QUATERNARY FAULT HISTORY AND EARTHQUAKE POTENTIAL OF THE HANSEL VALLEY AREA, NORTH-CENTRAL UTAH: FINAL TECHNICAL REPORT

BY JAMES McCALPIN

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FINAL TECHNICAL REPORT
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by
James McCalpin
Department of Geology
Utah State University
Logan, UT 84322-0705
(801) 750-1220

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INTRODUCTION

The Hansel Valley-Pocatello Valley area on the Utah-Idaho border has been the site of consistently intense historic seismicity, including a 1934 M6.6 event and a 1975 M6.0 earthquake. The 1934 event, largest in Utah's history, is one of only three historic earthquakes in the Intermountain Seismic Belt (ISB) to result in surface rupture and fault scarp formation. The apparent high seismicity contrasts with a scarcity of pre-historic fault scarps offsetting late Quaternary deposits, in spite of youthful range-front morphology on both margins of the valley (McCalpin et al., in prep.). The objective of this research was to assess the record of pre-historic seismicity by study of rare fault scarps, subsurface displacements, and liquefaction features, and to relate prehistoric frequency-magnitude patterns with those of the historic (1850-present) record.

PREVIOUS INVESTIGATIONS

Post-earthquake observations made immediately after the 1934 earthquake were published by Walter (1934), Neuman (1936) and Adams (1938). All three authors made similar observations regarding the 1934 ground cracks and scarplets, as well as on pre-historic fault scarps. However, the only map produced, a Brunton-and-pace map of ground cracks on the mudflats, was deposited with Utah State University in 1934 and subsequently lost (Walter, personal communication).

Areal geologic mapping covering the area includes that of Adams (1962), Doelling (1980), and Jordan (1985). None of these authors subdivided Quaternary lacustrine units according to the scheme of Scott et al. (1983) or Currey et al. (1983), so that task was an integral part of this investigation.

Historic seismicity of the area is summarized by Richins (1979). The relation of local seismicity to a more regional perspective is given by Smith and Arabasz (1979).

METHODS OF STUDY

Surficial geologic mapping and location of neotectonic features was performed by analysis of 1:40,000 black-and-white aerial photographs flown in 1974. Details of the 1934 ground cracks and the contiguous pre-historic scarp were mapped on 1:20,000 black-and-white aerial photographs flown in 1952 (the earliest available). Surficial mapping on mylar overlays at 1:20,000 and 1:40,000 was transferred with a Kargl Reflecting Projector onto a 1:50,000 mylar base map, which had been photo-reduced from 1:24,000 quadrangle topographic maps (Figure 1, in pocket).

Field mapping of fault scarps involved measurement of scarp profiles with a 4.5 m telescoping level rod and Abney level, after the method of Bucknam and Anderson (1979, p. 12). Arroyo wall profiling utilized the same rod, a 5m tape measure, and a Brunton compass for horizontal and vertical control. Stratigraphic units were sampled and grain size distribution measured following Folk (1974). Thermoluminescence (TL) samples were collected by augering two soup cans with serrated edges directly into vertical arroyo walls. Cans were then wrapped in aluminum foil, covered with duct tape, and placed in ziplock plastic bags.

LOCATION AND SETTING OF HANSEL VALLEY

Tectonic Setting

Hansel Valley is located in north-central Utah at the north end of the Great Salt Lake, between roughly 41° 37.5' to 42° N. Lat. and 112° 30' to 113° W. Long. (Fig. 2). It is an asymmetrical NNE trending graben, flanked on the west by the Hansel (or Summer Ranch) Mountains, and on the east by the North Promontory Mountains. The flanking ranges are dominantly comprised of sandstones and carbonates of the Permo-Pennsylvanian Oquirrh Group, which dip eastward at moderate angles. The Tertiary Salt Lake Group composed of

continental conglomerates and tuffaceous sandstones and exhibiting erratic dips, outcrops around the valley margins downslope of the main range-bounding faults. Late Tertiary basalt flows locally overlie the Oquirrh and Salt Lake Groups at the north end of the valley, and have been extensively faulted by north-striking normal faults accompanied by eastward rotation (Adams, 1962).

Historic Seismicity

Since 1850, the Idaho-Utah border area between 111°-130° W longitude has been one of the most seismically active areas of the southern ISB. At least 19 earthquakes with epicentral intensity of V or greater have occurred here (Arabasz et al., 1979, p. 340). Figure 3 shows the distribution of epicenters in the area from 1850-1962. The 1934 M6.6 earthquake epicenter was located on the west side of Hansel Valley, coincident with a line of ground cracks and up to 50 cm-high scarplets (heavy lines with bar and ball, Fig. 3).

No focal mechanisms have been derived for this earthquake, but an analysis of first-order leveling data from 1911, 1934, and 1953 by Bucknam (1978, p. 72-74) suggests that the scarps are antithetic features to a buried west-dipping normal fault. While this explanation is plausible, the author doubts it for two reasons. First, the relevelling line happened to pass well south of the zone of maximum down to the east rupture, but close to the only down to the west scarp, thus exaggerating net down to the west movement. If the level line would have been surveyed farther north, only down to the east displacements would probably have appeared. Second, this theory proposes that the mountain (western) side is downthrown, while the valley (eastern) side is upthrown. Not only does the topography refute this as a long-term trend, but subsurface reflection profiling by USGS along the same survey line shows no sign of any buried horst in the valley subsurface (Sam Harding, personal communication). The author proposes that the 1934 scarps which trend into the pre-historic southwestern boundary scarp are

true tectonic features, and that the other scarplets are syn- and antithetic features on the downthrown (eastern) block.

From 1962 to 1975, instrumental epicenters are scattered sparsely throughout the area (Fig. 3b); while some show coincidence with major structures, most do not. Since the installment of the University of Utah telemetered network, thousands of epicenters have been located (Fig. 3c; 1975-1985).

Richins (1979, Fig. 16-6) analyzed the frequency/magnitude relations of roughly 700 earthquakes in the November, 1975 swarm. Resulting "b" values varied quite widely, depending on which method was used to assign magnitudes to $M<1.5$ events ($b=0.61$, 1.02, or 1.79). The author notes that "These results also question the validity of recurrence intervals often based on a value of b determined from microearthquake data." (Richins, 1979, p. 420).
Focal mechanisms indicated normal faulting, down to the west, on a plane striking N 15° E, dipping 55° W. This plane was thought to coincide with an inferred fault which bounds the west side of the prominent south prong of the Hansel Mountains north of the West Gully (Fig. 1).

NEOTECTONIC FEATURES

The main neotectonic features of the Hansel Valley area include: 1) the North Promontory Fault, which bounds the valley on the eastern side, 2) an unnamed fault bounding the northwestern valley margin at the base of the North Hansel Mountains, and 3) the 1934 fault scarp and a pre-historic scarp bounding the southwest valley margin. In addition, lineaments and subsurface faults expressed on the valley floor represent pre-Quaternary (?) minor offsets.

North Promontory Fault

The north Promontory Fault on the east side of Hansel Valley is marked by an extremely linear range front with faceted spurs. Much of the inferred fault

trace is covered by talus, but occasional pillars of carbonate-cemented fault breccia poke through the talus and indicate the general location of the fault (Adams, 1962). Although the range front itself abuts Oquirrh Formation against pre-Bonneville cycle (i.e. older than 50 ka) alluvial fans, few fault scarps are visible. At the north end, a 10 m high scarp offsets a Bonneville-cycle delta (Fig. 1). A shorter splay scarp east of Bulls Pass offsets pre-Bonneville alluvial fans as much as 9.5 m, down to the west. Slope angle vs scarp height data suggest that the northern scarp is roughly contemporaneous with the Bonneville Shoreline (approximately 15 ka; Scott et al., 1983), while the splay scarp is older than the shoreline (Fig. 4).

Northwestern Margin Fault

On the west side of Hansel Valley, the Hansel (or Summer Ranch) Mountains exhibit a linear range front with the Bonneville shoreline at its base. Despite the youthful appearance of the range front, no evidence of post-Bonneville faulting was observed in shoreline terraces. Pre-Bonneville alluvial fans are not present along this range front, so a long history of possible tectonism is not available.

Southwestern Margin Fault

Farther to the south, the 1934 surface break across the mudflats is still expressed as a degraded east-facing scarp up to 50 cm high. North of the mudflats the trace continues for about 10 km as an east-facing scarp 1.6 m to 9.0 m high which offsets numerous shorelines below 4600 feet (Robison and McCalpin, 1985). Vertical displacement values vary widely, with no correlation to age of shorelines displaced. Instead, scarp height increases as the scarp ascends a larger pre-existing bedrock-cored escarpment, suggestive of slumping effects (Fig. 5). The slumping effects, seen most clearly where the fault develops arcuate headscarps, are inferred to operate as shown in Fig. 6. Unslumped throw values of 1.2 m to 2.5 m are probably indicative of displacement at depth. Profiles of

fault scarps are shown in Fig. 7a.

Geomorphic relations of the fault scarp with transgressive and regressive shorelines indicate that the scarp must have formed after the Bonneville-cycle transgression rose above 4600 ft. (about 26 ka; Scott, et al., 1983, Fig. 5), but before the Post-Provo regression fell below 4350 ft., about 12 ka (McCalpin, 1985a, 1985b). The reasoning which leads to this conclusin is explained as follows. Faulting in relation to a pluvial lake cycle could conceivably occur: 1) before the lake rose, 2) during a transgression, 3) during the lake highstand, 4) during a regression, or 5) after the lake dried up. Small fault scarps (1-2 m high) which formed <u>before</u> a major transgression would be reworked and destroyed, gauging from the thickness and coarseness of Bonneville transgressive bars. A scarp which offset shorelines <u>during</u> a transgression would be destroyed above the elevation of the shoreline when faulting occurred. However, transgressive shorelines which had formed <u>prior</u> to faulting would be offset and the scarp in these deposits would be preserved if below effective wave base (Fig. 8). In this instance, a scarp would traverse lake shorelines up to a certain elevation and then abruptly terminate, not offsetting higher (and younger) transgressive shoreline deposits. The shoreline at which the scarp terminates is the shoreline which was occupied at the time of faulting.

If faulting occurred during the lake highstand, all transgressive shorelines would be offset by the fault. If faulting occurred during a regression, small regressive shoreline features already formed as the lake receded would be faulted. Future regressive shorelines would be controlled by the position of the fault scarp, because only minor deposition accompanies the formation of regressive shorelines (except the Provo shoreline) in the Bonneville Basin. In this case, regressive shorelines would be clearly offset above a certain elevation; below it, shorelines would wrap around a modified

scarp of similar height (Fig. 9). The elevation of this transition shows where the shoreline was during its regression at the time of faulting. Surface faulting after the lake had completely dessicated would result in offset of all transgressive and regressive shoreline features.

In western Hansel Valley, the pre-historic scarp does not trend as to offset all possible shorelines, but gradually becomes parallel to them at approximately 4600 feet. All transgressive shorelines below 4600 feet are clearly faulted, indicating that surface faulting occurred after the Bonneville transgression had risen to 4600 feet (about 26 ka). Small regressive bars at 4350 feet terminate against the scarp, indicating that the scarp was already formed by the time the regression from the Provo level reached 4350 feet (about 12 ka). Therefore, the scarp must have formed after 26 ka but before 12 ka. Scarp height vs slope angle data suggest the scarp was formed between 15 ka ad 10 ka (Bucknam and Anderson, 1979), although scarps formed underwater are not strictly comparable to subaerial scarps (Fig. 4). The overlap between these age estimates (12 ka-15 ka) probably closely dates scarp formation.

Single-event displacements of 1.2 to 2.5 m should correlate with rupture lengths of 25 to 55 km, (Bonilla, 1982, p. 60), considerably larger than the ±10 km length of the pre-historic scarp. Subsurface evidence (discussed below) suggests that two fault events may have occurred within the 26-12 ka interval.

Fortuitously, a 10-15 m deep gully (West Gully in Fig. 5) crosses the trend of the pre-historic scarp. The scarp itself cannot be traced to the lip of the arroyo due to agricultural(?) disturbances, but it does exist both to the north and south. Excellent vertical exposures in the lower 5 m of the arroyo show multiple Quaternary stratigraphic units being offset by normal faults in two discrete zones. One major shortcoming, however, was that faults could not be traced to the surface through the grassy slopes of the upper gully walls.

