GEOLOGIC EVIDENCE FOR LATE QUATERNARY MOVEMENT ON THE CLAN ALPINE FAULT, WEST-CENTRAL NEVADA—TRENCH LOGS, SCARP PROFILES, LOCATION MAPS, AND SAMPLE AND SOIL DESCRIPTIONS

By

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2005

INTRODUCTION

As part of regional studies of paleoseismology in the northern Great Basin, we are studying selected major extensional Quaternary faults in a traverse from Reno, Nev., to Salt Lake City, Utah, between latitudes 39° and 41° N. In 2001, we trenched the southern part of the Clan Alpine fault (CAF) about 2 km northwest of the Alpine Ranch (see fig. 1). The fault separates the Edwards Creek Valley (on the east) from the impressive front of the uplifted Clan Alpine Mountains (on the west); faceted spurs along the front suggest substantial Quaternary movement along the CAF (dePolo, 1998). Based on the tectonic geomorphology of the mountain front, dePolo (1998) estimated a long-term slip rate of 0.15 mm/yr for the CAF. Conversely, conspicuous fault scarps exist along only part of the range front, suggesting that little movement has occurred on the CAF in late Quaternary time.

The purpose of this map product is to present stratigraphic, geomorphic, and structural evidence for interpreting the late Quaternary movement history of the CAF. The interpretive data will be presented elsewhere, pending results of further dating studies. Nevertheless, the stratigraphic relations shown on this map demonstrate two latest Quaternary surface-faulting earthquakes in the past 30 k.y., and suggest that latest Quaternary slip rates near the southern end of the fault zone are slower than previously suggested for the whole fault zone.

THE CLAN ALPINE FAULT

The Clan Alpine fault lies just to the east of the Central Nevada Seismic Belt—a zone of historically active faulting and seismicity that extends from Winnemucca, on the north, to Cedar Mountains, on the south (fig. 1). The most recent surface faulting in the vicinity was associated with the M_S 7.2 Fairview Peak and M_S 6.8 Dixie Valley earthquakes, which occurred about 4 minutes apart on December 16, 1954 (Caskey and others, 1996) about 30 km west of our study area. During these large earthquakes, minor surface ruptures also formed along the Gold King and Middlegate faults, the latter of which is a west-dipping normal fault at the southwestern margin of the Clan Alpine Mountains, about 12 km to the west-southwest of our study area.

The CAF is a major north- to northeast-striking, relatively narrow range-front fault zone that bounds the eastern flank of the Clan Alpine Mountains and the western flank of the Edwards Creek Valley. The Edwards Creek basin is probably a structural half-graben that deepens to the west. Faulting on the eastern side of the basin seems rather minor, and low bedrock knobs extend well out from the Desatoya Range, which bounds the eastern side of the Edwards Creek Valley. Near its southern end, the west-dipping Desatoya (DF) and Eastgate (EGF) faults become the major range-bounding faults of an eastward-deepening series of half-grabens. This north-to-south transition from a west-dipping half-graben to multiple east-dipping half-grabens is along a diffuse west-northwest transverse accommodation zone(?) that roughly defines the southern end of the CAF and the northern ends of the DF and EGF. Stewart and others (1999) mapped a west-northwest-trending fault that cuts across the southern part of the Clan Alpine Mountains and adjacent Miocene basin sediments; this fault may represent the surface manifestation of the suggested accommodation zone.

The Clan Alpine Mountains and Desatoya Range straddle the Edwards Creek Valley, which is presently a closed basin with a floor elevation of about 5,115 ft (1,560 m). [Elevations are shown in feet on the USGS topographic base map (fig. 1).] Lake Edwards has occupied this basin intermittently through the middle Pleistocene (750–130 ka) and late Pleistocene (130–10 ka). The latest Pleistocene lake was rather shallow (<50 m deep), rising to a maximum elevation of about 5,280 ft (1,610 m) (Mifflin and Wheat, 1979), well below all traces of the CAF. Most of the stratigraphic and geomorphic evidence for the lake are preserved at its northeastern end, where it formed a set of prominent bars, spits, and gravelly shorelines. Prior deep stages of the lake may have risen well above the 5,280-ft (1,610-m) shoreline, especially if overflow occurred from Lake Desatoya (Snyder and others, 1964) in the Smith Creek Valley. This connecting channelway has an overflow threshold at 6,230 ft (1,899 m), 8 m above the latest Pleistocene sill of Smith Creek Valley (Reheis, 1999).

The CAF extends about 35 km along the eastern front of the Clan Alpine Mountains. Along most of the range front, the fault shows down-to-the-southeast displacement of Quaternary piedmont-slope deposits against Tertiary bedrock (Dohrenwend and others, 1992). Scarps are relatively sparse and poorly preserved but consistently face east (Pearthree, 1990; Dohrenwend and others, 1992), except at the southern end where antithetic faults form about one-fourth of the young throw on the CAF. South of Starr Canyon (see fig. 1), the fault bifurcates into multiple subparallel traces that form a horsetail pattern. The largest and most continuous strand crosses Florence Canyon Road (fig. 2), and forms scarps that are as much as 8 m high. Smaller scarps (see fig. 3, scarp profile CAW-1) are formed on an alluvial-fan deposit (unit Qfm, fig. 2) that is believed to be either mid-Wisconsin (marine isotope stage IV) or pre-Wisconsin and related to the Bull Lake glaciation (marine isotope stage VI) of the Rocky Mountains. The large scarp that we trenched (fig. 6, west trench, CAW) is formed on a clearly older alluvial-fan deposit (unit Qfo), which we believe is pre-Wisconsin (marine isotope stage VI) and either related to the Bull Lake glaciation of the Rocky Mountains or to an older (marine isotope stage VIII?) glaciation of the Rocky Mountains. These deposits have not yet been dated by cosmogenic-nuclide methods; thus our correlations to geo-climatic events remain uncertain. We consider units Qfm and Qfo to be as young as 75–60 ka and 150–130 ka, respectively (younger interpretation), or to be as old as 150–130 ka and 250–230 ka, respectively (older interpretation). The estimated ages of these deposits are based on the soils developed on their relict alluvial-fan surfaces (see table 4, soil field properties). Unit Qfm is also present in the east trench (CAE, fig. 7).

Although most traces of the CAF are in a BLM Wilderness Study Area (WSA), we were able to trench a 7- to 8-m-high, partly buried scarp on the main fault in a narrow exclusion in the WSA (fig. 2) and a partly buried (<3 m high) antithetic fault scarp (fig. 4) 1.6 km downslope, east of the WSA. Exposures of the main fault (see fig. 6, CAW trench log) revealed two classic colluvial wedges (units 1 and 2, table 1) above a thicker wedge-like body of gravel (unit 3) and alluvial-fan deposits (unit 4). Unit 3 is interpreted as a combination of scarp colluvium and fluvial gravel that were deposited against the scarp from the third faulting event. The underlying and lowest unit on the hangingwall block is unit 4, a well-sorted sandy pebble to boulder gravel that was laid in against a preexisting fault scarp formed on units 6–8 of the upthrown fault block. Unit 4 is considered to be part of the fan-forming Qfm, which came from Florence Canyon and was deposited in a southerly direction (as indicated by pebble imbrication measurements). The two most recent surface-faulting earthquakes produced about 4 m of displacement in the trench and a 5- to 6-m-high scarp on the surface, about 100 m north of Florence Canyon Road. Fault-scarp colluvium units 1 and 2 gave preliminary luminescence ages of about 9±1 ka and 28±3 ka, respectively (see table 3A), which suggests that the most recent earthquake occurred at about 10 ka and the penultimate earthquake occurred at about 30 ka. Indirect evidence of older faulting (pre-unit 4) is recorded by more than 7 m of surface displacement in the older sequence of alluvial-fan deposits (units 6–8, about 250–130 ka).

