonate and subordinate clastic rocks of miogeosynclinal facies appear in the mountain front near American Fork Canyon, persisting thereafter as far south as Nephi, although localized areas of

Cambrian and upper Precambrian clastic rocks (east of Provo) and Tertiary red beds and conglomerate (southeast of Santaquin) are present.

The Wasatch fault transects major thrust faults in the Willard-Ogden areas, near Corner Creek southeast of Salt Lake City, and northeast of Nephi. Prominent east- to northeast-trending folds are visible east of Salt Lake City; elsewhere the fold trends are more variable. Remnants of late Quaternary alluvial, fluvial, lacustrine, glaciofluvial, and glacial sediments are preserved along most of the low flanks of the escarpment.

LATE QUATERNARY STRATIGRAPHY

Stratigraphic units representing repeated changes in depositional environments, relict and buried soils, and morphostratigraphic features resulting from erosional and depositional processes associated with late Quaternary climatic fluctuations characterize the surface and near-surface geology along much of the length of the Wasatch fault. These units define a stratigraphic sequence that has been the subject of considerable study and has provided significant information concerning the late Quaternary history of the region (Bissell, 1963; Morrison, 1965a, 1965b; Richmond, 1964; and others). Faulting of these stratigraphic units has been noted at many localities by previous investigators and during this study. The thesis of this investigation is that the systematic analysis of the amounts of displacement of the various late Quaternary units will provide new and significant information concerning the character and frequency of surface faulting along the Wasatch fault.

Rock-stratigraphic units displaced by the Wasatch fault include: lacustrine sediments deposited in large, fresh water pluvial lakes; glacial and glaciofluvial sediments associated with multiple glaciation in the Wasatch and Uinta Mountains; and alluvial fans and deposits of colluvium along the front of the Wasatch Range. The units are bounded vertically by unconformities representing intervals of non-deposition and local erosion. Individual units are commonly discontinuous and frequently exhibit rapid lateral changes in lithofacies, internal structures, textures, and thicknesses. The various deposits express the effects of climatic alternations between wetter-cooler and dryer-warmer conditions characteristic

of the late Quaternary. In general, wetter-cooler intervals were accompanied by lacustrine deposition in pluvial lakes and associated alpine glaciation of the higher portions of the Wasatch Range. Valley glaciers reached the fault zone at the range front in several places southeast of Salt Lake City during the Wisconsin glacial maximum. Glaciofluvial deposition occurred in the principal valleys in the Wasatch Range and near the mouths of these valleys at the range front. Dryer-warmer intervals were associated with alluvial and colluvial deposition and alluvial fan development at the mouths of the smaller valleys and along the base of the range front, together with the development of soils, particularly on deposits of lacustrine and fluvial sediments. Erosion of the lacustrine deposits and entrenchment of the larger (permanent) streams also characterized dryer-warmer intervals.

The Stratigraphic Sequence

The late Quaternary stratigraphic sequence used in this study (Figure 2) represents, with minor modifications, a composite of the stratigraphic sequences proposed by Bissell (1963), Morrison (1965b), Richmond (1964), and Van Horn (oral communication, 1974) for the eastern portions of the Jordan and Utah Valleys.

The sequence is subdivided into four formations consisting of broadly time-equivalent and genetically related lacustrine, fluvial, glaciofluvial, and glacial sedimentary facies. Locally, minor deposits of alluvial origin are also present. Formations are separated by unconformities, paleosols, alluvial fan deposits and colluvium. Detailed characteristics of the stratigraphy at each site are discussed in the following sections.

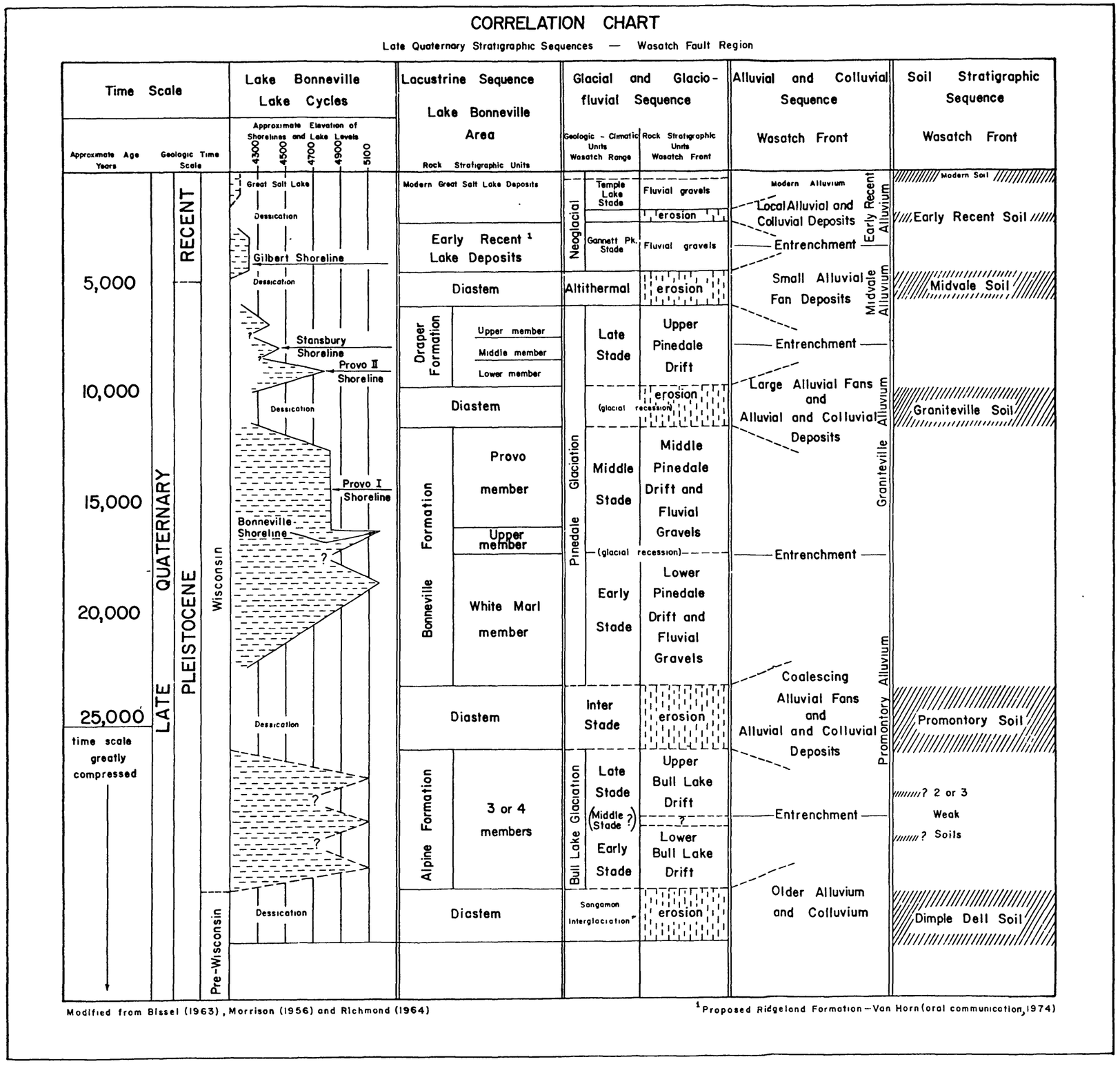
SITES RECOMMENDED FOR FURTHER INVESTIGATION

Six localities were selected for consideration in further investigations (Figure 1). These sites are discussed below in order from north to south.

JUMPOFF CANYON SITE

Location and Setting

The Jumpoff Canyon site includes the eastern one-third of Section 9 and the western margin of Section 10, T6N, R1W. The site is located on the northern margin of the City of Ogden (Figure 1). It includes alluvial fan



