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LOGS OF TRENCHES ACROSS THE CENTRAL PART OF THE FISH LAKE VALLEY FAULT ZONE, MONO COUNTY, CALIFORNIA

By

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INTRODUCTION

Selected fault strands in Fish Lake Valley, California and Nevada, were trenched as part of a project to evaluate late Cenozoic activity on the central part of the right-oblique Fish Lake Valley fault zone (northern end of the Death Valley-Furnace Creek fault zone) (fig. 1; Reheis, 1991, 1992; Reheis and others, 1993, and in press). Trench sites were selected on two fault strands with inferred or mapped right-lateral strike-slip offset (fig. 2; trenches T93-1 near Oasis and T93-2a and -2b near Furnace Creek) and one strand with vertical offset (T93-3 near the Buck Mine). The purposes of the trenching study were to determine the late Quaternary paleoseismic history of the central Fish Lake Valley fault zone and to evaluate the kinematics and possible segmentation of the fault zone. Unfortunately, the amount of Holocene offset could not be determined for the strike-slip faults because of a lack of geomorphic piercing points and access restrictions that did not permit trenching along strike.

PROCEDURES

Trenches were excavated, logged, and backfilled in June and July 1993. The trenches were excavated to a width of about 1 m by backhoe, shored with hydraulic shores, and cleaned with trowels and brushes. Trench 3 was only partly shored because the central part of the south wall collapsed at the fault zone. Unfortunately, the collapse buried the bottom meter of trench in this area and necessitated logging the sunlit north side of the trench that was partly disturbed by the adjacent spoil pile. One wall of each trench was gridded in 1-meter squares using nails and string; level lines were established using water-filled plastic tubing. Observations were also made at key sites and some samples were collected (annotated on trench logs 93-1 and 93-2a) on the unmapped walls. Stratigraphic boundaries, soil horizons, faults, fractures, and sample localities were marked with differently colored nails. The points were surveyed with tape measures and recorded at a scale of 2 inches to the meter (approximate scale 1:20). Most contacts were not traced behind shores, but where faults apparently disappeared behind shores, contacts and faults were mapped later as shores were being removed. The gridded walls of trenches 93-1, -2b, and -3 were photographed; only selected features were photographed in trench 93-2a due to the monotonous appearance of the silt beds and the subtle nature of the faults and fractures. In addition, the eastern 20 m of the 43-m-long trench 93-2a (not shown on log) mainly consisted of bouldery debris-flow and colluvial deposits with few (if any) faults and was not logged in detail.

Several types of samples were collected from the trenches. Charcoal samples (table 1) were collected using metal tools and placed in aluminum foil. Samples selected for dating by accelerator mass spectrometry were prepared by T. Stafford and personnel at the Institute of Arctic and Alpine Research in Boulder, Colorado and were dated at Lawrence Livermore Laboratory in Livermore, California. All but one sample were pre-treated using a standardized computer-driven course of washings in HCl and NaOH (table 1). A composite charcoal sample collected from bed S of trench 93-2a was pre-treated only with HCl because the first sample selected from this bed was destroyed by the NaOH treatment. Tephra samples (table 2) were taken from the cleanest-appearing lenses. Soil profiles (table 3) were described and collected in selected localities from trenches 1 and 3 to aid in correlation of the stratigraphic units in the trench with previously dated map units (table 4; Reheis and others, 1993, and in press). Analyses of the soil samples (table 5) were conducted by P. Fitzmaurice and D. Best (U.S. Geological Survey); these included measurement of pH, $CaCO_3$ and organic-matter content, and particle size by sieve and pipette analysis (procedures are described in Singer and Janitzky, 1986). In addition, pollen samples were collected for P. Wigand (Desert Research Institute, Reno, Nevada) to analyze from all stratigraphic units present in section 13 of trench 2a, except from the coarse-grained unit F. Samples were collected from 1-cm-thick intervals spaced 10 cm apart using a trowel and shovel; the sampling tools were rinsed with water between samples.

Tephra analyses by A.M. Sarna-Wocjicki and others are in progress; the tentative correlations in table 2 are based on soil and surficial properties and geometric relations of stratigraphic units (figs. 2a and 2b), and on previous tephra analyses (Reheis and others, 1993, and in press). Mono Craters tephra deposits in Fish Lake Valley originated from many different eruptions, but are mostly middle and late Holocene in age (A.M. Sarna-Wojcicki, written communs., 1989-1992). The age of the Mazama ash is about 6.85 ka (Bacon, 1983).