Detailed logging of stratigraphy and structure was performed across the two

deformation zones (Fig. 10). Twelve normal faults in the western 80 m wide zone define a broad graben structure. Net displacement across the graben, based on a single distinct contact, is roughly 1.3 m down to the east, a value similar to that computed for scarp profiles north of the arroyo.

Nine stratigraphic units are exposed, and display increasing tectonic deformation with age. The lowest unit is pervasively fractured with high-angle conjugate joints with small (several centimeters) displacements; joints increase in frequency towards major fault planes. A major unconformity which separates this unit from overlying Bonneville-cycle sediments is not offset along any of these minor fractures, although it is offset along major faults. In one locality, cross-bedded gravels of the Bonneville transgression infill an open tension fracture underlain by a fault, indicating that at least one fault event had disrupted this unit prior to about 26 ka.

Overlying stratigraphic units are disrupted only by major faults. In the lower 5m of the arroyo, no colluvial wedges are exposed in contact with the fault planes. This indicates that the ground surface at time of faulting was above existing good exposures, although not necessarily coincident with the modern ground surface.

QUATERNARY STRATIGRAPHY

Surficial geologic mapping and Quaternary stratigraphic investigations were performed to document the age relations of deposits offset by faulting or disturbed by liquefaction. Accordingly, Quaternary deposits were subdivided into 23 map units (Fig. 1). The main age divisions were related to fluctuations of pluvial lakes, especially the Lake Bonneville cycle (Scott et al., 1983). Quaternary deposits pre-dating the Bonneville lacustral cycle are exposed: 1) as alluvial fans (Qaf_1) above the Bonneville shoreline, along the base of the North Promontory Mountains, 2) as landslides off the North Hansel Mountain front

and 3) as lacustrine deposits found in the bottom of the West Gully (Fig. 10). The absolute age of the alluvial fans is not known, but they could be correlative with either of two pre-Bonneville lacustrine deposits which have been dated in the West Gully (see discussion below).

Deposits of the Bonneville cycle include shore deposits of beach gravel and sand (Qlg_2), deltas composed of coarse gravel (Qld_2), finer littoral sands and silts (Qls_2), lagoon deposits trapped behind bay-mouth bars (Qll_2), and lake bottom silts and clays (Qlb_2). After the lake dropped to the Provo shoreline level, lacustrine deposition again stabilized. Units laid down during this interval include gravelly spits and bars (Qlg_3), littoral sands (Qls_3), lagoonal muds (Qll_3), and lake bottom sediments (Qlb_3). All deposits laid down during the regression from the Provo level toward a lake lowstand during the Altithermal (Currey, et al., 1984), and during a subsequent readvance to the Gilbert Shoreline (approximately 4250 feet) are lumped together. These include bar and spit gravels (Qlg_4), littoral sands (Qls_4), lagoon deposits (Qll_4), lake bottom clays (Qls_4) and contemporary mudflats (Qmf_4). Subaerial deposits of this age include post-lake alluvium (Qas_4), alluvial fans (Qaf_4), talus deposits (Qmt_4) and slopewash (Qms_4). Almost all of these subaerial deposits are limited to range fronts and modern drainages.

The interaction of these surficial deposits with fault scarps provides a first approximation on age of faulting, as previously described in the Neotectonic Features section. Critical information also resides in the subsurface. Because no funding was provided for fault scarp trenching, study of subsurface stratigraphy near faults was limited to inspection of natural gullies and arroyos. Fortunately, the West Gully, astride the southwestern margin pre-historic scarp, provided excellent exposures. Stratigraphy of the West Gully is summarized in Fig. 11 (from McCalpin, in press).

A combination of evidence from physical stratigraphy, sedimentology, ostracod assembleges, and thermoluminescence (TL) dating indicate deposits of two pre-Bonneville ages are present. The older appears only in arroyo bottoms, consists of compact laminated silt and clay, and is disrupted by numerous high-angle fractures and faults of small displacement. Ostracod fauna indicate a deep lake environment, and a TL date of 115, 200 ± 17,500 yr BP suggests correlation with the Little Valley cycle of Scott et al. (1983), equivalent to oxygen isotope stage 6. Lying unconformably above this unit are shoreline gravels and lake-marginal marsh sediments with gypsum crystals, representing periodic subaerial exposure. Ostracods indicate an alkaline-poor, marginal lacustrine groundwater environment. TL dates of 65,900 ± 4200 year BP and 67,000 ± 3800 yr BP show that these deposits correlate with isotope stage 4, and probably represent an early-Wisconsin lake which rose no higher than about 4400 ft (Oviatt, et al., 1985). Most of the minor fracturing in Little Valley deposits does not disrupt these stage 4 deposits, but major faults do disrupt them.

Bonneville cycle deposits include transgressive beach gravels, highstand sands, silts and clays and minor regressive gravels. In the West Gully, lake bottom deposits include two widespread deformed stratigraphic units bounded above and below by laminated silts and clays. Folds, diapirs, roll structures, and floating pebbles typify the lower unit (#6 in Fig. 11) while the upper unit (#8 in Fig. 11) is composed of a mass of discrete, rotated slump blocks of well-laminated silt and clay. Each deformed unit is thought to result from seismic shaking; differences in failure mode may relate to lower pore pressures in younger units as the lake level fell. Radiocarbon and amino acid dates from the lower convoluted silt range from 15,450 ± 650 yr BP to about 21,000 yr BP. The TL date of 40,100 ± 3200 year BP has two possible explanations: 1) the silt fraction is partially reworked pre-Bonneville silt that was not fully "zeroed" prior to deposition, or 2) the severe churning of the lake bottom in places re-

suspended sediment of underlying unit 3, which resulted in mixing of 65 ka silt with 15 ka silt. It is also possible that Unit 6 was deposited as a massive turbidite contemporaneous with the catastrophic shoreline drop from the Bonneville to Provo levels, and did not result from earthquake shaking.

The upper unit (#8) with rotated blocks of otherwise undeformed, well laminated sand, silt and clay, appears to be the upslope part of a large lateral spread. A TL date on this unit of 11,700 + 1100 yr BP, when compared to the shoreline elevation curve of Scott et al. (1983) suggests that this unit should have been very near the shoreline and the time of deformation. A similar polygonal pattern of ground fissures in lake margin mudflats due to liquefaction was observed after the 1934 earthquake (Neuman, 1936).

LATE QUATERNARY HISTORY OF SURFACE FAULTING

North Promontory Fault

Only two fault scarps exist in Quaternary deposits along the North Promontory Fault, the remainder of the fault trace being covered by active and inactive talus. The northern scarp offsets a delta graded to the Bonneville Shoreline, and displaces it roughly 8 m down to the west. Scarp profiles (Fig. 7) show no obvious multiple crests or levels which might indicate multiple events, although with a 10 m height the scarp must represent several events. Scarp height vs slope angle data for two profiles suggest the scarp is contemporaneous with the Bonneville Shoreline, which is compatible with stratigraphic evidence. Because the scarp does not offset younger deposits along its trace, it is difficult to deduce the number and timing of surface faulting events. If we assume that displacement per event was 2.0-2.5 m, then 3-4 events are necessary in the last 15 ka. This recurrence interval (3750-5000 yr) seems too short in comparison with other nearby normal faults; for example, the

much more active-appearing Wasatch Fault has estimated recurrences of 1700-2700 yr (Hobble Creek; Swan et al., 1983) for events of similar displacement.

Independent evidence to bear of the late Quaternary history of the North Promontory Fault is exposed in a large roadcut on the south side of Interstate 84 as it traverses Rattlesnake Pass at the north end of the North Promontory Mountains (Fig. 1). Here a down-to-the-east vertical fault roughly 100 m east of the inferred trace of the North Promontory Fault offsets multiple Quaternary alluviums and soils deposited in a swale cut into Tertiary basalts. A detailed sketch of fault relations (Fig. 12) shows that a single-event offset of 2.6. m displaces all units except the Holocene colluvium. The age of the stacked alluvial units in the swale, estimated from the degree of K-horizon development, is at least 100 ka. Therefore, evidence here of only a single, very recent 2.6 m offset with no other events in the last 100 ka is not compatible with 3-4 events in the last 15 ka inferred from the delta scarp approximately 1.5 km to the south. Of course, not all rupture events on the main trace of the North Promontory Fault may have caused offset on this subsidiary trace. In fact, this fault partially defines a graben on the upthrown block, which is not a deformation feature typical of normal faulting.

The second scarp on the North Promontory fault occurs east of Bulls Pass (Fig. 1) as a southwest-trending splay scarp which offsets pre-Bonneville alluvial fan deposits. Scarp height decreases regularly from the range front out toward the valley center. Maximum surface offset measured on profiles was 9.5 m (Fig. 7b). Scarp height vs slope angle data suggest the scarp is slightly older than the Bonneville shoreline (Fig. 4). Because the scarp offsets no deposits except Qaf_1, it's age and the number of events are poorly constrained. The pre-Bonneville alluvial fans may be correlative with either isotope stage 4 (58-72 ka) or 6 (140 ka). If we assume that offset per event was 2.0-2.5 m, then 4-5 events may have occurred between either 15 ka and 58 ka (more likely; Recurrence Interval 8600-10,750 yr) or between 15 ka and 140 ka (R.I. 25,000-31,250 yr). These

recurrence intervals are considerably longer than those of post-Bonneville time (last 15 ka, based on the delta scarp). However, not all surface-faulting events at the range front may have created surface rupture on this splay fault, so the recurrence intervals should be taken as maxima for the range front fault itself.

Southwestern Margin Fault

Based on exposures in the West Gully, the following fault history is outlined: 1) multiple events of unknown displacement occurring between 115 ka and 67 ka, 2) no events between 67 ka and 26 ka, 3) one event between 26 ka and 12 ka, 4) one event at about 12 ka, and 5) the 1934 AD event. Displacements and magnitude estimates are limited because faults could not be traced to the surface. However, the 1934 earthquake of M6.6 resulted in a maximum 0.4 m of surface offset. The event between 26-12 ka together with the 12 ka event produced roughly 1.5-2.5 m of maximum surface offset. If both events were similar, then 0.7-1.2 m events have occurred at least as close together as 14 ka. The 0.45 m offset in 1934 occurred 12 ka after the previous event. In comparison, no event occurred in the 41 ka between 67 ka and 26 ka (isotope stage 3). This temporal clustering of events may be related to crustal loading by pluvial lakes, as discussed in a following section.

Valley Floor Faults

Hansel Valley Wash and its tributaries expose pre-Bonneville lacustrine and alluvial deposits, some as old as late Tertiary(?), which are folded and faulted. Immediately south of Interstate 84 in the northeastern valley corner, pre-Bonneville lake deposits are offset 4.5 m by a northeast-trending normal fault (Fig. 1). The fault displaces material to within less than 1 m of the present ground surface, but there is no topographic expression of the fault. No colluvial wedges were present, so the number of events is not known here.

Considering the topographic position and strike of this fault, it is probably not related to late Quaternary range-front faulting.

The drainage network in Northern Hansel Valley shows gullies composed of linear segments, many of which parallel the north-south inferred faults which offset and tilt Tertiary basalt flows north of Interstate 84 (Fig. 1; lineaments of inferred tectonic origin). One such fault is well exposed in an old south-facing roadcut east of the Hansel Valley Exit of I-84 where shattered Paleozoic carbonates of the Oquirrh Formation abut altered Tertiary basalts and overlying Quaternary alluvium/colluvium (Fig. 13). Volcanic ash interbedded in the Quaternary section has been tentatively identified as Bishop Ash (740 ka BP; Glen Izett, personal communication). This ash is dragged into the fault zone, indicating post 740 ka offset. Correlative Quaternary deposits are not present west of the fault zone, because either: 1) they were once there, but have been removed by erosion on the upthrown block, or 2) they were deposited in a swale bounded by the fault on the west (as at Rattlesnake Pass) and were never present west of the fault. Regardless of which is true, the amount of displacment, number of events, and timing of events can only be deduced as at least one faulting event post 740 ka. The fault does not offset surficial Holocene colluvium, indicating no Holocene surface rupture.

