U.S. Geological Survey Earthquake Hazards Reduction Program
Final Technical Report

Paleoseismic studies of the Little Valley fault

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Background

The frontal fault system that bounds the northern Carson Range in western Nevada (referred to as either the northern Carson Range fault system (NCRFS) or the Mt. Rose fault zone) is a major fault system that poses the principal seismic hazard to Reno, the second most populous area in the state. There is more than 5,000 ft (1,500 m) of topographic relief across the NCRFS, but only a part of this relief occurs across the range-front fault trace. Much of this relief occurs across faults within the range, across a highly distributed piedmont fault zone, or as warping. In this project, we tried to assess how activity is distributed across the system.

The NCRFS extends from southernmost Washoe Valley northward into downtown Reno (figure 1), for an overall length of ~34 km. In Washoe Valley, the zone includes an 11-km long frontal fault (Washoe Valley fault) and a major, subparallel fault within the Carson Range (Little Valley fault); taken together, these two faults have a length of ~17 km.

To the north, the fault system includes an 8-km long frontal fault, several synthetic faults within the Carson Range, and a complex, distributed zone of nested graben in the hanging wall (total length of ~25 km, and a width of up to 10 km). The fault system extends to downtown Reno as a narrow graben, sometimes referred to as the Virginia Lake fault zone.

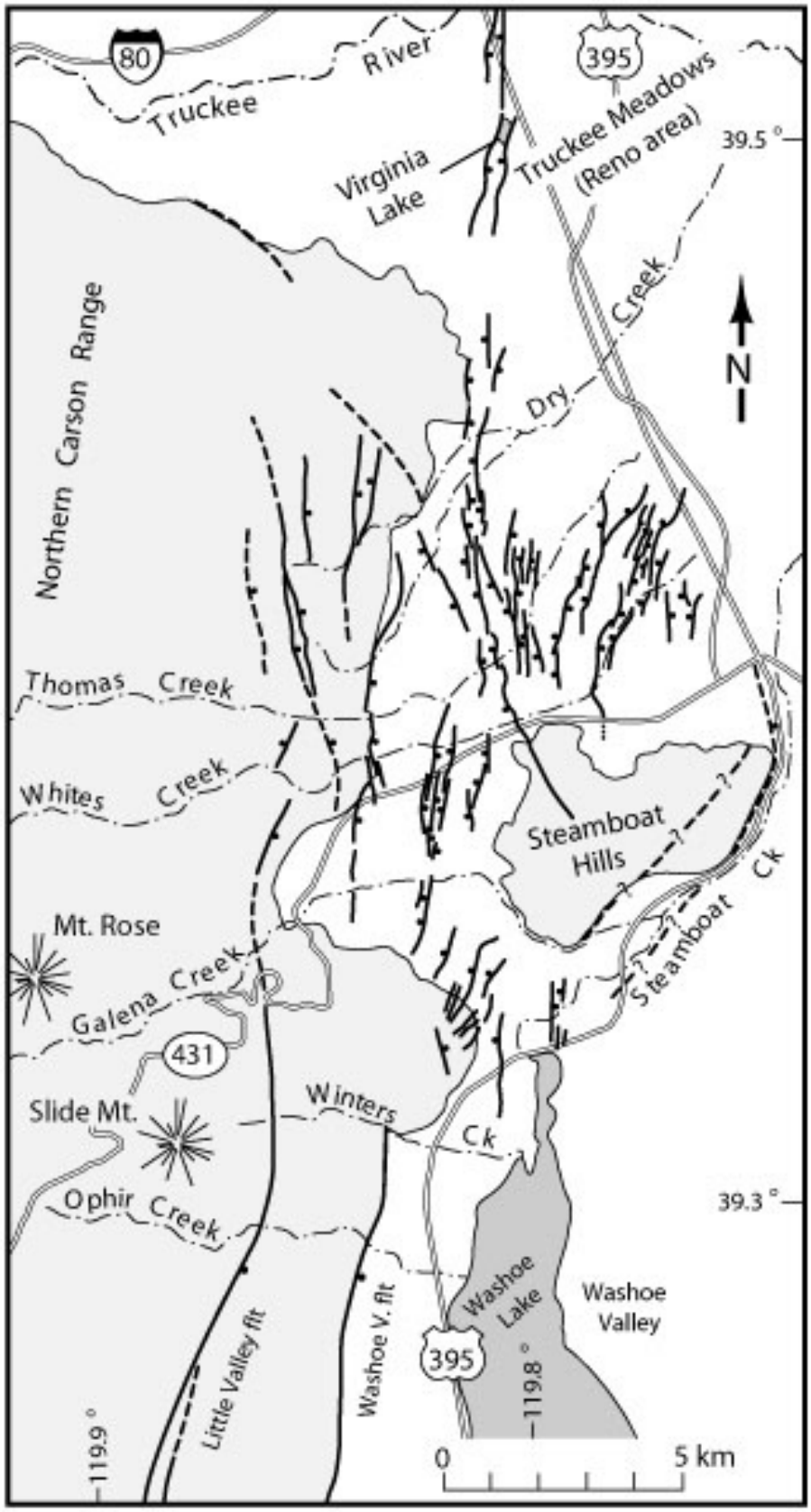

Figure 1: Generalized map of the northern Carson Range fault system

Figure 2: Washoe Valley (to left) and Little Valley (center) looking south from Slide Mt

Little Valley fault

The Little Valley fault is synthetic to the range-bounding Washoe Valley fault (figure 2). The two faults have similar topographic relief (~600 m) along much of their lengths, but there is also an estimated 600 m of basin fill in Washoe Valley (Peterson, 1993; Peterson and Karlin, 1997). The Washoe Valley fault thus has about twice the offset of the Little Valley fault, and net throw across the two faults is almost 2 km.

At Winters Creek, where the Washoe Valley fault abruptly dies out, most of the vertical relief across the system steps left to the Little Valley fault, which bounds the steep east flank of Slide Mountain.

The Washoe Valley fault is separated from distributed faults cutting the Mt. Rose piedmont (often called the Mt. Rose fan) by a ~2 km gap in obvious recent faulting, while the Little Valley fault overlaps with the Mt. Rose fan faults by ~6 km. North of Galena Creek, much of the vertical offset on the Little Valley fault steps right to the short (~8 km long) Mt. Rose range-front fault.

The northern part of the Carson Range is nearly entirely composed of Tertiary volcanic rocks, in contrast to the southern and central parts of the range which are dominantly granitic. At its north end, the range dies out into a large, northward-plunging antiform, and is cut by several poorly defined, northwest-striking faults.

Investigations undertaken

*Examined several geotechnical consultants' trenches, and logged three trenches that yielded radiocarbon age control on the most recent event.

*Constructed topographic profiles across faults within the northern Carson Range in order to estimate relative offsets

*Constructed topographic profiles across the Mt. Rose piedmont fault zone and within the city of Reno from two-foot contour data available from Washoe County

*Compiled and re-evaluated age constraints for the fault system as a whole

Results

Mt. Rose fan trenches

The Mt. Rose fan area is undergoing extensive development, mostly residential, and consulting companies have excavated many trenches in the area for geotechnical studies associated with development projects. Dozens of trenches have been examined in reconnaissance fashion over the years. The vast majority of these trenches revealed little other than evidence of generally small (tens of cm) recent offsets, but a few trenches have yielded datable material constraining the timing of the most recent event.

<u>Callahan Ranch trenches</u>

Two out of 18 trenches excavated for a development project in the Callahan Ranch area revealed fissures formed during the most recent surface rupturing event. These fissures are filled with dark, organic-rich material, presumably derived from mollic soil horizons present at the time of faulting. If mean residence time (MRT) uncertainties can be adequately accounted for, these dates should approximate the age of the event.

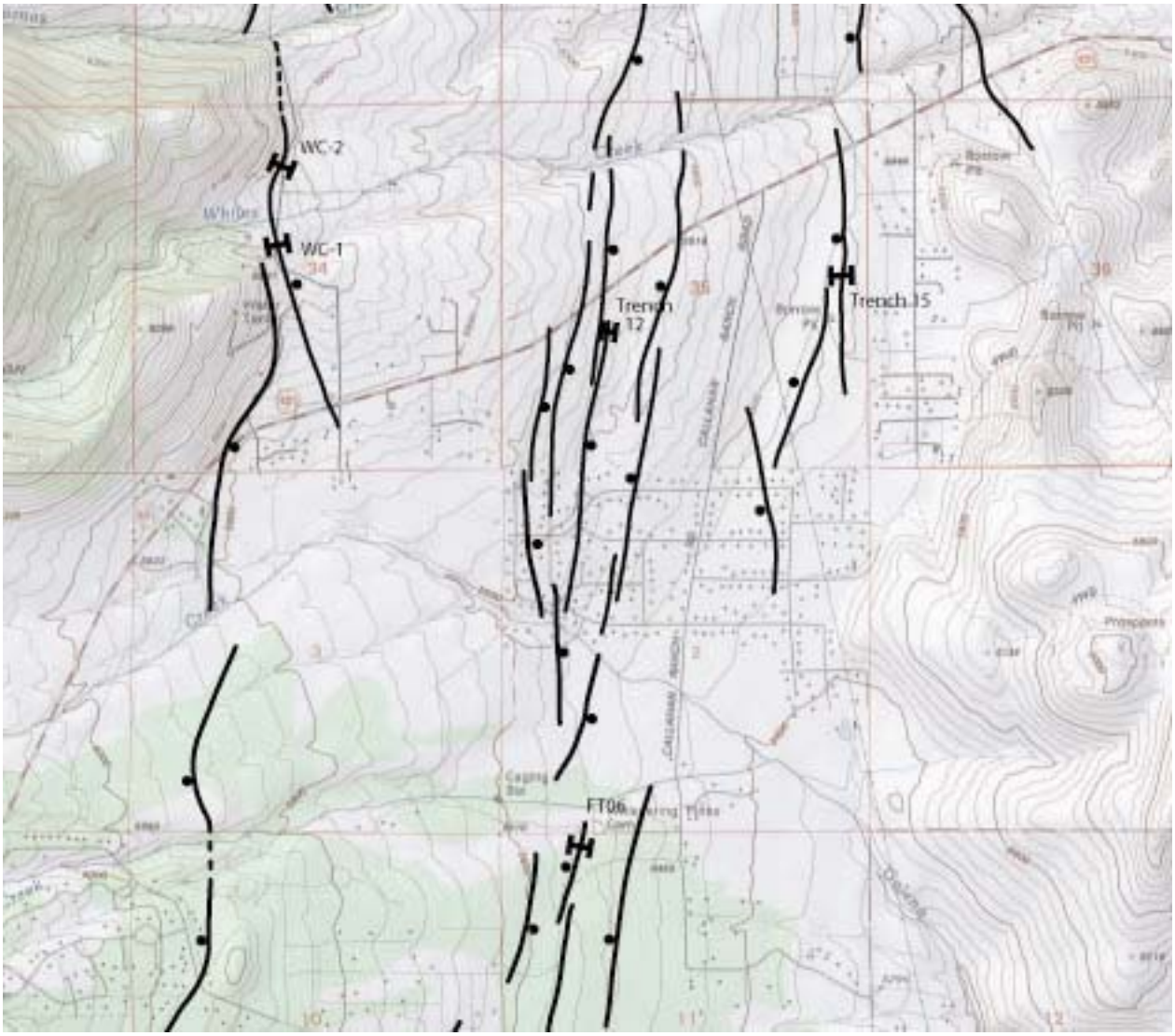

Figure 3: Locations of the five trenches in the southern Mt. Rose fan area that have yielded datable material. WC-1, excavated in the early 1980s (Schilling and Szescody, 1982; Bell and others, 1984), yielded constraints on the MRE. WC-2, a consultants' trench excavated in the 1990s, yielded two bulk radiocarbon dates from colluvial deposits that at least generally indicate the fault's rate of recent activity. Trenches 12 and 15, consultants' trenches excavated in the early 2000s, yielded radiocarbon dates that support the estimated age of the MRE from WC-1. FT06, a consultants' trench excavated in 2007, yielded detrital charcoal in a fissure formed during the MRE (results are pending).