The antithetic fault is about 1.7 km to the east, and its scarps are poorly preserved east of the road north from Alpine Ranch owing to its uphill (west-facing) aspect (fig. 5). Trenching here (see fig. 7, CAE trench log) shows direct evidence for three faulting earthquakes (about 6 m of vertical displacement). The fault-scarp colluvium (units 1 and 2, table 2) gave preliminary luminescence ages of about 10±1 ka and 28±2 ka, respectively (see table 3B), which suggests that the most recent event occurred at about 10 ka and the penultimate event occurred at about 30 ka—timing that is identical to that recorded in the CAW trench. The upthrown block is mantled by a relict Bt/Bk soil (see table 4, soil field properties) formed in coarse debris-flow deposits (about 100–50 k.y.?) that directly overlie distal alluvial-fan deposits, which we estimate to be about 130–60 ka. The antithetic fault records at least 6 m of displacement (since units can't be matched across entire fault zone) and has more earthquakes that affect unit Qfm than the main fault. Thus, the antithetic fault may be a transitional, intravalley link that moves along with the east-dipping CAF and the east-dipping DF to the southeast.

Based on reconnaissance photogeologic mapping, Dohrenwend and others (1992) assigned a latest Pleistocene to Holocene age to a faulted Quaternary deposit at one locality along the CAF. On the basis of morphologic analyses, Pearthree (1990) calculated a mean age of 16.9 ka (22.6–11.2 ka) for small scarps along the southern part of the fault zone and thought that middle Holocene alluvial surfaces were unfaulted. dePolo (1998) assigned a preferred age of 130 ka (220–74 ka) to the alluvial-fan surface that is displaced 19.4 m on the southern side of Starr Canyon (SC site, see fig. 1), farther north along the southern part of the CAF. From these data, dePolo (1998) calculated a preferred vertical slip rate of 0.15 mm/yr for this site. The 130-ka age for the surface was based on relative position, surface morphology, and the presence of soils that have characteristics similar to those on Donner Lake outwash (dePolo, 1998). Conversely, we suspect that the alluvial-fan surface could be 250 ka (that is, unit Qfo) or older and that the slip rate could be substantially less.

Although cosmogenic-nuclide dating will help determine the age of the faulted landforms, the existing luminescence dating and stratigraphic relations seen in trench CAW suggest that the CAF where we studied it has a low slip rate (0.025–0.08 mm/yr) and long recurrence intervals (≥20,000 yrs). The range front's seemingly young expression may be an artifact of the bedrock lithology and (or) faster slip rates earlier in the Quaternary or Pliocene. If the two to five times lower-than-reported slip rate on the CAF suggested from our preliminary work applies to the entire fault, it has important implications for the general activity rate of many of the major normal faults in the Basin and Range Province.

REFERENCES CITED

Birkeland, P.W., 1999, Soils and geomorphology, 3rd edition: New York, Oxford University Press, 430 p.

Caskey, S.J., Wesnousky, S.G., Zhang, P., and Slemmons, D.B., 1996, Surface faulting of the 1954 Fairview Peak (M_S 7.2) and Dixie Valley (M_S 6.8) earthquakes, central Nevada: Bulletin of the Seismological Society of America, v. 86, no. 3, p. 761–787.

dePolo, C.M., 1998, A reconnaissance technique for estimating the slip rate of normal-slip faults in the Great Basin, and application to faults in Nevada, U.S.A.: Reno, Nev., University of Nevada Ph.D. dissertation, 199 p.

Dohrenwend, J.C., Schell, B.A., and Moring, B.C., 1992, Reconnaissance photogeologic map of young faults in the Millett 1° by 2° quadrangle, Nevada: U.S. Geological Survey Miscellaneous Field Studies Map MF–2176, 1 sheet, scale 1:250,000.

Mifflin, M.D., and Wheat, M.M., 1979, Pluvial lakes and estimated pluvial climates of Nevada: Bulletin of the Nevada Bureau of Mines and Geology, v. 94, 37 p.

Pearthree, P.A., 1990, Geomorphic analysis of young faulting and fault behavior in central Nevada: Tucson, Ariz., University of Arizona Ph.D. dissertation, 212 p.

Reheis, M., 1999, Extent of Pleistocene lakes in the western Great Basin: U.S. Geological Survey Miscellaneous Field Studies Map MF–2323, scale 1:800,000.

Soil Survey Staff, 1975, Soil taxonomy: U.S. Department of Agriculture Handbook No. 436, 754 p.

Snyder, C.T., Hardman, G., and Zdenek, F.F., 1964, Pleistocene lakes in the Great Basin: U.S. Geological Survey Miscellaneous Geologic Investigations Map I–416, scale 1:1,000,000.

Stewart, J.H., Sarna-Wojcicki, A., Meyer, C.E., Starratt, S.W., and Wan, E., 1999, Stratigraphy, tephrochronology, and structural setting of Miocene sedimentary rocks in the Middlegate area, west-central Nevada: U.S. Geological Survey Open-File Report 99–350, 1 plate, scale 1:24,000.