RELATION OF SURFACE FAULTING TO LAKE BONNEVILLE FLUCTUATIONS

The faulting history deduced from well-dated strata in the West Gully implies multiple faulting from roughly 140?-115 ka to 67 ka (isotope stage 6 or 5), no events from 67 ka to 26 ka (isotope stages 4 and 3), probably two events from 26 ka to 12 ka (isotope stage 2), and one event in 1934 AD (isotope stage 1). The clustering of events during periods when deep lakes occupied the Bonneville Basin (isotope stages 6 and 2) contrasts with lesser activity during interpluvials (stages 5, 3, and 1) or when only a shallow lake existed in the basin (stage 4). This trend is especially significant when one considers what

the geometry of faulting must look like when offsetting a stratigraphic section that resulted from deposition in pluvial times, and erosion or soil formation in interpluvial times (Fig. 14). The diagram shows that faults displacing lacustrine units but truncated by unconformities would naturally be assigned to interpluvial intervals, thus skewing temporal interpretations in favor of interpluvial faulting. Significantly, this study has documented that faults offsetting pluvial lake deposits can occur during pluvial deposition, resulting in submarine fault scarps.

Previous authors have suggested that changes in pore pressure accompanying the Bonneville to Provo shoreline drop (and also rapid isostatic rebound shortly thereafter) "had an effect on the local stress field that could have triggered strain release along the Wasatch Fault Zone." (Swan et al., 1983, p. 15). The results of this study, while limited in estimating exact number of events, seem to support temporal clustering of surface-faulting events when large lakes loaded the crust of the Bonneville Basin. However, the 1934 M6.6 earthquake obviously occurred during an interpluvial climate, long after the lake load had vanished and ensuing rebound had been accommodated. Its relatively small maximum displacment (0.5 m) and long recurrence time (12 ka) may be typical of events occurring in interpluvial, rather than pluvial, times.

SUMMARY AND CONCLUSIONS

The North Promontory Fault has definitely sustained surface faulting in post-Bonneville time, but the number and exact timing of such events cannot be deduced without on-site trenching. The latest event resulted in 2.6 m displacement on an antithetic fault, sometime around 15-10 ka. If this displacement is typical, then there have probably been 3-4 events in the last 15 ka (R.I.=3.0-3.75 ka) and 4-5 events between 58 and 15 ka (R.I. 8.6-10.8 ka).

The 1934 M 6.6 surface rupture on the southwestern valley margin was the

latest in a series of surface-faulting events which stretch back as much as 115 ka. Detailed arroyo wall mapping and TL dates suggest multiple events of unknown displacement from 115 ka to 67 ka, no events from 67 ka to 26 ka, a probable event between 26 ka and 12 ka, one event at 12 ka, and another in 1934 AD. Single-event displacements are ambiguous, but could be as high as 2.5 m. The main source of ambiguity is not being able to trace subsurface faults to the ground surface.

Future research here should concentrate on digging two or three trenches across fault scarps to determine whether they are single- or double-event scarps. This relatively small expenditure of funds would eliminate the ambiguities inherent in the present non-trenching study.

REFERENCES

Adams, T.C., 1938, Land subsidence north of Great Salt Lake, Utah, Bulletin of the Seismological Society of America, Vol. 28 no. 2: p. 65-70.

Adams, O.C., 1962, Geology of the Summer Ranch and North Promontory Mountains, Utah: M.S. Thesis, Utah State University, 57 p.

Arabasz, W.J., Smith, R.B., and Richins, W.D. (eds.), 1979, Earthquake Studies in Utah, 1850 to 1978, Special Publication, University of Utah Seismograph Stations, Department of Geology and Geophysics, University of Utah, 552 p.

Bonilla, M.G., 1982, Evaluation of potential surface faulting and other tectonic deformation, USGS Open File Report 82-0732, 91 p.

Bucknam, R.C., and Anderson, R.E., 1979, Estimation of fault-scarp ages from a scarp-height-slope-angle relationship, Geology, Vol. 7, p. 11-14.

Bucknam, R.C., 1978, Northwestern Utah Seismotectonic Studies, Summaries of Technical Reports, Vol. 7, p. 72-74, USGS, National Earthquake Hazards Reduction Program.

Currey, D.R., Oviatt, C.G., and Plyer, G.B., 1983, Lake Bonneville Stratigraphy, Geomorphology, and Isostatic Deformation in West-Central Utah, Utah Geological and Mineral Survey Special Studies 62, p. 63-82.

Currey, D.R., Atwood, Genevieve and Mabey, D.R., 1984, Major levels of Great Salt Lake and Lake Bonneville, Utah Geological Mineral Survey Map 73, 1:750,000.

Doelling, H.H. (ed.), 1980, Geology and mineral resources of Box Elder County, Utah: Utah Geological and Mineral Survey, Bulletin 115, 251 p.

Folk, R.L., 1974, Petrology of Sedminentary Rocks: Hemphillis, Austin, TX, 170 p.

Jordan, T.E., 1985, Geologic map of the Bulls Pass Quadrangle, Box Elder County, Utah: U.S. Geological Survey Map MF-1491, 1:24,000.

McCalpin, James, 1985a, Quaternary fault history and earthquake potential of the Hansel Valley area, north-central Utah, in Summaries of Technical Reports, Vol. XIX, U.S. Geological Survey Open File Report 85-22, p. 126-129.

_____, 1985b, Quaternary fault history and earthquake potential of the Hansel Valley area, north-central Utah, in Summaries of Technical Reports, Vol. XX, U.S. Geological Survey Open File Report 85-464, p. 105-108.

_____, (in press), Quaternary fault history and earthquake potential of the Hansel Valley area, north-central Utah, in Summaries of Technical Reports, Vol. XXI, U.S. Geological Survey Open-File Report, 3 ms. pages.

McCalpin, James, et. al., (in prep.), Neotectonics of the Hansel Valley-Pocatello Valley corridor, northern Utah and Southern Idaho, in Hays, W.W. (ed.), Evaluation of Urban and Regional Earthquake Hazards and Risk in Utah: U.S. Geological Survey Professional Paper.

Neuman, F. (ed.), The Utah Earthquake of March 12, 1934 in United States Earthquakes, 1934, p. 43-48, U.S. Coast and Geodetic Survey, Serial 593.

Oviatt, C.G., McCoy, W.D., and Reider, R.G., 1985, Quaternary lacustrine stratigraphy along the lower Bear River, UT: evidence for a shallow early Wisconsin lake in the Bonneville Basin: Geological Society of America, Abstracts with Programs. Vol. 17, no. 4, p. 260.

Richins, W.D., 1979, The Hansel Valley, Utah, earthquake sequence of November, 1976, in Arabasz, W.J., et al. (eds.), Earthquake studies in Utah, 1850-1978, p. 409-421: Special Publication, University of Utah Seismograph Stations, Salt Lake City.

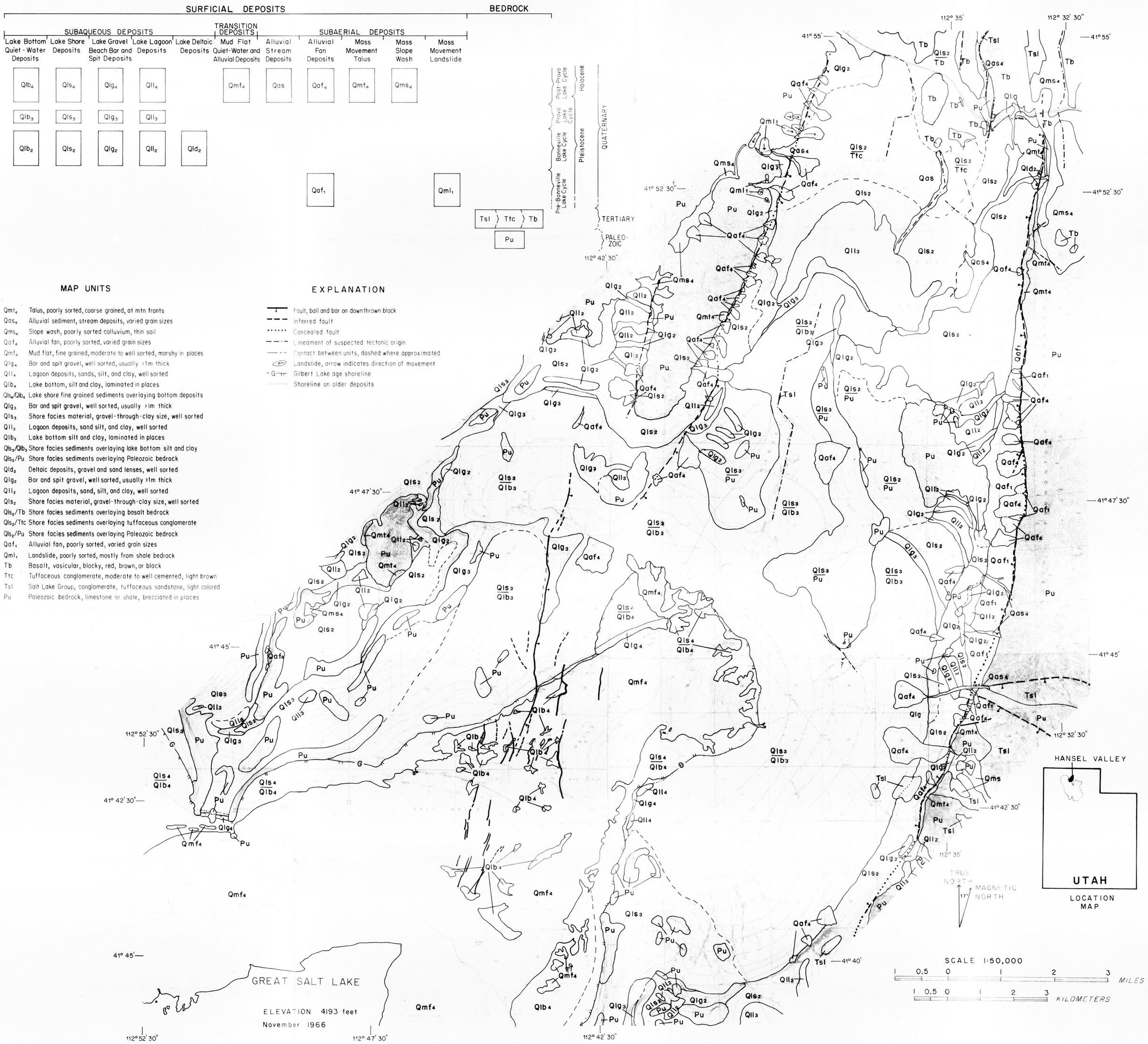
Robison, R.M. and McCalpin, James, 1985, Evidence for recurrent Quaternary normal faulting along the trace of the 1934 Hansel Valley fault scarp, north-central Utah: Geological Society of America, Abstracts with Programs, Vol. 17, no. 4, p. 262.

Scott, W.E., McCoy, W.Dd., Shroba, R.R., and Rubin, Meyer, 1983, Reinterpretation of the exposed record of the last two cycles of Lake Bonneville, western United States. Quaternary Research, Vol. 20, no. 3, p. 241-285.

Smith, R.B. and Arabasz, W.J., 1979, Seismicity, tectonics, and crustal structure in Utah: Important aspects from new data in Arabasz, W.J. et al. (eds.), Earthquake Studies in Utah, 1850 to 1978, p. 395-408, Special Publication, University of Utah Seismograph Stations, Salt Lake City.

Swan, F.H. III, Hanson, K.L., Schwartz, D.P., and Black, J.H., 1983, Study of earthquake recurrence intervals on the Wasatch fault, Utah, Eighth Semi-Annual Technical Report, May 1983 USGS Contract No. 14-08-0001-19842, 20 p.

Walter, H.G., 1934, Hansel Vally, Utah, earthquake, Compass of Sigma Gamma Epsilon vol. XIII no. 4: p. 178-181.