Callahan Ranch Trench 15

Trench 15 was excavated across an antithetic fault scarp just west of Steamboat Hills. With a height of ~10 m (estimated vertical displacement of 8-12 m), this is one of the largest fault scarps in the Mt. Rose fan area.

Trench 15 revealed relations that are fairly typical of fault scarps on the Mt. Rose piedmont, where fan deposits generally have thick, well-developed argillic soils, indicating fairly old ages (>100 ka). The scarp faces themselves also commonly have well-developed soils, indicating they have existed for a minimum of several tens of thousands of years. The soil on the Trench 15 scarp is not as well-developed as in some other locations, likely because the large, steep scarp face is not entirely stable. Similar to many other Mt. Rose piedmont fault scarps, the scarp-mantling soil is displaced by one or more recent faulting events.

The deposits exposed in Trench 15 generally consisted of massive gravelly sands. The lack of distinct stratigraphy limited interpretation of events, but relations nonetheless indicate several events with up to a few meters of offset per event. The only datable material obtained from the trench was dark, organic-rich material within a fissure formed by the most recent event, which yielded a radiocarbon date of 1,060 ± 70 ybp (figure 4).

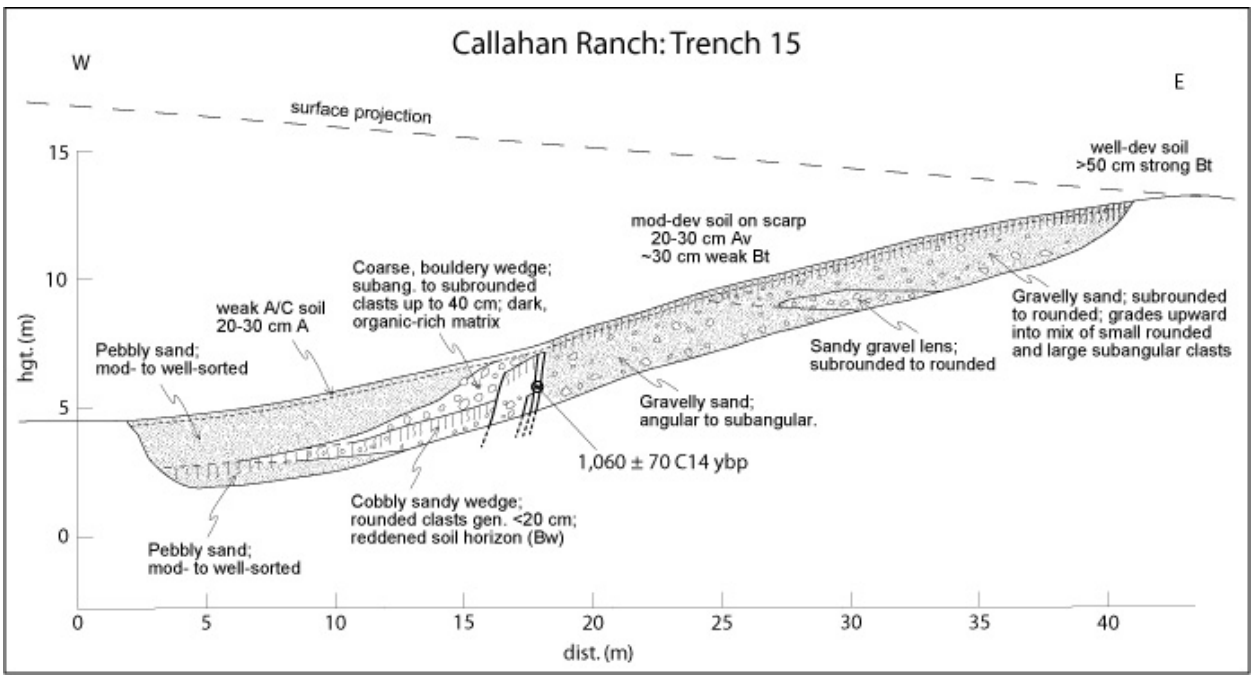

Figure 4: Log of Callahan Ranch Trench 15. See figure 3 for trench location.

Callahan Ranch Trench 12

Trench 12 was excavated across a small, synthetic fault scarp in the central part of the Callahan Ranch graben (figure 3). In contrast to the repeated events revealed in Trench 15, Trench 12 displayed only a single recent event offsetting a well-developed argillic soil. However, similar to Trench 15, Trench 12 exposed dark, organic-rich material filling a fissure formed during the most recent event. The sample yielded a radiocarbon date of 930 + 60 ybp, virtually identical to the date from Trench 15 and a prior radiocarbon date from the mouth of Whites Creek canyon (Szecsody and Schilling, 1982).

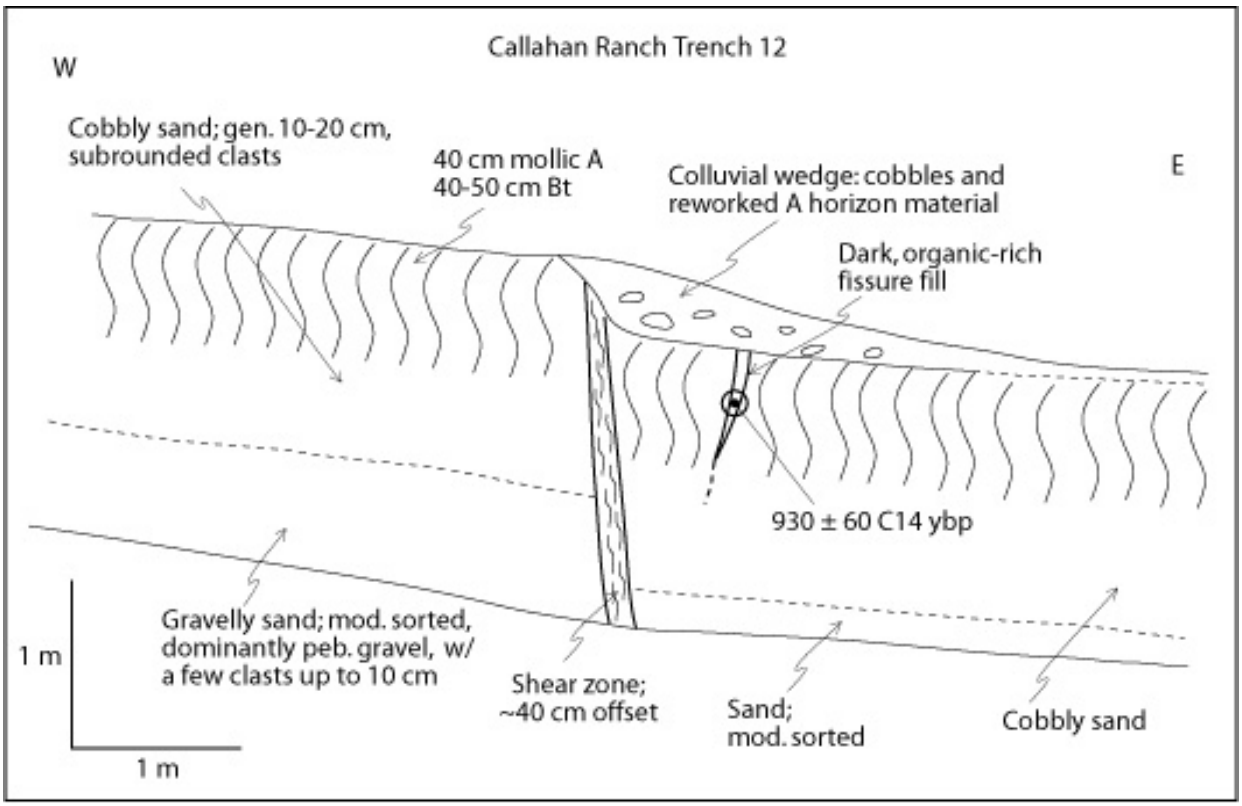

Figure 5: Sketch log of Callahan Ranch Trench 12. See figure 3 for trench location.

Montreaux trench FT06

Trench FT06, excavated across an antithetic fault in the Montreaux area (figure 3) during Summer, 2007, exposed detrital charcoal within a fissure formed during the most recent event. One of two charcoal samples was submitted for dating, and results are pending. Dating of detrital charcoal avoids some of the mean residence time (MRT) issues involved in dating bulk soil samples, so it is hoped that this sample will either support the estimated age of the MRE based on results from the other trench sites, or reveal whether the prior radiocarbon dates are significantly affected by MRT factors.

The event sequence in FT06 was complicated by both the bouldery nature of the fan deposits, and by erosion and subsequent deposition caused by fault-parallel drainage, so no detailed attempt was made to interpret event stratigraphy.