STRATIGRAPHIC CORRELATIONS FOR WASATCH FAULT SYSTEM

Project No. G-13187	Figure 2
WOODWARD-CLYDE CONSULTANTS	Page 7

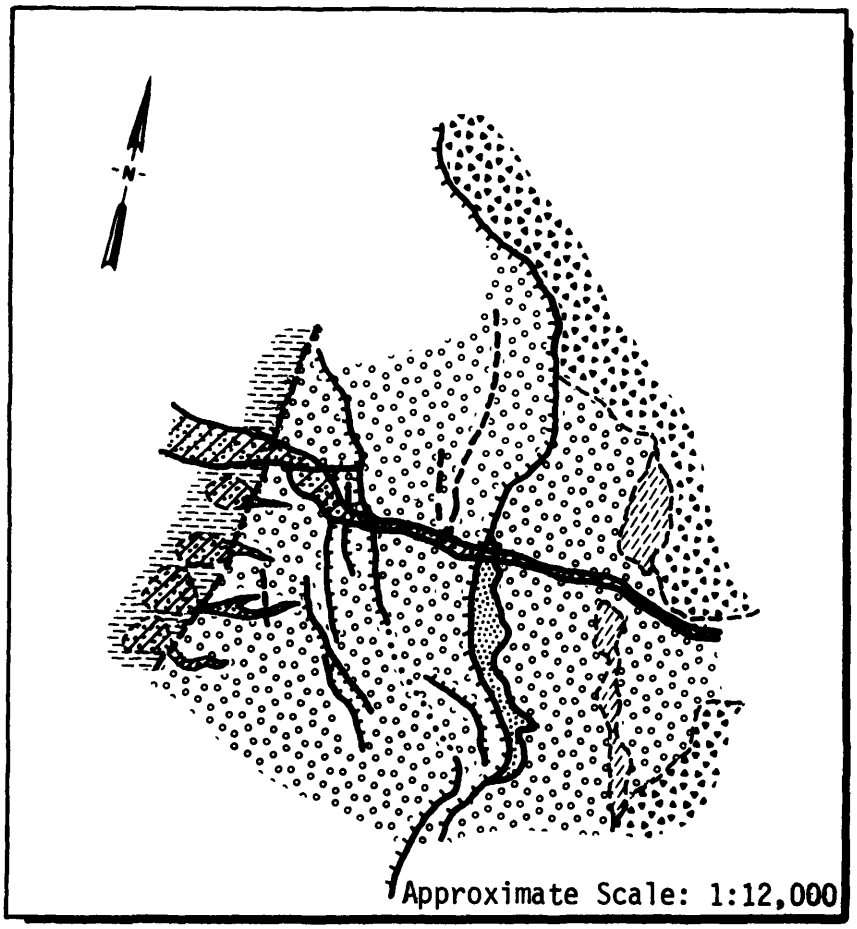
and mud and debris flow deposits that radiate into the valley from the mouth of Jumpoff Canyon, a steep and rugged canyon cut into the southern flank of Mt. Lewis (8031 feet). Also present are lacustrine sediments and a large landslide deposit. These deposits are complexly faulted across a zone approximately 2000 feet wide (Figure 3).

Stratigraphy

The oldest late Quaternary deposits visible are light-colored, thinly bedded, lacustrine silt exposed in the easternmost principal fault scarp, and in other scarps and elevated fault-bounded blocks within the fault zone. They are assigned to the Alpine Formation on the basis of the character and stratigraphic position of the sediments.

Other lake sediments include beach deposits along two distinct shorelines east of the fault at elevations of approximately 4800 and 5200 feet. These shoreline deposits are correlated with the Provo I and Bonneville lake levels respectively; the associated sediments are tentatively assigned to the Bonneville Formation (Upper and Provo members), although the lower shoreline may also be related, in part, to the Provo II shoreline. Buff silt, tentatively assigned to the Provo Member of the Bonneville Formation, crops out locally on the fan surface below the mouth of the canyon and rests on a well-developed zonal soil that formed on bouldery mud and debris flow deposits.

At least four distinct intervals of late Quarternary alluvial fan development are represented at the mouth of Jumpoff Canyon by a large, complex alluvial fan. The different components are separated by episodes of lacustrine sedimentation, shoreline erosion and deposition, and stream entrenchment. The oldest fan deposits consist of bouldery mudflow sediments and fanglomerate exposed mainly along the southern margin of the fan and at the mouth of Jumpoff Canyon, where they overlie silt of the Alpine Formation. The distinct shorelines at approximately 4800 feet and 5200 feet, correlated with the Provo I and Bonneville lake levels, are cut into these sediments. Thus, the sediments were deposited during the Alpine-Bonneville interpluvial interval. In the canyon mouth east of the fault, these older fan deposits and the Bonneville and Provo shorelines are deeply incised by Jumpoff Creek. A bouldery mudflow deposit



EXPLANATION:

- POST-MIDVALE INCISION & ALLUVIUM
- STANSBURY SHORELINE (?)
- PROVO SHORELINE
- UNDIFFERENTIATED FAN COMPLEX; INCLUDES OLDER & YOUNGER SOILS & LACUSTRINE UNITS
- ALPINE FORMATION
- BEDROCK OF WASATCH RANGE
- INFERRED CONTACT
- POSSIBLE FAULT
- FAULT SCARP; HACHURES ON DOWNTHROWN SIDE; DOTTED WHERE APPROXIMATELY LOCATED

RECONNAISSANCE GEOLOGIC SKETCH MAP OF THE JUMPOFF CANYON SITE

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forms a bulky fan within the fault zone at the mouth of the Jumpoff Creek incision. This deposit rests upon the Alpine-Bonneville interpluvial alluvium and on lacustrine silt that is tentatively correlated with the Provo I lake cycle, although the silt may be older. The fan is faulted in several places. Portions are partially buried by younger sediments. Exposed surfaces on the deposit are deeply weathered and eroded, and are mantled by a patchy soil possibly equivalent to the Graniteville soil. Based upon their apparent position between the Provo Member and Draper Formation, the fans were deposited during the Provo I-Provo II interpluvial period.

Younger alluvium and colluvium are present as channel filling east of the fault, and around the margins of the Graniteville alluvial fan deposits in the fault zone. These sediments also mantle much of the surface of the Bonneville-Provo I fan deposits. They are distinguished from older fan deposits by the lack of large boulders, the fine-grained matrix of the sediments, and stratigraphic position. The deposits are capped locally by a well-developed Midvale soil believed to be Midvale alluvium resulting from an interval of active fan development associated with the altithermal.

The youngest alluvial fan deposits recognized at the Jumpoff Creek site consist of small fanlets formed at the base of some of the fault scarps and at the mouths of gullies cut into the older deposits. These sediments include alluvial gravel and colluvium which are stratigraphically above the Midvale soil and are in turn mantled by an incipient soil. They are correlated with the early Recent and post-early Recent deposits of the lacustrine and alluvial stratigraphic sequences.

Other deposits at Jumpoff Creek include a large, partially buried landslide north of the canyon mouth. The landslide deposit consists of bouldery debris partially covered with alluvial fan sediments and lacustrine silt. Neither the age nor stratigraphic position of the landslide deposit are known. The presence of typical hummocky landslide topography on the valley floor suggests that the deposit rests on top of the generally

thick lake deposits of the Alpine Formation. Provo I shoreline sediments appear to mantle the landslide debris north of the mouth of Jumpoff Canyon. Lacustrine silt, which mantles much of the lower part of the deposit, may belong to the Provo Member of the Bonneville Formation or may represent younger lake deposits. Many closed depressions are present on the slide surface, and a large marshy area is present on the slide deposit along the main trace of the Wasatch fault.

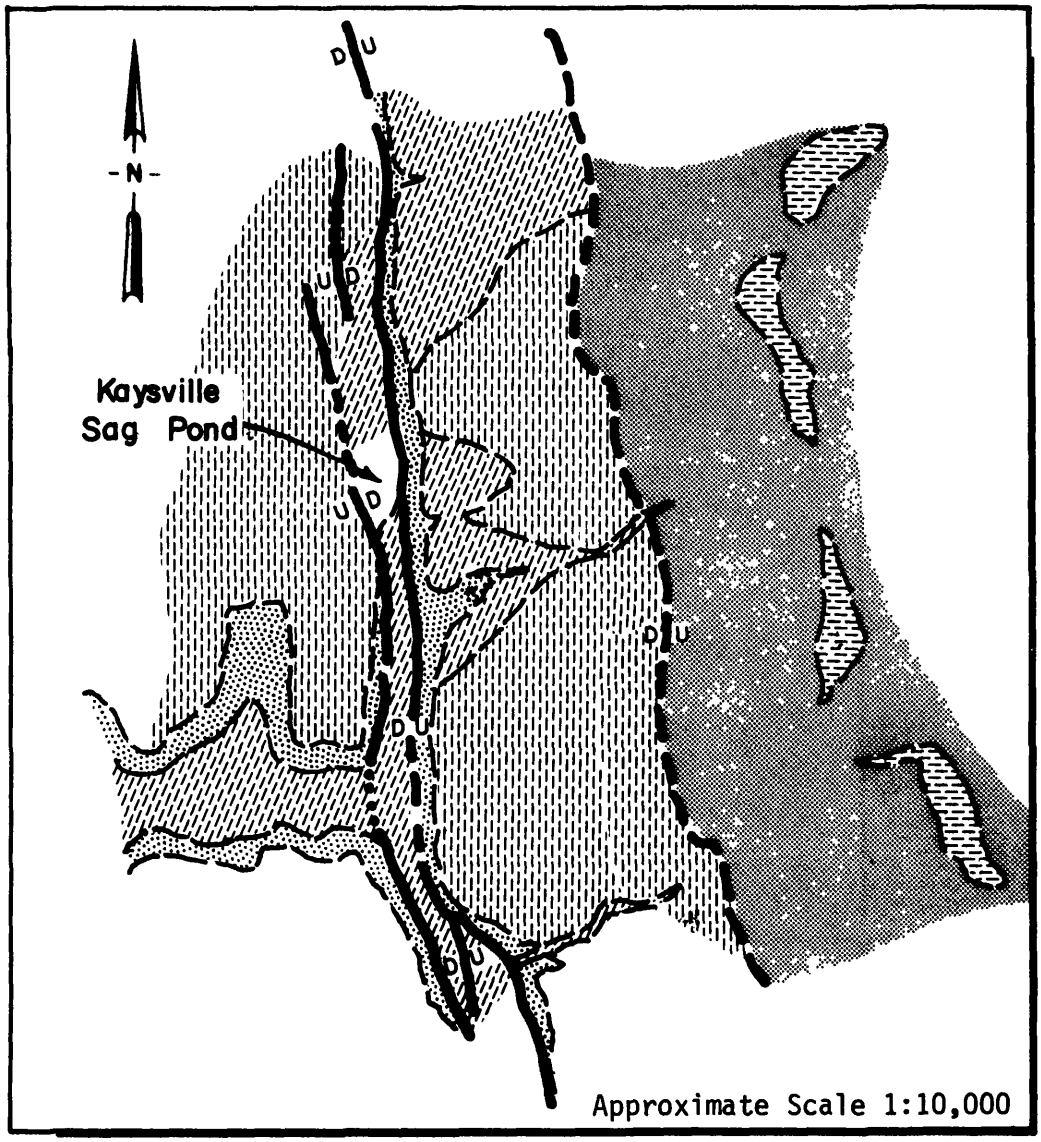
Faulting

Late Quaternary displacement of the Wasatch fault at Jumpoff Creek has resulted in displacement of the various alluvial fan and lacustrine deposits along one main fault trace and a number of subsidiary branches and traces within a zone approximately 2000 feet wide. The faulting has created a series of scarps and associated fault features including several small graben. Drainage has been disrupted and faulting has influenced erosional and depositional patterns on the fan. In general, scarp heights are greater along fault-trace segments cutting older deposits. However, some portions of the scarps are considerably modified by erosion or are partially buried. Presently available data are insufficient to allow the development of a time-displacement history for the fault at the Jumpoff Canyon site; however, a detailed mapping program augmented by trenching and shallow drilling could result in a detailed time-displacement history of faulting for this segment of the Wasatch fault.