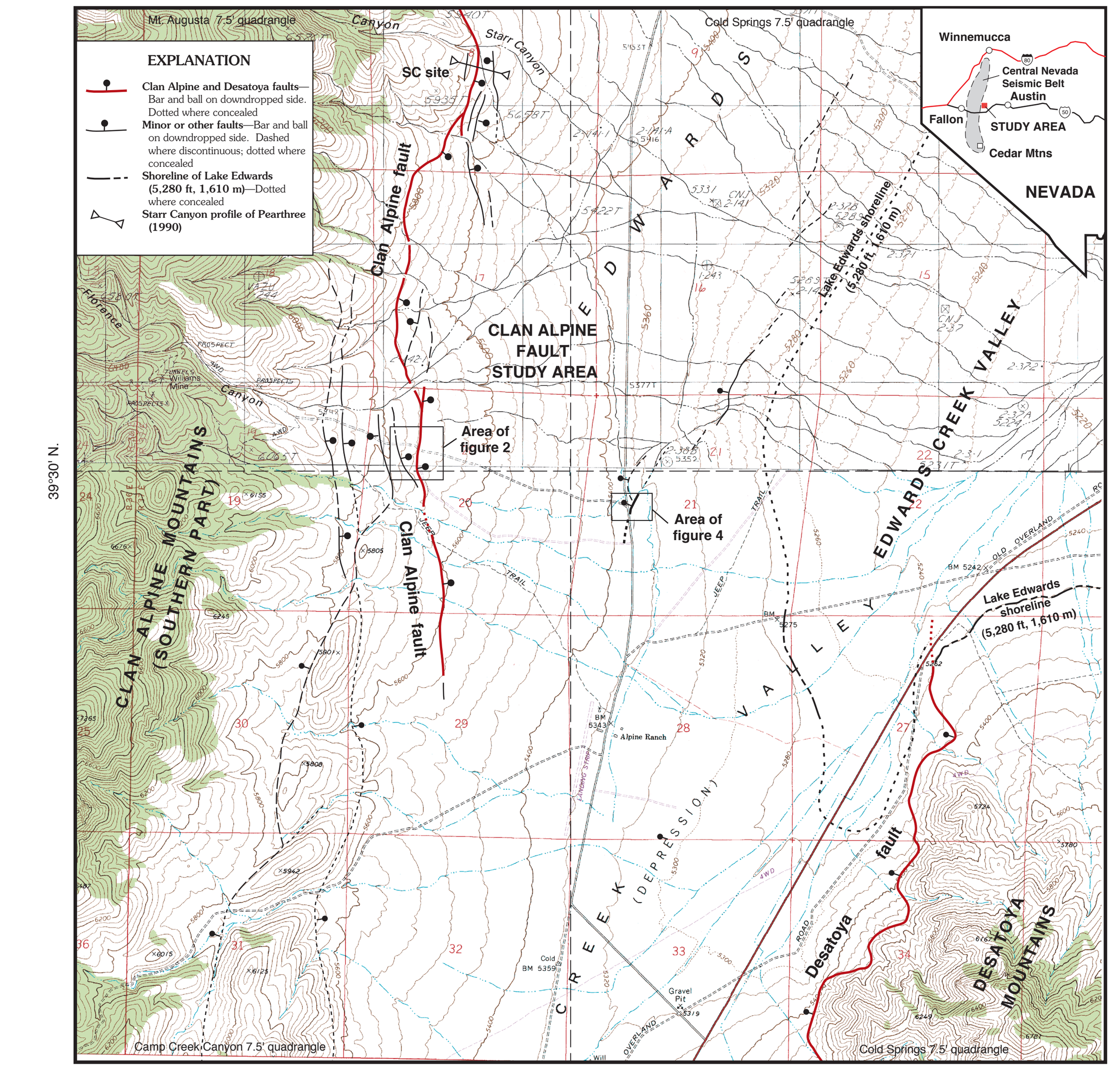

Figure 1. Topographic base map for Clan Alpine fault trenching study, west-central Nevada.

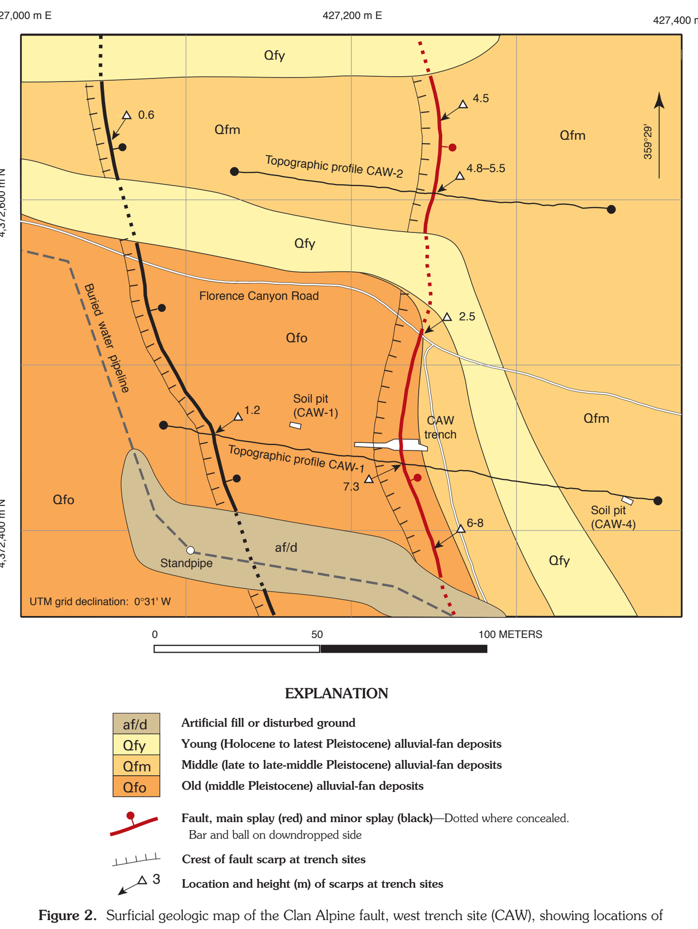

Figure 2. Surficial geologic map of the Clan Alpine fault, west trench site (CAW), showing locations of trench, scarp profiles, and soil pits.

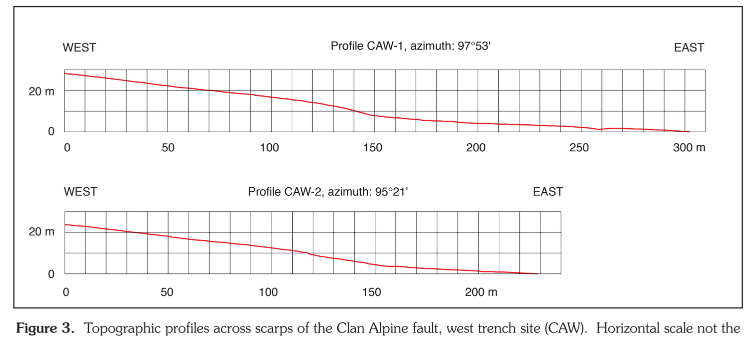

Figure 3. Topographic profiles across scarps of the Clan Alpine fault, west trench site (CAW). Horizontal scale not the same as on figure 2.

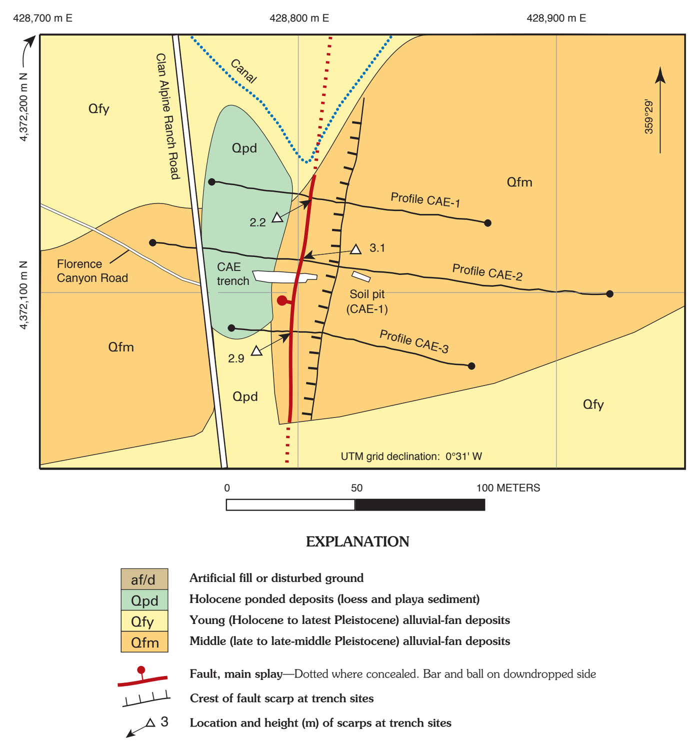

Figure 4. Surficial geologic map of the Clan Alpine fault, east trench site (CAE), showing locations of trench, scarp profiles, and soil pits.