TECTONIC SETTING OF TRENCH SITES

Movement along the Fish Lake Valley fault zone apparently began between 12 and 4 Ma. Total right slip in the southern part of Fish Lake Valley is probably about 50 km based on offset of an intrusive contact of Jurassic rocks and offset of sedimentary facies of Precambrian rocks, giving a lateral-slip rate of about 4-12 mm/yr (Reheis, 1993). The late Pleistocene lateral-slip rate for the presently active fault strands, based on offset features on the surface of unit Qfi and its estimated age (50-125 ka), is a minimum of 0.7-1.8 mm/yr at Leidy Creek (fig. 1) and about 1.0-2.5 mm/yr at Indian Creek (Sawyer, 1990). At Furnace Creek, in the vicinity of trenches T93-2a and -2b, the late Pleistocene lateral-slip rate is at least 0.9 mm/yr and could be as high as 7 mm/yr; the maximum rate is within the range of 6-12 mm/yr estimated from the offset of a shutterridge of unit Qfm (fig. 2b; Reheis and others, in press). Estimated vertical-slip rates on the Fish Lake Valley fault zone vary both spatially and temporally; in general, both total and Quaternary vertical-slip rates are highest in the central part of the fault zone (area near Dyer, fig. 1) and appear to decrease to the north and south (Reheis and McKee, 1991).

Trench 93-1 is across a prominent vegetation lineament that is the easternmost of three subparallel faults (fig. 2a) west of Oasis. The lineament is a continuation of a northwest-striking fault that locally offsets unit Qfcm slightly down to the west (fig. 2a), forming a sag pond; this fault is inferred to have mainly strike-slip offset based on the lack of prominent vertical scarps and on its strike relative to the approximate west-east direction of least principal stress. The trench exposed a 14-m-wide zone of mainly vertical faults in a well-bedded sequence of fine-grained late Holocene alluvium that contains locally abundant charcoal and three tephra layers. The upper 75 cm of sediment is not faulted, consistent with the subdued nature of the lineament.

Trench 93-3 is located on the westernmost of the three subparallel faults (fig. 2a). This fault strikes northwest to north-northwest along the range front about 2 km west of trench 93-1. Fault scarps in unit Qfcm along this fault are 1.0-1.5 m high. The range-front fault is inferred to have undergone mainly vertical offset in the late Pleistocene based on the fault strike, its arcuate trace, and the vertical offset of Quaternary deposits. However, some northwest-striking strands of the range-front fault within bedrock or between bedrock and alluvium contain clayey fault gouge with horizontal slickenside striae that indicate strike-slip displacement of unknown age (fig. 2a). Trench 93-3 exposed a 12-m-wide zone of steeply east-dipping faults and shear zones in late Pleistocene and Holocene fan alluvium. Several faults come to within a few decimeters of the ground surface and offset late Holocene deposits.

The north-northwest-striking fault between the two trenched faults near Oasis is buried by small deposits of unit Qfcm north and south of the latitude of trench 93-1 (fig. 2a and Reheis and others, in press), but appears to offset unit Qfcm due west of the trench. This discrepancy could be due either to the range in age of unit Qfcm (1.1-1.7 ka, table 4) or to localized displacement associated with an earthquake that mainly affected one or both of the trenched faults. The strike of the middle fault, the large fault scarps, and the back-rotation of deposits between the middle and range-front faults (fig. 2a) together indicate vertical displacement on the middle fault near Oasis; however, strike-slip displacement has also been mapped on the northward projection of the middle fault between Indian Garden Creek and Furnace Creek (fig. 1).

Trench 93-2a is located on the middle of three parallel and closely spaced northwest-striking fault strands located south of Furnace Creek (fig. 2b). The two eastern strands together form the west side of a shutterridge that ponds a small on-fan drainage. Previous coring to a depth of 6.5 m by hand-auger in the ponded deposits (Qpd) near the trench site penetrated a layer of the Mazama ash (A.M. Sarna-Wojcicki, written commun., 1990) less than 1 cm thick at about 2.25 m depth. The two eastern strands apparently intersect to the northwest where a single fault offsets unit Qfce (fig. 2b) but not the younger unit Qfcm (trench log 93-2b). A single abandoned debris-flow channel on the surface of unit Qfi (50-125 ka) on the west side of the western fault strand may correspond to one or all of the four abandoned channels located east of the eastern strand. These relationships indicate that the channel has been right-laterally offset a minimum of 110 m and a maximum of 335 m by the three fault strands near trench 2b; vertical offset of the channel is a maximum of 15 m across the three strands. Trench 93-2a exposed a wide zone of mainly vertical faults in silty, finely bedded Holocene alluvium (Qpd) that spanned the entire 23 m of the logged part of the trench; only one possible fault was observed in the bouldery late Pleistocene alluvium (Qfi) and Holocene alluvium and colluvium of the north-eastern, unlogged 20 m of the trench. Most of the faults did not penetrate the upper two units, but at least one came to within a few decimeters of the ground surface. Trench 93-2b exposed a single vertical fault in middle Holocene fan alluvium with about 50 cm of displacement.