KAYSVILLE SAG POND SITE

Location and Setting

The Kaysville sag pond is located two miles southeast of the town of Kaysville, Davis County, in Section 1, T3N, R1E. It occupies a closed depression in a graben that parallels the steep front of the range and lies approximately 1000 feet west of it (Figure 4). Recent episodes of surface faulting have occurred along the zone occupied by the graben. Faulting prior to this may have followed this same trace or may have broken along the steep range front. Supporting the first suggestion is the possible presence of a narrow pediment between the recent trace



EXPLANATION:

POST-PROVO MEMBER - ALLUVIAL DEPOSITS

PROVO I MEMBER - BONNEVILLE FORMATION

BONNEVILLE SHORELINE

ALPINE FORMATION

PRE-QUATERNARY ROCKS

FAULTS - DASHED WHERE APPROXIMATELY LOCATED, DOTTED WHERE CONCEALED OR INFERRED

INFERRED CONTACT

GEOLOGIC SKETCH MAP OF THE KAYSVILLE SAG POND SITE

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and the steep front, suggesting that all displacement has been along the presently active trace; but a long period of inactivity prior to the development of the recent scarp permitted eastward retreat of the range front as the narrow pediment formed. Evidence for a pediment there consists of the presence, on aerial photographs, of linear bedrock structures in the mountain block south of the sag pond area that appear to project across the oldest trace mentioned above and to be planed off by the supposed pediment. This has not been verified in the field. Evidence for former faulting directly at the base of the steep front consists of the abrupt steepening of topography along this alignment and surface expression suggestive of a dissected scarp.

In this sector, the Wasatch Range rises steeply eastward to an altitude of over 9000 feet in a horizontal distance of two miles. Rocks in the range are schist, gneiss, and migmatite of the Precambrian Farmington Canyon complex.

Stratigraphy

The Quaternary stratigraphy is poorly exposed and must, therefore, be largely inferred. Beneath the sag pond itself, an unknown thickness of organic mud is expected, deposited during swampy periods, interbedded with coarse deposits derived from erosion of the scarp and mountain block on the east. Provided that the fan on the south blocked drainage in that direction, deposition of the lowest organic muds should closely follow the inception of the sag pond--and presumably the faulting associated with it--whereas, the coarse layers may record pulses of scarp incision associated with the faulting. One anticipated difficulty in interpreting borings from this sag pond would be in distinguishing such tectonically induced alluvial deposits from those brought in from the range to the east by the influx of mudflow debris associated with cloudburst floods. Perhaps the latter will be texturally and compositionally different (more angular, more soily matrix) from the former. The latter may also show an abrupt change upward from coarse to fine material, whereas the former would grade upward from coarse to fine.

The late Quaternary stratigraphy in the scarp east of the sag pond is poorly known. The inferred stratigraphy would consist of a series of interbedded lacustrine and beach layers, fan deposits, and associated soils representing the pluvial and interpluvial sequence, commencing with those deposited in Lake Alpine, and ending stratigraphically upwards with the post-Provo-II-level fans. One good exposure of Alpine-like layered silt is present in the south side of the first large gully 800 feet south of the sag pond. Since the Stansbury shoreline is located west of the site, lake or shoreline sediments of this time were not contributed to the sequence.

Faulting

The sag pond lies in a graben at the base of a west-facing piedmont scarp that is approximately 74 feet high and has the upper 16 feet at a lower angle than the lower portion. The western side of the graben is formed by a minor antithetic fault scarp approximately 6 feet high. A natural rise in elevation northward closes the sag there; to the south, it is closed by an alluvial fan. The time of inception of this faulting is probably Provo I time or later, as the fault cuts a surface that most likely has a veneer of Provo I sediments. One-half mile to the south, where the scarp crosses the first large gully north of Shepard Creek, three periods of faulting are clearly evident in the scarp east of the sag pond. However, it is not known if the graben and sag pond came into being with the first or a later period of faulting along the scarp.

LITTLE COTTONWOOD-BELLS CANYONS SITE

Location and Setting

The Little Cottonwood-Bells Canyons site is located in southeastern Salt Lake County at the mouths of Little Cottonwood Canyon and Bells Canyon in the northeastern part of T35, R1E (Sections 1, 2, 11, 12, 13, and 14). The Wasatch Mountains rise abruptly from the Salt Lake Valley, attaining elevations of over 11,000 feet within three miles of the base of the range. Two large, glacially carved valleys, Little Cottonwood and Bells Canyons, are deeply incised into the range. The Wasatch fault in this segment trends approximately north. Bedrock in the mountain front consists of

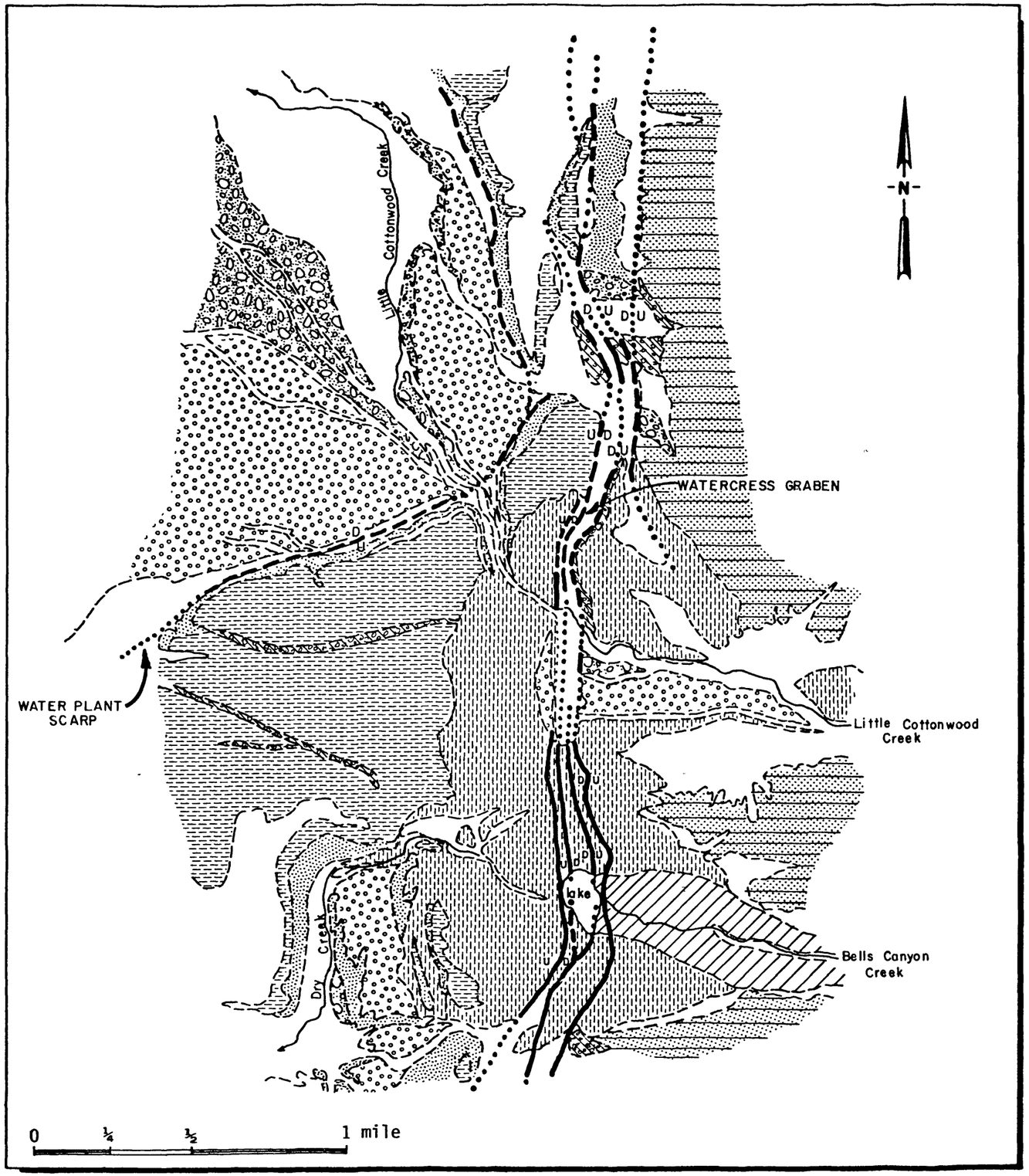
late Precambrian clastics (mostly quartzite) intruded by quartz monzonite of the early Tertiary Little Cottonwood Stock. Late Quaternary lacustrine, fluvial, alluvial, glaciofluvial, and glacial sediments abut the mountain front at the mouths of Little Cottonwood and Bells Canyons (Figure 5). Spectacular fault features (multiple scarps, grabens, sags, tilted surfaces) lie in a zone as wide as one-quarter mile at the base of the range.