SURFICIAL GEOLOGIC MAP OF HANSEL VALLEY, BOX ELDER COUNTY, UTAH

by

ROBERT M. ROBISON

1985

BEDROCK GEOLOGY COMPILED FROM:
ADAMS, O.C., 1962
DOELLING, H.H., 1980

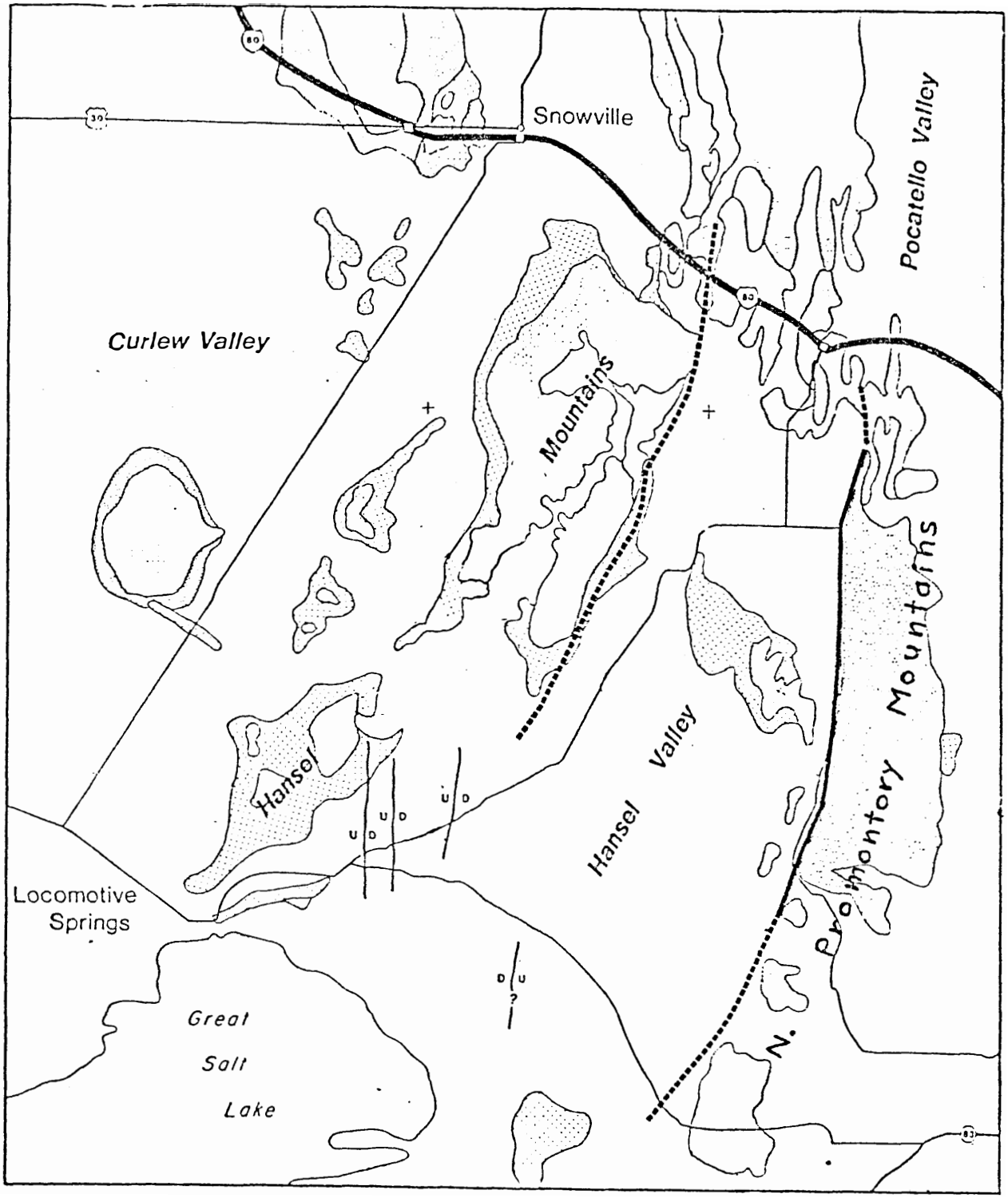


Figure 2.

Location map of Hansel Valley, northern Utah. Inferred faults are heavy dashed lines, faults are heavy solid lines. Scarps of the 1934 earthquake are thin solid lines, with sense of displacement marked. Modified from Richins, 1979, Fig. 16-6.

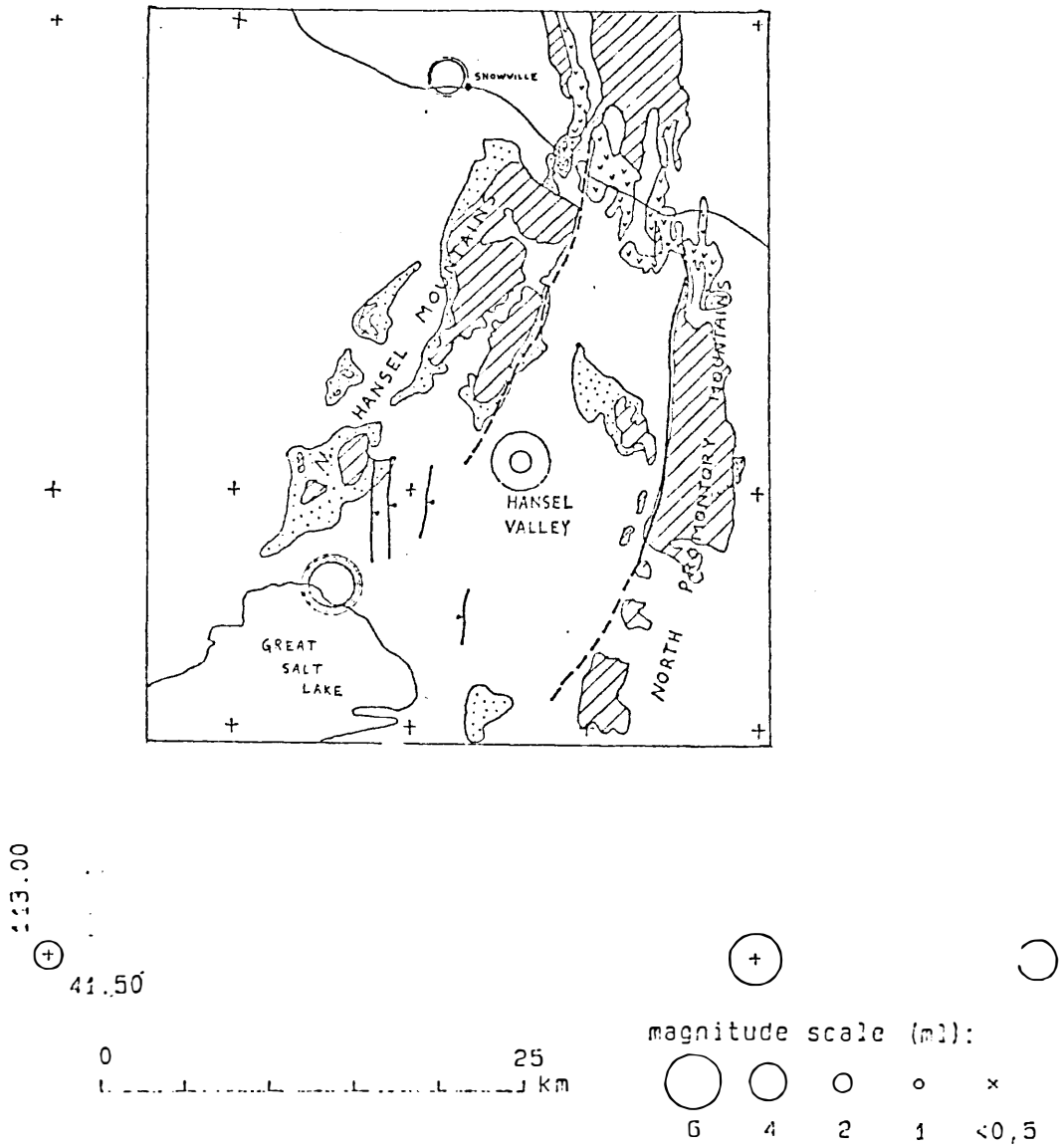


Figure 3a.

Earthquake epicenters in the Hansel Valley area, from 1850 to 1962 (non-instrumental records). The epicenter of the 1934 M6.6 earthquake is marked by concentric circles on the edge of the Great Salt Lake. Data plotted by the University of Utah Seismograph Station.

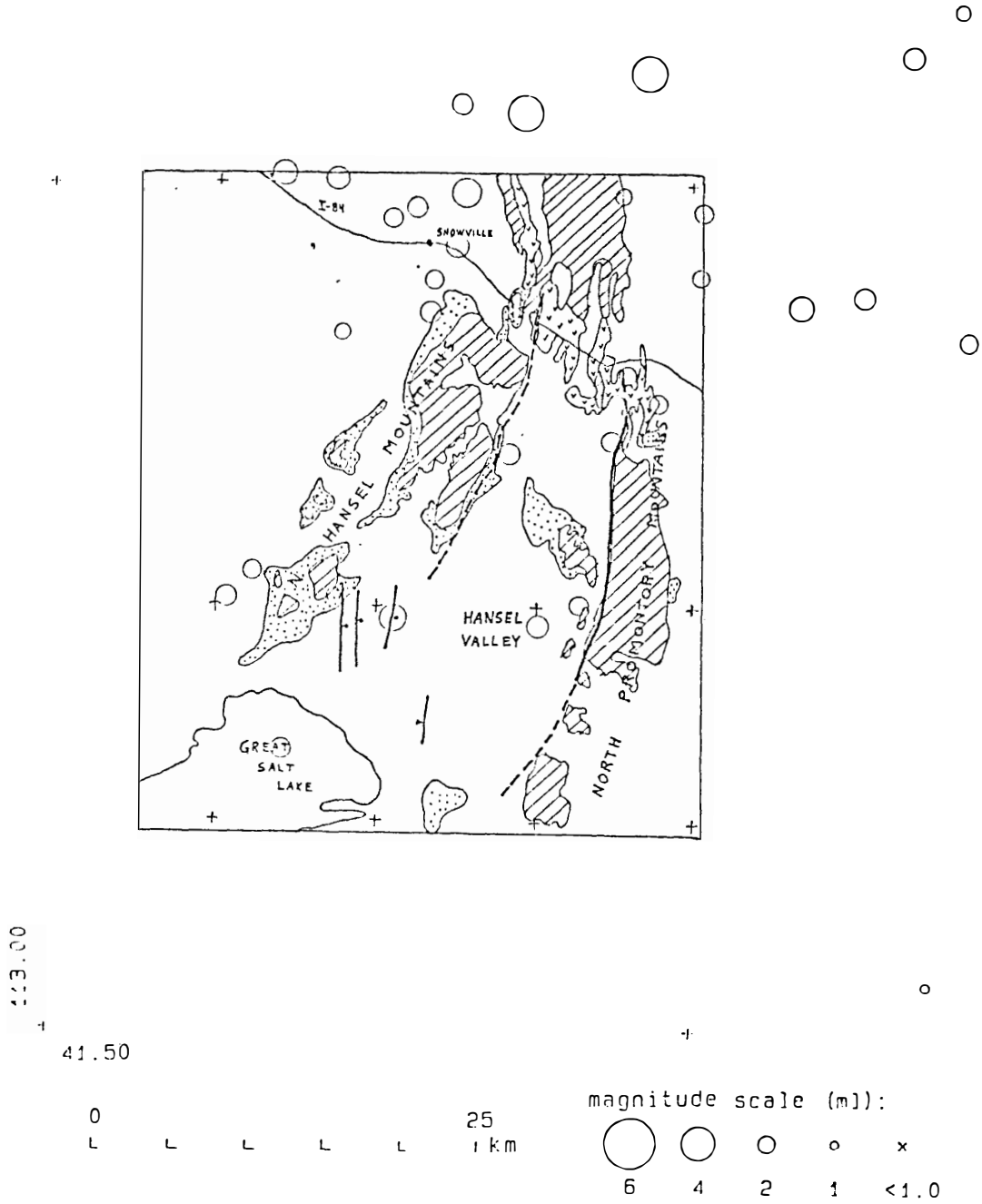


Figure 3b.

Earthquake epicenters in the Hansel Valley area, from 1962 to 1975 (instrumental records). Data plotted by the University of Utah Seismograph Station.

