SUPPLEMENTAL DATA
FOR INCLUSION IN GSA DATA REPOSITORY

1. Map showing seismicity in the vicinity of the Saddle Mountains.

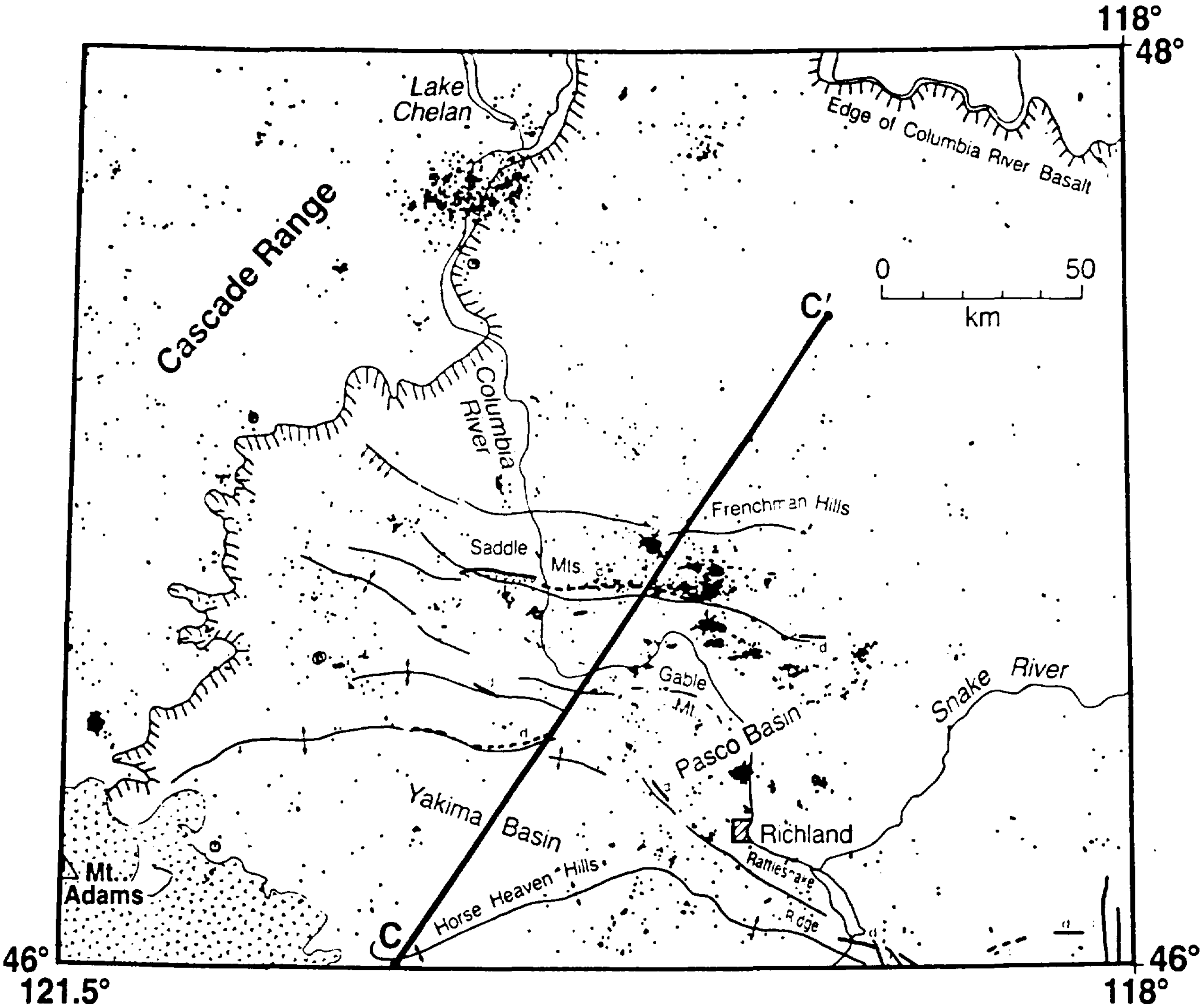
2. Cross section showing seismicity in the vicinity of the Saddle Mountains.

3. Trench #1 detailed unit descriptions

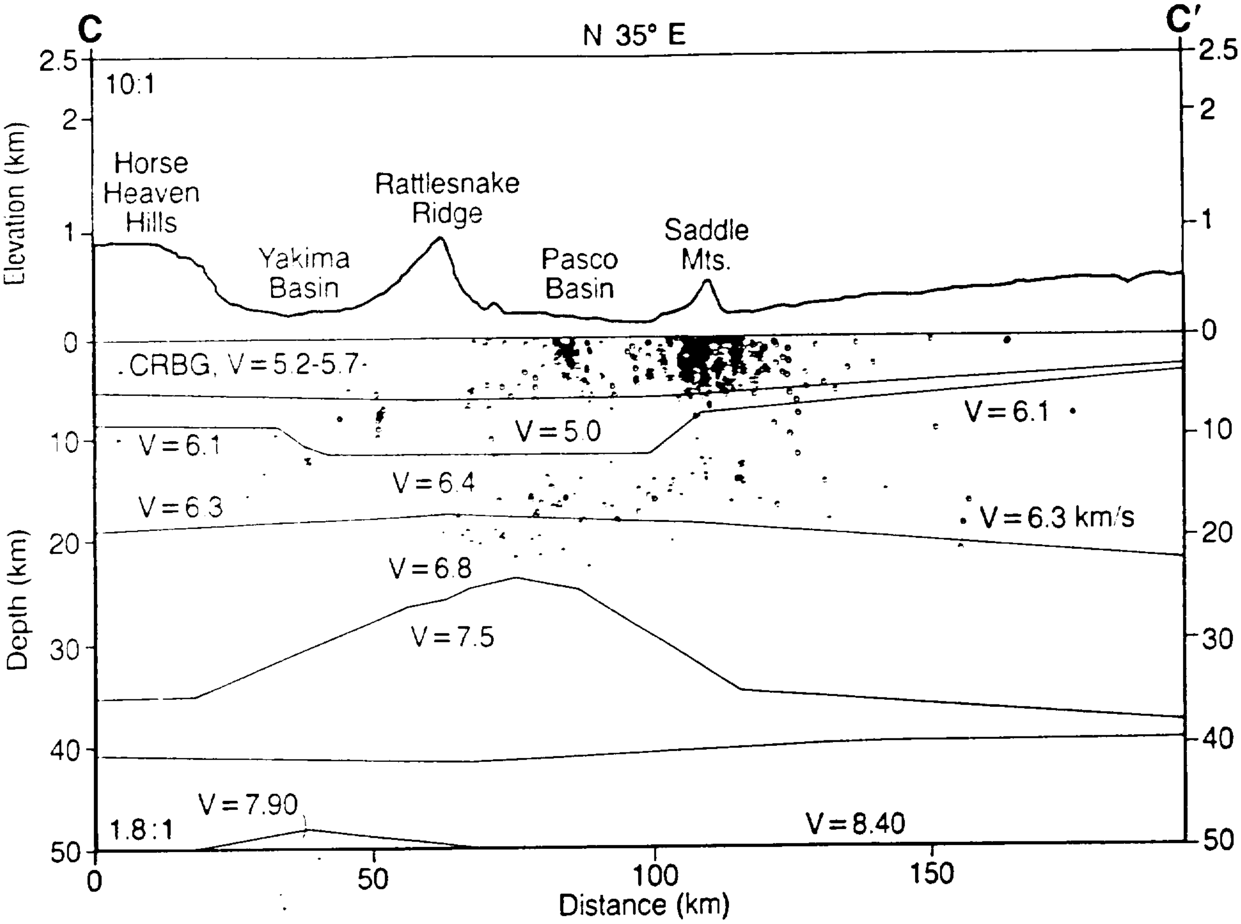
4. Trench # 2 log.