Stratigraphy

The following summary of the late Quaternary stratigraphy at the mouth of Little Cottonwood and Bells Canyons is taken largely from Morrison (1965b). These localities are the only ones along the Wasatch front where lake sediments and Wisconsin glacial sequences are known to intertongue and can be directly correlated.

Three and possibly four successive units of till (and associated outwash) are present and can be correlated with stades of the Bull Lake glaciation. They are underlain and separated by wedges of lake sediments (sand, gravel, silt) of the Alpine Formation that record rises of the lake (Lake Alpine) approximately synchronous with the glaciation. At the top of the highest till-outwash unit is an unconformity that locally bears a strongly developed pedalfer soil, correlated with the Promontory soil. Thus an extended period of subaerial exposure is indicated following the early Wisconsin later levels and associated glacial advances. Overlying this soil and unconformity and extending to the Bonneville shoreline are several feet to more than 25 feet of lacustrine sand, gravel, and local marly silt, which are correlated with the white marl and upper members of the Bonneville Formation. Although direct correlation of these younger Lake Bonneville sediments with glacial stades is difficult, indirect correlation is achieved by soil stratigraphy and comparison of similar climatic-depositional cycles. On this basis, the white marl and upper members are correlated with early and middle stades of the Pinedale glaciations.

The rapid drop in lake level to the Provo I level resulted in aerial exposure and weathering of the sediment in the areas above approximately



EXPLANATION:

- POST DRAPER FORMATION ALLUVIUM, COLLUVIUM, TALUS, EOLIAN DEPOSITS
- ALLUVIAL SAND & GRAVEL CORRELATING WITH THE DRAPER FORMATION
- PINEDALE GLACIATION TILL & OUTWASH
- ALLUVIAL GRAVEL CORRELATING WITH PROVO I MEMBER OF BONNEVILLE FORMATION
- BONNEVILLE FORMATION – WHITE MARL & UPPER MEMBERS
- UNDIFFERENTIATED ALLUVIAL GRAVELS OF LAKE ALPINE-BONNEVILLE AGE
- UNDIFFERENTIATED LACUSTRINE SEDIMENTS
- BULL LAKE GLACIATION TILL & OUTWASH
- ALPINE FORMATION-LACUSTRINE SEDIMENTS
- PRE-LAKE ALPINE-BONNEVILLE SLOPE DEPOSITS & BEDROCK UNDIFFERENTIATED
- FAULTS - DASHED WHERE APPROXIMATELY LOCATED, DOTTED WHERE CONCEALED OR INFERRED
- INFERRED CONTACT

Generalized and modified slightly from Plate I of Morrison (1965a)

GEOLOGIC SKETCH MAP OF THE LITTLE COTTONWOOD - BELLS CANYONS SITE	
Project No. G-13187	Figure 5
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4800 feet elevation at the mouths of Little Cottonwood and Bells Canyons, with an attendant prolonged period, extending to the present time in places, of erosion and/or soil formation, plus deposition of alluvium, colluvium, and glacial outwash material. Provo I and later lake sediments were deposited west of the area, and the late Pinedale glacial till did not extend to the mouths of the canyons.

The mature soil that developed on the surface that lies east of the Provo I level and was not eroded or covered by younger sediments is called the Graniteville soil.

Faulting

The spectacular features of recent Quaternary faulting along this segment of the Wasatch fault have long received attention (Morrison, 1965a, 1965b; Richmond, 1964). Large, clearly defined scarps cut a variety of glacial, fluvial, and lacustrine deposits and land forms. The landscape includes numerous scarps or scarp-like features of various origins, including fluvial terraces, wave-cut scarps, landslide scarps, and fault-related scarps of several types. Three prominent scarps or groups of scarps have been identified as possible fault scarps. These are:

(1) A deeply eroded and partially buried basal scarp along the range front.

(2) A large, fresh-looking arcuate scarp, herein called the "water plant scarp", located immediately east of the municipal water treatment plant approximately one-half mile northwest of the mouth of Little Cottonwood Canyon.

(3) A zone approximately one-quarter mile wide of prominent scarps and other fault-related features trending generally parallel to the range and located a few hundred yards west of the base of the range.

Of these three features, the basal scarp along the range front appears to be the oldest. It is visible between Big and Little Cottonwood Canyons

as a somewhat subdued and dissected scarp, cutting early Bull Lake till just north of the mouth of Little Cottonwood Canyon and continuing northward toward Big Cottonwood Canyon as a line between the valley and the mountains. On the south side of Little Cottonwood Canyon and at the mouth of Bells Canyon, the scarp apparently is obscured by younger Bull Lake till. The most recent displacement on this scarp can be dated as mid-Alpine or older; it appears to cut the older Bull Lake till at the mouth of Bells Canyon and is overlapped by the younger Bull Lake till. No sizeable displacement has occurred on this trace since that time. The height of this scarp is roughly 100 feet at a locality one-half mile north of Little Cottonwood Canyon.

There is no clear evidence in the Little Cottonwood-Bells Canyon area of faulting between the middle or older Alpine phase and post-Bonneville faulting described below, although some faulting during this time may have occurred along the zone of scarps paralleling the range (Figure 5).

The water plant scarp was formed during or following the highest stand of Lake Bonneville. This abrupt and fresh-looking scarp, just northwest of the mouth of Little Cottonwood Canyon (Figure 5), trends west-southwest through Sections 2 and 10 (T3S, R1E). The nature and origin of this escarpment is conjectural. The arcuate shape, orientation, and location of the scarp indicate that it may be the head scarp of an area of slumping and/or differential compaction in the valley fill to the northwest, possibly triggered by an earthquake. According to Morrison (1965a), this scarp "displaces the Bonneville Member and appears to date from the recession of the Bonneville-Provo lake cycle, after the Bonneville shoreline maximum, and probably shortly before or perhaps even during the Provo stillstand." Morrison (1965a) also states that the contact between Lake Alpine sediments and the underlying lower till and outwash of the Bull Lake stade in the scarp "appears to be dropped down at least 110 feet below its position as projected from exposures in the scarp." The scarp forms the southeastern edge of the terraces graded to the Provo and lower levels of Little Cottonwood Creek. The scarp may have been somewhat modified by lateral cutting of the creek during the Provo stillstand.

The water plant scarp diminishes rapidly in height to the southwest, where it appears to merge with the foreset area of the Little Cottonwood delta complex. To the northeast it joins, or has been displaced by, the zone of faults paralleling the front of the range. Recent construction in this northeastern area obscures many of the geologic relationships. There does not appear to have been appreciable displacement along the water plant scarp following the Provo I level stillstand; alluvium at the base of the scarp, graded to the Provo I level, appears undisturbed.

The most conspicuous zone of faulted terrain lies between the two features discussed, paralleling the range front. This zone contains well-known examples of complex scarps, displaced moraines, tilted fields, and graben. Lateral moraines of the early and late Bull Lake stades are displaced at the mouths of both Little Cottonwood and Bells Canyons (Richmond, 1964; Morrison, 1965a). The amount of vertical displacement of the older till is difficult to measure; that of the younger till on the north side of Bells Canyon approximates 85 feet. The faulting across the mouth of Bells Canyon displaces middle Pinedale outwash; so the faulting is, in part, post-middle Pinedale in age.

Northward from Bells Canyon, this conspicuous zone of faulting crosses the mouth of Little Cottonwood Canyon as a graben in the Pinedale outwash. Terraces present in the canyon upstream from the graben may be tectonic in origin, representing three or four major episodes of faulting and resulting in entrenchment of streams on the upthrown block. One such terrace is mapped as alluvium of late Provo (Provo II) age, while the next lower terrace is composed of alluvium deposited during the Stansbury stillstand (both late Pinedale in age; Morrison, 1965a). If the terraces can be shown to have resulted from faulting, then significant time-displacement information for post-Provo I interval could be acquired. The topographically higher area west of the Little Cottonwood graben and east of the water plant scarp is practically without terraces along the stream, and apparently represents a horst-like block through which the stream has downcut continuously without appreciable widening. Upper Bull Lake outwash, as mapped by Richmond (1964), rests on top

of this "horst" and just to the north of the stream is only approximately 40 feet lower than the equivalent deposits to the east of the graben. The bottom of the graben, however, is about 100 feet lower than the Bull Lake outwash to the east, and 60 feet lower than that to the west. The graben attains its most striking development in the half-mile stretch north of the stream. In the northern portion of this graben, the scarp on the east side rises 114 feet without apparent break in slope angle (44°). The upfaulted block to the west (northward continuation of the "horst") is only 24 feet above the graben. Thus, the total vertical displacement increases rapidly northward so that the upper Bull Lake till east and west of the graben has been displaced approximately 90 feet.