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DESCRIPTION OF TRENCH UNITS

[Trench locations are given either as ranges (for example, sections 1-4) or as grid squares: for example, section 23S2, where 23S refers to the horizontal axis and 2 refers to the vertical axis. Age assignments are from correlation to map units (table 4) and radiocarbon dates (table 1)]

Trench 93-1 (Oasis)

WATER-LAID DEPOSITS

A **Part of map unit Qfcl, late Holocene**--Coarse to medium sand, moderately well sorted; locally trough crossbedded. Contains clasts as large as cobbles near base in sections 24-26 in north (unlogged) wall of trench. Capped by small coppice dunes surrounding rooted brush in southwest half of trench (not shown on log). Lower contact wavy; locally slightly channeled into unit B. Weakly calcareous except locally noncalcareous near surface, but no visible $CaCO_3$; very slightly oxidized in upper 10 cm. Unfaulted

B **Part of map unit Qfcl, late Holocene**--In southwestern part of trench, unit is fine to medium sand, with sparse lenses of coarse sand and small isolated pebbles; in center part, interbedded fine sand and pebbly coarse sand; in northeastern part, interbedded silty fine sand, fine to medium sand, and medium to coarse sand. Mostly finely laminated, locally ripple cross-stratified. Top marked by concentration of plant roots and slight darkening of upper 1-3 cm, indicating a very weakly developed buried soil. Basal 1-2 cm mostly organic-rich silt containing charcoal west of section 19. Lower contact wavy; locally channeled into unit C. Two charcoal dates: 920 ± 60 yr B.P. and 1,210 ± 70 yr B.P. (latter believed to be too old; table 1). Unfaulted

D **Part of map unit Qfcm, late Holocene**--Mostly fine to coarse sand and some silt, moderately to poorly sorted; poorly bedded. Marked by weakly developed buried soil (T1-S1, table 3). Av horizon (upper contact where preserved) contains dispersed tephra, locally concentrated in lenses (FLV-220-O, table 2). Organic litter locally present at top of Av horizon. Contains charcoal dated at 1,230 ± 60 yr B.P. (table 1). Faulted in sections 18-23, but faults appear to be truncated by Av horizon

F **Part of map unit Qfcm, late Holocene**--Fine to coarse sand, moderately well sorted; poorly to moderately bedded. Unit is lenticular and pinches out within the trench. Lower contact locally channeled into unit G. Charcoal in upper part of unit F dated at 1,200 ± 80 yr B.P., in lower part dated at 1,380 ± 60 yr B.P. (table 1). Faulted in sections 16-24

G **Part of map unit Qfce, middle Holocene**--Fine to coarse sand, moderately well sorted; poorly to moderately bedded. Marked by weakly developed buried soil (T1-S2, table 3). Av horizon (upper contact where preserved) contains generally dispersed (but locally more concentrated) tephra (FLV-222-O, sections 3-4S2; table 2). Buried soil overlain by coppice dunes in sections 1-4S2. Charcoal dated at 2,870 ± 50 yr B.P. Many faults commonly "flower" upward into Av horizon in sections 14-24; other faults terminate within about 50 cm above base of unit G

H **Part of map unit Qfce, middle Holocene**--Silt and fine to medium sand, moderately sorted; finely laminated. Pinches out to east against unit I in section 15. Faulted in sections 16-24. In section 23S2 at top of unit H, fault offsets dipping laminae about 2 mm thick at base of a 1-cm-thick bed and is overlain by flat laminae in upper part of bed

I **Part of map unit Qfce, middle Holocene**--West of section 15, consists of bed of medium to coarse sand overlain by finely laminated, locally cross-stratified, silty fine-grained sand. To east, fine sand pinches out and sand bed becomes thicker, coarser, and more poorly sorted; contains large pebbles in section 12S3. Pinches out to east against unit K in section 6S2. Faulted in sections 11-24; some faults terminate in this unit in sections 11-14

J **Part of map unit Qfce, middle Holocene**--Present only in sections 10-18; fills channel in unit K. Medium to coarse sand, moderately sorted; moderately bedded. West of section 15, uppermost bed consists of fine to medium sand. Offset by all faults in trench

DEBRIS-FLOW DEPOSITS

C **Part of map unit Qfcl, late Holocene**--Silt to medium pebbles, poorly sorted; massive. Maximum clast size larger in southwestern part of trench. Lower contact sharp and relatively flat, but channeled into unit D in sections 14-16S1. In sections 22-23S1, unit overlies a thin lens of waterlaid sand between units C and D. Unfaulted

E **Part of map unit Qfcm, late Holocene**--Silt to sparse small pebbles, poorly sorted; massive. Upper contact locally indistinct due to reworking upward into unit D. Abrupt but wavy lower contact; apparently channeled into unit F in sections 23-24. In sections 1-4S2, unit E overlies coppice dunes (well-sorted, steeply crossbedded sand) preserved above buried soil of unit G. Charcoal at base of unit dated at 1,260 ± 70 yr B.P. (table 1); possibly reworked from charcoal in upper part of unit F. Faulted in sections 18-24; faults in sections 23 and 24 apparently truncated by overlying unit D