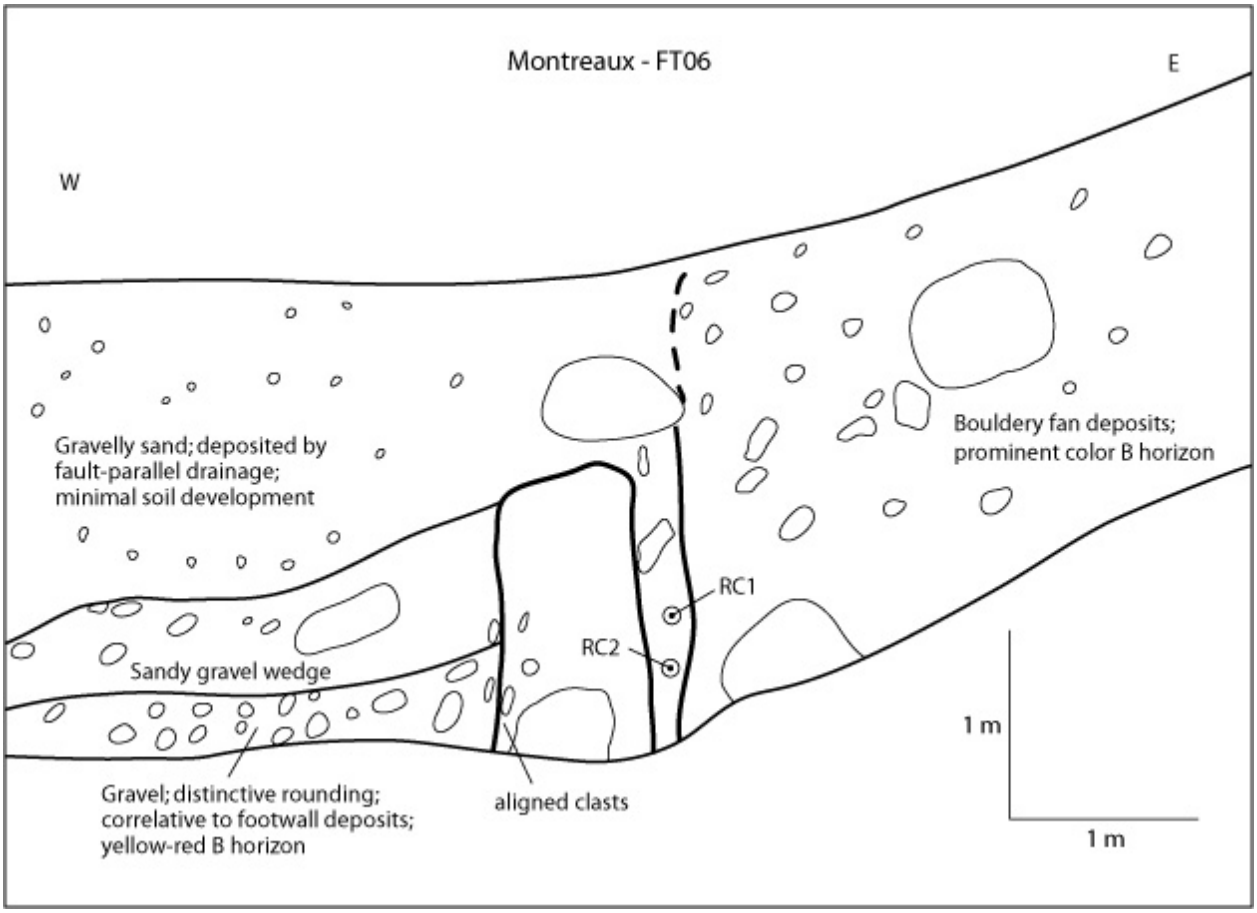

Figure 6: Sketch log of Montreaux trench FT06. See figure 3 for trench location.

Faults within the Northern Carson Range

Several subparallel faults cut the northern Carson Range (figure 7). These faults are within the footwall of the range-front fault, and most strike NNW, slightly oblique to the range front. Most of these faults are synthetic to the range front (down-to-the-east displacement), and in general, these faults decrease in displacement away from the frontal fault.

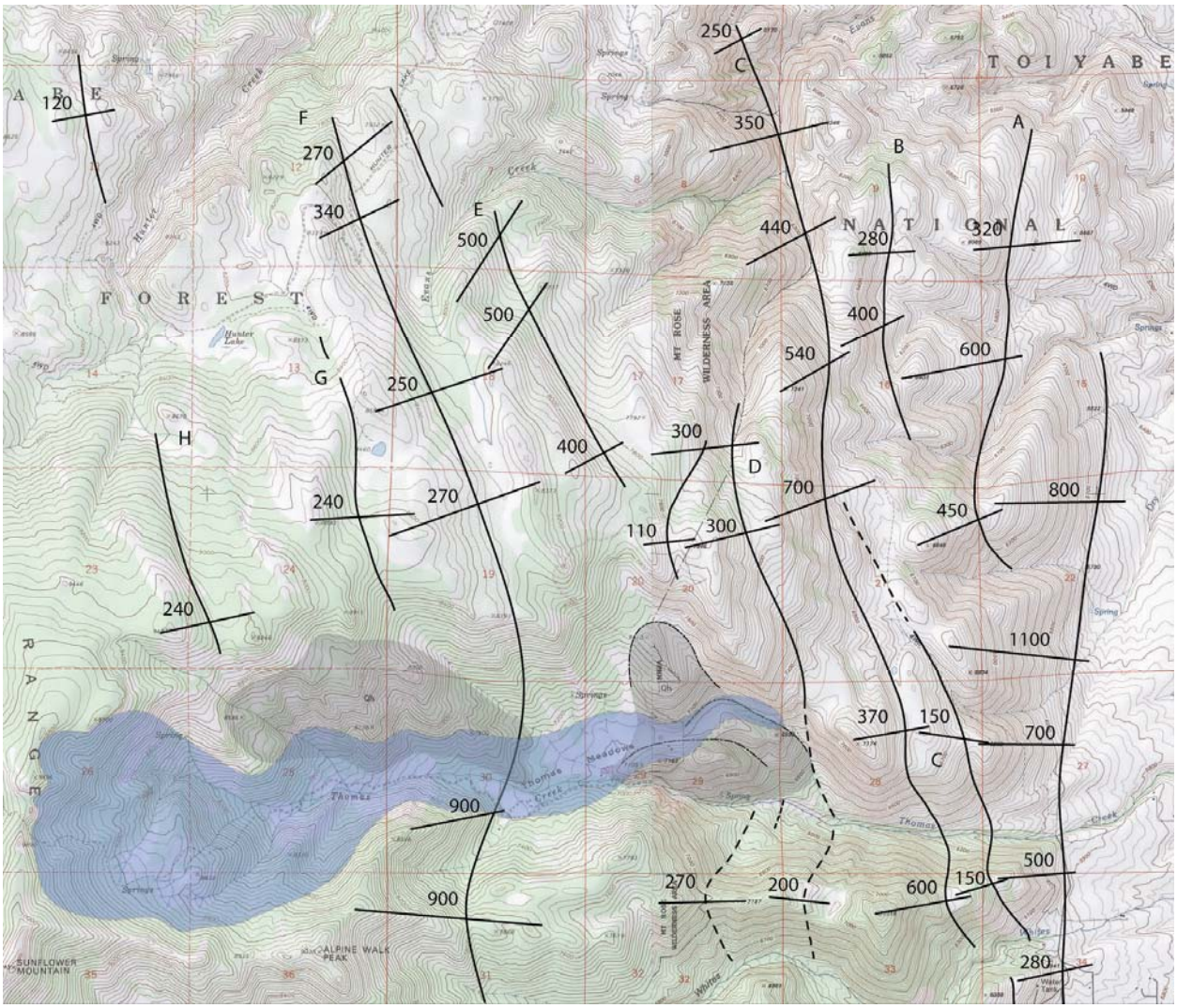

Figure 7: Escarpment heights (in feet) along principal faults within the northern Carson Range. The two largest faults (F and C) have maximum escarpment heights of about 900 ft (270 m) and 720 ft (220 m), respectively, and cut alluvial deposits in Thomas Creek canyon. Blue shading – estimated maximum extent of the late Pleistocene glacier in Thomas Creek canyon. Grey shading – major Quaternary landslide areas.

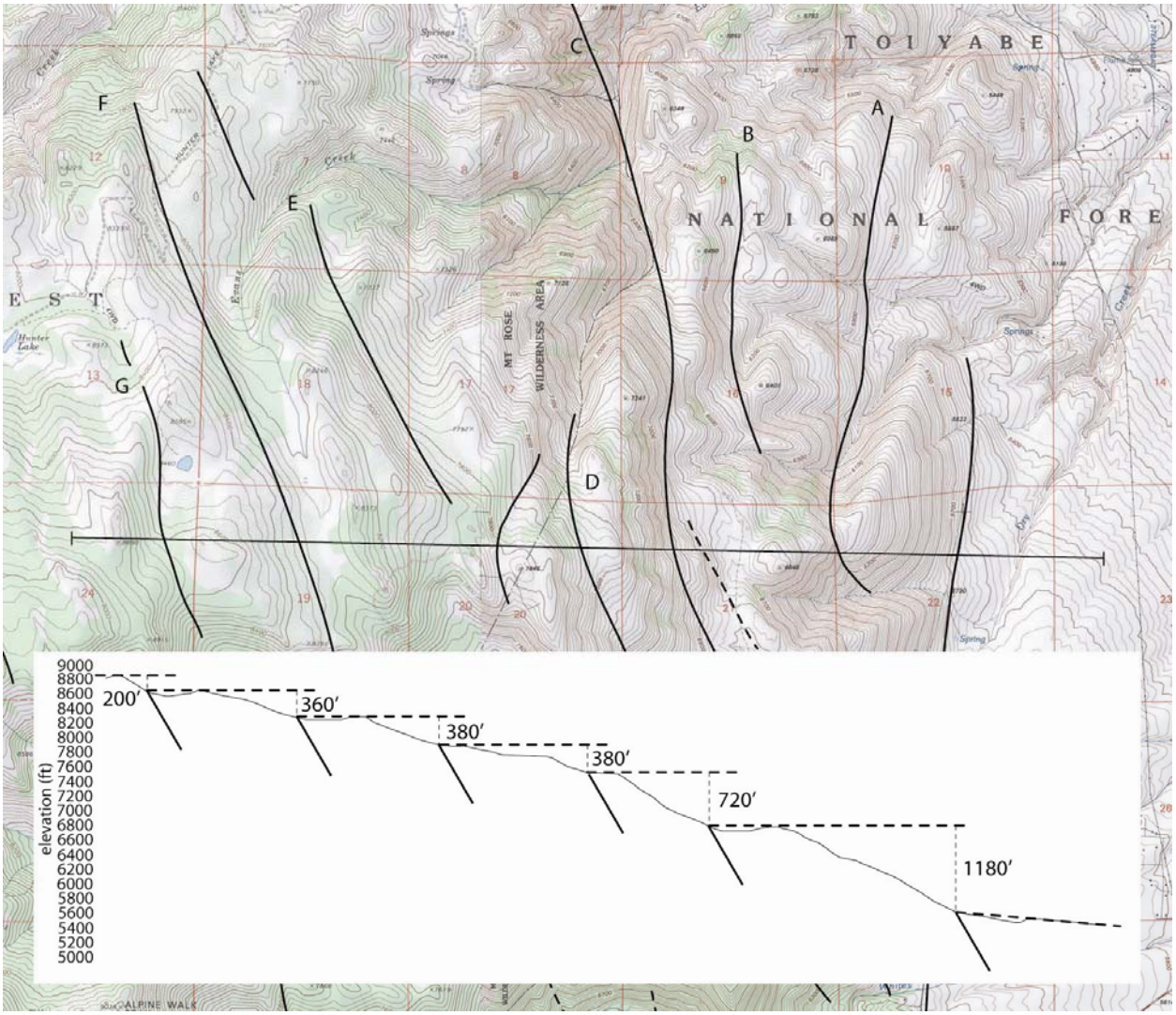

Figure 8: Topographic profile 1, crossing faults within the northern Carson Range. Profile line is located at ~39.4146 deg N, about 1 mi north of Thomas Creek canyon. For estimating vertical separations, surfaces are projected horizontally because here the range is composed of volcanic rocks that are presumed to have been originally flat lying. However, the volcanic rocks are moderately tilted, especially toward the range front, and vertical separations are thus a combination of faulting and tilting. Vertical exaggeration - 1.8X.