5. Trench #2 detailed unit descriptions.

6. Berger, G.W., February 27, 1996, Report on the thermoluminescence dating of loess from Saddle Mountains, Eastern Washington.



Map of seismicity in eastern Washington, 1970-1987, magnitude 1.0 and larger. Also shown are mapped faults of post-Miocene age (heavy lines) and axes of major anticlines. Note concentration of seismicity on the north flank of the Saddle Mountains anticline. Note also that seismicity appears to be transposed from the north flank of the Saddle Mountains anticline to the south flank near the transition from the Smyrna Bench to the Saddle Gap segments east of section line C-C'. The western margin of the Columbia River Basalt Group is indicated by hachures. Cross-section C-C' is illustrated on the following figure. (From Ludwin et al., 1991)



Eastern Washington cross section C-C' showing earthquake hypocenters near the Saddle Mountains anticline and related Yakima fold belt structures. 10:1 vertical exaggeration of topography; 1.8:1 vertical exaggeration of subsurface. The Columbia River Basalt Group is labeled CRBG. Best-located earthquake hypocenters since 1970, regardless of magnitude, are shown by a single symbol size. Earthquakes for 50 km on either side of line C-C' (Figure 3) are projected on to a vertical plane striking N35°E. (From Ludwin et al., 1991)

UNIT DESCRIPTIONS
TRENCH #1, SMYRNA BENCH GRABEN

NO.	UNIT	AGE	COLOR (Dry; Moist)	$CaCO_3$ STAGE	DESCRIPTION
18	**Slope colluvium/A Horizon**				
18a	Slightly sandy silt		Light yellowish brown 2.5Y 6/4; Dark yellowish brown 10YR 4/4.	None	Slightly sandy silt; very well-sorted; non-stratified; sand is fine-grained; numerous rootlets; upper boundary is ground surface; lower boundary with Unit 15a is clear, smooth.
18b	Slightly gravelly, slightly sandy silt		Light olive brown 2.5Y 5/4; Dark yellowish brown 10YR 4/6.	None	Slightly gravelly, slightly sandy silt, moderately well-sorted, non-stratified; non-cemented; sand is fine-grained; basalt clasts are subrounded to subangular; numerous rootlets; upper boundary is ground surface.
18c	Sandy, gravelly silt		Pale yellow 2.5Y 7/4; Light olive brown 2.5Y 5/4.		Sandy, gravelly silt; composition varies with slope position; poorly sorted, non-stratified; non-cemented; numerous rootlets upper boundary is ground surface; lower boundary is generally clear, smooth.
17	**Colluvium** Slightly gravelly, sandy silt		Pale yellow 2.5Y 7/4; Olive brown 2.5Y 4/4.	I	Slightly gravelly, sandy silt; poorly sorted; non-stratified; very weakly cemented by carbonate; sand is fine, medium, and coarse grained; contains basalt and sandstone clasts derived from Unit 1, subrounded to subangular; 8 cm max. dia.; disoriented carbonate rinds; upper boundary with Unit 18c is clear, irregular; lower boundary with Unit 16b is clear, wavy to irregular.
16	**Colluvium**				
16a	Slightly gravelly, sandy silt; gravel lenses indicating transport direction to north(?).	Contains Mazama climactic tephra, 6850 yr.	Light brownish gray 2.5Y 6/2; Dark grayish brown 2.5Y 4/2.	None	Slightly gravelly, sandy silt; moderately well-sorted, non-stratified except for gravel lenses indicating transport direction to north(?); sand is fine to medium-grained; basalt clasts are subangular; 1 cm max. dia.; rootlets; upper boundary with Unit 18 is abrupt to clear, smooth; lower boundary with Unit 16b is abrupt to clear, wavy.

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16b	Similar to Unit 16a with Stage I carbonate.		Pale olive 5Y 6/3 to light brownish gray 2.5Y 6/2; Dark grayish brown 2.5Y 4/2.	I	Similar to Unit 16a with Stage I carbonate; carbonate is invisible but causes strong reaction to acid across an abrupt to clear boundary.
15	**Soil**				
15a	Bw Horizon: Slightly sandy silt.		Light yellowish brown 2.5Y 6/4; Olive brown 2.5Y 4/4.	None	Slightly sandy silt; very well-sorted; non-stratified; non- to very slightly cemented, loose; sand is fine-grained; upper boundary with Unit 18 is clear, smooth; numerous rootlets; lower boundary with Unit 15b is clear, smooth to wavy.
15b	Bk Horizon: Similar to Unit 15a with Stage I carbonate.		Light yellowish brown 2.5Y 6/4; Olive brown 2.5Y 4/4.	I	Similar to Unit 15a with Stage I carbonate; carbonate is invisible but causes strong reaction to acid across an abrupt to clear boundary.
14	**Fissure fill**				
14a	Silty, sandy gravel; non-cemented, very loose; basalt with minor sandstone clasts; carbonate rinds on clasts.		Light gray 2.5Y 7/2; Light yellowish brown 2.5Y 6/4.	I	Silty, sandy gravel; non-sorted, non-stratified; non-cemented, very loose; sand is fine, medium, and coarse-grained; clasts are predominantly basalt with minor sandstones, subrounded to subangular; 19 cm max. dia.; numerous 1 mm thick carbonate rinds on clasts.
14b	Similar to Unit 14a; predominantly sandstone clasts.		Light gray 2.5Y 7/2; Light yellowish brown 2.5Y 6/4.	I	Similar to Unit 14a except that clasts are predominantly sandstone derived from Unit 1.
14c	Gravelly, sandy silt; clasts are basalt, bedrock-derived (Unit 3), and Unit 10 paleosol fragments.		Light gray 2.5Y 7/2; Grayish brown 2.5Y 5/2.	I	Gravelly, sandy silt; non-sorted; non-stratified; sand is fine and medium-grained with lesser amounts of coarse-grained sand; clasts consist of subangular to angular basalts, bedrock derived from Unit 3, and fragments of Unit 10 paleosol; 10 cm max. dia.
14d	Similar to Unit 14c without paleosol (Unit 10) fragments.		Light gray 2.5Y 7/2; Grayish brown 2.5Y 5/2.	I	Similar to Unit 14c without paleosol (Unit 10) fragments.