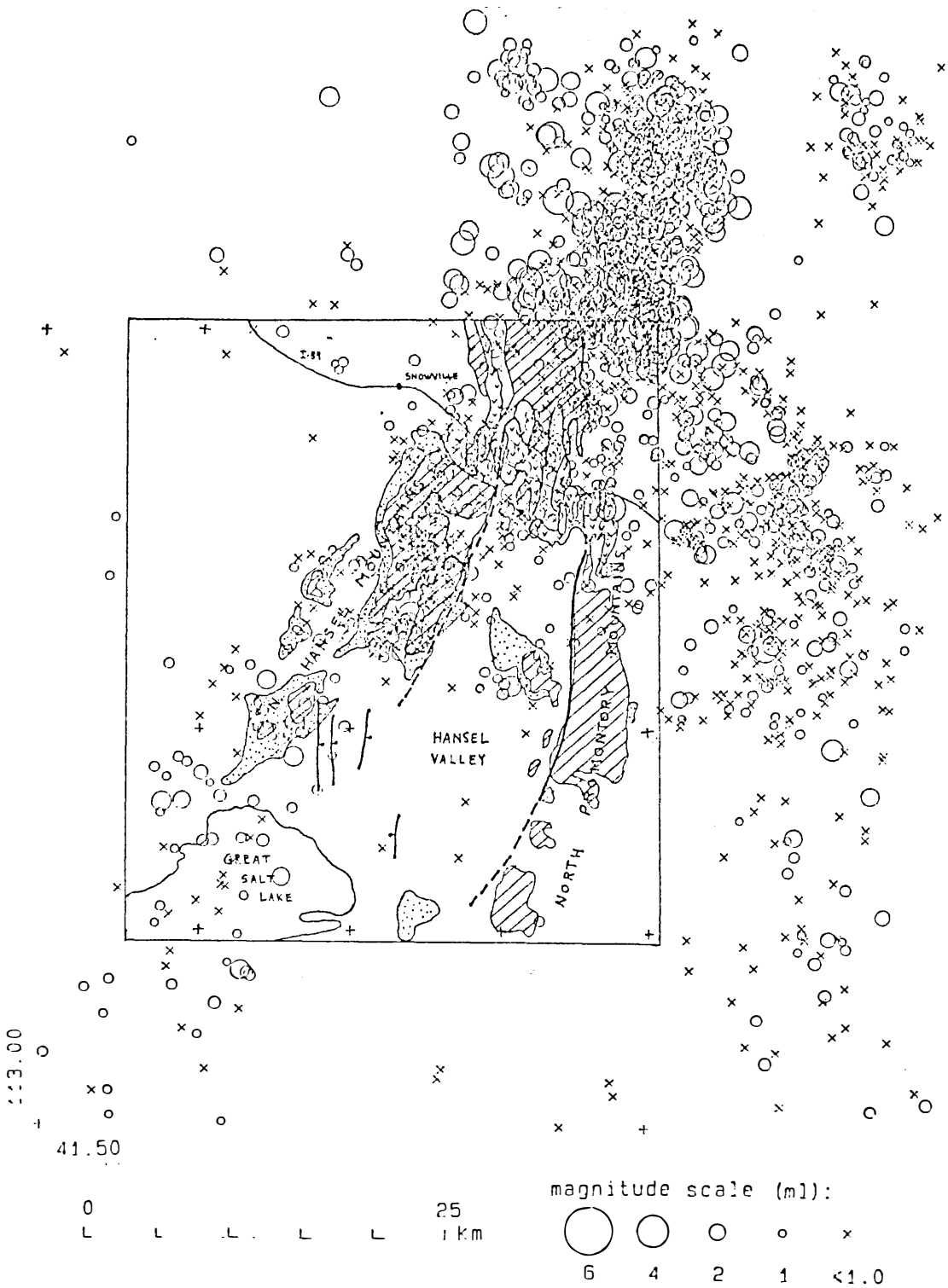


Figure 3c.

Earthquake epicenters in the Hansel Valley area, from 1975 to 1985 (instrumental data)- This period includes two large earthquake swarms: 1) that surrounding the 1975 M6.0 Pocatello Valley earthquake (northeast study area), and 2) that surrounding the 1976 M4.0 earthquake in the Hansel Mountains. Data plotted by the University of Utah Seismograph Station.

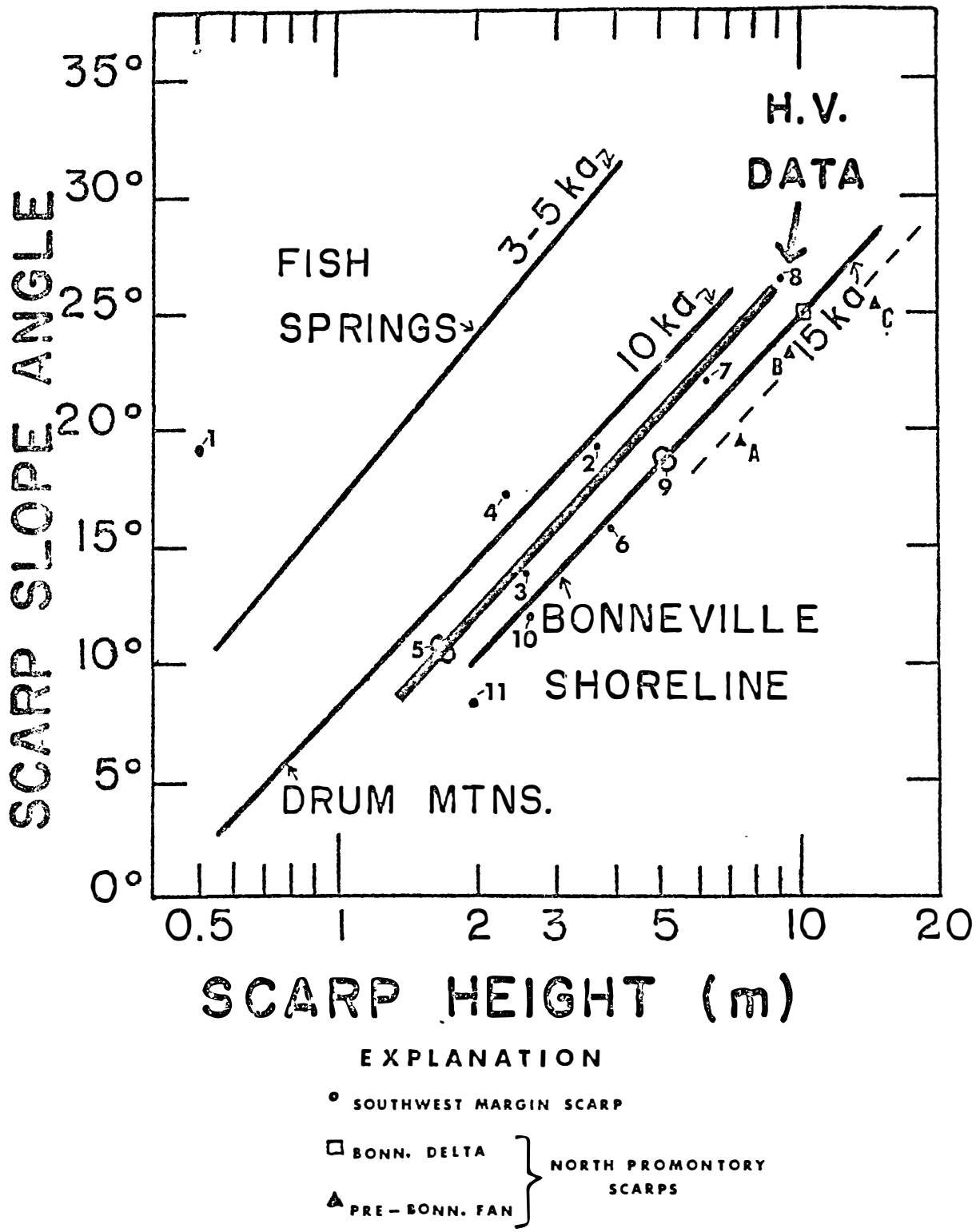


Figure 4.

Scarp height versus maximum scarp slope angle for fault scarps of the southwestern margin fault and North Promontory Fault. Dated regression lines for the Fish Springs, Drum Mountains, and Bonneville Shoreline scarps are from Bucknam and Anderson (1979). Data point numbers and letters correspond to Fig. 7.

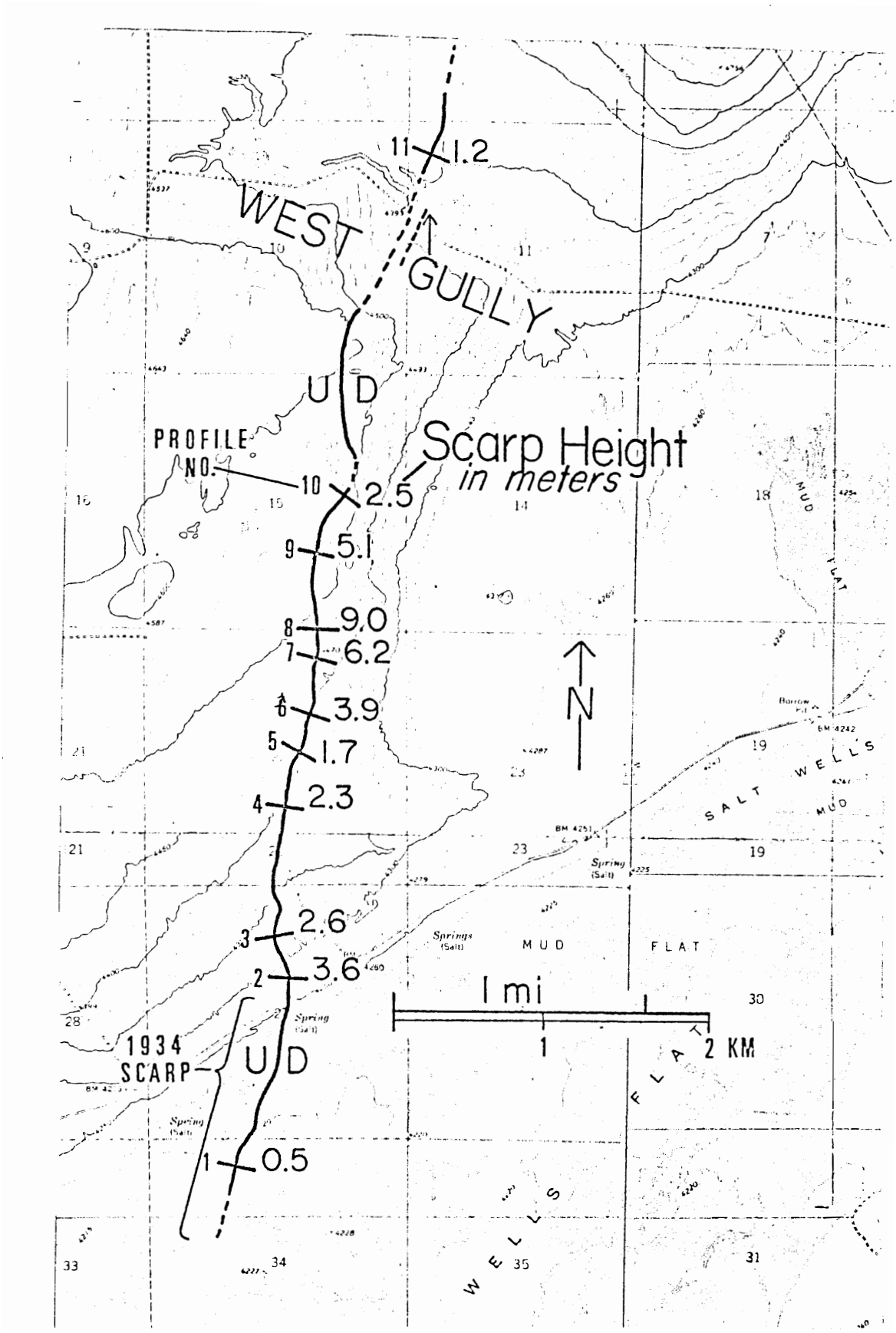


Figure 5.

Map of the southwestern margin pre-historic fault scarp showing profile locations, numbers, and measured scarp heights. All breaks of the 1934 event are not shown. Scarp heights vary according to the degree of syntectonic slumping (see text and Fig. 6). Scarp profiles are shown in Figure 7a.