A portion of this graben forms a closed depression 0.4 mile north of Little Cottonwood Creek. This depression, here named the "watercress graben", was very likely a closed depression throughout most of the interval of graben formation. Surface drainage of the depression is blocked to the north by alluvial fans on the graben floor, and to the south by a ridge of upper Bull Lake till. Coring of this depression might provide a complete record of sediments representing phases of infilling and, presumably, might show indirectly episodes of faulting. The lowermost deposits in the undrained depression may yield datable organic material that could provide a minimum age for the creation of the graben. The fan across the north end of the graben has been displaced at least once by faulting, indicating that there were at least two periods of faulting involved in the graben formation.

North of the watercress graben, the fault separates into several subparallel traces. Recent construction has obscured the pattern in places. Nevertheless, an irregular and complex graben, with subordinate parallel fault traces, can be followed northward as far as the mouth of Big Cottonwood Canyon.

HOBBLE CREEK SITE

Location and Setting

The Hobble Creek site is located on the eastern fringe of Utah Valley where the west-flowing Hobble Creek leaves the Wasatch Range three

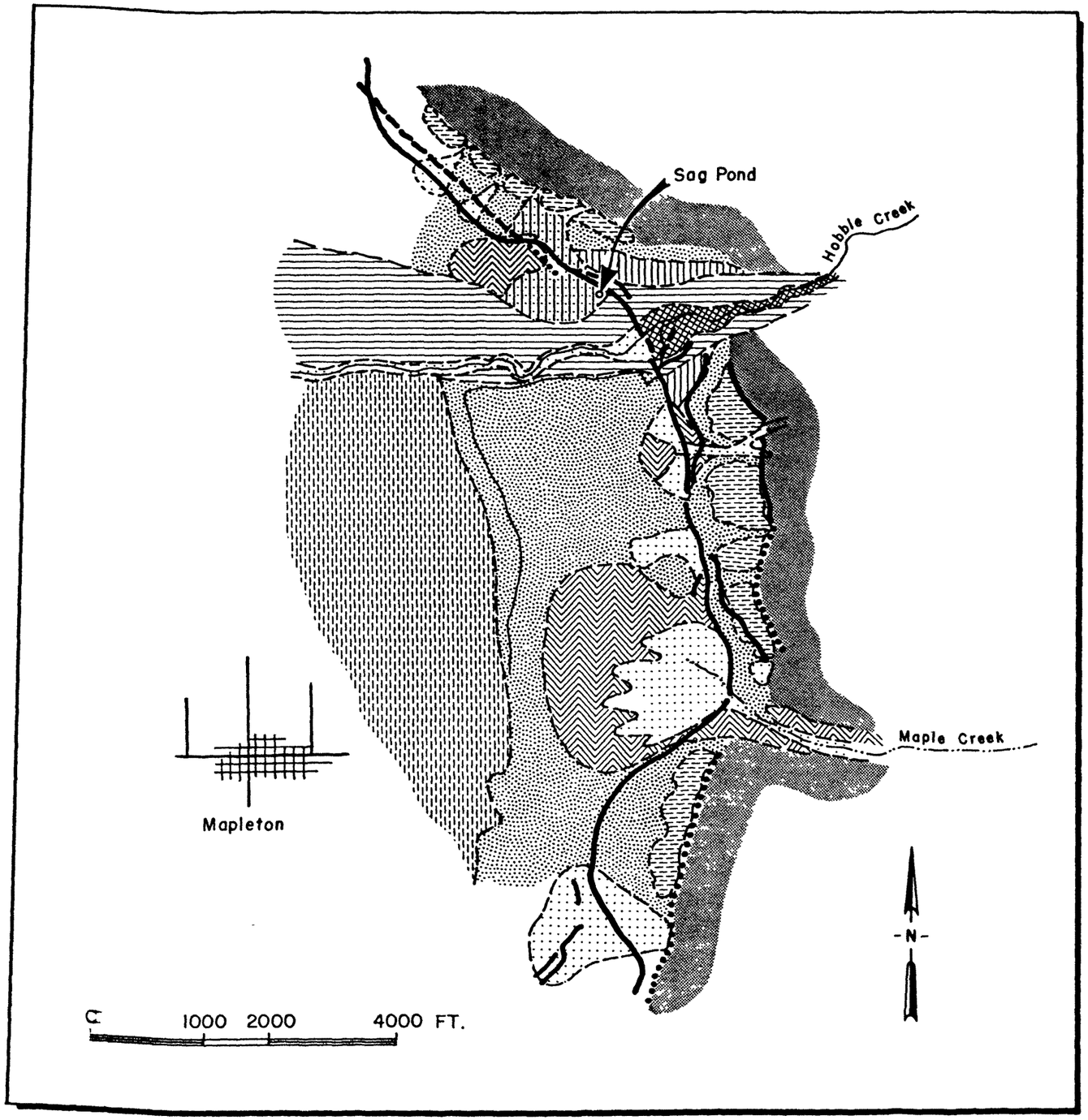
miles east of the town of Springville (Sections 1, 2, and 12, T8S, R3E). Although the range is comparatively low at this point, some of the most obvious and interesting basal scarps are located along this section of the fault. Rocks cropping out in the Wasatch Mountains are the upper Paleozoic Oquirrh Formation; those in the valley block are Quaternary alluvium and lacustrine deposits (Figure 6).

Stratigraphy

The following discussion of stratigraphic units at the mouth of Hobble Creek Canyon is based on the work of Bissell (1963), and includes modifications based on field observations and analysis of aerial photographs during the present study.

The oldest Quaternary unit exposed along the fault zone is the Alpine Formation, corresponding to the Bull Lake glaciation. Bissell (1963) measured 335 feet of predominantly medium- to coarse-grained brown and gray-brown silt less than one mile south of the mouth of Hobble Creek. He described subordinate layers of sand and gravel; the base of the unit is not exposed. This unit is present in steep slopes associated with the basal scarp of the Wasatch fault, and is visible in the sides of gullies incising the Alpine-Bonneville terrace east of this scarp. Bissell (1963) shows that the Alpine underlies much of the surface immediately west of the fault, overlapped by fan and stream alluvium. It is anticipated that post-Alpine/pre-Bonneville fan material is present west of the scarp resting on Alpine sediments; however, none was observed exposed at the surface, as it is covered by post-Bonneville alluvium. Alpine sediment west and east of the scarp should be mantled by a Promontory soil, if the soil has not been stripped or buried by younger deposits; however, this was not verified.

Bissell (1963) shows up to 35 feet of Bonneville cobble and boulder gravel mantling the higher (inner) part of the Alpine-Bonneville terrace. Since the Provo Member of the Bonneville Formation was deposited at a considerably lower altitude, these high-level gravels would represent shore deposits of only the white marl and/or upper member of the Bonneville Formation.



EXPLANATION:

- POST-DRAPER ALLUVIUM - UNDIFFERENTIATED
- POST-DRAPER ALLUVIUM - SHOWING "TECTONIC TERRACES"
- POST-DRAPER PRE-EARLY RECENT ALLUVIUM
- DRAPER FLUVIAL GRAVEL - GRADED TO EARLY UTAH LAKE LEVEL OF BISSELL (1963) (STANSBURY LEVEL)
- POST-BONNEVILLE - PRE-DRAPER FAN DEPOSITS
- FLUVIAL DEPOSITS - GRADED TO THE PROVO I LAKE LEVEL (UPPER BONNEVILLE FORMATION ALLUVIUM)
- PROVO I MEMBER - BONNEVILLE FORMATION
- BONNEVILLE SHORELINE - LOCAL DEPOSITS OF UPPER MEMBER BONNEVILLE FORMATION
- ALPINE FORMATION - VENEERED BY FLUVIAL DEPOSITS GRADED TO PROVO I LAKE LEVEL WEST OF THE FAULT
- PRE-QUATERNARY ROCKS
- FAULTS - DASHED WHERE APPROXIMATELY LOCATED, DOTTED WHERE CONCEALED OR INFERRED
- INFERRED CONTACT

RECONNAISSANCE GEOLOGIC SKETCH MAP OF THE HOBBLE CREEK SITE

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Provo I sediment (highest unit of the Bonneville Formation) is shown by Bissell as lapping onto the Alpine sediment about one-half to three-fourths mile west of the basal scarp. The interpretation based on the present study (not shown on the sketch map) would have much of this narrow corridor overlain by a thin veneer of Provo alluvium (resting mostly on Alpine sediment) that was deposited as part of the floodplain of Hobble Creek when it was graded to the Provo I shoreline. The prominent terrace at the mouth of Hobble Creek next below the Alpine-Bonneville terrace east of the basal scarp would also represent this level. If not eroded or covered by younger deposits, a Graniteville soil should exist on this terrace; such was tentatively identified east of the fault, just south of the mouth of Hobble Creek.

Fans present at the base of the fault scarp represent composite fans, the construction of which continues today. They must both interfinger with, and overlap, the various lacustrine and alluvial sediments.

The present broad floodplain of Hobble Creek west of the fault is believed to be an alluvial plain graded to the early Utah Lake level of Bissell (equivalent to the Stansbury level), although it may well have a veneer of younger floodplain debris. Since the first large fan north of Hobble Creek overlaps both the Provo terrace and this younger (Stansbury age?) floodplain, it must be younger, at least in its upper (near surface) part.