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13	**Colluvium**				
13a	Gravelly, sandy silt; non-cemented; basalt and sandstone gravels; some disoriented carbonate rinds.		Pale yellow 2.5Y 7/4; Light olive brown 2.5Y 5/4.	1	Gravelly, sandy silt; poorly sorted, suggestion of stratification in upper part of unit; non-cemented, friable; sand is fine, medium, and coarse grained; gravels consist of subrounded to subangular basalt and sandstone with a few scattered cobbles; 10 cm max. dia.; faint carbonate coating on bottoms of clasts; some disoriented 1-mm-thick carbonate rinds; upper boundary with Unit 16b is clear to gradual, smooth; lower boundary with Units 12 and 16b is clear to gradual, smooth to wavy.
13b	Similar to Unit 13a; second wedge indicated by stone lines.		Pale yellow 2.5Y 7/4; Light olive brown 2.5Y 5/4.	1	Similar to Unit 13a; suggestion of second wedge indicated by increase in clast content and stone lines as shown on log.
12	**Colluvium**		Light brownish gray 10YR 6/2; Dark grayish brown 2.5Y 4/2.	1	Gravelly, sandy silt; poorly sorted; non-stratified, non- to slightly indurated; sand is predominantly medium grained with lesser amounts of fine- and coarse-grained sand; gravel clasts are subangular to angular basalt, sandstone, and carbonate fragments; some broken cicada burrows; 7 cm max. dia.; clast percentage decreases to south; contains incipient, overtoppled blocks of sandstone derived from Unit 1; upper boundary with Unit 13a is clear to gradual, wavy.
11	**Loess (Parent for Unit 15 soil)**		Pale yellow 2.5Y 7/4; Light olive brown 2.5Y 5/4.	1	Slightly sandy silt; slightly indurated, friable; well-sorted; non-stratified; sand is fine grained; some pods of slightly more indurated soil with tubules present; upper boundary with Unit 15b is abrupt to clear to gradual, smooth; lower boundary with Unit 10 is abrupt, irregular to broken.
10	**Paleosol**	Contains Mt. St. Helens set M tephra, >18,560±180, <20,350±350 ^{14}CyrBP	Pale yellow 2.5Y 7/4; Light olive brown 2.5Y 5/6.	1	Slight gravelly, slightly sandy silt; moderately well to well-sorted; non-stratified; slightly indurated; sand is fine, medium, and coarse grained; basalt clasts are subrounded to subangular; 5 cm max. dia.; carbonate veining and filaments; upper boundary with Unit 11 is abrupt, irregular to broken; lower boundary with Unit 8 is abrupt, irregular.
9	**Colluvium**				

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9a	Gravelly, sandy silt; moderate carbonate cementation; contains tubules; exhibits block soil-like structure.		Pale yellow 2.5Y 7/4; Light olive brown 2.5Y 5/4.	I	Gravelly, sandy silt; poorly sorted; non-stratified; moderate cementation by carbonate; sand is fine, medium, and coarse grained; basalt clasts and carbonate fragments are subangular; 5 cm max. dia.; contains tubules and exhibits blocky, soil-like structure; unit beaks up and pinches out to the north; upper boundary is abrupt to clear, smooth; lower boundary with Unit 8 is abrupt to clear, irregular.
9b	Similar to Unit 9a but less indurated.		Pale yellow 2.5Y 7/4; Light olive brown 2.5Y 5/4.	I	Similar to Unit 9a but less indurated.
8	**Loess (Parent for Unit 10 paleosol)**		Pale yellow 2.5Y 7/4; Light olive brown 2.5Y 5/6.	I	Slight gravelly, slightly sandy silt; moderately well to well-sorted; non-stratified; very slightly indurated, friable; sand is fine, medium, and coarse grained; basalt clasts are subrounded to subangular; 5 cm max. dia.; upper boundary with Unit 10 is abrupt, irregular; lower boundary with Unit 7 is abrupt, smooth.
7	**Petrocalcic Horizon**				
7a	Slightly gravelly, slightly sandy, platy, carbonate-cemented silt; hard to very hard.		White 2.5Y 8/0 to 2.5Y 8/2; White 2.5Y 8/2 to pale yellow 2.5Y 7/4.	IV	Slightly gravelly, slightly sandy, platy, carbonate-cemented silt; hard to very hard; well-sorted; stratification(?) masked by platy carbonate; sand is fine to medium grained; basalt gravel is subrounded to subangular; 1 cm max. dia.; manganese dendrites present; upper boundary with Unit 7b is clear to gradual, smooth; lower boundary with Unit 7 is abrupt, smooth to broken.
7b	Slightly gravelly, sandy, carbonate-cemented silt; moderately hard.		White 2.5Y 8/2 to pale yellow 2.5Y 7/4; Light olive brown 2.5Y 5/4.	III	Slightly gravelly, sandy, carbonate-cemented silt; moderately hard; well-sorted; non-stratified; sand is fine, medium, and coarse grained; basalt gravel is subrounded; 3-4 cm max. dia.; upper boundary with Units 7c and 7d is abrupt, broken; lower boundary with Unit 7a is clear to gradual, smooth; unit may be scarp colluvium or in-fill against the roll scarp in Unit 7a.
7c	Slightly sandy, platy, carbonate-cemented silt; hard.		Pinkish white 5YR 8/2 to pink 5YR 8/3; Light reddish brown 5YR 6/3 to 5YR 6/4.	IV	Slight sandy, carbonate-cemented silt; hard; very well-sorted; platy carbonate; sand is fine-grained; some manganese dendrites; upper boundary with Unit 7d is abrupt, irregular to broken by back thrusts; lower boundary with Unit 7b abrupt, broken.

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TRENCH #1, SMYRNA BENCH GRABEN