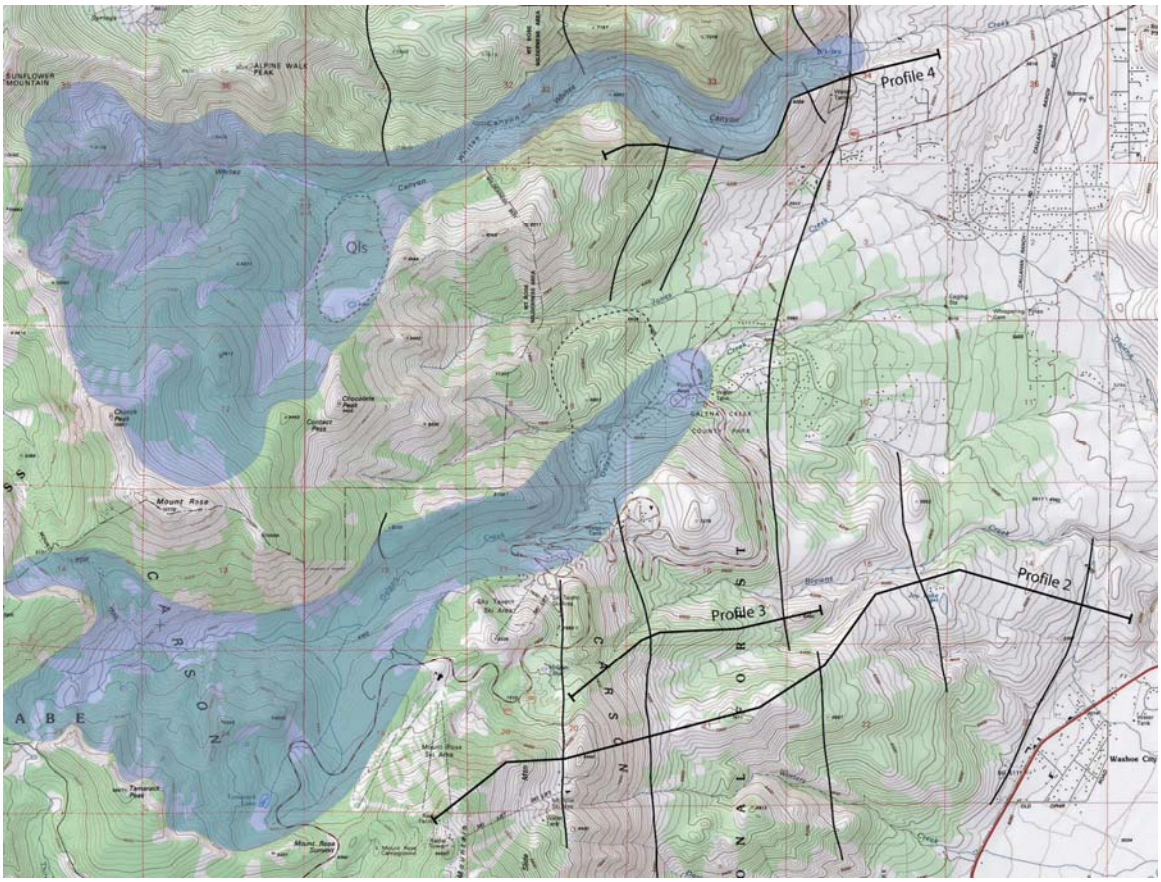

Figure 9: Locations of topographic profiles 2, 3, and 4 (see figure 10). Blue shading – estimated extent of late Pleistocene glaciers in Whites Ck (top) and Galena Ck (bottom); eastern extents of both are uncertain. Glaciation was more extensive than shown in the Mt. Rose summit area, but only the main source area for Galena Creek is depicted. Dashed outline – Quaternary landslides.

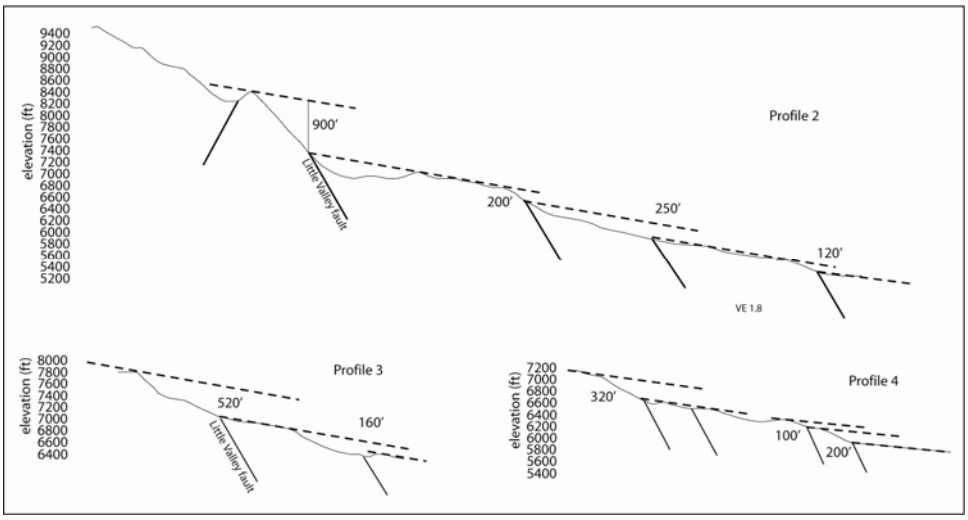

Figure 10: Topographic profiles and estimated vertical separation (in feet) across faults within the Carson Range. Profile 2 (top) and profile 3 (middle) cross the Little Valley fault at Slide Mt. Profile 4 (bottom) extends along the crest of the right lateral glacial moraine at Whites Creek. See figure 9 for profile locations. Vertical exaggeration – 1.8X.

Topographic Profiling in the Mt. Rose fan and Reno areas

The Mt. Rose piedmont (commonly called the Mt. Rose fan) is dominated by glacial outwash deposits of Tahoe age or older (generally >100ka). The piedmont is broadly warped and cut by a series of subparallel, nested graben (compare figures 1, 3, and 7). The southern part of the piedmont is characterized by a 2.5-km wide nested graben separating Steamboat Hills from the Carson Range. North of Steamboat Hills, the piedmont fault zone is about 7 km wide and includes at least five subparallel, sygmoidal graben. These two sections appear to be separated by a northwest-striking, antithetic fault zone. This northwest-striking fault has a left-stepping pattern, suggesting a right-lateral component, and it may also truncate the range-front fault.

Figure 11: Low sun angle photograph of the Callahan Ranch area, southern Mt. Rose fan

A persistent feature of the Mt. Rose piedmont fault zone is a relatively narrow (~0.5 km wide), linear zone of graben, generally located a little more than 1 km east of the range front. This discontinuous zone includes the central part of the Callahan Ranch graben (figure 7) and extends north into Reno, forming the Virginia Lake fault zone (figure 1).

The Mt. Rose piedmont fault zone includes both synthetic and antithetic faults. To evaluate net displacements across the zone, more than 40 topographic profiles were constructed from two-foot contour data available from Washoe County. http://www.washoecounty.us/gis

Profile locations are shown on figures 12-14, best-estimate displacement calculations are shown in Table 1, and representative profiles are shown in figures 15-20.

Limitations:
*Fan surfaces are not perfectly planar
*Many of the surfaces are relatively old (>100 ka) and thus variably eroded
*Surfaces are in places greatly altered by urban development
*Surfaces on either side of a fault (or graben) commonly have different slopes (with the up-slope surface typically being steeper)
*Surface ages are poorly constrained
*Differing age surfaces are present on either side of faults in some locations
*Further work on ranges of uncertainty is needed

The topographic profiles generally reveal little to no net vertical displacement across the entire zone, although locally net displacement appears to be down-to-the-west (i.e., antithetic to the range front) . The largest fault scarps generally are antithetic faults forming the east side of the main graben zone, but this is due at least in part to a lack of scarps on old surfaces along the range front. The one location where old surfaces are preserved along (or near) the range front has comparable sized scarps (figure 19).

General observations:

1) Scarps on “Tahoe-aged” surfaces along the range-front fault trace show fairly similar offsets of 6-9 m (figure 15).
2) Profiles of the Callahan Ranch graben (figure 16) show little net displacement. The central part of the graben generally has a small down-to-the-east displacement, but if the main antithetic fault is included, displacement is down-to-the-west.
3) Profiles of the main antithetic fault (figures 17, 18) show significant down-to-the-west displacement, but in most locations there is no comparable-age synthetic scarp along the range-front trace, so net displacement is problematic.
4) The most complete set of profiles crossing (almost) the entire zone (figure 19) suggests there is a small amount of down-to-the-east net displacement across the zone as a whole, but more work to determine whether these profiles cross similar-aged surfaces, as mapped, is warranted.
5) To the north, profiles at Virginia Lake show slight down-to-the-east displacement, but even further north there is clearly a larger amount of down-to-the-west displacement (figure 20).