Faulting

The present fault scarp cutting the Alpine and younger deposits just south of Hobble Creek is believed to represent the sum of all post-Alpine, and possibly some late Alpine faulting. Some could be late Alpine if the upper Alpine deposits south of Hobble Creek in the scarp face are foreset beds. Actually, because the lower part of the scarp is buried by an unknown amount of debris, the present visible height gives only a minimum figure for vertical displacement during this time interval. Likewise, minimum figures for vertical displacements can be obtained for the fault for the post-Provo period where it displaces alluvium graded to that time. Tilting and antithetic faulting must be calculated into all

of these figures, when possible. For example, the actual minimum scarp height of the displaced Provo I alluvium just south of Hobble Creek is about 90 feet; but when the obvious tilt of the downthrown side toward the fault is taken into account, the real vertical displacement is closer to 50 feet. Figures thus obtained for the total displacement since late or post-Alpine time amount to approximately 250 feet (minimum); for Provo and younger, about 50 feet (minimum); and for all post-Stansbury, about 50 feet.

It is impossible at this time to determine the number of individual episodes of faulting within these cumulative displacements. Such a determination should be the primary objective of the next phase of this investigation. Since the Provo and Stansbury sediments appear to be displaced approximately the same amount, it would seem that there was little if any faulting between these two times. However, three, or possibly four, post-Stansbury terraces along Hobble Creek east of the fault suggest three or four major events in post-Stansbury time, aggregating at least 50 feet of vertical displacement. This is based on the assumption that these stream terraces are tectonic in origin; that is, related to rapid episodes of downcutting in the upthrown block associated with its sporadic elevation. That they occur in the upthrown block east of the fault, and not in the downthrown block on the west, supports this assumption.

It is difficult to conceive of the long period represented by the Alpine lakes and interpluvials as being without faulting. The stratigraphically highest, and therefore youngest, Alpine sediment may be displaced a minimum of approximately 250 feet. If Alpine deposition ended about 26,000 years ago and if Stansbury-age sediment, deposited about 8,000 years ago, is displaced a minimum of 50 feet, at least 200 feet of displacement should have occurred in the intervening 18,000 years. These figures, approximate as they are, and without knowing the depth of fill, give average rates of vertical displacement as follow: post-Alpine/pre-Stansbury, 0.9 feet per 100 years; post-Stansbury to present, 0.6 feet per 100 years. Such rates projected back to the beginning of Lake Alpine time (perhaps 75,000 years before present) would suggest

the possibility that the oldest Alpine sediment might be displaced as much as 460 to 800 feet.

If the upper part of the sequence of Alpine sediments, which is exposed in the fault scarp south of Hobble Creek, contains foreset beds, these might indicate that part of this scarp was created during the existence of Lake Alpine; an underwater scarp would create a favorable slope over which to drape foreset beds. If such was the case, the above figures would be too high by an unknown amount.

WATER CANYON-DREAM MINE SITE

Location and Setting

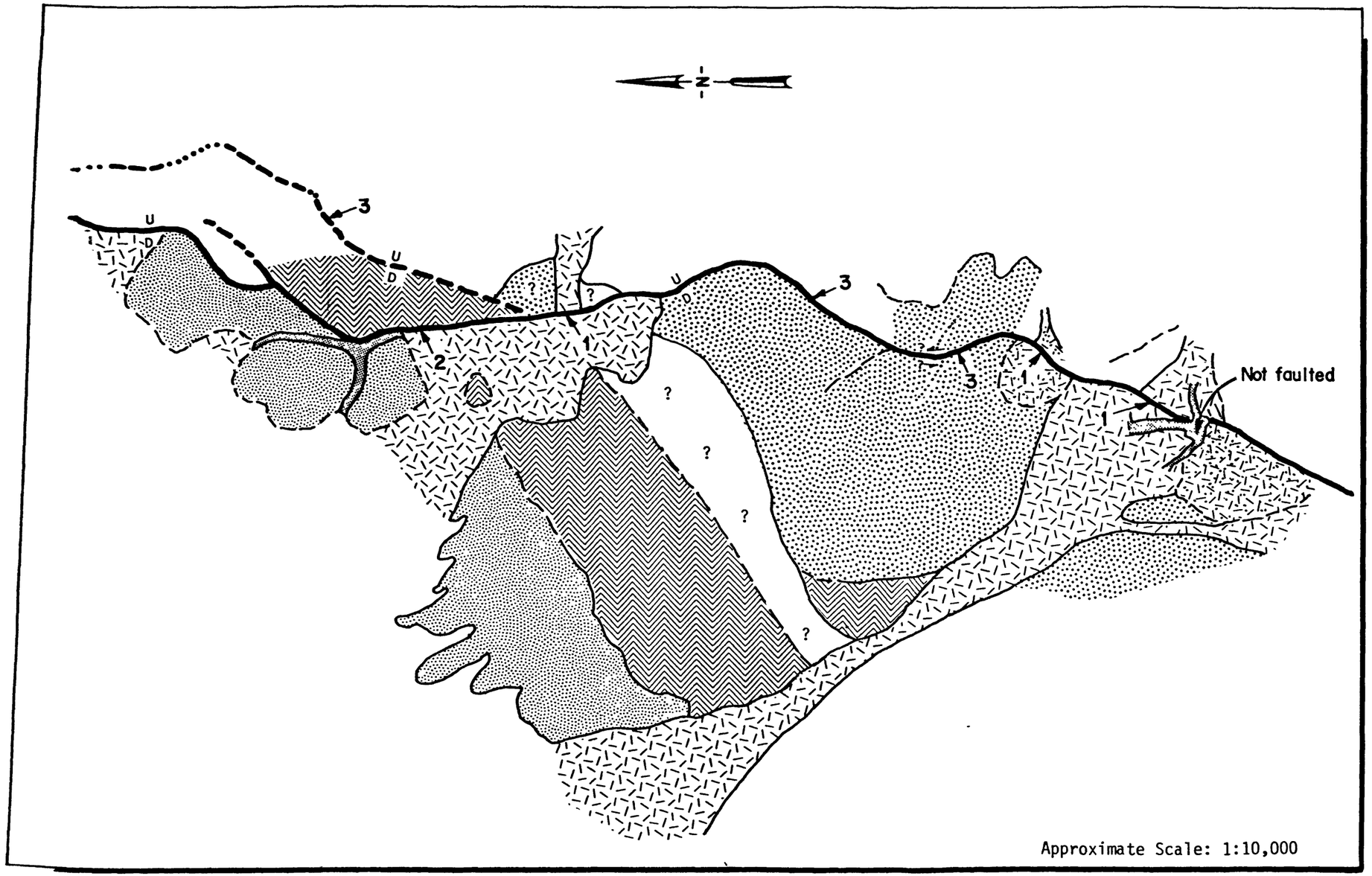
The Water Canyon-Dream Mine site is located approximately 4 miles south of the town of Spanish Fork, near the intersection of Sections 7, 8, 17, and 18 in T9S, R3E, Utah County. It lies west of Loafer Ridge, which separates southern Utah Valley from Spanish Fork Canyon.

Between Spanish Fork Canyon and Santaquin, the west front of the Wasatch Range trends irregularly southwestward. The Wasatch fault controls this irregular trace and is easily identified in the northeastern part of this segment by young scarps fronting the base of the range (Figure 7). These become less obvious south of the Water Canyon area because of a combination of heavy scrub oak and diminished scarp height.

Stratigraphy

The oldest exposed Pleistocene deposits are dissected pre-Lake Alpine fans fronting the range south of Water Canyon. Bissell (1963) describes these as bouldery and gravelly fan material, locally topped by a very mature calcic brown soil 10 or more feet thick. East of the fault, two isolated upfaulted remnants of this older fan material are present on the north and south sides of the mouth of Water Canyon. There is some possibility, however, that these could be remnants of younger fans, perhaps related to a Lake Alpine interstadial.

Deposits belonging to the Lake Alpine high water stages are exposed in gravel pits in the upper piedmont area northwest of Water Canyon (Figure 7)



EXPLANATION:

- MODERN ALLUVIUM
- LATE POST-BONNEVILLE ALLUVIUM } Draper?
- EARLY POST-BONNEVILLE ALLUVIUM } Draper?
- ? ? UNDIFFERENTIATED ALLUVIUM AND COLLUVIUM
- BONNEVILLE FORMATION
- ALPINE FORMATION
- PRE-ALPINE ALLUVIUM
- 1 POST-BONNEVILLE DISPLACEMENT
- 2 BONNEVILLE DISPLACEMEMT
- 3 PRE-ALPINE DISPLACEMENT
- FAULTS - DASHED WHERE APPROXIMATELY LOCATED, DOTTED WHERE CONCEALED OR INFERRED
- CONTACT - DASHED WHERE APPROXIMATELY LOCATED

RECONNAISSANCE GEOLOGIC SKETCH MAP OF THE WATER CANYON - DREAM MINE SITE

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and also in the lower piedmont as somewhat dissected aprons valleyward from the pits. Post-Lake Alpine/pre-Lake Bonneville fan material, now mostly lag deposits and covered by younger lake deposits and alluvium, lies west of the scarp. Examination in two gravel pits showed thin layers of coarse lag deposits, which were interpreted as belonging to this stage, resting on coarse lacustrine deposits believed to be Alpine in age. An exposure in a pit near the southeastern corner of Section 7, T9S, R3E showed over 30 feet of coarse Alpine (?) foreset or backbar deposits overlain by a thin layer of coarse lag deposits, then by up to 10 feet of well-bedded lacustrine sand, gravelly at the base and silty at the top, believed to be Bonneville in age.