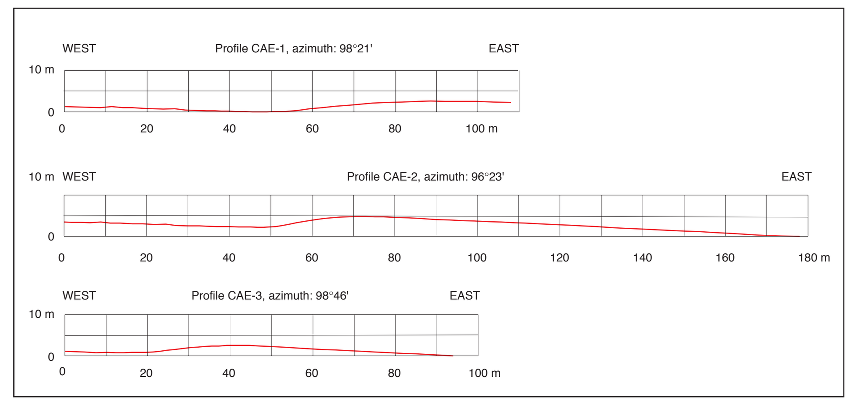

Figure 5. Topographic profiles across scarps of the Clan Alpine fault, east trench site (CAE). Horizontal scale not the same as on figure 4.

Figure 6. Trench log for Clan Alpine fault, west trench (CAW).

Mapped and described by M.N. Machette, K.M. Haller, C.A. Ruleman, K. Okumura, and S. Debray; September 9–17, 2001.
Horizontal and vertical control by EDM theodolite (<1 cm accuracy).
Trench location: UTM Zone 11S, $^{43}72^{450}$ m N, $^{04}27^{225}$ m E (NAD 27).
Trench axis is 270° (E to W).

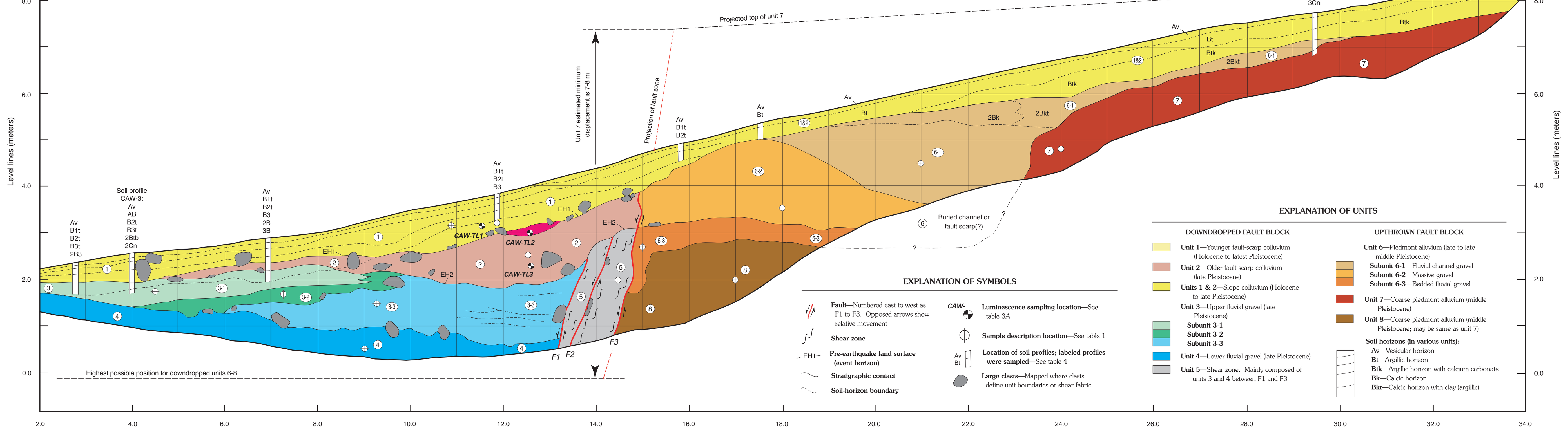

Table 3A. Luminescence age data from Clan Alpine fault, west trench site (CAW).

Sample number	Location x/y (m)	Unit number	Dating[a] method	Temperature[b] data (°C)	Equivalent[c] dose (grays)	Field & Sat.[d] moistures	Modeled[e] moisture	Dose rate[f] (grays/ka)	Luminescence age[g] (ka)	Preferred age[h] (ka, rounded)	Comments
Trench on west trace of Clan Alpine fault, south wall											
CAW-TL1	11.85, 3.20	1	TL-tb	124°/62 hrs	39.69 ± 1.12%	4.7 (41)	10	7.323 ± 3.7%	5.42 ± 0.41	5.2 ± 0.4	Average of TL-tb and IRSL ages. From middle of younger colluvial wedge (unit 1); minimum time for most recent faulting event (MRE).
			IRSL	124°/62 hrs	35.94 ± 1.19%	do	do	do	4.91 ± 0.37		
CAW-TL2	12.55, 3.00	2	TL-tb	124°/62 hrs	63.10 ± 1.96%	3.2 (39)	10	7.057 ± 3.5%	8.94 ± 0.73	9.3 ± 0.7	Average of TL-tb and IRSL ages. From top (sand) of older colluvial wedge (unit 2); older than MRE, must be younger than sample CAE-TL3.
			IRSL	124°/62 hrs	67.93 ± 0.92%	do	do	do	9.63 ± 0.72		
CAW-TL3	12.60, 2.32	2	TL-tb	140°/7 hrs	175.97 ± 3.68%	4.5 (43)	20	6.202 ± 3.6%	28.37 ± 2.96	27.6 ± 2.6	Average of TL-tb and first of two IRSL ages. From near base of older colluvial wedge (unit 2); minimum time since penultimate event (PE). Average age including all three samples is 30.6 ± 4.2 ka.
			IRSL	124°/62 hrs	166.0 ± 1.80%	do	do	do	26.77 ± 2.20		
			IRSL	140°/7 hrs	227.50 ± 0.44%	do	do	do	[36.68 ± 7.45]		

Notes for tables 3A and 3B:
[a]TL-tb: thermoluminescence–total bleach on polyminerals; IRSL: infrared-stimulated luminescence on feldspar.
[b]Values for TL are plateau temperatures; values for IRSL are preheat temperatures.
[c]Error is ± 1 sigma.
[d]All field moisture contents of sealed field samples measured in the laboratory. Values in parentheses represent saturated (Sat., maximum possible) moisture content.
[e]Average (modeled) moisture content since sampled material was deposited.
[f]Dose rate from in-situ measurements with Exploranium GR-256 gamma-ray spectrometer at field moisture, recalculated here for modeled moisture[e]; error is ± 1 sigma.
[g]All ages are ± 2 sigma; ages in square brackets had analytical problems (S. Mahan, written commun., 2002) and were not used to compute preferred ages in next column.
[h]Preferred ages, single or averaged; averaged ages are error weighted with ± 2 sigma errors.