Table 1: Mt Rose piedmont fault zone: profile summary

profile	fault trace	VS (ft)	corr.*	net disp (ft)	net disp (m)	map surf	est age (ka)	slip rate (m/ka)
Thomas Creek 2	range front	55	1.2	66	20.1	Qdm	300	0.067
Thomas Creek 1	range front	16	1.2	19.2	5.9	Qtm	100	0.059
Whites Creek 1	range front	18	1.2	21.6	6.6	Qtm	100	0.066
Whites Creek 2	range front	18	1.2	21.6	6.6	Qtm	100	0.066
Whites Creek 3	range front	20	1.2	24	7.3	Qtm	100	0.073
Galena 1-1	range front	25	1.2	30	9.1	Qmb	100	0.091
Galena 1-2	range front	21	1.2	25.2	7.7	Qgo2	100	0.077
Galena 2	antithetic 1	17	1.1	18.7	5.7	Qgo2	100	-0.057
Galena 3-1	antithetic 1	30	1.1	33	10.1	Qgo2	100	-0.101
Galena 3-2	antithetic 1	6	1.1	6.6	2.0	N/A	20	-0.101
Browns Creek 1	graben	22	1.1	24.2	7.4	Qgo2	100	-0.074
Browns Creek 2	graben	8	1.1	8.8	2.7	Qgo2	100	-0.027
Callahan Ranch 1	graben	12	1.1	13.2	4.0	Qtm	100	-0.040
Callahan Ranch 2	graben	18	1.2	21.6	6.6	Qgo2	100	0.066
Callahan Ranch 3B	graben	19	1.2	22.8	6.9	Qtm	100	0.069
Lower Whites 1-1	graben	0	1.1	0	0.0	Qtm	100	0.000
Lower Whites 1-2	graben	12	1.2	14.4	4.4	Qtm	100	0.044
Callahan Ranch 1	antithetic 2	23	1.15	26.45	8.1	Qtm	100	-0.081
Callahan Ranch 2	antithetic 2	19	1.15	21.85	6.7	Qgo2	100	-0.067
Callahan Ranch 3A	antithetic 2	34	1.15	39.1	11.9	Qtm	100	-0.119
Lower Whites 2	antithetic 2+3	60	1.1	66	20.1	Qdm?	300	-0.067
Saddlehorn 1	antithetic 3	40	1.1	44	13.4	Qdm	300	-0.045
Saddlehorn 2	antithetic 3	19	1.1	20.9	6.4	Qtm?	100	-0.064
Arrowcreek 1	antithetic 4	25	1.1	27.5	8.4	Qdm	300	-0.028
Dry Creek 1A	antithetic 4	64	1.1	70.4	21.5	Qdm	300	-0.072
Dry Creek 1B	antithetic 4	78	1.1	85.8	26.2	Qdm	300	-0.087
Dry Creek 2A	antithetic 4	30	1.1	33	10.1	Qdm	300	-0.034
Dry Creek 2B	antithetic 4	8	1.1	8.8	2.7	Qp	300	-0.009
Dry Creek 3	synthetic	12	1.2	14.4	4.4	Qp/Qoa	300	0.015
Windy Hill South	antithetic 4	8	1.1	8.8	2.7	N/A	100	-0.027
Wolf Run 1	graben	16	1.2	19.2	5.9	Qdm	300	0.020
Virginia Lake 1	graben	10	1.2	12	3.7	Qdo	300	0.012
Virginia Lake 2	graben	5	1.2	6	1.8	Qdo	300	0.006
Holcomb 1	graben	40	1.1	44	13.4	Qdo	300	-0.045
Holcomb 2	graben	15	1.1	16.5	5.0	Qdo	300	-0.017
Holcomb 3	graben	35	1.1	38.5	11.7	Qdo	300	-0.039

*correction factor assuming 60 deg fault dip and 4 deg surface slope

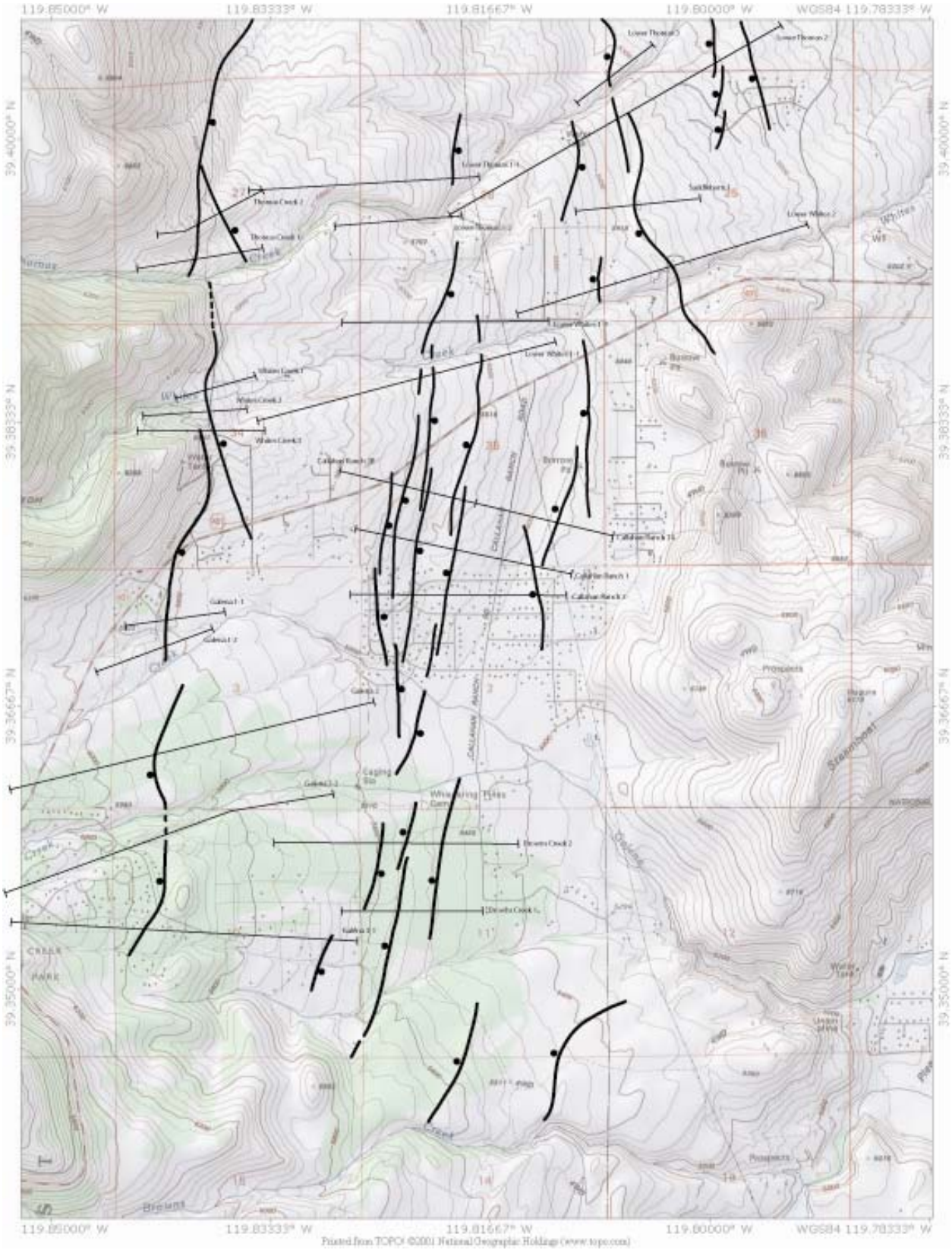

Figure 12: Locations of topographic profiles, southern Mt. Rose fan.

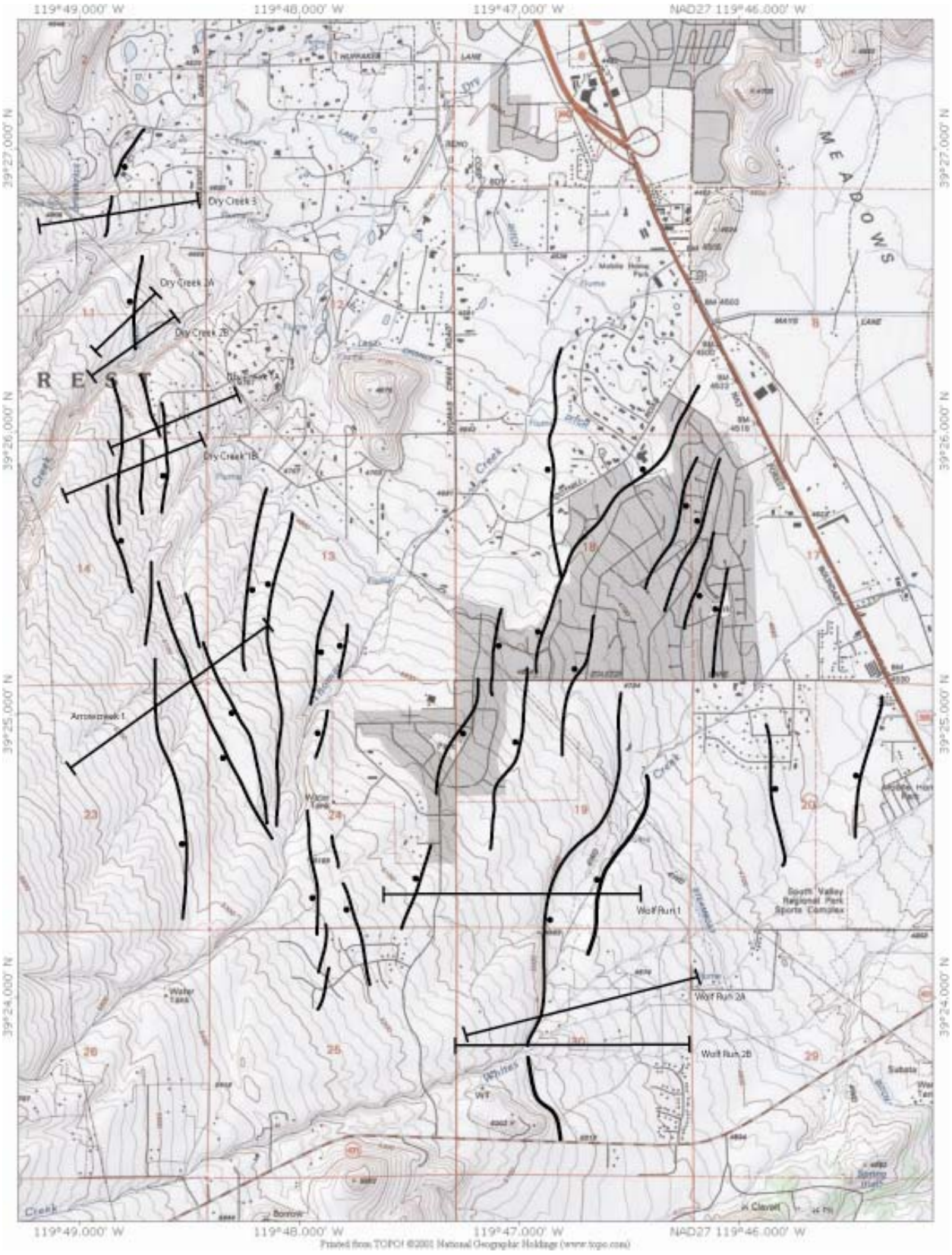

Figure 13: Locations of topographic profiles, northern Mt. Rose fan.