Deposits of the Bonneville stage are exposed in two general areas. One is an upfaulted segment north of Water Canyon between the steep range front (which may represent an older trace of the fault) and a fresher scarp to the west, which cuts the piedmont. The other area is a broad southwest-trending bar located west and southwest of Water Canyon and forming a mantel on an older Lake Alpine gravel bar deposit occupying the same position.

Post-Bonneville sediment close to the range front consists of alluvial fan material associated with the various dessications following Bonneville time. The fan at the mouth of Water Canyon is probably composite and thus with further work should be divisable into several stages. Interpretation of aerial photographs suggests a different tonal development on this fan, possibly representing successive cuts and fills.

Faulting

A tentative interpretation of the history of late Pleistocene fault displacements in this section of the range front consists of the following episodes:

(1) Faulting during Lake Alpine pluvial and interpluvial periods. Remnants of faulted fans immediately south and north of the mouth of Water Canyon on the upthrown (east) side of the fault suggest pre-Alpine, or possibly Alpine, interpluvial

fans. The visible scarp height here is estimated to be 150 feet (higher on the north side), but the actual displacement of this older fan material must be somewhat greater, as the downthrown side has been buried by an unknown amount of younger material. North and south of the canyon, this faulting is believed to have followed the immediate base of the range and is deeply dissected. The surface trace of more recent faulting north of Water Canyon departs from this alignment, following an irregular course through the upper piedmont approximately one-fourth mile to the west.

(2) Possible faulting during the interpluvial time between Lakes Alpine and Bonneville.

This faulting appears to have created the initial displacement of the recent fault trace north of Water Canyon, mentioned in number 1, which has an upper portion more rounded and dissected than the lower, suggesting two (or more) displacements on this trace. Deposits of the Bonneville level form a veneer on the upfaulted side.

(3) Faulting following the post-Provo I dessication.

Following the post-Alpine/pre-Bonneville period of faulting, the lake rose twice to the Bonneville level, then dropped rapidly to the Provo I level where it stabilized for an extended period, forming a shoreline approximately one mile northwest of the mouth of Water Canyon. During these high water times, the flow of water from Water Canyon must have increased sufficiently for incision to occur east of the shoreline positions. However, the dryer period following the Provo I phase was accompanied by aggradation in the lower portion of the canyon, creating the present broad, flat canyon floor; west of the canyon mouth, a large alluvial fan developed, overlapping the prominent bar formed during Bonneville time. This fan has since been faulted, with a presently observed vertical displacement at the mouth of the canyon of approximately 35 feet. Since the upper

part of this scarp appears to be somewhat rounded, there may have been at least two periods of faulting involved in its formation. The presence of only one tectonic terrace upstream, however, suggests that the total displacement occurred during one event. The incision creating this tectonic terrace is very narrow and extends only several hundred feet upstream from the scarp, suggesting relative recency of the latest faulting.

GARDNER CREEK-BIRCH CANYON SITE

Location and Setting

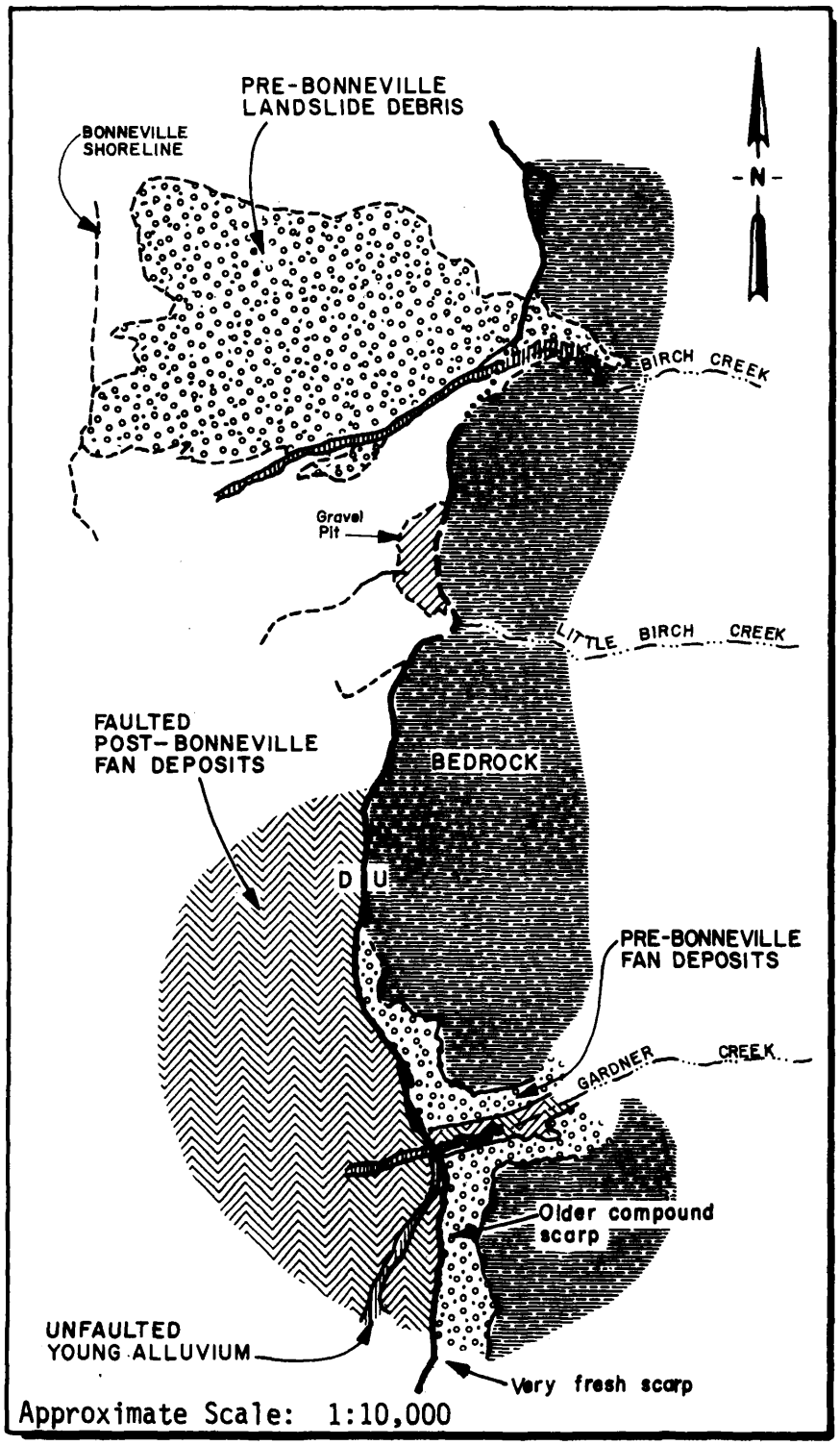
South of Santaquin, the Wasatch fault has clear indications of late Quaternary displacement along several distinct segments. These segments are separated by gaps of up to 16 miles long that have experienced little or no late Quaternary faulting. The recently active segments range up to 14 miles in length and contain nearly continuous fresh-looking scarps.

The Gardner Creek-Birch Canyon site (Figure 8), 2 to 3 miles north of Nephi, is situated in the southern portion of the longest active segment of the southern Wasatch fault. Along this segment, large alluvial fans coalesce to form an alluvial apron that slopes gently upward to the Wasatch front from northern Juab Valley.

The Wasatch fault extends along the base of the range, cutting fans at the mouths of Birch, Little Birch, Gardner, and neighboring canyons. The fault is in a narrow zone marked by a continuous, steep scarp.

Stratigraphy

Late Quaternary deposits along this portion of the fault consist of coarse, poorly sorted alluvial fan sediment representing at least three episodes of fan development. The oldest fan deposit, west of the fault, consists of a dissected and partially buried remnant of a large alluvial fan west of the mouth of Birch Creek; however, this area of outcrop could be alternately interpreted as a subdued and dissected remnant of an old landslide deposit. East of the fault, the older fan material forms bulky terraces that extend up Birch and Gardner Creek canyons.



RECONNAISSANCE GEOLOGIC SKETCH MAP OF GARDNER CREEK - BIRCH CANYON SITE

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The young alluvial fans that overlap the older fan deposit west of the fault coalesce to form the surface of a gently sloping piedmont between the range front and the valley. Bonneville-level shoreline deposits appear to overlie these fan sediments on the lower portion of the Birch Creek fan. Buried soils were observed in these younger fan deposits in the gravel pit at the mouth of Little Birch Canyon. An attempt to date charcoal and seeds from one of these soil horizons was unsuccessful. The younger fan sediment extends up Birch and Gardner Canyons as a narrow valley-fill deposit inset into the terraces formed by the older fan sediments.

The youngest fan deposits include channel fillings on the fan surface that extend up the canyons along the present drainage lines.

Faulting

The basal scarp of the Wasatch fault in this segment consists of a continuous, fresh-looking main scarp accompanied by small branch scarps. It closely follows the foot of the mountains. At the canyon mouths, scarp heights are greatest (108 feet at Gardner Creek Canyon) in the older fan material, whereas smaller scarps cut the younger fan material (14 feet at Gardner Canyon). The youngest alluvium is not displaced.