K **Part of map unit Qfce, middle Holocene**--Silt to granules, poorly sorted; massive. Upper contact locally channeled. Locally overlies bedded sand not mapped separately at base of exposure. Charcoal dated at 4,760 ± 70 yr B.P. Offset by all faults in trench

Trench 93-2a (Furnace Creek)

PONDED DEPOSITS

[Water-laid deposits accumulated primarily by overland flow reworking alluvial-fan and eolian deposits in a small drainage ponded by a shutterridge; unit F represents fluvial deposition]

A **Part of map unit Qpd, late Holocene**--Silt; platy. Vesicular pores throughout; pores are largest and most abundant near surface. Breaks to large blocky peds. Sharp, nearly flat lower contact. Continuous in logged part of trench, but pinches out against unit D about 9 m east of grid. Charcoal in section 7S1 dated at 1,600 ± 60 yr B.P. Tephra layer, one grain thick, at lower contact in sections 10-11S1 (FLV-227-FC, table 2). Unfaulted

B **Part of map unit Qpd, middle(?) Holocene**--Silt; platy. Vesicular pores throughout; pores are largest and most abundant near upper contact. Slight darkening near upper contact suggests very weakly developed buried soil; stage I $CaCO_3$ also present. Diffuse lower contact difficult to map. Unit continuous in logged part of trench, but pinches out against unit D about 9 m northeast of grid. Faulted in sections 18-19

C **Part of map unit Qpd, middle(?) Holocene**--Silt to fine sand, well sorted; finely laminated. Only in east end of trench; apparently pinches out in section 18, but may merge (less likely) with upper part of unit D. Upper contact irregular and difficult to map; lower contact sharp. Faulted in sections 18-22

D **Part of map unit Qpd, middle Holocene**--Mostly silt, some very fine sand; locally coarser sand present along faults and cracks; well sorted; mostly finely laminated. Coarsens to east and contains isolated grains of coarse sand to small pebbles in sections 1-2. Extensively burrowed; burrows commonly filled with finely laminated silt. Laminae in both burrowed and unburrowed areas commonly truncated against or dragged along faults. About 10 m east of grid, coarsening unit resembles colluvium, appears to bifurcate, and contains a buried soil. Charcoal in upper third of unit dated at 5,620 ± 110 yr B.P. Contains numerous faults, many of which appear to flower upward near top of unit. Upper contact appears warped over several closely spaced faults in section 14S1

E **Part of map unit Qpd, middle Holocene**--Silt to medium sand, moderately sorted; finely laminated to massive. Fining-upward (reworked?) facies of unit F, hence upper contact is gradational; lower contact commonly well defined. Upper contact dashed in central part of trench where drag and contortion along numerous faults blur contact with unit D

F **Part of map unit Qpd, middle Holocene**--Fine to coarse sand, granules, and small pebbles, moderately sorted; mostly unbedded, normally graded throughout. Lower contact abrupt and gently concave upward. Maintains constant grain size and thickness nearly across trench, but fines and thins east of section 4 and pinches out 4.3 m east of grid. Intensely faulted and fractured; single faults at base commonly splay into several conjugate faults and fractures within unit. Commonly contains injection dikes of sandy silt (many of which are too small to show at map scale) along faults; some dikes cut entirely through unit F (see, for example, sections 1S3 and 8S3)

G **Part of map unit Qpd, early(?) Holocene**--Silt to medium sand, moderately sorted; well bedded. Lower contact apparently channeled; probably deposited by fluvial reworking of unit I and perhaps unit H. Present only in northeastern part of trench. Contains a few small charcoal fragments (destroyed by sample pre-treatment process). Locally forms injection dikes that extend upward into units F and E. Several faults in sections 1-15 terminate in or at upper contact of unit G (or equivalent level of unit S to southwest)

H **Part of map unit Qpd, early Holocene**--Silt to fine sand, well sorted; finely laminated. Pinches out against unit I and truncated by unit G in section 7S3; fines and merges with unit S to west in section 10. Locally forms injection dikes that extend upward into units F and E

I **Part of map unit Qpd, early Holocene**--In northeastern part of mapped area, consists of silt to small pebbles, poorly sorted; a few silt lenses mostly confined to infilled burrows; poorly bedded to massive. Sharp lower contact. Fines southwestward to silt, finely laminated; merges with unit S in section 10. Apparently pinches out against unit J about 5 m northeast of mapped part of trench

S **Part of map unit Qpd, early Holocene**--Equivalent to units H and I southwest of section 10. Silt with some very fine sand, well sorted, finely laminated. Extensively burrowed. Thin tephra lens (FLV-225-FC, table 2) in section 15S3 and small pod of tephra in section 14S3. Composite charcoal sample from upper part of unit dated at 6,320 ± 60 yr B.P. (probably minimum age; pre-treatment by HCl only). Laminae in both burrowed and unburrowed areas commonly truncated against or dragged along faults