7d	Slightly gravelly, slightly sandy, carbonate-cemented silt; moderately hard.		Pinkish white 5YR 8/2; Pink 5YR 7/3.	IV	Slightly gravelly, slightly sandy, carbonate-cemented silt; moderately hard; moderately-well sorted; non-stratified; sand is fine, medium, and coarse grained: basalt clasts are subrounded to subangular, 3-5 cm max. dia.; upper boundary with Units 7e an 8 is very abrupt to abrupt, smooth; lower boundary with Unit 7b and 7c is very abrupt, irregular to broken.
7e	Slightly gravelly, slightly sandy, carbonate-cemented silt; moderately hard to chalky and friable.		White 5YR 8/1; Very pale brown 5YR 8/3.	IV	Slightly gravelly, slightly sandy, carbonate-cemented silt; moderately hard to chalky and friable; moderately well-sorted; non-stratified; sand is fine, medium, and coarse grained; basalt clasts are subrounded to subangular, 5 cm max. dia.; contains rounded, pebble-like structures of carbonate, 1-10 cm in diameter; upper boundary with Unit 8 is abrupt, smooth; lower boundary with Unit 7d is abrupt to clear, smooth to wavy.
6	**Paleosol**				
6a	Slightly gravelly, sandy silt; semi-indurated cicada burrows, worm/root tubules		Light gray 2.5Y 7/2 to white 2.5Y 8/2; Light yellowish brown 2.5Y 6/4.	II-III	Slightly gravelly, fine-grained sandy silt; moderately well-sorted; suggestion of stratification (platy soil structure?); gravels are subangular to angular basalt with some carbonate fragments; 2-3 cm max. dia.; contains semi-indurated cicada burrows, worm/root tubules, and carbonate seams; upper boundary with Unit 7 is smooth to irregular to broken, very abrupt to abrupt; lower boundary with Unit 4 is wavy to irregular to broken, clear to gradual.
6b	Similar to Unit 6a but more indurated.		Light gray 2.5Y 7/2 to white 2.5Y 8/2; Light yellowish brown 2.5Y 6/4.	II-III	Similar to Unit 6a but more indurated.
6c	Slightly gravelly, sandy silt; suggestion of cicada burrows; some carbonate tubules, vuggy appearance.		Pale yellow 2.5Y 8/4; Light yellowish brown 2.5Y 6/4.	II-III	Slightly gravelly, sandy silt; moderately well-sorted; stratification inferred from 12 cm thick, carbonate horizon at bottom of unit; sand is fine, medium and coarse grained; gravels are subrounded to subangular; 2-3 cm max. dia.; suggestion of cicada burrows; some carbonate tubules and/or dissolution of carbonate giving vuggy appearance; upper boundary with Unit 7 is clear, irregular to broken; lower boundary with Unit 5 is clear to gradual, irregular.
5	**Debris flow deposits**	**<150 ka**			

UNIT DESCRIPTIONS
TRENCH #1, SMYRNA BENCH GRABEN

	5a	Gravel, cobbles and scattered boulders in oxidized, slightly silty, sand matrix; minor pedogenic carbonate.		Matrix: Light yellowish brown 10YR 6/4; Dark yellowish brown 10YR 4/6.	I-II	Gravel, cobbles and scattered boulders in an oxidized, slightly silty; medium- to coarse-grained sandy matrix; poorly sorted, non-stratified; fines upwards; gravels and cobbles are subrounded to subangular with carbonate coatings on bottoms of clasts; 50 cm max. dia.; markedly less carbonate cementation than overlying Unit 5b; upper boundary with Unit 5b is clear to gradual, irregular; lower boundary with Unit 3 is abrupt, smooth.
	5b	Gravel, cobbles and scattered boulders in a silty, sand matrix; significant pedogenic carbonate.		White.	III	Gravel, cobbles and scattered boulders in a silty, fine-, medium- and coarse-grained sand matrix; poorly sorted; non-stratified; clasts are subrounded to subangular with carbonate coatings on bottoms and sides; 60 cm max. dia.; upper boundary with Unit 7d is abrupt, irregular to broken; lower boundary with Unit 5a is clear to gradual, irregular.
4		**Colluvium**	**<150 ka**			
	4a	Loose, poorly sorted, gravelly, sandy silt with carbonate replaced root holes and krotovinas.		Light gray 2.5Y 7/2; Light yellowish brown 2.5Y 6/4.	II	Slightly gravelly, sandy silt; poorly sorted; non-stratified; may contain pods or fragments of slightly more indurated soil; sands consist of equal amounts of fine, medium and coarse-grained basalt and caliche fragments; gravels consist of subangular to angular basalt clasts and carbonate fragments; 13 cm max. dia.; numerous carbonate replaced root holes and krotovina walls; unit is noteworthy for its poor sorting suggesting a colluvial or channel fill genesis; unit is prone to wind-etching which accentuates carbonate-cemented features and shear/joint planes; upper boundary with Unit 6a is abrupt, irregular to broken; lower boundary with Unit 3 is clear to gradual, smooth to wavy.
	4b	Indurated, slightly gravelly, sandy silt with contorted, co-planar carbonate seams.		White 2.5Y 8/2; 2.5Y 6/4 Light yellowish brown.	III	Slightly gravelly, sandy, indurated silt; poorly to moderately well-sorted; suggestion or stratification by co-planar carbonate seams; sands consist of equal amounts fine-, medium- and coarse-grained basalts; basaltic gravels and carbonate fragments are subangular to angular; 5 cm max. dia.; scattered cicada burrows; numerous co-planar, folded and contorted carbonate seams; co-planar seams suggest primary stratification; upper boundary with Unit 6b clear to gradual, wavy, irregular or broken depending on location.

UNIT DESCRIPTIONS
TRENCH #1, SMYRNA BENCH GRABEN

4c	Slightly silty, gravelly sand derived from bedrock Unit 3i.		Yellowish brown 10YR 5/4; Dark yellowish brown 10YR 3/6.	II	Slightly silty, gravelly sand derived from bedrock Unit 3i; poorly sorted; no stratification; sand ranges from fine to coarse-grained; gravels are subrounded with weathering rinds and manganese coatings.
3	**Ringold(?) Formation and/or Ellensburg(?) Formation**	**Plio-Pleistocene**			
3a	Sandstone (sheared)		Very pale brown 10YR 8/4 to light yellowish brown 10YR 6/4; Dark yellowish brown 10YR 4/4 to yellow 10YR 7/8.	N.A.	Very fine-grained, slightly clayey, silty sandstone; well-sorted occurs in blocks and wedges between shear planes; highly sheared fabric.
3b	Conglomerate		Light yellowish brown 10YR 6/4; Dark yellowish brown 10YR 3/6.	N.A.	Gravelly to slightly cobbly conglomeratic sandstone; poorly sorted with equal amounts of fine-, medium- and coarse-grained sand consisting of subrounded basalt-derived grains and clasts.
3c	Siltstone		Yellowish brown 10YR 5/4; Dark yellowish brown 10YR 4/4.	N.A.	Fine to medium-grained, subrounded, sandy to very sandy, well-indurated siltstone; appears to coarsen from fine- to medium-grained sand toward bottom of unit; manganese staining.
3d	Conglomerate		Light yellowish brown 10YR 6/4; Dark yellowish brown 10YR 3/6.	N.A.	Similar to but stratigraphically different than Unit 3b; gravelly to slightly cobbly conglomeratic sandstone; poorly sorted with equal amounts of fine-, medium- and coarse-grained sand consisting of subrounded basalt-derived grains and clasts.
3e	Siltstone (sheared)		Light olive gray 5Y 6/6; Olive 5Y4/3.	N.A.	Slightly sandy, clayey siltstone with irregular calcite veinlets and manganese staining; sheared, gouge-like fabric.