Table 3B. Luminescence age data from Clan Alpine fault, east trench site (CAE).

Sample number	Location x/y (m)	Unit number	Dating[a] method	Temperature[b] data (°C)	Equivalent[c] dose (grays)	Field & Sat.[d] moistures	Modeled[e] moisture	Dose rate[f] (grays/ka)	Luminescence age[g] (ka)	Preferred age[h] (ka, rounded)	Comments
Trench on east (antithetic) trace of Clan Alpine fault, south wall											
CAE-TL1	8.25, 2.32	1	TL-tb	124°/62 hrs	77.99 ± 1.53%	2.4 (27)	10	6.477 ± 3.6%	12.04 ± 0.94	10.7 ± 0.8	Average of TL-tb and IRSL ages. From middle of younger colluvial wedge (unit 1-2); minimum time for most recent faulting event (MRE).
		1-2	IRSL	124°/62 hrs	59.95 ± 0.72%	do	do	do	9.25 ± 0.68		
CAE-TL2	10.97, 1.73	2-2	TL-tb	124°/62 hrs	105.56 ± 1.68%	3.3 (41)	15	6.811 ± 3.5%	15.50 ±1.20	15.2 ± 1.2	Average of TL-tb and IRSL ages. From middle of older colluvial wedge (unit 2-2); older than penultimate event (PE), must be younger than sample CAE-TL3.
		2-2	IRSL	124°/62 hrs	101.29 ± 0.93%	do	do	do	14.87 ± 1.08		
CAE-TL3	10.94, 1.14	2-2	TL-tb	124°/62 hrs	204.06 ± 3.13%	2.6 (33)	20	6.907 ± 3.5%	29.54 ± 2.77	27.6 ± 2.4	Average of TL-tb and first of two IRSL ages. From near base of older colluvial wedge (unit 2-2); minimum time since PE. Preferred age including all three samples is 30.2 ± 2.7 ka.
		2-2	IRSL	124°/62 hrs	177.76 ± 1.64%	do	do	do	25.74 ± 1.99		
		2-2	IRSL	140°/7 hrs	216.66 ± 2.88%	do	do	do	[35.54 ± 3.27]		

Figure 7. Trench log for Clan Alpine fault, east trench (CAE).

Described and mapped by M.N. Machette, K.M. Haller, C.A. Ruleman, K. Okumura, and S. Debray; September 10–17, 2001.
Horizontal and vertical control by EDM theodolite (<1 cm accuracy).
Trench location: UTM Zone 11S, $^{43}72^{105}$ m N, $^{04}28^{800}$ m E (NAD 27).
Trench axis is 90° (W to E).

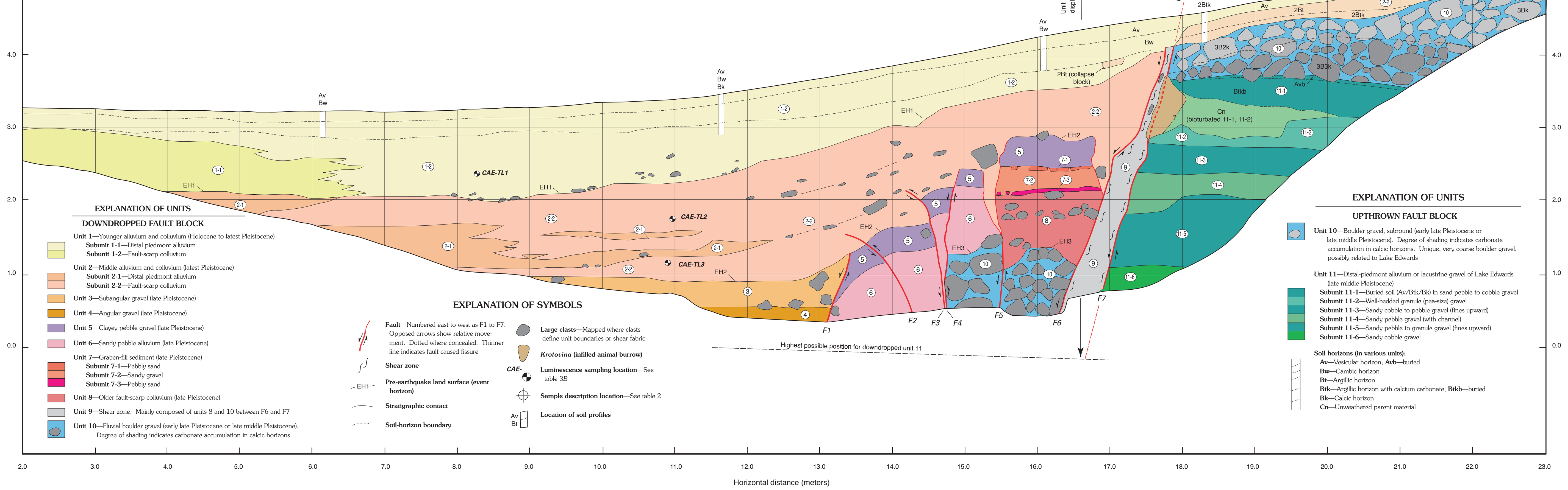

Table 1. Description of units from the Clan Alpine fault, west trench (CAW).