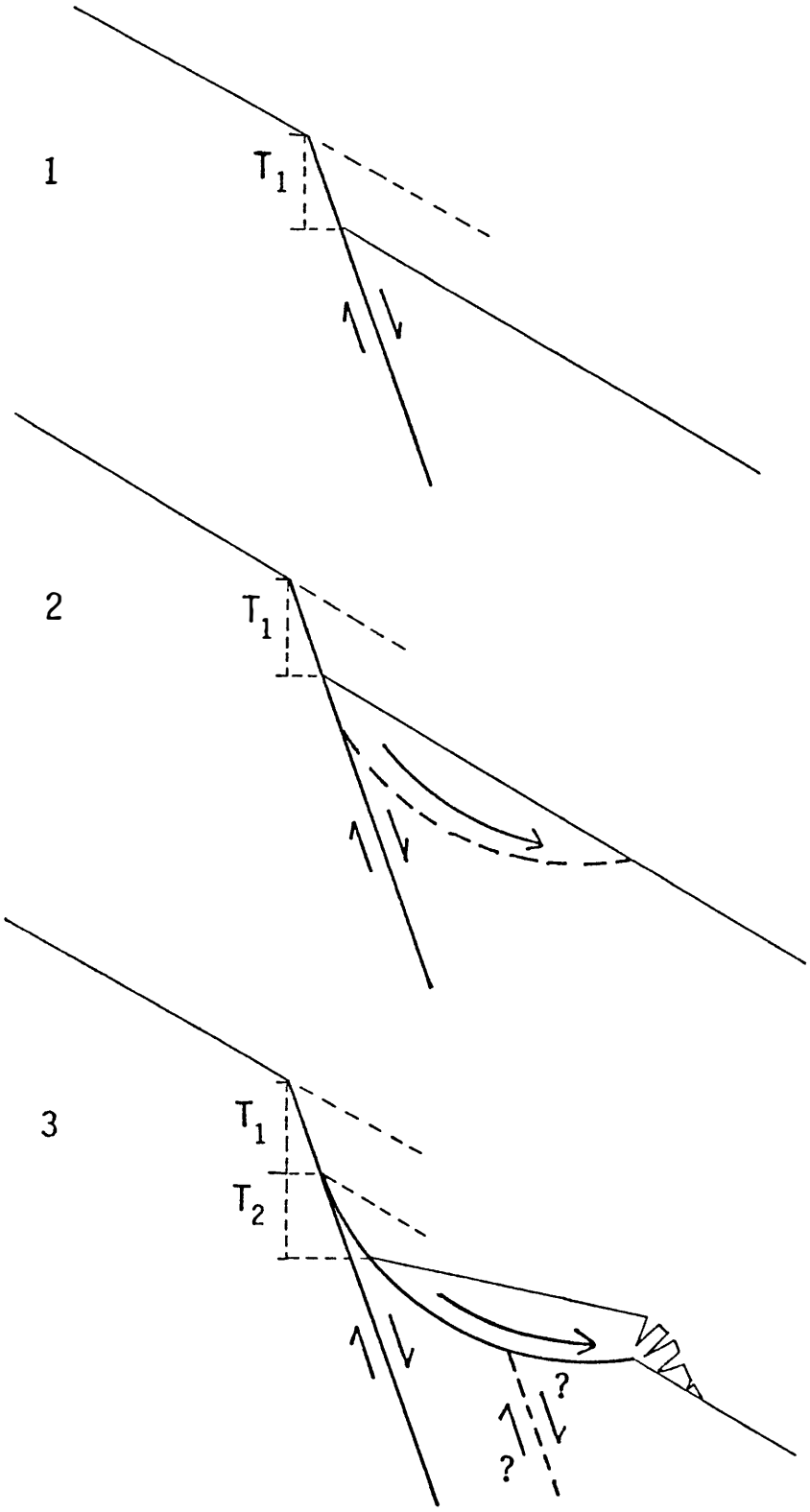


Figure 6.

Schematic diagram showing how syntectonic slumping is thought to control scarp height on the southwestern margin fault scarp. Theoretically, surface offset would not be affected if scarp profiles extended beyond the slumped segments on the downhill end.

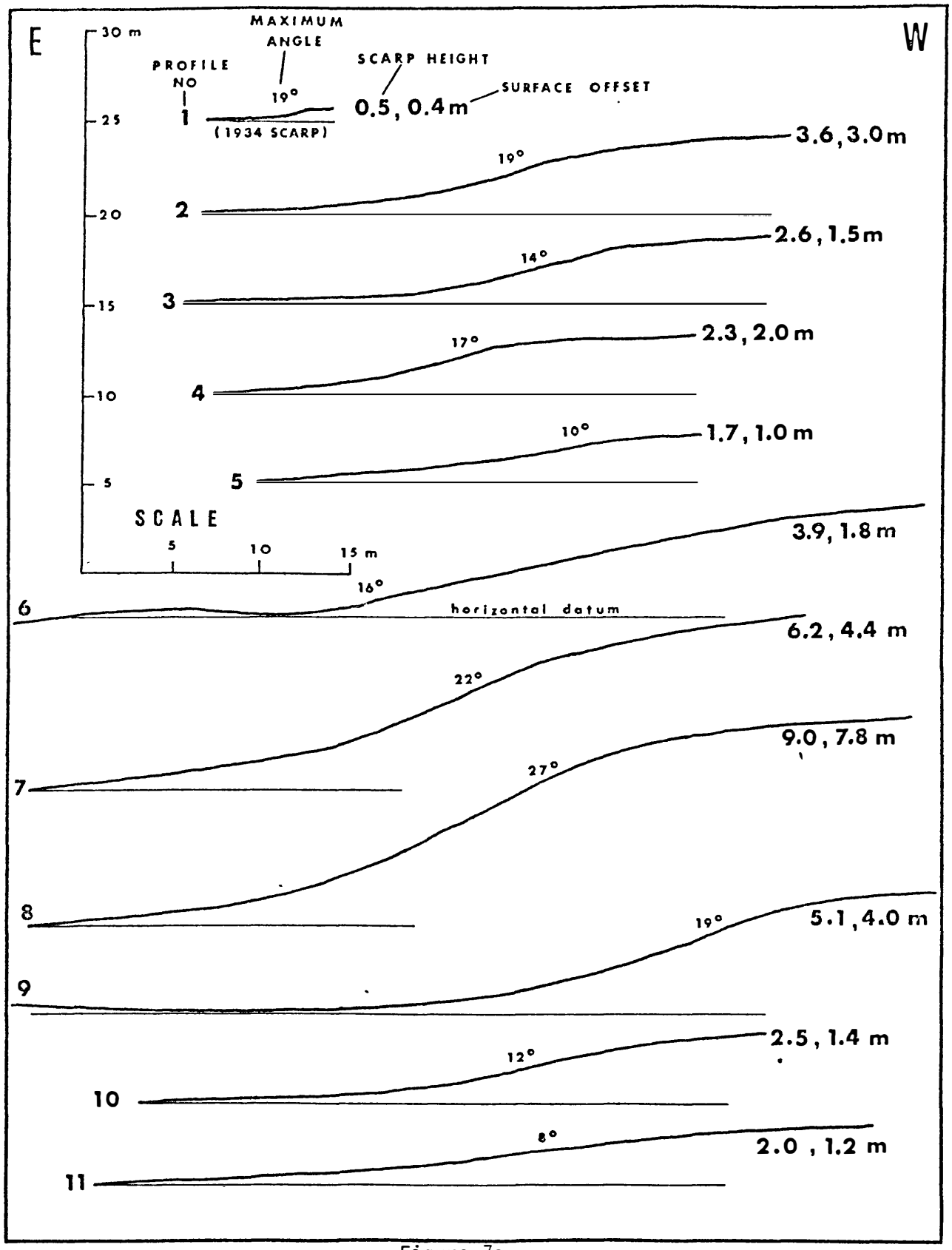


Figure 7a.

Fault scarp profiles of the southwestern margin scarp. Profile #1 is of the 1934 scarp; all others are of the pre-historic scarp. Most profiles do not show clear evidence of rejuvenation by the 1934 earthquake, except for #6, the steepest segment of which occurs immediately above the graben.

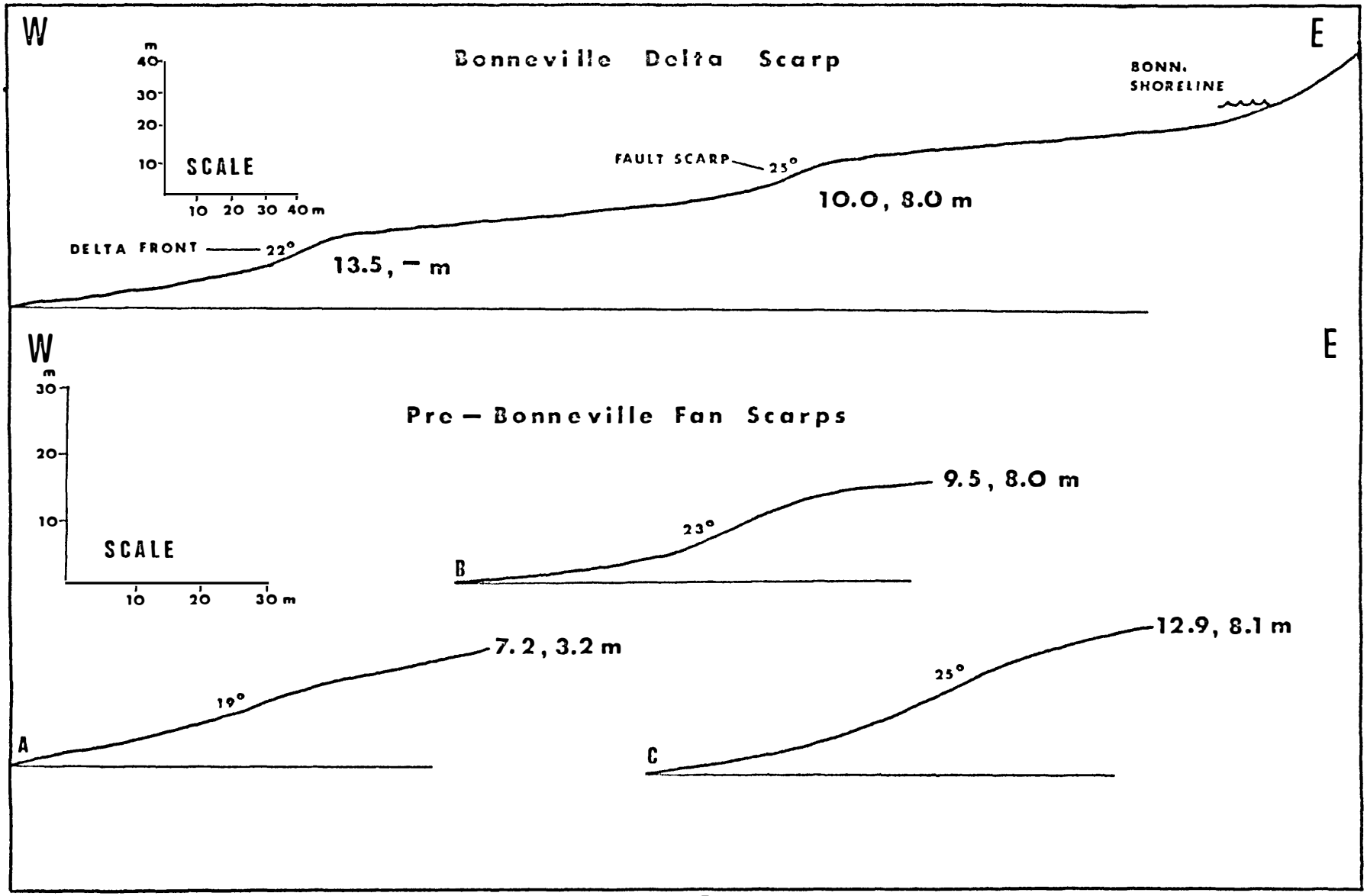


Figure 7b.
Fault scarp profiles of the North Promontory Fault scarps, offsetting the Bonneville delta (south of Rattlesnake Pass, Fig. 1) and pre-Bonneville alluvial fans (east of Bulls Pass, Fig. 1).