DEBRIS-FLOW DEPOSITS

J **Part of map unit Qfi, early late Pleistocene**--Gravel, sand, and silt with clasts as much as 2 m in diameter, very poorly sorted; massive. Upper contact marked by moderately developed buried soil with an Av horizon locally present, mostly removed by erosion; argillic B horizon as much as 50 cm thick with abundant clay films; and Bk horizon with stage II $CaCO_3$. Stage III $CaCO_3$ may begin just at base of trench, judging from difficulty of excavation. Present only east of section 4. Faults difficult to trace through unit

Trench 93-2b (Furnace Creek)

DEBRIS-FLOW AND COARSE WATER-LAID DEPOSITS

A **Part of map unit Qfcm, late Holocene**--Sand, pebbles, and small cobbles, moderately sorted; poorly bedded. Lower contact locally channeled into units B and C. Surface soil locally has 1- to 2-cm-thick sandy Av horizon, slightly oxidized Bw horizon, and stage I $CaCO_3$. Unfaulted

B **Part of map unit Qfcm, late Holocene**--Silt, sand, and pebbles, unsorted; massive. Northeastern part of unit (bounded by dashed line) contains clasts (mostly too small to show on log) that dip irregularly away from fault bounding northeast side of unit, suggesting that this part of unit could be a fault-colluvial wedge derived from unit C on upthrown side of fault. Contact between "wedge" area and unit B weakly defined by clast orientation and subtle color change, but "wedge" area contains no large clasts like those in unit C. Either unit B was emplaced against a colluvial wedge shortly after faulting event or unit B was faulted against unit C and no wedge exists. Lower contact abrupt

C **Part of map unit Qfce, middle Holocene**--Sand to small boulders, unsorted; massive. Buried soil marks upper contact, but has been mostly removed by erosion northeast of fault; soil has weakly developed Av horizon and Bk horizon with stage II $CaCO_3$. Faulted in section 1, downthrown to southwest; minimum vertical offset 47 cm

Trench 93-3 (Buck Mine)

DEBRIS-FLOW DEPOSITS

A **Part of map unit Qfcl, late Holocene**--Sand and small pebbles with minor silt, poorly sorted; massive. Extends east from fault scarp in section 7; thickens markedly east of faults in sections 9 and 10. No surface soil. Lower contact generally sharp. Unit is mostly debris-flow deposits derived from small drainage on north side of trench (fig. 2b); possibly in part fault-scarp colluvium at western edge, but critical relationships were erased by cave-in of spoil pile at fault. Probably unfaulted

B **Part of map unit Qfcl, late Holocene**--Sand and clasts as large as small cobbles with minor silt, poorly sorted; poorly bedded to massive; long axes of pebbles in section 10N3 roughly oriented parallel to degraded fault scarp. Unit extends eastward as a wedge from this fault and pinches out in section 14N4; overlies buried soil on unit C. Unit may, in part, represent fault-scarp colluvium derived from fault in section 10, but also in part derived from small drainage on north side of trench (fig. 2b). Probably correlative with FC5. Apparently offset by fault in section 10N3

C **Part of map unit Qfcm, late Holocene**--Sand and clasts as large as small cobbles with minor silt, mostly poorly sorted; massive to poorly bedded. Forms surface unit at west end of trench; buried by units A and B at east end. Toward east end of trench, unit contains moderately sorted small lenses of sand and locally imbricated clasts. Thinnest in central part of trench; thickens markedly eastward. Surface soil (T3-S1a, table 3) at west end of trench better developed than where soil is buried (T3-S2a, table 3). Offset by three faults in sections 7, 8, and 10

F **Part of map unit Qfl?, early Holocene**--Mostly sand and pebbles with minor silt and clay, poorly sorted; massive. Some clasts consist of reworked pedogenic $CaCO_3$. Matrix is reddish throughout. Unit probably consists of debris-flow deposits and possibly sheet-wash deposits derived from erosion and reworking of Av, Bt, Btk, and Bk horizons of unit H to the west. East of section 8, upper part probably includes some fault colluvium (FC2) as indicated by, for example, large clast of Btk horizon in section 12N5

G **Part of map unit Qfl?, early Holocene**--Sand to large cobbles with minor silt, unsorted; massive to weakly bedded. Weakly calcareous throughout. Commonly contains clasts of pedogenic $CaCO_3$. Probably debris-flow deposits and possibly sheetwash deposits, in part derived from reworking of soil on unit H, but may contain some fault colluvium (unit FC1) in upper part