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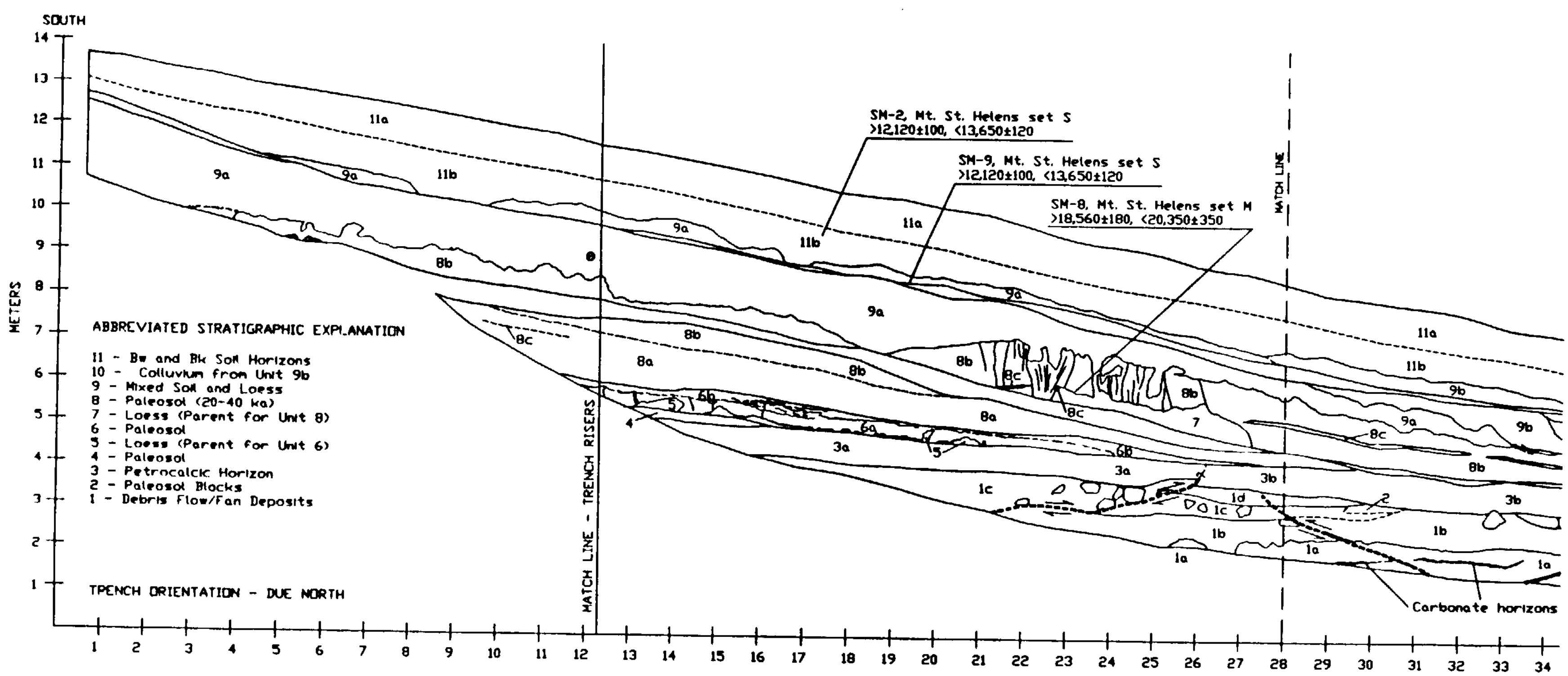
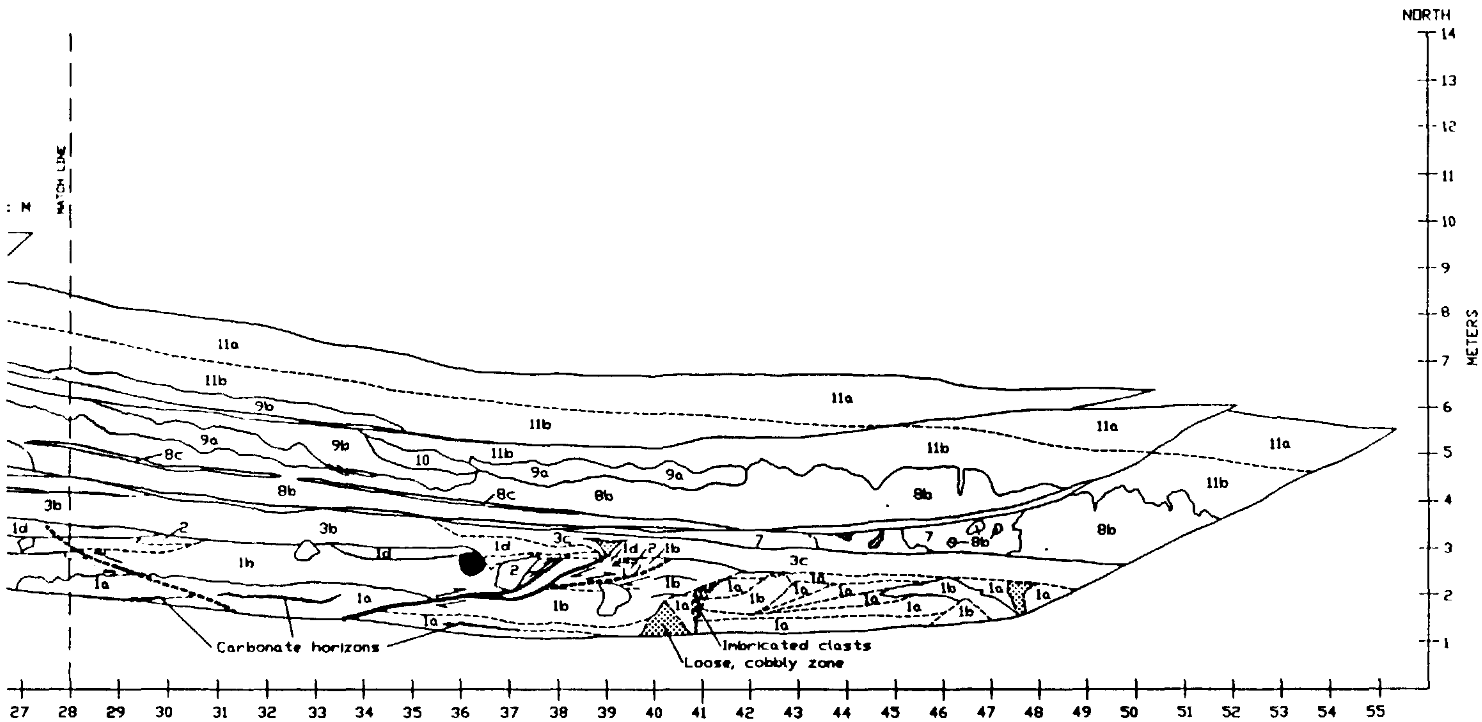
TRENCH #1, SMYRNA BENCH GRABEN