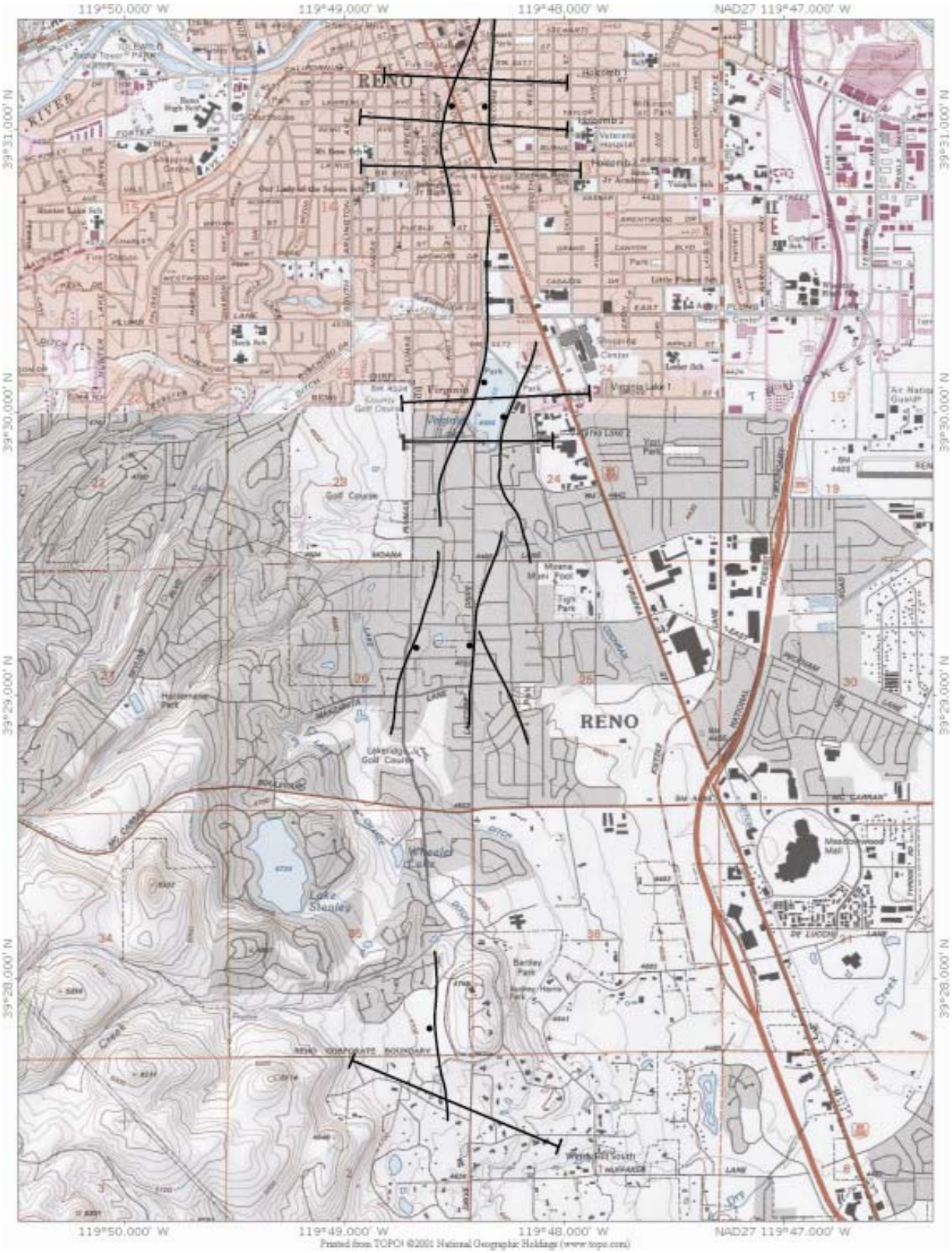

Figure 14: Locations of topographic profiles, southwest Reno.

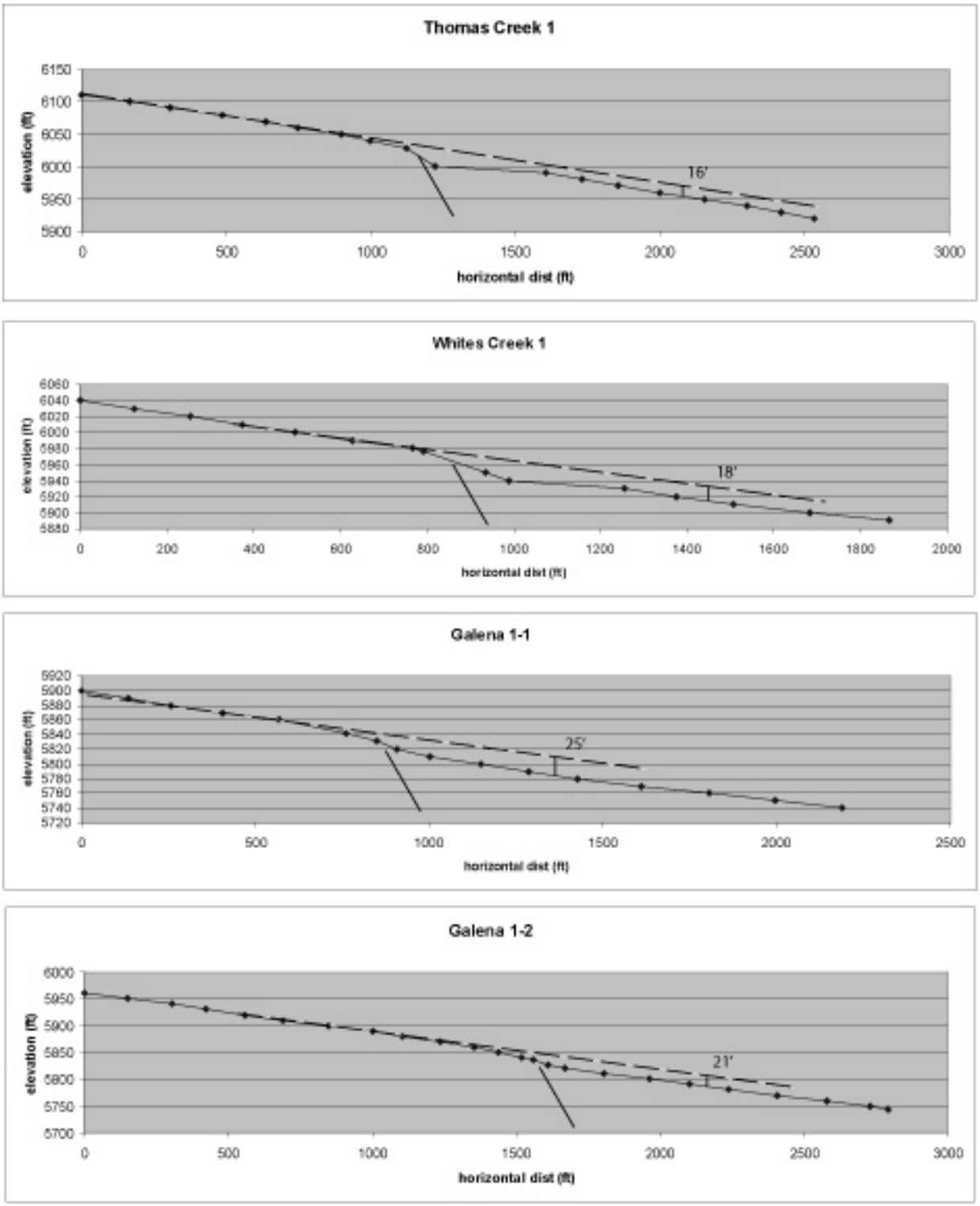

Figure 15: Topographic profiles across the Mt. Rose range-front fault trace.

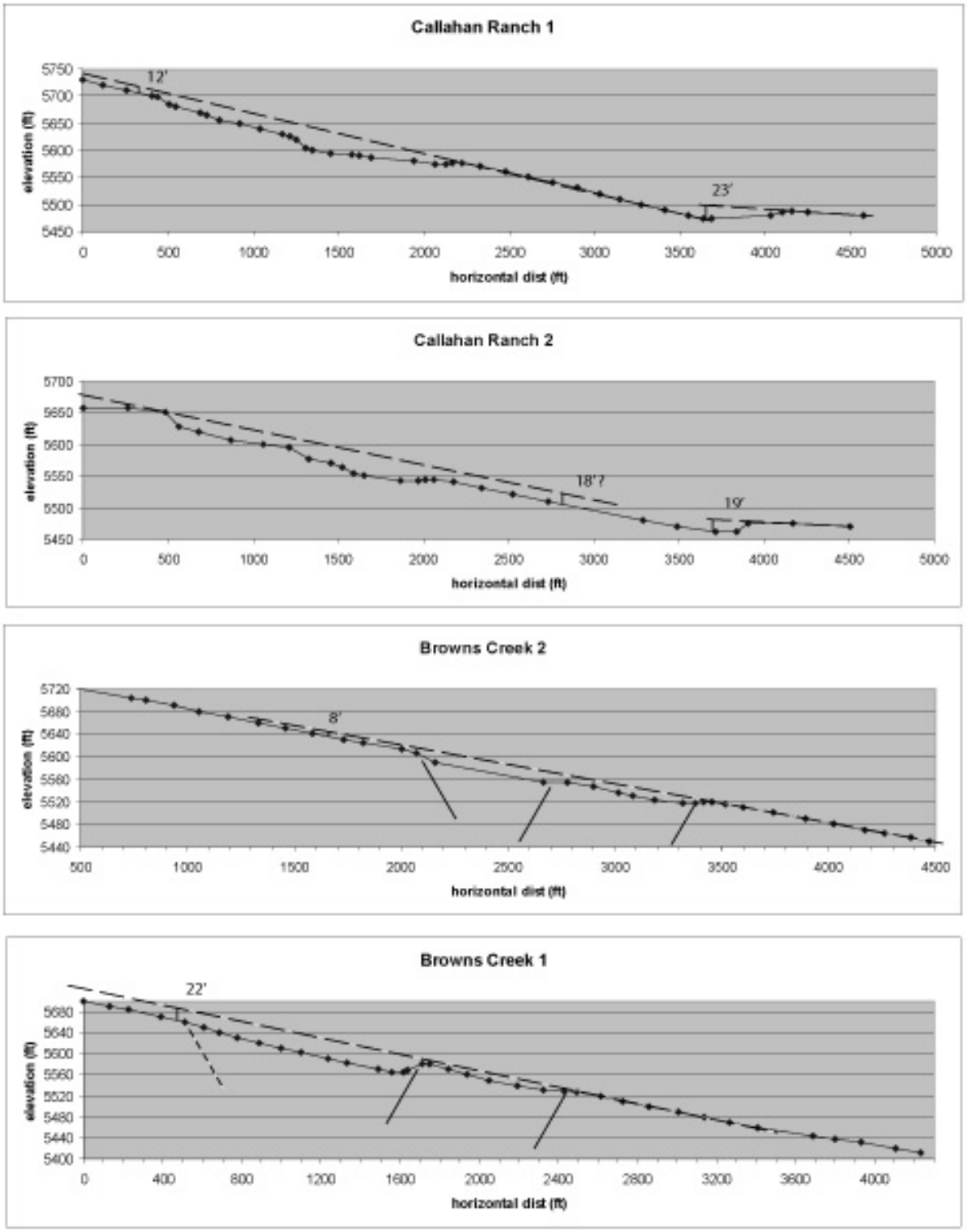

Figure 16: Topographic profiles across antithetic fault and central graben, southern Mt. Rose fan