H **Part of map unit Qfi, early late Pleistocene**--Sand to large cobbles with minor silt, unsorted; massive. Upper contact marked by moderately developed buried soil: on west end of trench, Bkmq horizon forms top of soil and original Av, Bt, and Btk horizons are eroded (about 50 cm estimated removed); on east end, Btk horizon forms top of soil and original Av and Bt horizons are eroded (less than 20 cm estimated removed). Two main sets of faults offset unit H in sections 1-5: one set cuts both deposits and Bkmq horizon and average apparent dip angle of faults is 58°; the other set cuts deposits but is apparently truncated by Bkmq horizon and average apparent dip angle is 50°. Cumulative vertical offset across all faults in trench (adjusted for depositional surface slope and erosion of upper soil horizons) about 4 m

WATER-LAID DEPOSITS

D **Part of map unit Qfce, middle Holocene**--Sand, pebbles, and sparse small cobbles, moderately sorted; moderately well bedded, especially in east half of trench, less well bedded to west. Upper contact generally sharp, but indistinct and only inferred in sections 1 and 2. Lower contact sharp (except where overlying unit E) and locally channeled into under-lying units. Offset by all faults east of section 5. Unit generally thickens to east, but is locally thinnest in central part of trench between pairs of faults, possibly indicating erosion prior to deposition of unit FC3

E **Part of map unit Qfce, middle Holocene**--Similar to unit D, but coarser grained with clasts as large as medium cobbles. Present only in sections 4 and 5 and east of section 10. Lower contact channeled into buried soil on unit F. Offset by two faults in sections 11 and 12

FAULT-SCARP COLLUVIAL DEPOSITS

FC6 Part of map unit Qfcl, late Holocene--Two thin wedges of fault-scarp colluvium in sections 8 to 9 and 10 to 11. Sand and pebbles with minor silt, unsorted; massive. Western wedge was derived from ravelling of debris from unit C exposed in scarp in section 8N2; buries soil on unit FC5, is contiguous with soil on unit C, and fills collapsed void between degraded fault scarp and unit FC5. Eastern wedge is less distinct, but apparently was derived from exposure of unit C in small scarp in section 10N3; buries western edge of unit B. Both wedges buried by unit A

FC5 Part of map unit Qfcm, late Holocene--Wedge of fault-scarp colluvium in sections 8 and 9. Sand and pebbles with minor silt, unsorted; massive. Formed by ravelling of debris from unit C exposed in both east- and west-facing faults of small graben; deeper part of unit may consist of older colluvium (FC4?). Offset by fault in section 8

FC4 Part of map unit Qfcm, late Holocene--Wedge of fault-scarp colluvium in sections 9-11. Sand and pebbles with minor silt, unsorted; massive. Formed by ravelling of debris from unit FC3 exposed in fault scarps in section 9N3, and possibly also fault scarps in sections 8 and 9 where unit may form basal part of unit FC5. Offset by fault in section 10N3

FC3 Part of map unit Qfce, middle Holocene--Elongate wedge of mostly fault-scarp colluvium in sections 7-11 (originally called "unit X" in field notes). Silt, sand, and pebbles, unsor-ted; massive. Interpreted to be formed largely by ravelling of debris from unit D exposed in fault scarp in section 7 and by erosion of unit D west of scarp, but may contain sheet-wash or other material. Upper contact marked by weakly developed buried soil, locally with 1- to 2-cm-thick silty Av horizon and stage I $CaCO_3$ (not described in table 3 due to poor preservation). Lower contact generally sharp. Extensively disrupted by small faults in graben

FC2 Part of map unit Qfl?, early Holocene--Sand and unoriented clasts as large as large cobbles, with minor silt and clay, unsorted; massive. Many clasts consist of pedogenic $CaCO_3$ and (locally) reworked Btk horizon derived from soil formerly present on unit H. Matrix is reddish. Lower contact mapped from photographs of sections 6-8; probably forms upper part of unit F east of section 8. Interpreted to be fault colluvium formed by ravelling of debris from fault scarp (or scarps) once present in sections 6 and 7. Upper contact locally marked by pedogenic $CaCO_3$, indicating weakly developed buried soil (same as T3-S2b, table 3) mostly removed by erosion

FC1 Part of map unit Qfl?, early Holocene--Sand and unoriented clasts as large as small cobbles with minor silt, unsorted; massive. Clasts are predominantly reworked pedogenic $CaCO_3$ derived from Bk horizon of unit H. Mapped in field in sections 4 and 5; lower contact in sections 6 and 7 mapped from photographs. Interpreted to be fault colluvium derived from scarps once present in section 4. In section 7N3, capped by weakly developed buried soil (stage I $CaCO_3$) that was elsewhere apparently removed by erosion prior to deposition of unit E

DESCRIPTION OF MAP UNITS

(FIGURES 2a AND 2b)

[Descriptions are simplified from Reheis and others (1993 and in press). Combined map sym-bols (Qfcm+Qfcl) are used where two Quaternary map units are interspersed at such a small scale that separate mapping is impractical. Fractional map symbols (Qes/Qfc) are used where a thin veneer of a younger unit overlies an older unit.]