Block	Unit number	Location[a] x/y (m)	Matrix texture (<2 mm)	Gravel (percent)	Clast sizes (mm): Max. (average)	Sorting	Colors, dry (d) and moist (m)	Dry[b] consistence	Wet[c] consistence	Lower[d] boundary	Genesis Major/minor	Comments
DOWNDROPPED BLOCK	1	11.9, 3.2	Silt loam	10-20	20-25 (5-10)	Poor	10YR 5.5/3d 10YR 4.5/2m	lo	s, po	c, w	Colluvium	Younger fault-scarp colluvium from most recent event (MRE). Fines downslope from proximal, gravelly colluvium to distal, pebbly colluvium. See table 3A for luminescence age estimate and table 4 for soil-profile descriptions.
	2	12.5, 2.5	Sandy silt	25	50	Poor	10YR 5.5/4d 10YR 4.5/4m	sh	ss, po	a, s	Colluvium	Older fault-scarp colluvium from penultimate event (PE). Fines downslope from proximal, bouldery colluvium to distal, cobbly colluvium. Contains several thin lenses of eolian sand. See table 3A for luminescence age estimates.
	3	In general	Sand	--------		Moderate to well	------------	--	-------	---	Fluvial/ colluvium	Upper fluvial gravel deposited against preexisting fault scarp (pre-penultimate event, PE2). Subunits reflect position and origin. Gravel not suitable for luminescence dating.
	3-1	4.5, 1.75	Sand	25	20-35 (7-10)	Moderate	10YR 6.5/3.5d 10YR 4.5/4m	lo	so, po	g, w	Fluvial	Gravel, stage I carbonate of base of clasts. Poorly bedded, may contain admixed loess(?).
	3-2	7.2, 1.7	Sand	25-50	12 (2-5)	Moderate to well	10YR 6.5/3d 10YR 4.5/4m	lo	ss, po	c, i	Fluvial	Sandy gravel, contains more cobbles than unit 4, grades up into unit 3-1.
	3-3	9.3, 1.5	Sitly sand	50-75	40-50 (10-15)	Well	10YR 6.5/4d 10YR 4.5/4m	lo	so, po	c, i	Fluvial	Sandy pebble to cobble gravel partly buries preexisting fault scarp (PPE). Sandy beds are horizontal; clay laminae indicate paleo-water table. Imbricated cobbles show southward deposition. Bedding not rotated by PE or MRE.
	4	9.0, 0.5	Sand	>75	35-45 (15)	Well	10YR 6.5/3d 10YR 4.5/4m	lo	ss, ps	n.e.	Fluvial	Lower fluvial gravel partly buries preexisting scarp (PE2); abundant imbricated cobbles show deposition from the north (169° ± 39°, n = 70). Bedding is rotated by PE2. Clast-to-clast contact, subrounded, main-stream fluvial deposits.
SHEAR ZONE	5	14.5, 2.0	Sand	50-75	10-45 (5-10	Moderate	10YR 6.5/3.5d 10YR 4.5/4m	lo	ss, ps	n.e.	Shear zone	Sheared zone of deposits from units 3-3 and 4. Unbedded, sandy pebble to large cobble gravel; has subvertical shear fabric and elongate clasts. Fault F3 is locally cemented by iron-oxide-rich minerals.
UPTHROWN BLOCK	6	In general	-----	-----	-------	-----	------------	---	so, po	---	Fluvial (piedmont)	Piedmont alluvium (alluvial fan) with debris flows(?). Inset into units 7 and 8, which may be correlative. Probably graded to lower base level caused by older faulting events (pre unit 4, post unit 7).
	6-1	21.0, 4.5	Sand	10-15 (4-8)	25-35	Poor	10YR 6.5/4.5d 10YR 4.5/4m	sh	so, po	g, w	Fluvial (piedmont channel)	Sandy cobble to pebble gravel fills channel in subunit 6-2 and (or) is faulted against unit 7. Crude imbrication suggests north or south flow direction in channel.
	6-2	18.0, 3.5	Sand (medium-coarse)	30 (8-10)	25-40	Poor	10YR 6.5/3.5d 10YR 4.5/4m	sh	so, po	g, w	Fluvial (piedmont)	Sandy pebble to cobble gravel with 10 percent boulders. Iron-stained matrix; unit is crudely bedded.
	6-3	15.0, 2.7	Sand	20 (6-10)	35-40	Poor	10YR 6.5/4.5d 10YR 4.5/4m	sh	so, po	a, w	Fluvial (piedmont)	Sandy cobble to pebble gravel; cut meter-deep channel into unit 8. May have been deposited across preexisting fault scarp on units 7 and 8.
	7	24.0, 4.8	Sand	20-45 (15)	45-70	Poor	10YR 6.5/4.5d 10YR 4.5/4m	h	so, po	n.e.	Fluvial (piedmont)	Coarse piedmont alluvium comprising sandy boulder to cobble gravel; may be correlative with unit 7 (but not continuous). Unbedded; no obvious pebble imbrication. Carbonate in upper part from soil in subunit 6-3.
	8	17.0, 2.0	Sand	25 (14-18)	50-75	Poor	10YR 5.5/4.5d 7.5YR 4.5/4m	h	so, po	n.e.	Fluvial (piedmont)	Coarse piedmont alluvium comprising sandy cobble to boulder gravel; clasts float in iron-stained matrix. Poorly bedded; no pebble imbrication; stage I+ carbonate coatings on clasts and along fault F3.

Notes: [a]Location: all are located in south wall of trench.
[b]Dry consistence: lo—loose, sh—slightly hard, h—hard.
[c]Wet consistence: stickiness: so—nonsticky, ss—slightly sticky, s—sticky; plasticity: po—nonplastic, ps—slightly plastic.
[d]Lower boundary: distinctness: a—abrupt (<1 cm), c—clear (1–5 cm), g—gradual (>5 cm); shape—s, smooth, w—wavy, i—irregular; n.e.—not exposed.

Table 2. Description of units from the Clan Alpine fault, east trench (CAE).