3f	Siltstone (sheared)		Light olive gray 5Y 6/2; Olive 5Y 4/4.	N.A.	Slightly sandy, slightly clayey siltstone with calcite veinlets; unit is similar to Unit 3d, but less clayey; suggestion of burrowing/bioturbation; two sets of calcite veins/shears: (1) subvertical truncating (2) south-dipping.
3g	Siltstone		White 5Y 8/1; Olive gray 5Y 5/2.	N.A.	Sandy to slightly gravelly, hard to very hard, carbonate-cemented siltstone; 4 cm subrounded basalt gravel at top of unit; carbonate cementation may be pedogenic; upper surface is very abrupt and may be erosional; subvertical shears with mm-scale displacements; grades laterally into Unit 3g.
3h	Sandstone		Yellowish brown 10YR 5/4; Dark yellowish brown 10YR 4/6.	N.A.	Silty to gravelly coarse-grained sandstone; clasts are basaltic and increase from 0% to 20% of unit near the bottom at the expense of sand; manganese coatings and minor carbonate veinlets exhibit drag folding and shearing; upper surface is weathered.
3i	Conglomerate		Yellowish brown 10YR 5/4; Dark yellowish brown 10 YR 3/6.	N.A.	Slightly silty to sandy, gravel-cobble conglomerate; poorly sorted; no stratification; sand ranges from fine to coarse grained; gravels and cobbles are subrounded with weathering rinds and manganese coatings; contains high-angle to subvertical carbonate filled shears.
2	**Elephant Mountain Member, Saddle Mountains Basalt**	**Late Miocene** (K-Ar age 10.5 Ma) - Correlation confirmed by whole-rock chemical analysis.	Dark gray 2.5Y 4/0; Black 2.5Y 2/0.	N.A.	Basalt, fine-grained, pillow structures with 20-25-cm-thick vesicular zone at top of unit.
1	**Ellensburg Formation**	**Miocene**			
1a	Sandstone		White 5Y 8/1 to 7/1; Light gray 5Y 6/1 with pods of pale yellow 5Y 8/3.	N.A.	Very fine-grained, silty, arkosic sandstone with dark mineral/rock fragments; massive, no unequivocal bedding apparent; grains are sub-angular to subrounded, well-sorted, uniform grain size. Calcite-filled joints, typically 50 cm long, dipping 30° south (bedding?) and 40°-65° north.
1b	Volcanic ash(?) or fault gouge.		White 5Y 8/1; Gray 5Y 8/5.	N.A.	Predominantly silt with calcite veinlets; forms a wedge adjacent southernmost normal fault exposed in trench; highly jointed and sheared. Strikes N 88°E



Log of west wall of Trench #2 excavated across 5 m high scarp north of the Smyrna Bench graben. Note increasing elevation of the ground surface to the left (south). The 100-400 ka petrocalcic horizon developed on debris flow/fan deposits is Unit 3 in the lower part of the trench. The depositional environment at the top of the petrocalcic horizon changes abruptly from debris fan to loess deposition and records truncation of the debris fan source area in the higher terrain to the south by development of the Smyrna Bench graben. Stacked paleosols, developed on loesses which thin and pinch out to the right (north), form the 5 m high scarp. Note the planar nature of the upper boundary, Unit 3, and its divergent position with respect to modern topography, indicating that it has been buried by loess sheets originating to the left (south). We infer the active trace of the Saddle Mountains fault lies between the south end of Trench #2 and the north flank of the Smyrna Bench graben. Small displacement thrust and backthrust faults are present in debris fan deposits between Stations 21 and 40. These faults do not displace the upper surface of the petrocalcic horizon, Unit 3. The trench was excavated in three risers separated by two treads as shown to maintain stability.


NORTH
METERS
MATCH LINE
Carbonate horizons
Imbricated clasts
Loose, cobbly zone
11a
11b
9a
9b
10
8b
8c
7
3b
3c
2
1a
1b
1d

UNIT DESCRIPTIONS
TRENCH #2, 5 m SCARP NORTH OF THE SMYRNA BENCH GRABEN

NO.	UNIT	AGE	COLOR (Dry; Moist)	$CaCO_3$ STAGE	DESCRIPTION
11	**Soil**				
11a	Bw Horizon: Slightly sandy silt.		Light yellowish brown 2.5Y 6/4; Olive brown 2.5Y 4/4.	None	Slightly sandy silt; very well-sorted; non-stratified; non- to very slightly cemented, loose; sand is fine grained; upper boundary with is ground surface; numerous rootlets; lower boundary with Unit 11b is clear, smooth to wavy.
11b	Bk Horizon: Similar to Unit 11a with Stage I carbonate.	Contains Mt. St Helens set S tephra >12,120±100, <13,650+120 ^{14}C yr BP.	Light yellowish brown 2.5Y 6/4; Olive brown 2.5Y 4/4.	I	Similar to Unit 11a with Stage I carbonate; carbonate is invisible but causes strong reaction to acid across an abrupt to clear boundary.
10	**Colluvium derived from soil block (Unit 9b).**				
9	**Mixed soil and loess.**				
9a	Sandy, slightly gravelly silt with numerous, irregular soil pods.	Contains Mt. St Helens set S tephra >12,120±100, <13,650±120 ^{14}C yr BP.	Olive 5Y 5/3; Olive brown 2.5Y 4/4.	I	Sandy, slightly gravelly silt; loose to slightly indurated, friable; moderately well-sorted; non-stratified; sand is fine grained; numerous pods and blocks of slightly more indurated soil in irregular pattern; soil pods disappear downslope near Station 20, and unit becomes predominantly non-indurated sandy silt; irregular nature of soil pods may be related to insect/animal burrowing and/or transportation downslope; unit has distinct proximal distal relations indicating downslope movement; contains basalt gravels up to 2 cm max. diam.; gastropods found in krotovina; upper boundary with Unit 11b is abrupt, wavy; lower boundary with Unit 8b is abrupt to clear, irregular to broken.

UNIT DESCRIPTIONS
TRENCH #2, 5 m SCARP NORTH OF THE SMYRNA BENCH GRABEN

9b	Slightly sandy silt; soil block.		Pale olive 5Y 6/3; Olive 5Y 4/3.	I	Slightly sandy silt; sand is fine grained; well-sorted; stratified in lower 35 cm above contact with Unit 8b and appears similar to Unit 8a; upper part contains tubules similar to Unit 8b; unit appears to rest on Unit 8b and imbricate carbonate seams between Stations 33 and 34; upper boundary with Unit 11b is abrupt, irregular to broken; lower boundary with Unit 8b is clear to gradual, smooth to wavy.
8	**Paleosol**				
8a	Slightly sandy silt with massive lobate aspect.		Light gray 2.5Y 7/2; Grayish brown 2.5Y 5/2.	II	Slightly sandy silt; well-sorted; sand is fine grained; possible poorly-developed, laminar cross stratification; slightly indurated; scattered cicada burrows and numerous tubules in lower part of unit; upper part of unit exhibits massive, lobate appearance and contains distinct, light-colored tephra layer (Unit 8c); upper boundary with Unit 8b is abrupt to clear, smooth to wavy; lower boundary is clear, smooth to wavy.
8b	Sandy silt with numerous root/worm tubules.		Light brownish gray 2.5Y 6/2; Olive brown 2.5Y 4/4.	II	Sandy silt; moderately well to well-sorted; non-stratified; slightly indurated; sand is fine and medium grained; numerous distinctive root/worm tubules; carbonate veining and filaments; upper boundary with Unit 9a is abrupt to clear, irregular to broken; lower boundary with Unit 8a is abrupt to clear, smooth to wavy; unit appears to be arched and fractured between Stations 19 and 29.
8c	Tephra	Mt. St. Helens set M tephra, >18,560±180, <20,350±350 ^{14}C yr BP			Layer and pods of light-colored tephra.
7	**Loess (Parent for Unit 8 paleosol)**		Pale yellow 2.5Y 7/4; Light olive brown 2.5Y 5/6.	I	Slightly sandy silt; well-sorted; non-stratified; very slightly indurated, friable; sand is fine grained; upper boundary is abrupt, irregular to broken; lower boundary is abrupt, smooth to wavy.
6	**Paleosol**				