ALLUVIAL-FAN DEPOSITS

[The alluvial-fan deposits are similar in grain size and bedding; the following description applies to each alluvial unit described below: gravel, sand, and silt; intermixed and interbedded, moderately sorted to unsorted, moderately to poorly stratified. Clasts commonly pebbles to cobbles but, near range front, commonly as large as 2 m in diameter. Beds range from about 0.5 to 2 m thick. Commonly, beds appear to be matrix supported, but when outcrops are excavated, many clasts are touching (hyperconcentrated flood-flow deposits); less commonly, beds are clearly either clast supported (stream-flow deposit) or matrix supported (debris-flow deposit). Contains thin lenses of sand and silt. Fan surfaces are highest above drainages near Dyer due to greater vertical faulting in that area (fig. 1)]

Qfc — **Alluvium of Marble Creek (late and middle Holocene)**--Underlies inset terraces and constitutes large areas of alluvial fans. Locally includes small areas of eolian sand (Qes, Qed). Includes colluvium on valley sides. Subdivided into units Qfcl, Qfcm, and Qfce where needed to interpret fault history

Qfcl — **Late alluvium of Marble Creek (late Holocene)**--Active stream-channel deposits and debris-flow deposits as high as 2.5 m above modern channels on alluvial fans; recent activity indicated by sparse vegetation. No modification of depositional topography; no pavement; no varnish on clasts; no diagnostic soil horizons

Qfcm — **Middle alluvium of Marble Creek (late Holocene)**--Underlies surfaces of alluvial fans as much as 6 m above modern channels. Slightly subdued depositional topography; no pavement; locally small spots of varnish on clasts. Maximum soil development: 2- to 3-cm-thick sandy Av horizon, weakly developed Bw horizon, and stage I $CaCO_3$

Qfce — **Early alluvium of Marble Creek (middle Holocene)**--Underlies surfaces of alluvial fans as much as 13 m above modern channels. Subdued depositional topography; incipient pavement in small areas; thin patches of varnish on clasts are common. Maximum soil development: 3- to 5-cm-thick Av horizon, Bw horizon, and stage I-II $CaCO_3$

Qfl — **Alluvium of Leidy Creek (early Holocene)**--Underlies surfaces of alluvial fans as much as 13 m above modern channels. Depositional topography preserved only on large debris flows; locally smooth interlocking pavement but clasts unsorted; thin continuous varnish on most clasts. Maximum soil development: 5- to 7-cm-thick loamy Av horizon, incipient Bt horizon, and stage II $CaCO_3$

Qfi — **Alluvium of Indian Creek (early late Pleistocene)**--Underlies surfaces of alluvial fans as much as 40 m above modern channels. Depositional topography preserved only on very large debris flows; smooth pavement, well-sorted clasts; thick continuous varnish on clasts. Maximum soil development: 10- to 15-cm-thick silty Av horizon, moderately developed Bt horizon, and stage III $CaCO_3$ as much as 50 cm thick

Qft — **Alluvium of Trail Canyon (middle Pleistocene)**--Underlies surfaces of alluvial fans as much as 60 m above modern channels. No depositional topography preserved; smooth pavement, well-sorted clasts; thick continuous varnish on clasts. Maximum soil development: 10- to 15-cm-thick silty Av horizon, strongly developed Bt horizon, and stage III $CaCO_3$ as much as 1 m thick

Qfm — **Alluvium of McAfee Creek (middle Pleistocene)**--Underlies surfaces of alluvial fans as much as 95 m above modern channels. Dissected; relict surface generally not preserved. Where preserved, surface has smooth pavement with abundant carbonate rubble; thick continuous varnish on clasts. Maximum soil development: thick silty Av horizon, strongly developed Bt horizon, and stage IV $CaCO_3$

OTHER MAP UNITS

Qpd **Ponded deposits (Holocene)**--Silt and sand; at edges of deposits interfingers with colluvium and debris flows derived from adjacent fan deposits. Minimum thickness in auger hole at Furnace Creek, 6.5 m

Qes **Sheet sand (Holocene)**--Fine to medium sand; well sorted, silty. Mostly eolian sand reworked by fluvial processes. Thickness usually less than 1 m

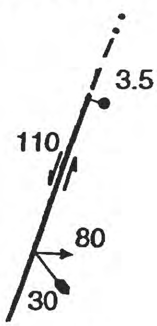
Tv **Volcanic rocks (late Miocene)**--Andesite, locally underlain by thin rhyolite bed

Mzm **Intrusive rocks (Mesozoic)**--Includes adamellite and quartz monzonite; age is Cretaceous and Jurassic

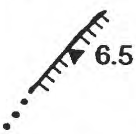
MAP SYMBOLS FOR FIGURES 2a AND 2b

Contact

Relict debris-flow channel



Fault--Dashed where inferred; dotted where concealed. Bar and ball on downthrown side; number indicates vertical offset (m) at measured locality. Arrow indicates dip of fault plane; diamond indicates direction and amount of plunge of slickenside striae. Opposed arrows indicate sense of strike-slip motion; number indicates amount of lateral offset (m) of Quaternary deposits and features either surveyed in field or estimated from aerial photographs