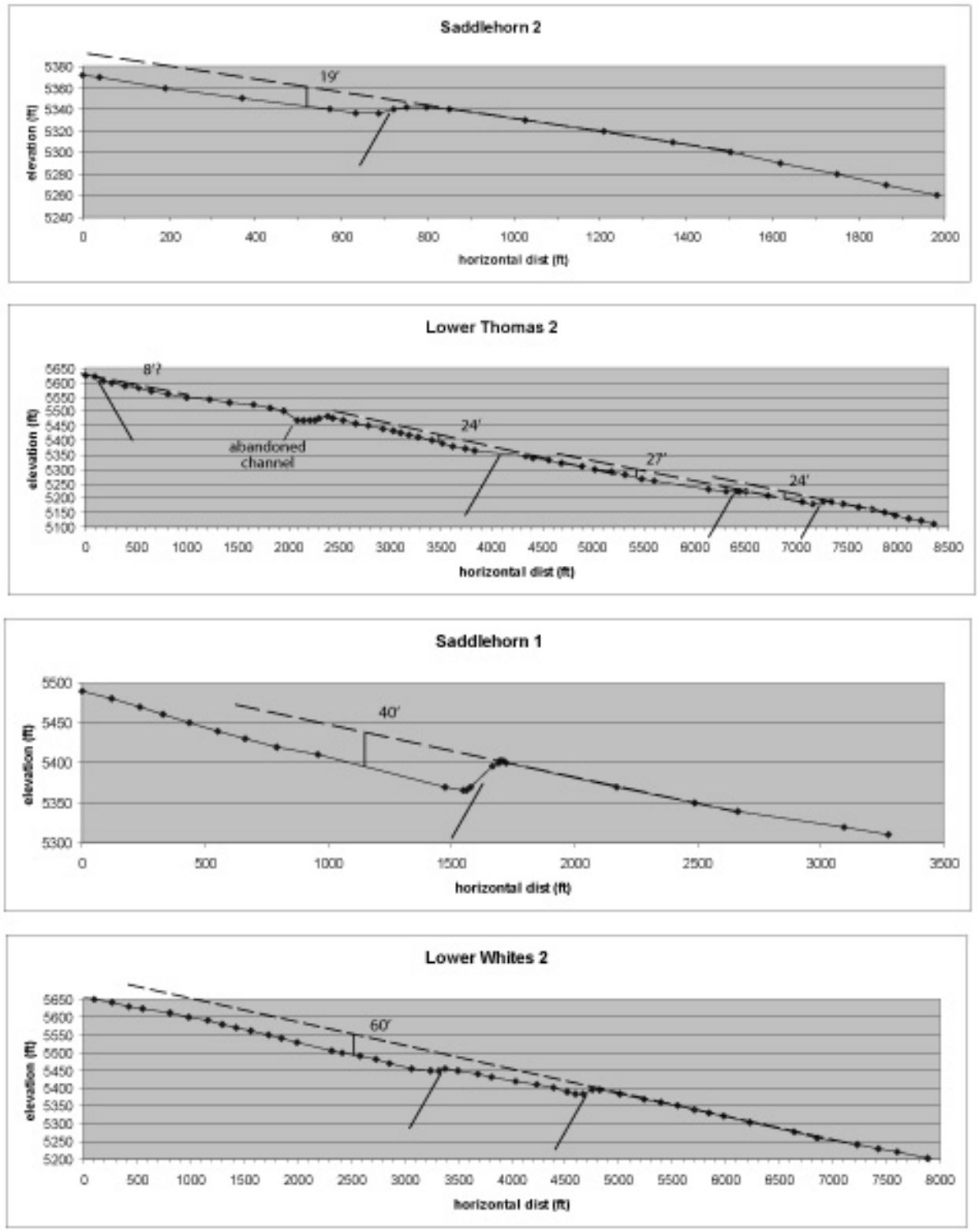

Figure 17: Topographic profiles across the main antithetic fault zone

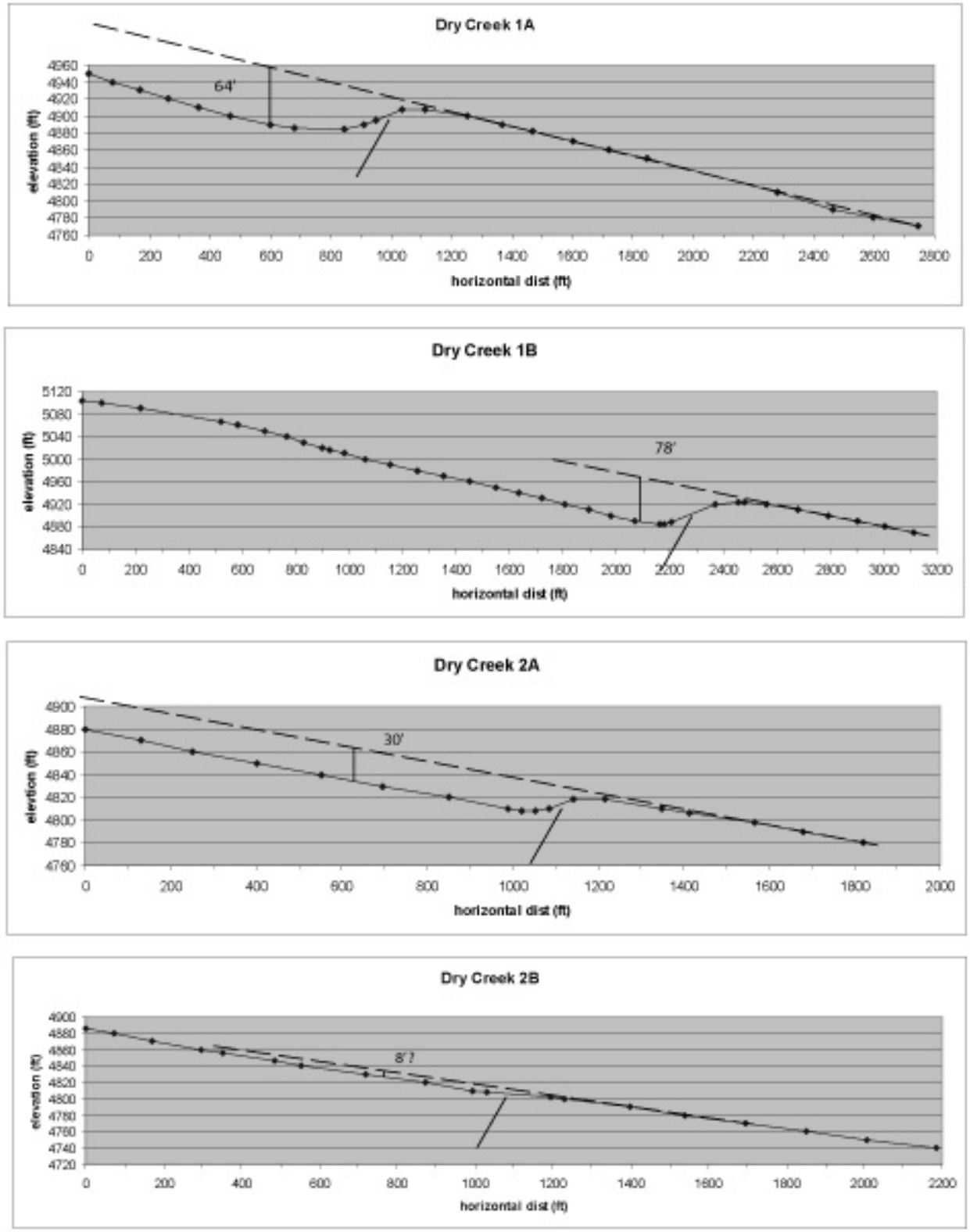

Figure 18: Topographic profiles across the main antithetic fault in the vicinity of Dry Creek.

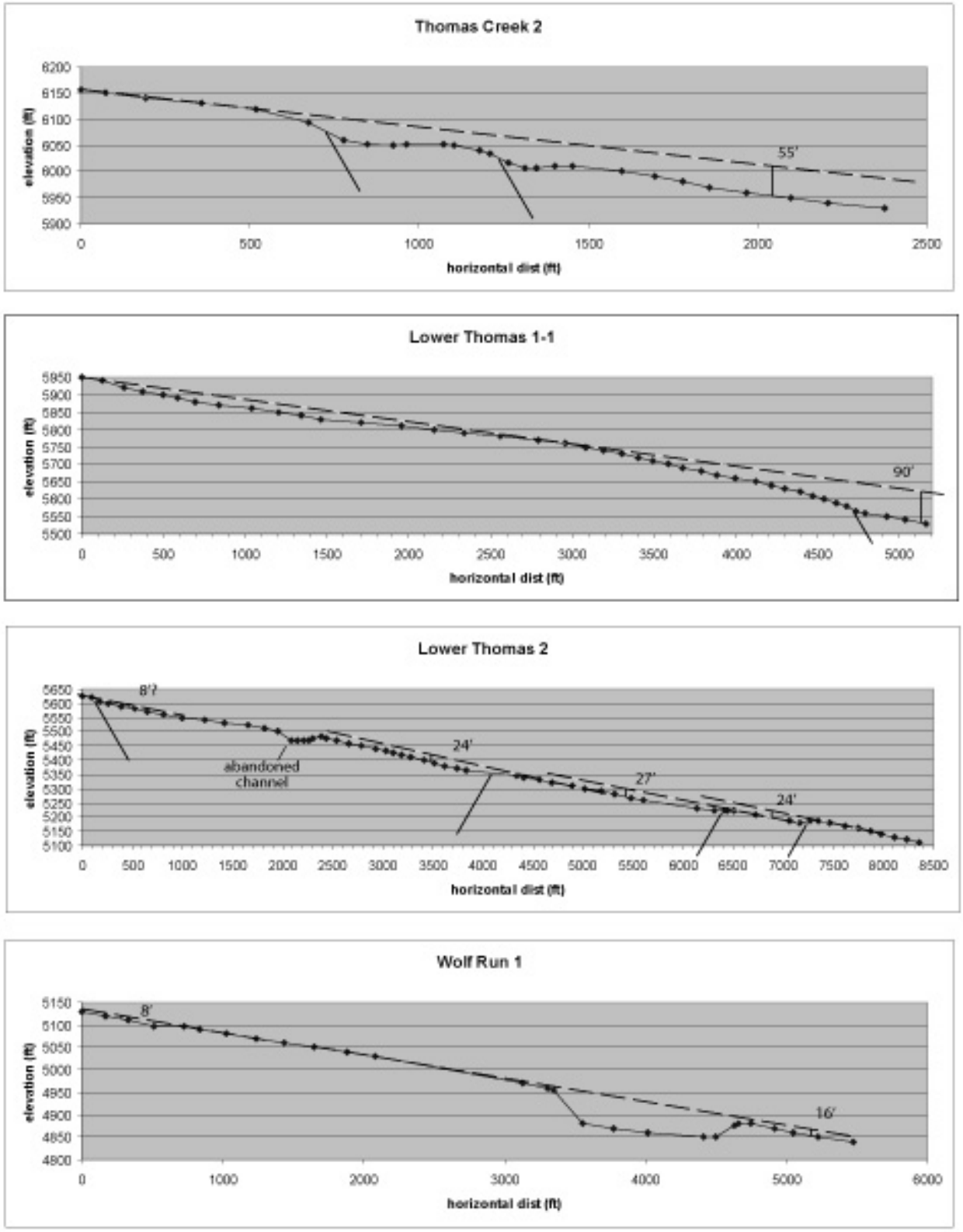

Figure 19: Topographic profile transect, generally parallel to Thomas Creek.