UNIT DESCRIPTIONS
TRENCH #2, 5 m SCARP NORTH OF THE SMYRNA BENCH GRABEN

6a	Slightly sandy silt.		Yellowish brown 2.5Y 6/4; Olive brown 2.5Y 4/4.	II-III	Slightly sandy silt; moderately hard, crumbles with difficulty; well-sorted; sand is fine grained; carbonate seams separating Units 6a and 6b indicates stratification; lower part of unit is intensively burrowed by small animals; numerous distinctive cicada burrows; upper boundary is defined by very abrupt to abrupt, irregular carbonate seams; lower boundary is abrupt, broken to irregular due to burrowing.
6b	Slightly sandy silt, platy to blocky.		Yellowish brown 2.5Y 6/4; Olive brown 2.5Y 4/4.	II-III	Slightly sandy silt; moderately hard, crumbles with difficulty; well-sorted; sand is fine grained; carbonate seams separating Units 6a and 6b indicates stratification; numerous distinctive cicada burrows; weak plate to blocky pedogenic structure; upper boundary with Unit 8a is clear, smooth ; lower boundary with Unit 6a is defined by very abrupt to abrupt, irregular carbonate seams.
5	**Loess (Parent for Unit 6 paleosol) and/or krotovina fill**		Pale yellow 2.5Y 7/4; Light olive brown 2.5Y 5/6.	I	Slightly sandy silt; well-sorted; non-stratified; very slightly indurated, friable; sand is fine grained; upper boundary is abrupt, broken to irregular; lower boundary is abrupt, smooth to wavy; unit may be mainly krotovina fill.
4	**Paleosol**		Light brownish gray 2.5Y 6/2; Olive brown 2.5Y 4/4.	II-III	Sandy silt; hard; sand is fine to medium-grained; moderately well-sorted; non-stratified; weak platy structure; numerous cicada burrows; upper boundary with Unit 5 is abrupt, smooth to wavy; lower boundary with Unit 3 is abrupt, smooth to wavy.
3	**Petrocalcic horizon developed on debris flow/fan deposits**				
3a	Massive calcium carbonate with chalk-like appearance.		White 2.5Y 8/0 to 2.5Y 8/2; White 2.5Y 8/2 to pale yellow 2.5Y 7/4.	IV	Gravel, cobbles and boulders; very poorly sorted; non-stratified; clasts are subangular.

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3b	Open-work broken plates, blocks of calcium carbonate.		White 2.5Y 8/0 to 2.5Y 8/2; White 2.5Y 8/2 to pale yellow 2.5Y 7/4.	IV	Gravel and cobbles; poorly sorted; non-stratified; clasts are subangular; stalactite-like forms suggesting disturbance and dissolution of carbonate are present.
3c	Open-work, gravelly to cobbly calcium carbonate.		White 2.5Y 8/0 to 2.5Y 8/2; White 2.5Y 8/2 to pale yellow 2.5Y 7/4.	IV	Bedded sand and gravel with scattered cobbles in a slightly silty, medium- to coarse-grained sandy matrix; poorly sorted, crudely stratified; individual beds fine upwards; gravel and cobbles are subrounded to subangular; stalactite-like forms suggesting disturbance and dissolution of carbonate are present.
2	**Paleosol blocks.**		Light gray 2.5Y 7/2; Grayish brown 2.5Y 5/2.	III	Sandy silt; moderately indurated by calcium carbonate, hard; sand is fine, medium and coarse grained with scattered subangular gravel, 2 cm max. dia.; generally poorly sorted; non-stratified; insect burrow-like structures; platy carbonate horizon preserved locally near top; upper boundaries are clear, smooth; lower boundaries are clear to gradual, irregular; unit appears to be isolated blocks of paleosol.
1	**Debris flow/fan deposits**	**<150 ka**			
1a	Bedded sand and gravel with carbonate horizons locally.		Matrix: Yellowish brown 10YR 5/4 to Light yellowish brown 10YR 6/4; Dark yellowish brown 10YR 4/4.		Bedded sand and gravel with scattered cobbles in an oxidized, slightly silty, medium to coarse-grained sandy matrix; poorly sorted, crudely stratified; individual beds fine upwards; gravels and cobbles are subrounded to subangular.

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1b	Gravel and cobbles.		White 2.5Y 8/0 to 2.5Y 8/2; White 2.5Y 8/2 to pale yellow 2.5Y 7/4.	III-IV	Gravel and cobbles; poorly sorted; non-stratified; clasts are subangular.
1c	Gravel, cobbles and boulders.		White 2.5Y 8/0 to 2.5Y 8/2; White 2.5Y 8/2 to pale yellow 2.5Y 7/4.	II	Gravel, cobbles and boulders; very poorly sorted; non-stratified; clasts are subangular.
1d	Bedded sand and gravel.		White 2.5Y 8/0 to 2.5Y 8/2; White 2.5Y 8/2 to pale yellow 2.5Y 7/4.	III	Similar to Unit 1a; bedded sand and gravel with scattered cobbles in a slightly silty, medium- to coarse-grained sandy matrix; poorly sorted, crudely stratified; gravel and cobbles are subrounded to subangular.

NOTE: TRENCH #2 AS USED IN THIS REPORT REFERS TO TRENCH #1 IN THE ASSOCIATED PAPER AND DATA REPOSITORY.

Report on the Thermoluminescence Dating of Loess from Saddle Mountain, Eastern Washington

(February 27, 1996)

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Introduction

On June 16, 1994, I collected three loess samples from within and near Trench #2 at Saddle Mountain. Within a few days, I moved my thermoluminescence (TL) sediment dating laboratory from Bellingham to Reno, in part necessitating a lengthy delay in the analysis of these samples.

TL Dating Principles

The last exposure to daylight of detrital minerals can be dated by TL methods (Aitken 1985). Daylight empties light-sensitive electron traps (thermally stable lattice-defect sites), and after burial natural ionizing radiations repopulate emptied traps. In the laboratory, traps are again emptied, by heating now, with electron-hole recombination producing luminescence. When the TL is related to an "equivalent dose" (D_E) by use of calibrated laboratory radiation sources, and an effective radiation dose rate is measured in separate experiments on separate fractions, then a TL age = D_E/D_R where D_R is effective dose rate). Common units are grays (1 Gy = 1 joule/kg) for D_E and Gy/ka for D_R.