Block	Unit number	Location[a] x/y (m)	Matrix texture (<2 mm)	Gravel (percent)	Clast sizes (mm): Max. (average)	Sorting	Colors, dry (d) and moist (m)	Dry[b] consistence	Wet[c] consistence	Lower[d] boundary	Genesis Major/minor	Comments
DOWNDROPPED BLOCK	1	In general	-----	------	-----	-----	-----	---	------	------	Mixed	Younger fault-scarp colluvium from most recent event (MRE). Grades laterally (to west) into distal, fine-grained alluvium of distal piedmont slope.
	1-1	5.0, 2-2.7	Sand	10-25	10 (2-4)	Mod	10YR 6/3d -----	lo	ss, po	g, s	Fluvial	Fine-grained, parallel-bedded channels of sandy pebble gravel and pebbly sand. Elongate clasts in lenses have eastward imbrication, suggesting deposition from west (downslope). Not suitable for luminescence dating.
	1-2	11.2, 2.45	Silty sand	<5	10-25 (3-4)	Poor	10YR 6.5/3d	lo	ss,sp	c, s	Colluvial, eolian, and playa	Fine-grained colluvium, loess, and playa (ponded) deposits. Colluvium grades laterally into playa; loess is intermixed with both. See table 3B for luminescence age estimate and table 4 for soil-profile descriptions.
	2	In general	-----	-------	------	------	-----	--	-----	-----	Mixed	Older fault-scarp colluvium from penultimate event (PE). Grades laterally (to west) into distal, fine-grained alluvium of distal piedmont slope.
	2-1	11.2, 2.45	Sand (m-c)	2-3	10-14 (2-3)	Mod	10YR 5.5/4d	sh	so, po	c, w	Fluvial	Fine-grained, parallel-bedded channels of sandy pebble to cobble gravel and pebbly sand; forms channels and lenses that are complexly interbedded with unit 2-1. Not suitable for luminescence dating.
	2-2	11.0, 1.7	Silty sand	25-35	(7-10)	Poor	10YR 6/3d	h	ss, po	c, s	Colluvial, eolian, and playa	Fine-grained colluvium with crude west-dipping fabric. Colluvium grades laterally into unit 2-1; loess is intermixed with both. At 15–17 m horizontal, deposit has unbedded collapse blocks, coarse gravel (35 cm diameter), and slope colluvium. See table 3B for luminescence age estimate and table 4 for soil-profile descriptions.
	3	11.9, 0.8	Sand	25-50	20-25 (5-8)	Moderate	10YR 5/4d	sh	ss, po	a, s	Fluvial	Subangular fluvial(?) gravel; crudely bedded.
	4	11.8, 0.6	Silty sand	10-20	5-10 (2-5)	Poor	7.5-10YR 4/4d	sh	ss, sp (in Btk)	n.e.	Colluvial	Gravelly colluvium contains 20-cm-thick Btk horizon with stage 1 carbonate in upper part. Base not exposed, nor is unit preserved east of most westerly fault (F1). May be evidence of pre-penultimate faulting (PE2) event.
	5	14.2, 1.5	Sandy clay loam	25-40	15 (4-6)	Poor	10YR 6/4d 10YR 5/4m	sh	s, p	a, s	Fluvial(?)	Sandy pebble to small cobble gravel with 20% clay in matrix (soil?). Crudely bedded; may be debris flow; clasts subrounded. Extends across faults F2–F5 with fairly uniform thickness, suggesting deposition on flat surface.
	6	13.3-14.5, 0.8-1.1	Loamy sand	5-15	10 (2-5)	Poor	10YR 6.5/4d 10YR 5.5/4m	lo, so, sh	so, po	a, w	Fluvial or colluvial	Sandy to silty small pebble cobble gravel; poorly bedded fines upward. Unit only found between faults F1 and F5; thus, may represent a wedge of colluvium (at least 75 cm thick).
	7	In general	-----	-----	-----	-----	-----	-----	-----	-----	Fluvial	Graben-filling sediment. Includes upper (subunit 7-1) and lower (subunit 7-1) fine-grained sediment and intervening coarse bed of sandy gravel. Only preserved between faults F5 and F6.
	7-1	16.25, 2.5	Sand (c)	5-10	3 (1)	Moderate	10YR 6.5/4d 10YR 3.5/4m	sh	so, po	a, s	Fluvial	5-cm-thick bed of coarse sand to small pebble gravel; smooth upper and lower contacts. Bed broken into blocks; not continuous across graben.
	7-2	16.25, 2.35	Sand (c)	10-15	4-5 (2)	Poor	10YR 6.5/3d 10YR 3.5/4m	lo, so, sh	so, po	a, s	Fluvial	20- to 25-cm-thick bed of coarse sand to pebble gravel with inclined fabric. Resembles debris flow; homogeneous, massive with no bedding.
	7-3	16.25, 2.2	Loamy sand (f-m)	<10	3 (1)	Moderate	10YR 6/3d 10YR 4/4m	sh	so, po	a, s	Fluvial	5- to 7-cm-thick bed of fine to medium pebbly sand; smooth upper and lower contacts. Crude, but finely laminated (water-laid) and planar. Bed broken into blocks, not continuous across graben.
	8	16.0,1.7-2.0	Loamy sand (c)	25-40	10-20 (2-5)	Poor	10YR 6/3d 10YR 5/3m	sh	ss, po	a, w	Colluvial	Heterogeneous sandy pebble to large cobble gravel; unbedded; crudely stratified in upper part. Gravel bi-modal; large clasts derived from unit 10 and small clasts from unit 11, which requires a 1.7-m-high free face for source.
	10	18.0, 1.0	Sand	65-70	45-55 (15)	Well	10YR 6/3d 7.5YR 5/4m	sh ($CaCO_3$)	so, po	n.e.	Fluvial or lacustrine	Sandy boulder gravel; well to subrounded; predominantly volcanic. Much coarser than other units in trench. Fluvial or possibly lacustrine (shoreline deposit). Soil (Bk horizon) not as well developed as on upthrown block.
SHEAR ZONE	9	16.5-17.7, 1.0-2.5	Loamy sand	50-65	15-20 (2-5)	Moderate	Variable, like units 10 & 11	lo	so, po	n.e.	Fluvial in shear zone	Fluvial deposits; sandy cobble, sandy boulder, and sandy pebble gravels faulted and sheared between faults F6 and F7. Clasts subrounded (from unit 11) to rounded (from unit 10). Upper boundary based on coarse gravel.
UPTHROWN BLOCK	10	20.5, 3.6-4.3	Sand	65-75	50 (15-20)	Well	10YR 6/3d 7.5YR 4.5/4m	sh ($CaCO_3$)	so, po	a, s	Lacustrine(?)	Sandy boulder gravel; well to subrounded; predominantly volcanic. Much coarser than other units in trench. Fluvial or possibly lacustrine (regressive beach-shoreline deposit). Contains mature soil (see table 4).
	11	In general	------	-----	-----	-----	-----	-----	-----	-----	Lacustrine(?)	Sandy pebble to cobble gravel; moderately to well-bedded repetitious sequence at least 3 m thick. May be distal piedmont deposit, but sorting and parallel bedding suggest transgressive deposition in quiet water (lake).
	11-1	19.5, 3.5	Sand	45-60	15 (5-8)	Moderate	-----	lo	so, po	a, s	Lacustrine(?)	Sandy pebble cobble gravel. Contains buried soil (Av, Btk, and Bk horizons) that formed prior to burial. Av is 2–3 cm thick; Btk (20–25 cm thick) is stage II–III, and has thin clay films on peds; Bk is stage I and 10–15 cm thick.
	11-2	19.8, 3.0	Loamy sand	50-60	4 (0.5)	Well	-----	sh	so, po	g, w	Lacustrine(?)	Sandy granule gravel. Fines upwards on centimeter-scale cycles; contains abundant lenses of pea-size granule gravel. Top is bioturbated (mixed by animals).
	11-3	18.5, 2.4	Sand	35-50	13 (4)	Moderate	-----	lo, so, sh	ss, po	a, s	Lacustrine(?)	Sandy cobble gravel; poorly bedded; well stratified; fines upwards.
	11-4	17.5, 2.25	Loamy sand	45-60	8 (1-2)	Poor to moderate	-----	sh	so, po	a, s	Lacustrine(?)	Sandy pebble gravel; poorly stratified and bedded; clasts subrounded to subangular. Forms channel in subunit 11-5 (below).
	11-5	18.0, 1.7	Sand	25-50	5-15 (2-6)	Poor to moderate	-----	lo, so, sh	ss, po	a, s	Lacustrine(?)	Sandy cobble gravel at base; fines upward into sandy pebble gravel and pebbly sand. Upper 35 cm distinctly finer grained.
	11-6	17.5, 1.0	Sand	40-60	10 (2-3)	Poor to moderate	-----	sh	so, po	n.e.	Lacustrine(?)	Sandy cobble gravel; poorly bedded and moderately stratified. Poorly exposed; base covered.

Notes: [a]Location: all are located in south wall of trench.
[b]Dry consistence: lo—loose, so—soft, sh—slightly hard, h—hard.
[c]Wet consistence: stickiness: so—nonsticky, ss—slightly sticky, s—sticky; plasticity: po—nonplastic, ps—slightly plastic, p—plastic.
[d]Lower boundary: distinctness: a—abrupt (<1 cm), c—clear (1–5 cm), g—gradual (>5 cm); shape: s—smooth, w—wavy; n.e.—not exposed.

Table 4. Soil-profile descriptions from the Clan Alpine fault, west (CAW) and east (CAE) trench sites.