TECTONIC GEOMORPHOLOGY OF A FAULT SCARP FORMED DURING A LAKE TRANSGRESSION

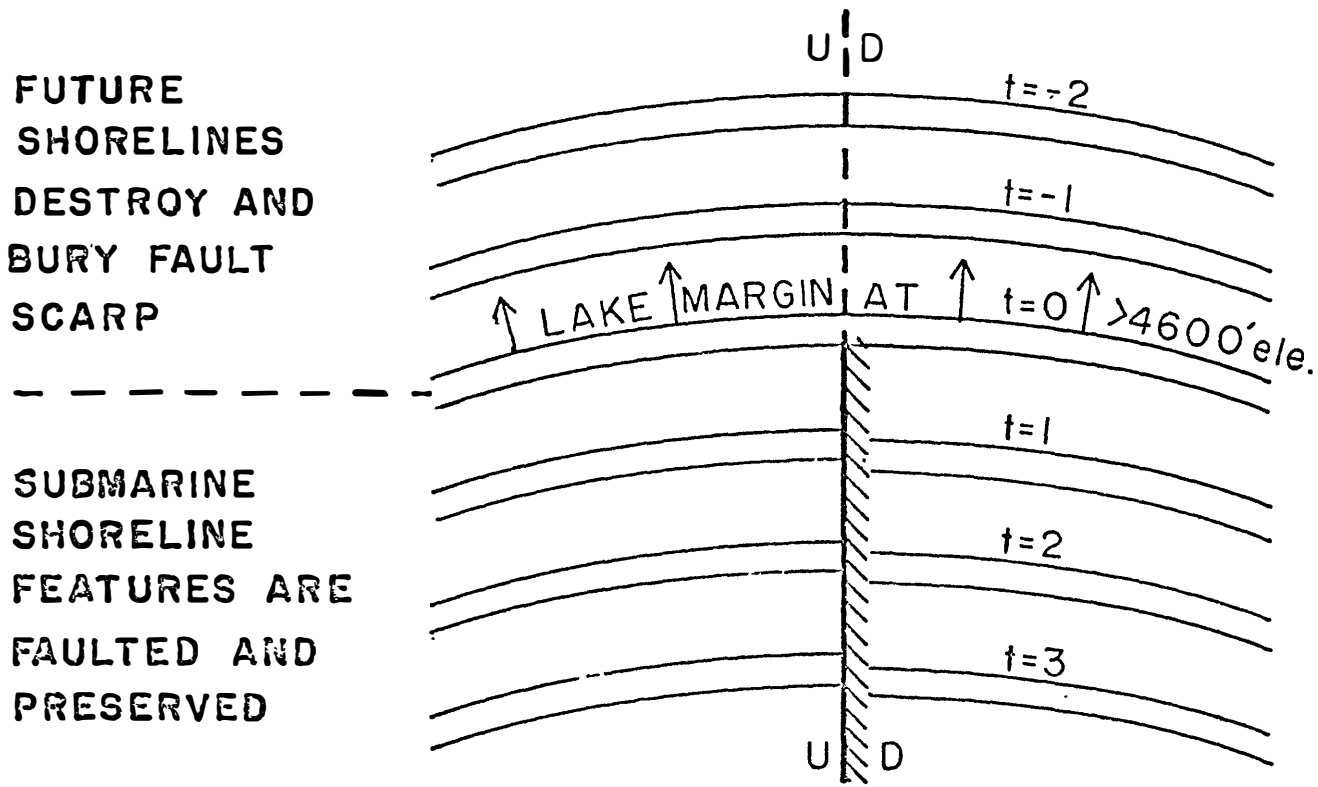


Figure 8.

Schematic diagram of geomorphic relations between transgressive shoreline deposits and a fault scarp which forms during the transgression (while lake margin is at 4600 ft. elevation and rising). t=3 is oldest, t= -2 is youngest.

TECTONIC GEOMORPHOLOGY OF A FAULT SCARP FORMED DURING A LAKE REGRESSION

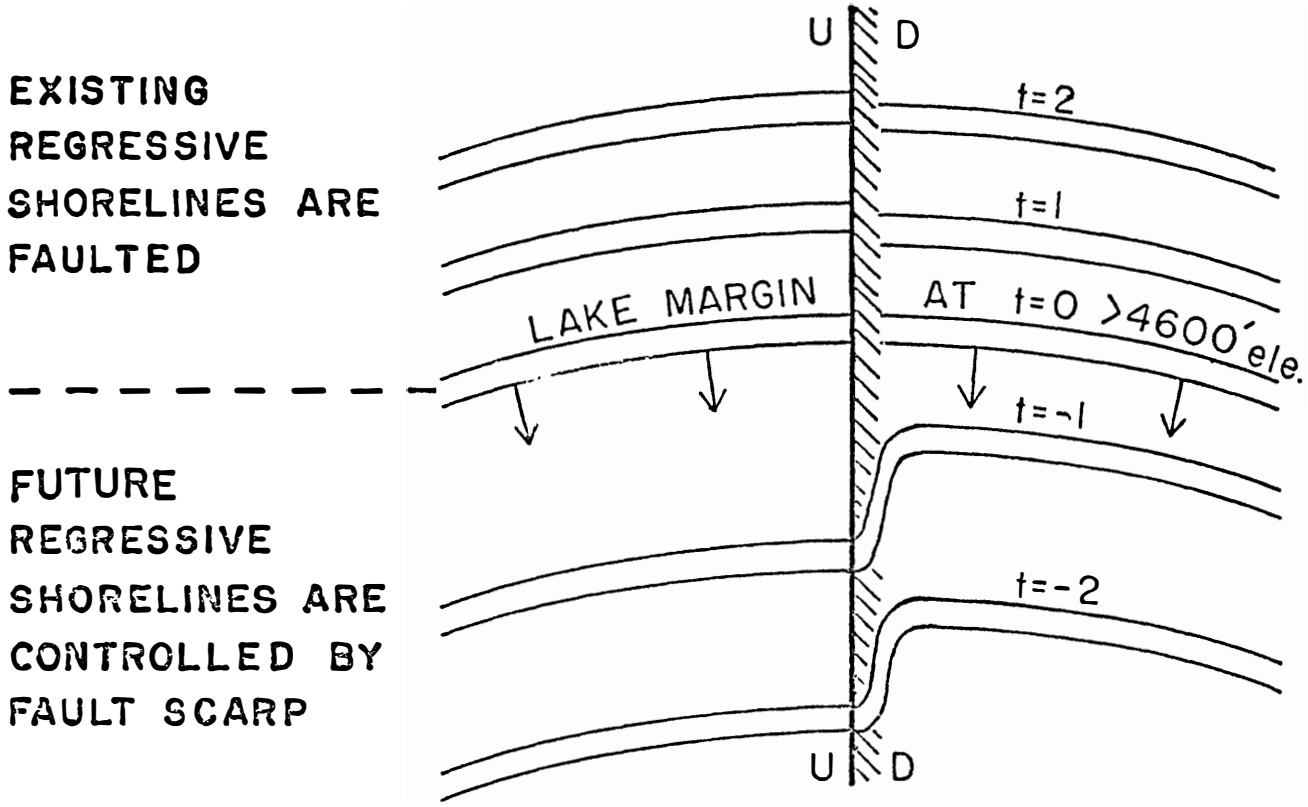


Figure 9.

Schematic diagram of geomorphic relations between regressive shoreline deposits and a fault scarp which forms during the regression (while lake margin is at 4600 feet elevation and falling). t=2 is oldest, t= -2 is youngest.

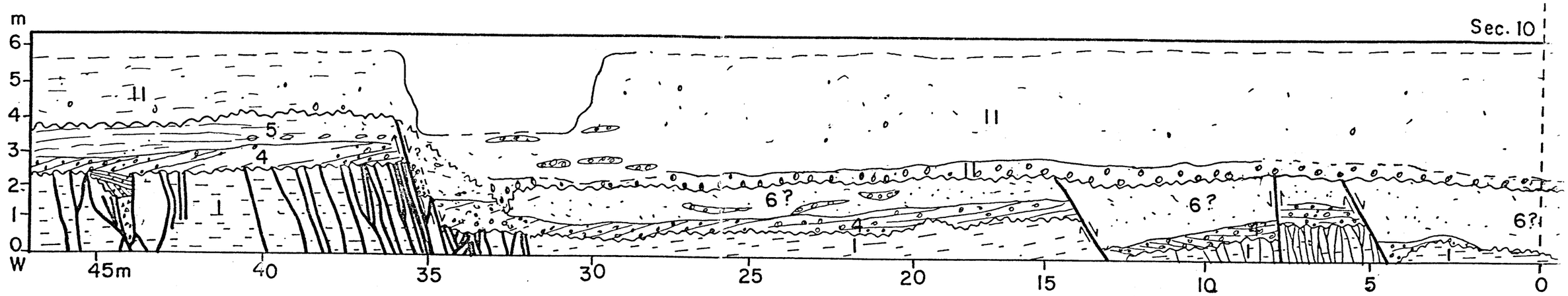
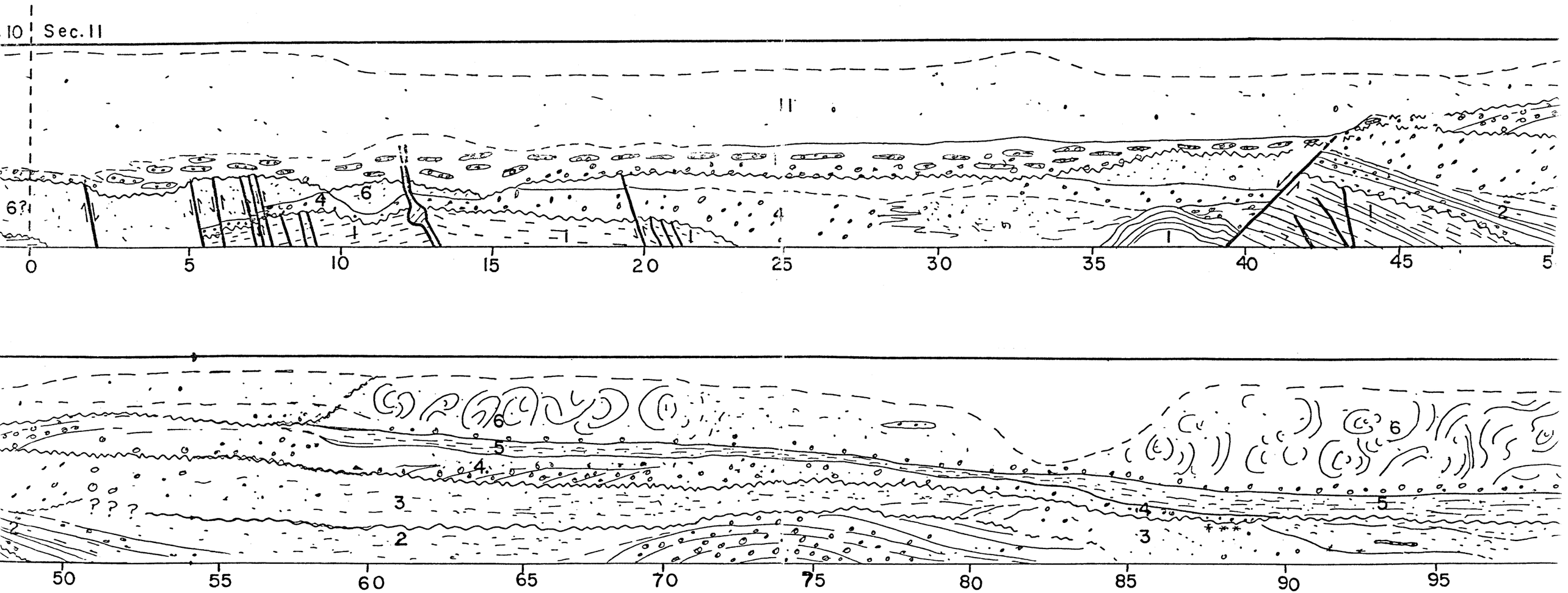
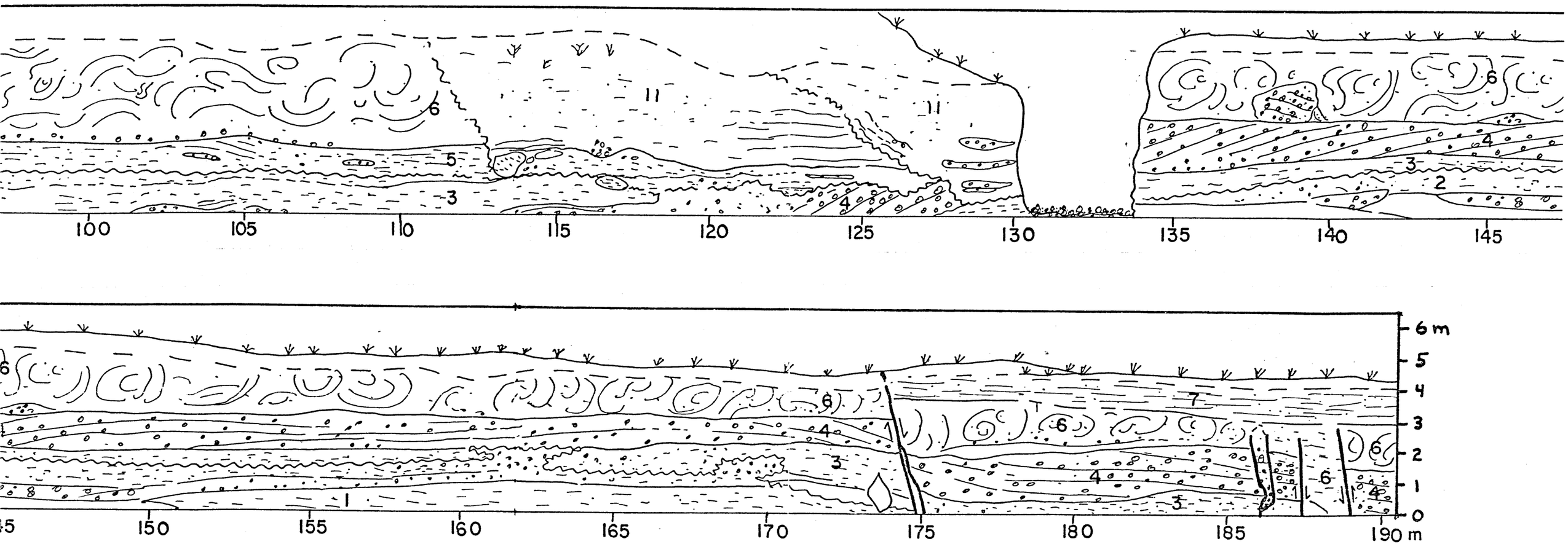
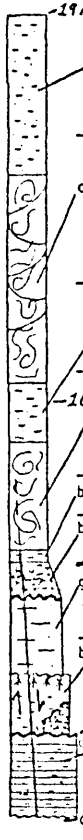