Sample Collection

Although most of the silt at Trench 2 appeared to be eolian, closer inspection suggested to me that some fraction could have originated by slope wash or fan deposition, at least at the more southerly (up-slope) end of the trench, where a sand component was noticed. In light of these and other considerations (Berger, field notes), I decided to collect two "surface" samples of silt to check the TL-zeroing assumption, and one trench-wall silt sample. If the trench silt contains a fraction deposited analogously to the surface silt (eolian plus slope-fan component), then the apparent TL ages of the surface samples should provide an upper limit to the relict or inherited TL age component of the trench sample. For example, strictly eolian silt is expected to have a relict TL age of <500 yrs (Berger, 1990). The measured 500-yr relict age of Berger (1990) corresponded to eolian silt transported only briefly, over a probable distance of 1-5 km.

The following remarks elaborate on the sample locations. Full sample names have the prefix "SDLM94-". Sample 7 was collected 20-30 m west-by-northwest of the northern end of the trench (Berger-West letter of Oct. 19, 1995, incorrectly states "NE"). It was taken just below a thin tephra layer (see Table 1 below). Sample 7 was presumed to have the lessor fraction (if any) of slope-wash or fan-deposit), compared to sample 8. Sample 8 was collected perhaps 100-200 m south of the trench, up-slope on a fan surface, just north of the neck of the fan, near a channel bed. Here also the tephra layer was observed in the upper 4 cm, and the silt was collected just below the tephra. Sample 5 within the trench was collected

~30 cm above the top of the Washtucna Soil, ~20 cm below a red string, which was 10-20 cm below an undulating blue-pin line (A.J. Busacca line), and 60-70 cm below a lemon-yellow-pin line. From a photo, sample 5 appears to occur ~2.5-3 m below the surface, probably ~2.7 m.

Sample Preparation and TL Dating Procedures

For sample 5, associated samples (collected above, at and below the horizon of the TL sample) were prepared for K, U, Th analyses and measurement of saturated water. These data are essential for calculating the dose rate (see Berger, 1988). To determine the effective dose rate, several independent measurements were made. Thick-source alpha-particle counting was used to measure U and Th concentrations in dried, finely powdered samples and commercial atomic absorption spectrophotometry was chosen to measure K concentrations. These data were combined with estimates of average cosmic-ray dose rate and an estimate of past average water content in the sample and surrounding deposits to yield an effective dose rate (Table 1), using the conversion factors of Berger (1988). Alpha-efficiency values were determined from a comparison of extrapolated alpha-dose-response curves with beta-dose-response (see below) curves. Alpha doses were administered by sealed-foil ^{241}Am sources. Source literature is cited in Berger and Busacca (1995).

Interior portions of the collected samples were removed from the light-tight containers in the amber laboratory illumination. Steps were followed to remove carbonate and organics and to produce 4-11 μm polymineral grains. For the two surface samples, the conservative recommendation of Berger (1990) for low-energy (~550-700 nm wavelengths) laboratory illumination (optical bleaching) was used in estimating the D_E values, to allow for the possibility that some grains were deposited by slope-wash slurry. For the older sample 5, a fuller bleaching spectrum (~435-700 nm) was used. A maximum estimate of D_E was obtained for sample 5 by using higher-energy (<435 nm wavelengths) optical bleaching for 24 hr (Berger et al., 1994).

D_E values were determined from extrapolations of beta-dose-response curves. Beta doses were administered by an ~125 mCi sealed-foil ^{90}Sr-^{90}Y source. The partial-bleach (PB) (R-beta) and total-bleach (TB) procedures (Aitken 1985, Berger, 1988) were used to measure D_E values, which were then plotted against readout temperature to provide a plateau test (Aitken 1985). To remove thermally unstable and anomalous-fading TL components from the laboratory-irradiated subsamples prior to TL readout, elevated-temperature storage treatments were employed (cited literature in Berger, 1994). An illustration of the effects of such pre-readout heat treatments on untreated (N) is given in lower Fig. 1.

Results and Discussion

The small difference between the lower two readout curves in upper Fig. 1 demonstrates that little light-sensitive TL remains in this sample, compared to the corresponding difference for trench sample 5 (curves N+120°C and N+PB+120°C). This is as expected. Also in lower Fig. 1 is shown the minimum light-insensitive signal (curve N+TB+120°C). The TB experiment was used for the reason mentioned above.

An example of the PB dose-response curves and intercept estimate of D_E value is given in Fig. 2A. The corresponding D_E-T plots for surface samples 7 and 8 are shown in

Figs. 2B and 2C. Using the rule-of-thumb estimate of 2-4 Gy/yr dose rate for most land sediments, notice that the plateau D_E values in Figs. 2B and 2C correspond roughly to 2 and 1 ka relict ages respectively. The exact TL apparent ages are listed in Table 1. Fig. 3 illustrates the PB and TB data for sample 5. Note that in the inset, there is no difference between the PB and TB results, implying that the TL in this sample was well-zeroed at deposition. Note that the high D_E values above ~330°C in the D_E-T plots have been observed for many "young" New Zealand loess samples (Berger et al., 1994), and are not clearly understood. This high-temperature "plateau" is observed only in TB experiments. Only the region below ~300°C is used for age calculation here.

I conclude that the relict TL age of 0.8-1.4 ka associated with the "surface" samples 7 and 8 is a maximum estimate for relict TL ages (because these samples may in fact be 500-700 yrs old). Thus, relict TL is barely significant in sample 5 (at most, about the magnitude of 1σ analytical errors at 15 ka). Thus sample 5 was deposited 15 ± 1 ka ago. This is consistent with TL ages of ~20 ka in loess from Bw horizons in the upper zone of the preserved Washtucna Soil at other sites (Berger and Busacca, 1995), and is consistent with TL ages of ~17 ka in the BC horizon of the loess overlying Washtucna Soil at these other sites in eastern Washington.

References Cited

Aitken, M.J. 1985. Thermoluminescence dating. Academic Press, New York.

Berger, G.W. 1988. Dating Quaternary events by luminescence.,*In* Dating Quaternary sediments. *Edited by* D.J. Easterbrook. Geological Society of America, Special Paper 227, pp. 13-50.

Berger, G.W. 1990. Effectiveness of natural zeroing of the thermoluminescence in sediments. Journal of Geophysical Research, 95: 12,375-12,397.

Berger, G.W. 1994. Thermoluminescence dating of sediments older than ~100 ka. Quaternary Science Reviews, 13(5-7), 445-455.

Berger, G.W. and A.J. Busacca. 1995. Thermoluminescence dating of late-Pleistocene loess and tephra from eastern Washington and southern Oregon, and implications for the eruptive history of Mount St. Helens. Journal of Geophysical Research, 100(11), 22,361-22,374.

Berger, G.W., Lockhart, R.A., and Kuo, J. 1987. Regression and error analysis applied to the dose response curves in thermoluminescence dating. Nuclear Tracks and Radiation Measurements, 13: 177-184.

Berger, G.W., B.J. Pillans and A.S. Palmer. 1994. Test of thermoluminescence dating of loess from New Zealand and Alaska. Quaternary Science Reviews, 13(4), 309-333.