Horizon[a]	Trench unit	Depth to top (cm)	Depth to base (cm)	Lower[b] boundary	Color[c], dry	Color[c], moist	Texture[d]	Gravel (percent)	Structure[e]	Consistence[f] dry	Consistence[f] wet	Clay[g] films	Comments[h]
Profile CAW-1 – Soil pit, hangingwall, 65 m east of fault													
Av	--	0	10	c, w	10 YR 6/2	10 YR 3/3	SL	<10	1, m, pl	so	ss, ps	none	Vesicles are <0.5 mm diameter.
2Bt	--	10	28	c, w	7.5 YR 4/4	10 YR 4/3	GLSCL	50	3, c, abk	h	ss, p	2, d, pf & co	Strong Bt horizon.
2Btk	--	28	35	c, w	10 YR 6/4	10 YR 4/4	SL	20	2, m, sbk	h	ss, ps	1, f, pf	Stage II carbonate in matrix. Clasts are angular, small.
2Bk	--	35	65	g, w	10 YR 7/3	10 YR 6.5/6	GSL	20-40	3, c, pr	sh	so, po	none	Stage III carbonate in upper 15 cm. Clasts are angular, small.
3Bk	--	65	175	d, w	10 YR 8/3	10 YR 6/4	GS	40-60	M	so	so, po	none	Stage II carbonate; unit 3 is debris flow deposit; no oxidation.
4Cn	--	175	---	n.e.	10 YR 7/3	10 YR 6/4	VGS	75	SG	lo	so, po	none	Unbedded, poorly sorted pebble gravel; discontinuous carbonate.
Profile CAW-2 – Trench footwall, south side, 29.5 m horizontal													
Av	1&2	0	5	a, s	10 YR 6.5/3	10 YR 3.5/3	SiL	10-20	2, m-c, pl	so	so, ps	none	Abundant 0.5–1 mm vesicles, 1–3 mm maximum.
Bt	1&2	5	35	c, s	7.5 YR 4.5/4	7.5 YR 4.5/2	SCL	10	2-3, m, abk	so-sh	s, p	2, d, pf & co	Strong Bt horizon.
Btk	1&2	35	56	a, s	10 YR 4/4	7.5 YR 4.5/4	SCL	5	1, f, sbk	h	s, p	1, f, pf	Stage II carbonate; 15 percent of volume in upper part.
2Bkt	6-1	56	86	d, w	7.5 YR 5/6	10 YR 5.5/4	GSCL-	5-10	M	so	ss, ps	n.d.	Stage I carbonate in matrix; 25–50 percent gravel in lower part.
3Cn	7	>86	---	n.e.	n.d.	n.d.	GSL	75	SG	lo	so, po	none	Formed on poorly sorted sandy boulder to cobble gravel.
Profile CAW-3 – Trench hangingwall, south side, 4.0 m horizontal													
Av	1	0	12	a, s	10 YR 6.5/3	10YR 3.5/4	SiL	<5	2, m, abk	so	ss, ps	none	Abundant <0.5-mm-diameter vesicles.
AB	1	12	20	a, s	10YR 5/3	10YR 4/3	SiL to SCL	<5	1, f, pl	so	s, ps-p	1, f, pf	Few weak <1-mm-diameter vesicles in upper part.
B2t	1	20	36	c, s	10YR 5/3	10YR 4.5/3	SCL	<5	1, f, sbk	h	ss, ps	1 f, pf & co	
B3t	1	36	64	g, w	10YR 6/4	10YR 4.5/4	SCL-	5-10	1, f, sbk	h	ss, p	2 d, pf & co	
2Btb	3-1	64	80	g, w	10YR 6/4	10YR 4.5/4	GSCL-	50-60	1, f, sbk	sh	ss, p	1 f, pf & co	Formed on poorly sorted sandy cobble gravel.
2Cn	3-1	>80	---	---	n.d.	n.d.	GSL	60-75	M	lo	so, po	none	
Profile CAW-4 – Soil pit, hangingwall, 130 m east of fault													
Av	---	0	14	a, s	10 YR 6/3	10 YR 5/3	L	<5	2, c-2, m, pl	so	ss, ps	none	30 percent volume 1- to 2-mm vesicles; material is loess.
2B2t	4	14	30	c, w	7.5 YR 5/6	10 YR 4.5/4	GSCL	50	3, c, sbk	sh	s, ps	2 d, pf & co	Medium to coarse sand.
2B3t	4	30	55	c-g, w	7.5 YR 5/6	10 YR 6/5	VGSL	75	2, f-m, sbk	h	ss, ps	1 f, pf & co	Silica(?)-cemented peds.
3Bk	4	55	135	n.d.	10 YR 8/3	10 YR 6/4	VGS	85	M	sh-h	so, po	none	Discontinuous stage II–III carbonate suggests leaching.
3Cn	4	135	>240	n.e.	10 YR 7/3	10 YR 6/4	VGS	75	SG	lo	so, po	none	Discontinuous carbonate stage I–II on clasts along bedding planes.
Profile CAE-1 – Soil pit, footwall, 25 m east of fault													
Av	1-1	0	10	a, s	10 YR 6.5/3	10 YR 4/3	SiL	<2	3, c, pl	so	so, ps	none	Adundant <0.5-mm-diameter vesicles; material is loess.
2Avb/Bw	2-2	10	37	a, w	10 YR 6/4	10 YR 4.5/3	L	5-10	2, c, sbk	sh	ss, ps	none	
2Bt	10	37	57	g, w	10 YR 6.5/4	7.5 YR 4/3.5	SCL-	15-20	3, c, sbk	sh	ss, p	1 f, pf & co	Discontinuous stage I carbonate.
2Bk	10	57	105	a, s	10 YR 6/3	7.5 YR 4.5/4	GS to SL	60-70	1, f, sbk	so	so, po	none	Thin layer of laminated carbonate along base of horizon.
3Bk	10	>105	---	n.e.	10 YR 7/3	10 YR 6/4	VGS	75-80	SG	lo	so, po	none	Discontinuous carbonate in fissures, veinlets, and lenses (see note h).

Notes: [a]Horizon nomenclature from Soil Survey Staff (1975) and Birkeland (1999).
[b]Lower boundary: distinctness: a—abrupt, d—distinct, c—clear, g—gradual; shape: smooth, w—wavy; n.e.—not exposed.
[c]Colors: From Munsell Soil Color Chart (Munsell Color Co., Baltimore, Md.,1954 or later editions); n.d., not determined.
[d]Texture classes: CL—clay loam, L—loam, LS—loamy sand, SL—sandy loam, S—sand, SiL—silt loam, G—gravelly, VG—very gravelly; -, less clay.
[e]Structure: grade: 1—weak, 2—moderate, 3—strong; size class: f—fine, m—medium, c—coarse; type: pl—platey, abk—angular blocky, sbk—subangular blocky, pr—prismatic, SG—single grain, M—massive.
[f]Consistence: dry: lo—loose, so—soft, sh—slightly hard, h—hard; wet: stickiness: so—nonsticky, ss—slightly sticky, s—sticky; plasticity: po—nonplastic, ps—slightly plastic, p—plastic.
[g]Clay films: amount: 0—none, 1—few, 2—common; distinctness: f—faint, d—distinct; location: pf—on ped faces, co—coats grains; n.d.—not determined.
[h]Carbonate nomenclature from Birkeland (1999).
[i]The carbonate in this horizon was probably deposited by ground water and is not pedogenic in origin. Therefore, the "k" subhorizon designation for this part of the profile is not appropriate, but is used here to signify the abundant amount of post-depositional carbonate in this deposit.

Suggested citation: Machette, M.N., Haller, K.M., Ruleman, C.A., Mahan, S.A., and Okumura, K., 2005, Geologic evidence for late Quaternary movement on the Clan Alpine fault, west-central Nevada—Trench logs, scarp profiles, location maps, and sample and soil descriptions: U.S. Geological Survey Scientific Investigations Map 2891, 1 sheet.

Manuscript approved for publication June 28, 2005
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