The large scarp in the older alluvium at the mouth of Gardner Creek Canyon shows changes in slope angle upward. A lower slope segment forms a steep (34° to 35°) fresh scarp that cuts both older and younger alluvium. The upper portion of the scarp slopes at an angle of about 26° . The crest of the scarp is broadly rounded.

SUMMARY OF FINDINGS

1a. Three general settings are present along the fault. These are: (1) steep, continuous escarpments; (2) complex alluvial fans, locally interbedded with lacustrine sediments, located at the mouths of small canyons cut into the escarpment; and (3) fluvial, glaciofluvial, and lacustrine sediments located at the mouths of large stream and river valleys that cut into or through the Wasatch Mountains.

1b. These settings appear to be important in studies of the recurrence of large-magnitude earthquakes. For example, fault scarps identified in setting (3) are typically higher than in adjacent settings. Thus, if earthquake magnitudes were based entirely upon these large displacements, the magnitudes would be greater than from analogous scarps in other settings.

2a. Two general categories of fault geometry have been identified along the Wasatch fault. These are: (1) segments in which the strike of the fault is relatively linear and the fault zone is generally narrow; and (2) curving or sinuous segments that often display broad fault zones within which are located multiple en echelon fault traces.

2b. These two categories are important to studies of recurrence as one event of faulting may result in displacement on one or several traces. Thus, a single fault trace may provide only partial data for estimating recurrence of faulting at that locality.

3. Recurrence intervals may vary from one segment of the fault to another. This is suggested by: (1) gaps in surface expression of recent fault activity; (2) different degrees of erosion of young fault scarps, suggesting different ages of the most recent faulting; (3) scarplets of varying prominence and height along the fault; and (4) varying relief along the fault scarp (mountain front) in various segments.

4. Scarp heights in geologically young materials will give approximate values for only the minimum displacement at a point. Displaced stratigraphic markers would provide more precise values. Thus, fault displacements based upon late Quaternary scarp heights, without adequate stratigraphic control, may be misleading; likewise, values of earthquake magnitudes based upon these scarp heights (other than in the setting described in 1b above) may be biased toward smaller magnitudes.

5. Detailed stratigraphic data and relative age dates are essential for estimating the recurrence of faulting along the Wasatch fault. Useful stratigraphic data include late Quaternary lacustrine sequences of Lake Bonneville, glacial and glaciofluvial sequences of the Wasatch Range, alluvial and colluvial sequences along the Wasatch front, and the soil-stratigraphic sequence. Prominent time-stratigraphic markers within this stratigraphic record include lake shorelines and soils. Radiometric age dates have been obtained for some units within the sequence; these dates provide a broad framework for correlation. Additional age dates are essential, as correlations to undated lake shorelines or soils provide only broad estimates of age.

6. Lacustrine units appear to provide the best bases for detailed studies of recurrence of surface faulting. The Alpine Formation, approximately 25,000 to 75,000 years old, has been displaced greatly by faulting along the Wasatch fault; deposits younger than the Alpine Formation are displaced progressively less with time.

7. Six localities are unusually favorable for studies of the recurrence of surface faulting along the Wasatch fault. These six localities, shown in Figure 1, include (from north to south) Jumpoff Canyon, Kaysville Sag Pond, Little Cottonwood-Bells Canyons, Hobble Creek, Water Canyon, and Gardner Creek-Little Birch Creek Canyons.

8. Of the six localities, the Hobble Creek site appears to be optimum for subsurface studies. This site, shown in Figure 3, offers a great diversity of late Quaternary stratigraphy and distinct fault traces, a combination that should preserve the record of multiple late Quaternary displacements and be favorable for testing and calibrating various subsurface techniques. For these reasons, subsurface investigations should be initiated at the Hobble Creek site prior to subsurface investigations at other localities.

IMPLICATIONS OF FURTHER RESEARCH

Further studies of the recurrence of surface faulting along the Wasatch fault should refine the classifications of faulting noted in summary items 1, 2, and 3. This refinement would best be envisioned in terms of a matrix that would combine these variables and be applied to maps of the fault that are presently available.

Further research in the form of detailed surface mapping and subsurface investigations should be especially revealing in at least two ways: (1) it is likely that the unique late Quaternary stratigraphic record along the Wasatch fault may provide a large number of points in time that can be related to the recurrence of surface faulting; and (2) the subsurface investigations could provide adequate control for determining the reliability of surface investigations of the recurrence of faulting. Thus, there would be a basis for comparing recurrence of faulting based upon fault scarp morphology and subsurface data.

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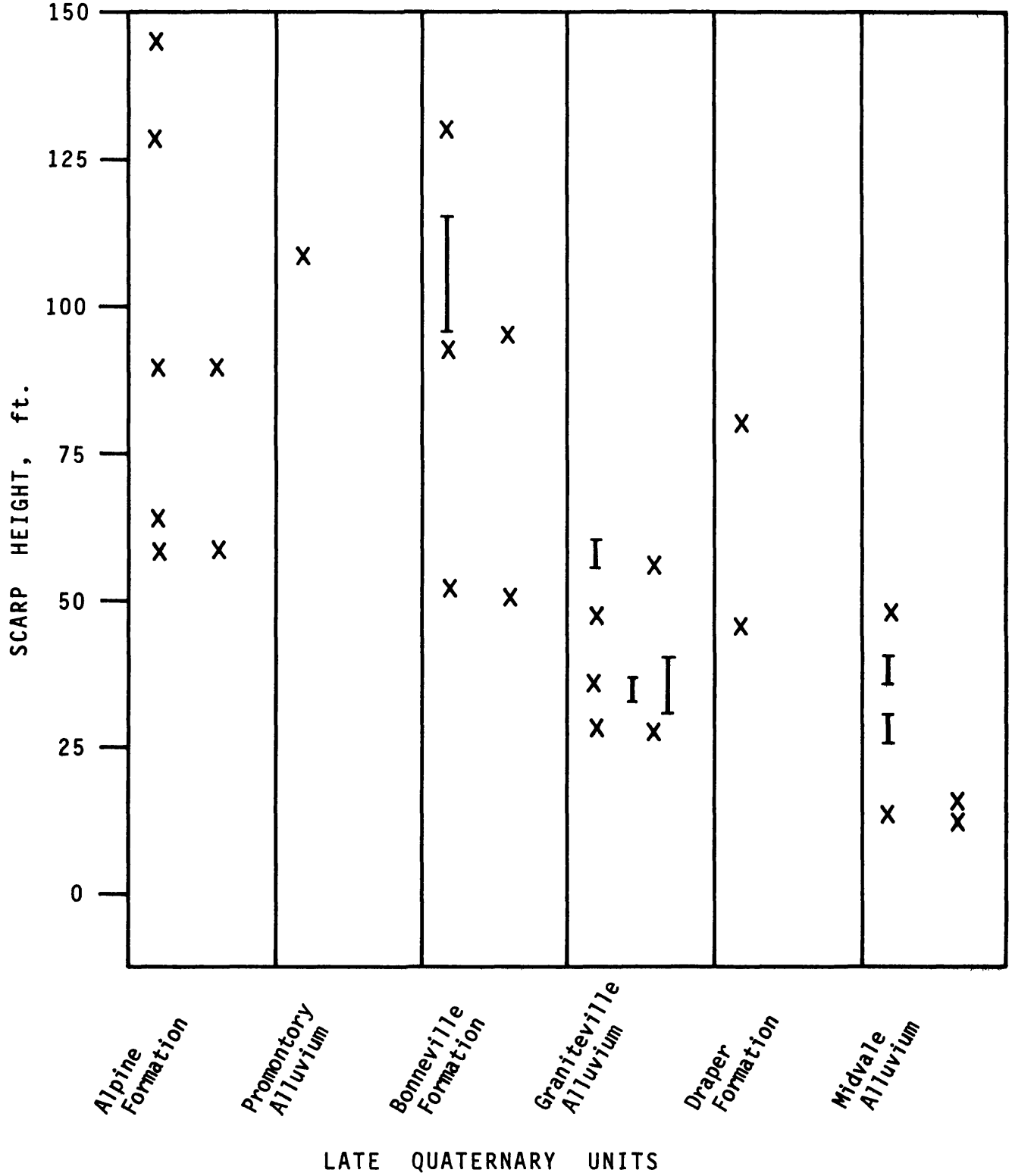
APPENDIX A

FAULT SCARP MEASUREMENTS

During the field investigation phase of this study, scarp heights were measured at a number of locations along the Wasatch fault. Where possible, scarp height measurements were made where displacements were restricted to a single stratigraphic unit. Figure A-1 shows results of measurements of scarp heights in stratigraphic units of several different ages. In general, scarps are progressively higher in older sediments. The wide range of scarp heights reflects differences in the degree of erosion of the scarps, the amount of burial of their lower portions by locally derived sediments, the types and thicknesses of the material through which the scarp is cutting, and differences in the amount of displacement along the fault at different locations. The scarp height measurements represent minimum limiting values for displacement on the fault, and indicate that intermittent fault displacement has occurred throughout the late Quaternary Period.



SCARP HEIGHTS IN SELECTED LATE QUATERNARY UNITS ALONG THE WASATCH FAULT BETWEEN NEPHI AND BRIGHAM CITY

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