Fig. 10-Log of the north wall, West Gully (Unit numbers correlate to Fig. 11)




100
105
110
115
120
125
130
135
140
145
150
155
160
165
170
175
180
185
190 m
6 m
5
4
3
2
1
0

STRATIGRAPHY DISRUPTED BY TRACES OF THE 1934
HANSEL VALLEY FAULT SCARP AND BY OLDER PRE-HISTORIC EVENTS



STRATIGRAPHIC UNITS	SEDIMENTOLOGY & Deformation	OSTRACODS (by Rick Forester) Species	Inferred Environment	ABSOLUTE AGES ^{14}C	amino acids	TL	LAKE BONNEVILLE CHRONOLOGY	Oxygen Isotope Stage
upper laminated silt 9	well laminated silt & clay	mixture of species	mixed alkaline poor & alkaline rich waters; lake regressing				Bonneville cycle-regression from Provo shoreline	1
upper convoluted silt 8	intact, rotated blocks of well laminated silt & clay, similar to unit above					*11,700± 1100 (not fully zeroed) Too old	-drop to Provo shoreline? -Bonneville flood?	2
lower laminated silt 7	alternating silt & clay laminae with 5 cm thick, rippled med-cse sand beds	"profundal assemblege"	alkaline rich water-deep lake			(not fully zeroed)	Bonneville cycle highstand	2
lower convoluted silt 6	intensely convoluted mixture of clay, silt, sand, & floating pebbles; roll structures common			*15,450 + 650 (min.date)	*21,000 prelim	Too old *40,100± 3200	deepening water	2
brown lam.silt 5	well laminated silt		alkaline poor water, low-stand lake lake level rising					2
beach gravel 4	cross-bedded, well sorted medium pebble gravel						Bonneville cycle transgression	2
MAJOR UNCONFORMITY								
green silt 3	green silt with some clay, poorly laminated		alkaline poor water, low-stand lake			*67,000 ± 3800 (best date)	"Alpine" (early Wisconsin) cycle	4
brown silt 2	brown massive silt, gypsum crystals at top, laminations better defined toward bottom; locally overlies lacustrine bar gravels	Heterocypris n.sp. C. rawsonii Listaplini L. bradvii	alkaline poor water marginal lacustrine groundwater environment			(some trap saturation) *65,900 ± 4200		4
MAJOR UNCONFORMITY								
compact silt 1	well laminated silt & clay, very compact; intensely fractured w/ steeply dipping small displacement joints	C.sp. caudata type L. Sappaersis L. ceriotuberosa L. staplini C. beacorensis	alkaline rich water, deep lake			115,200 ± 17,500	Little Valley Cycle	6?

Figure 11.

Summary chart of the Quaternary stratigraphy exposed in the West Gully (located on Fig. 5). Unit numbers are also used in Fig. 10, with the addition of Unit 11 (Holocene alluvium).

34

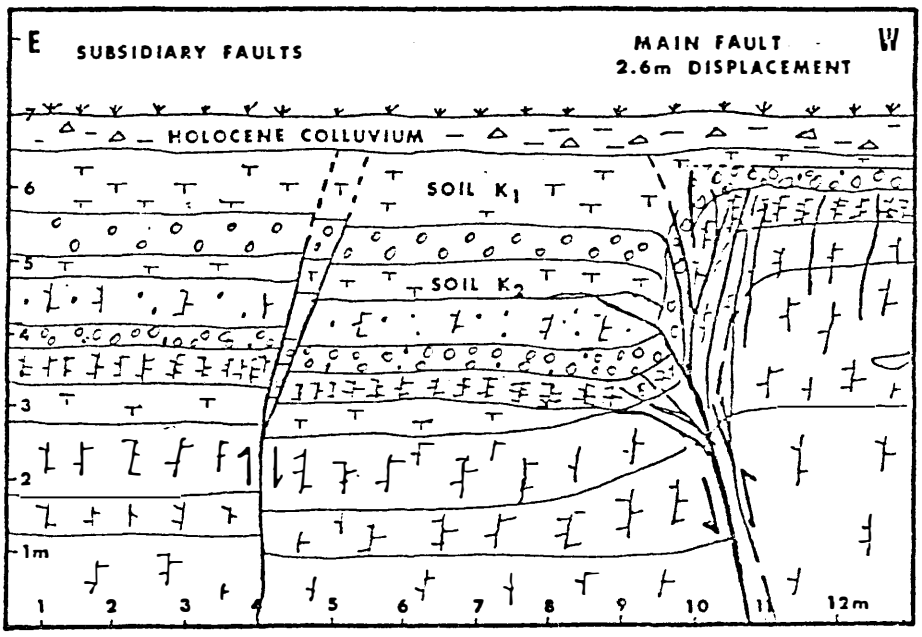


Figure 12.

Sketch of the Rattlesnake Pass roadcut fault. A single 2.6 m displacement offsets all deposits except the surface Holocene colluvium. The upper part of the soil carbonate in Soil K1 also extends across the fault, suggesting it is younger than faulting. Intensity of line patterns in soil B horizons indicates degree of development.

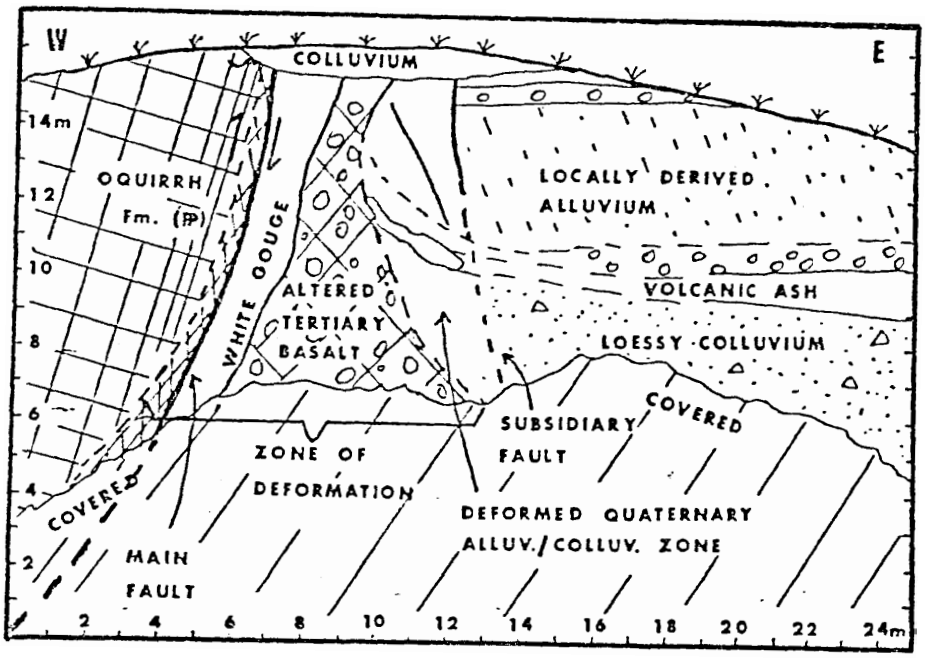


Figure 13.

Sketch of the Hansel Valley Exit roadcut fault which juxtaposes progressively more shattered and altered Paleozoic carbonates against Tertiary basalts and Quaternary alluvium/colluvium. The east side of the cut represents a depositional swale, so the complete Quaternary section was not necessarily ever deposited to the west of the fault; thus, displacements can only be estimated.

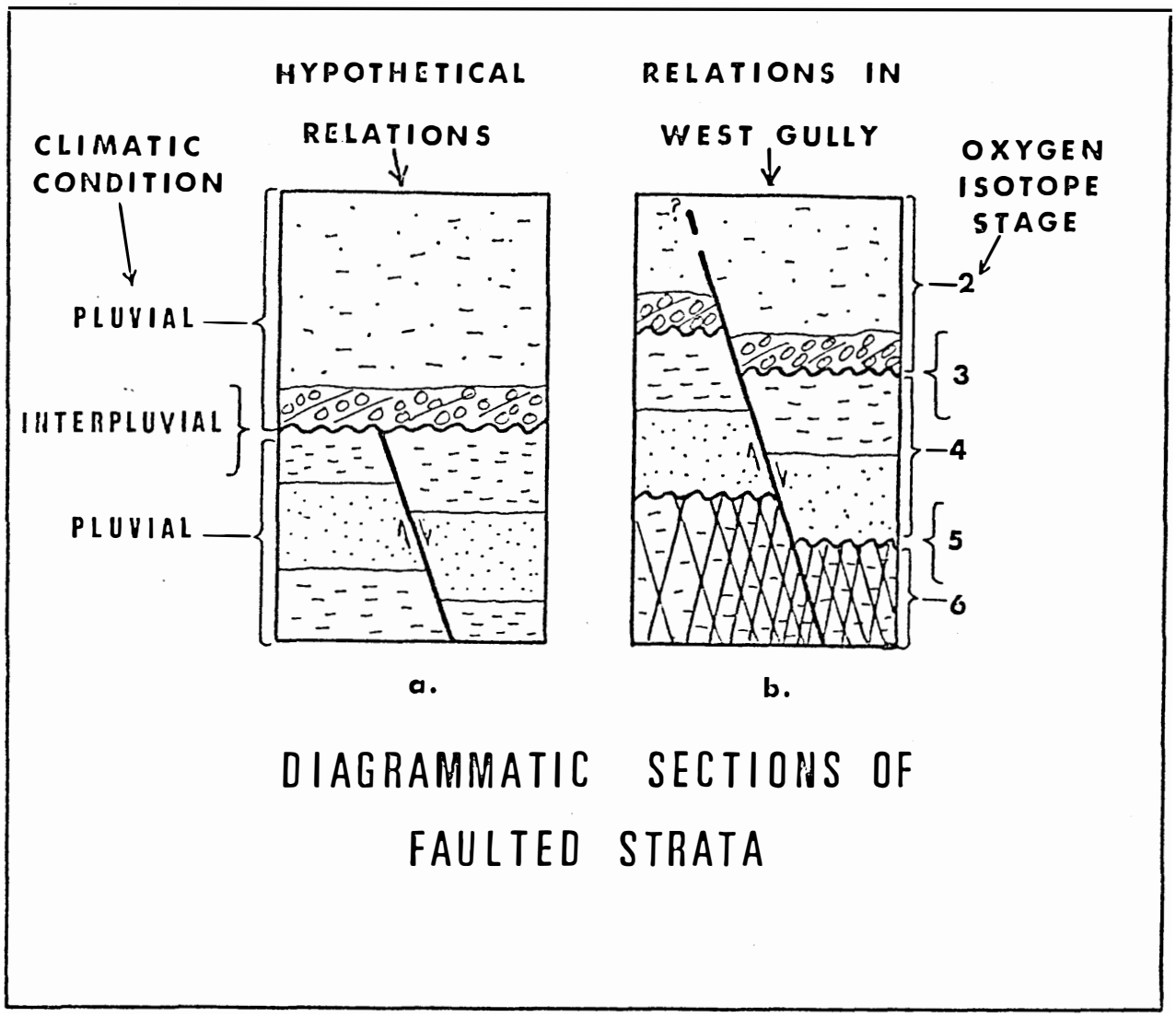


Figure 14.

Diagram showing typical fault/strata relations in deposits of a pluvial/interpluvial/pluvial cycle. Because basin-margin deposition usually accompanies pluvial conditions, and soil formation or erosion characterizes interpluvials, a typical fault which offsets a lower unit but not an upper one will be assigned to interpluvial time (Fig. a). The relations in the West Gully, by contrast, appear as in Fig. b (see text for discussion).