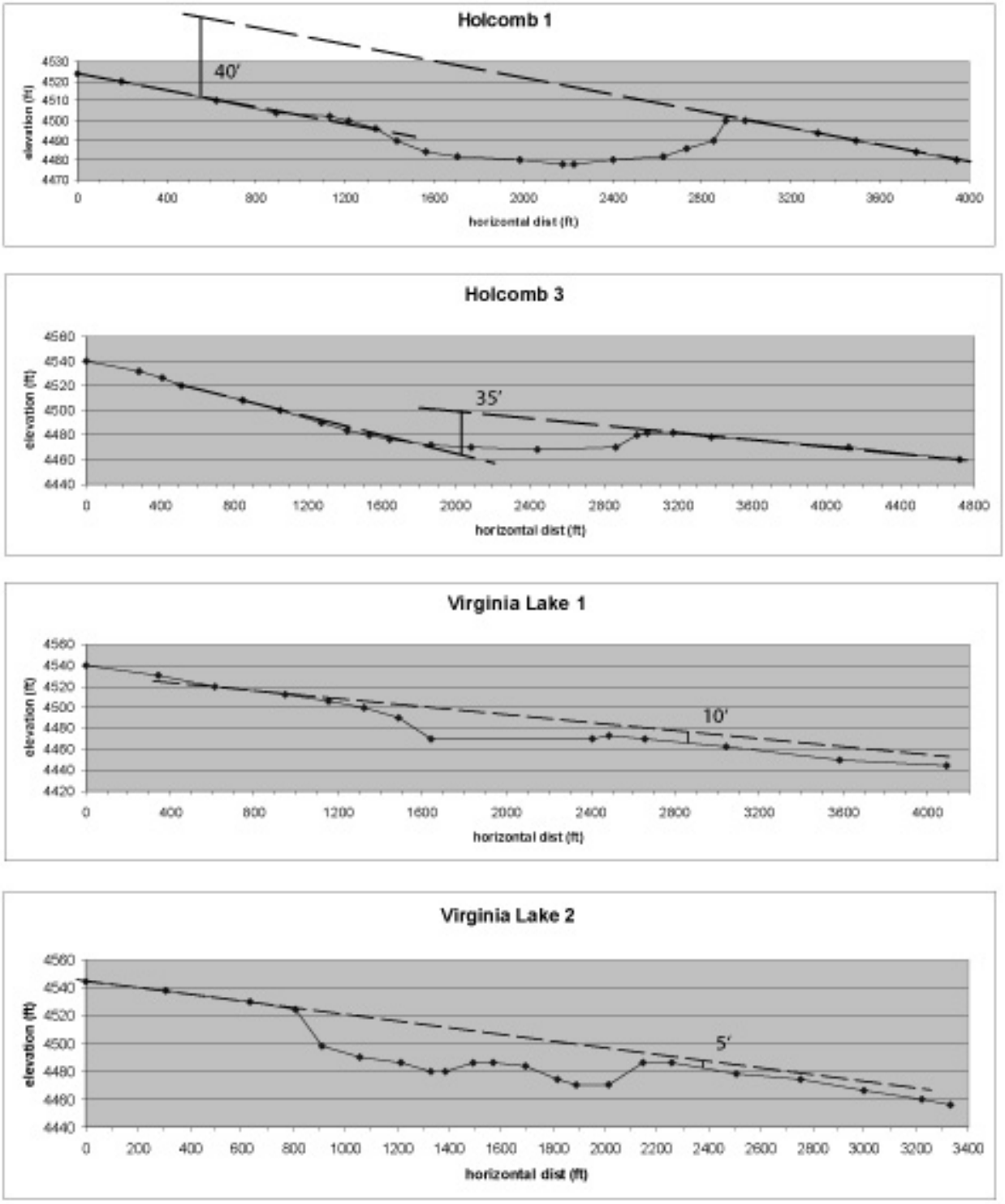

Figure 20: Topographic profiles across the northernmost CRFS in southwest Reno

Summary of age constraints

Age analyses for the Carson Range fault system as a whole were compiled and re-evaluated. The radiocarbon dates interpreted to provide the closest constraints on timing of the two most recent events on the Carson Range fault system are depicted in figure 21. These results suggest the most recent event is somewhat older along the northern part of the system than to the south (i.e., Genoa fault); alternatively, this apparent difference may be due to mean residence time (MRT) complications in radiocarbon dating. The penultimate event is less well constrained, but the results nonetheless show that the entire system has ruptured twice within the last couple thousands of years.

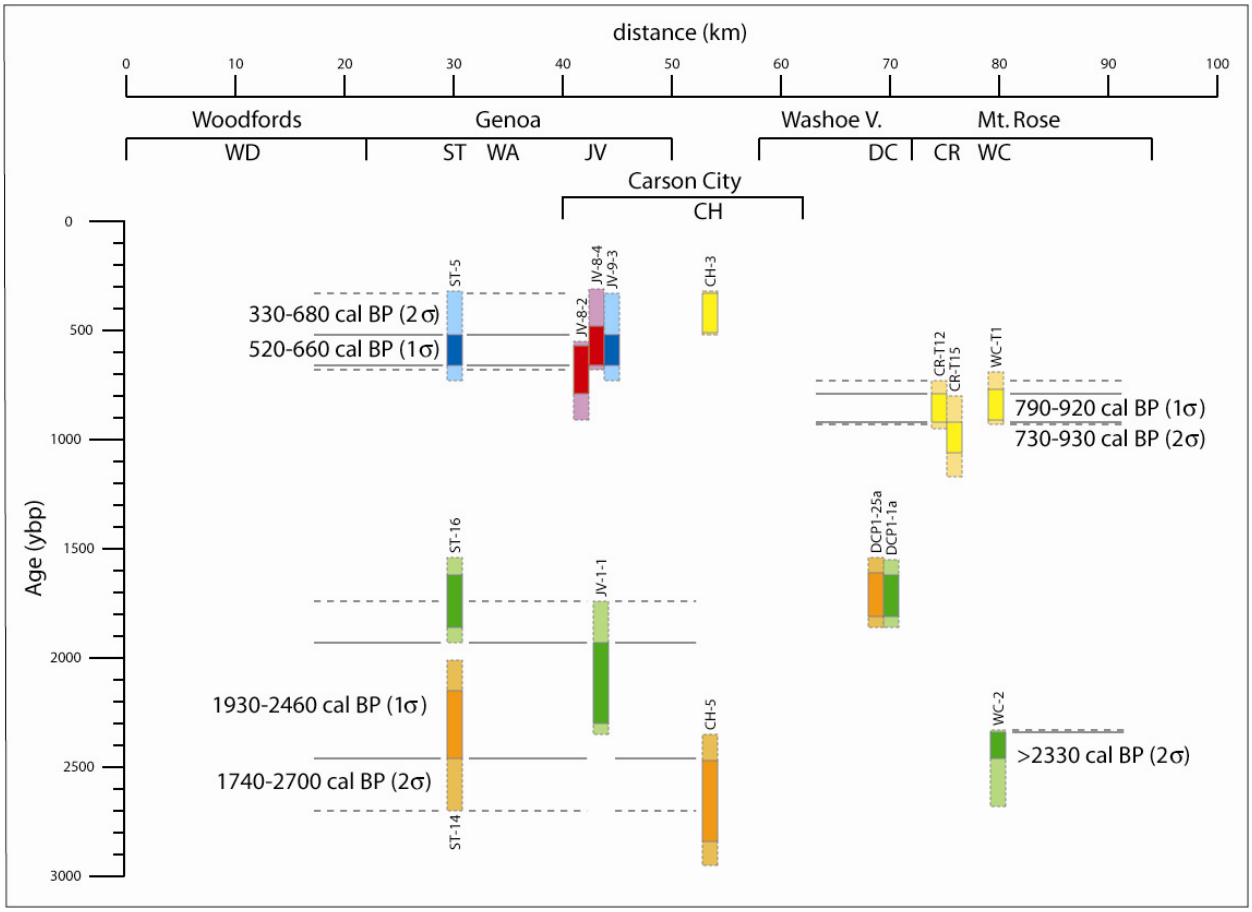

Figure 21: Summary of radiocarbon age-control for the Carson Range fault system. Blue=samples postdating MRE; red=samples predating MRE; yellow=samples approximating MRE; green=samples postdating penultimate event; orange=samples predating penultimate event. Dark colors=1 sigma ranges; light colors=2 sigma ranges.

Non-technical Summary: The frontal fault system bounding the northern Carson Range in western Nevada poses the principal seismic hazard to Reno, the second largest city in the state. In this area, the fault system is broad and complex, and much of the more than 1,500 m (5,000 ft) of topographic relief between the Carson Range and Truckee Meadows (Reno basin) occurs across faults within the range or on the Mt. Rose alluvial fan, or as warping. In this project, we tried to assess how activity is distributed across the system, and examined several trenches to better constrain ages of faulting.

Three consultants' trenches yielded age constraints on the most recent event. Two of these support prior data indicating an event ~1,000 yr ago; results from the third trench are pending. Topographic profiling of faults within the Carson Range show that two faults generally account for most of the offset within the range. With up to 270 m (900 ft) of displacement, these two faults have substantial offset, but they are nonetheless much smaller than the range front fault. Profiling of faults on the Mt. Rose fan and within Reno show only a small amount of down-to-the-east displacement, and locally displacement may actually be down-to-the-west.

Reports published: None

Availability of seismic, geodetic, or processed data: Not applicable.

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