Fault scarp--Dotted where concealed. Hachures on downthrown side; surface unit on downthrown side commonly not faulted. Number at triangle indicates scarp height (m), measured by Abney level and Jacob's staff, and adjusted for depositional slope of fan surface

Vegetation lineament--Indicates location of buried fault or fault with little vertical offset

6 **Strike and dip of beds**

Horizontal beds

T-93-3 **Location and number of fault trench**

Soil description site--See Slate (1992)

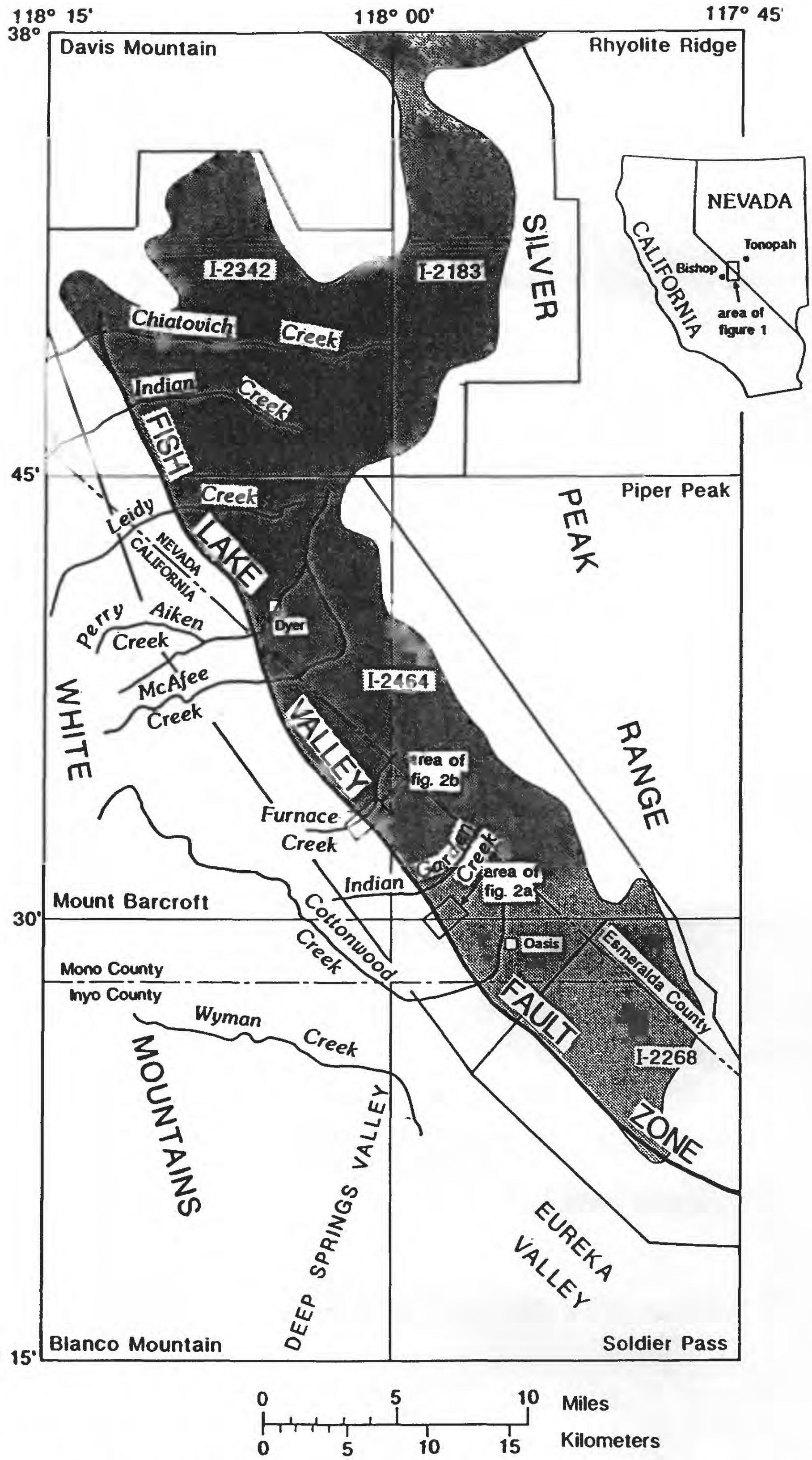


Figure 1. Index map showing Fish Lake Valley fault zone (thick line) and areas of figures 2a and 2b, areas of published geologic maps (outlined by heavy lines; labelled I-2183, I-2268, I-2342, and I-2464; Reheis, 1991, 1992, and Reheis and others, 1993 and in press, respectively), the names of the 30-minute quadrangles that cover the map area, and major drainages. Valley floor is shaded.

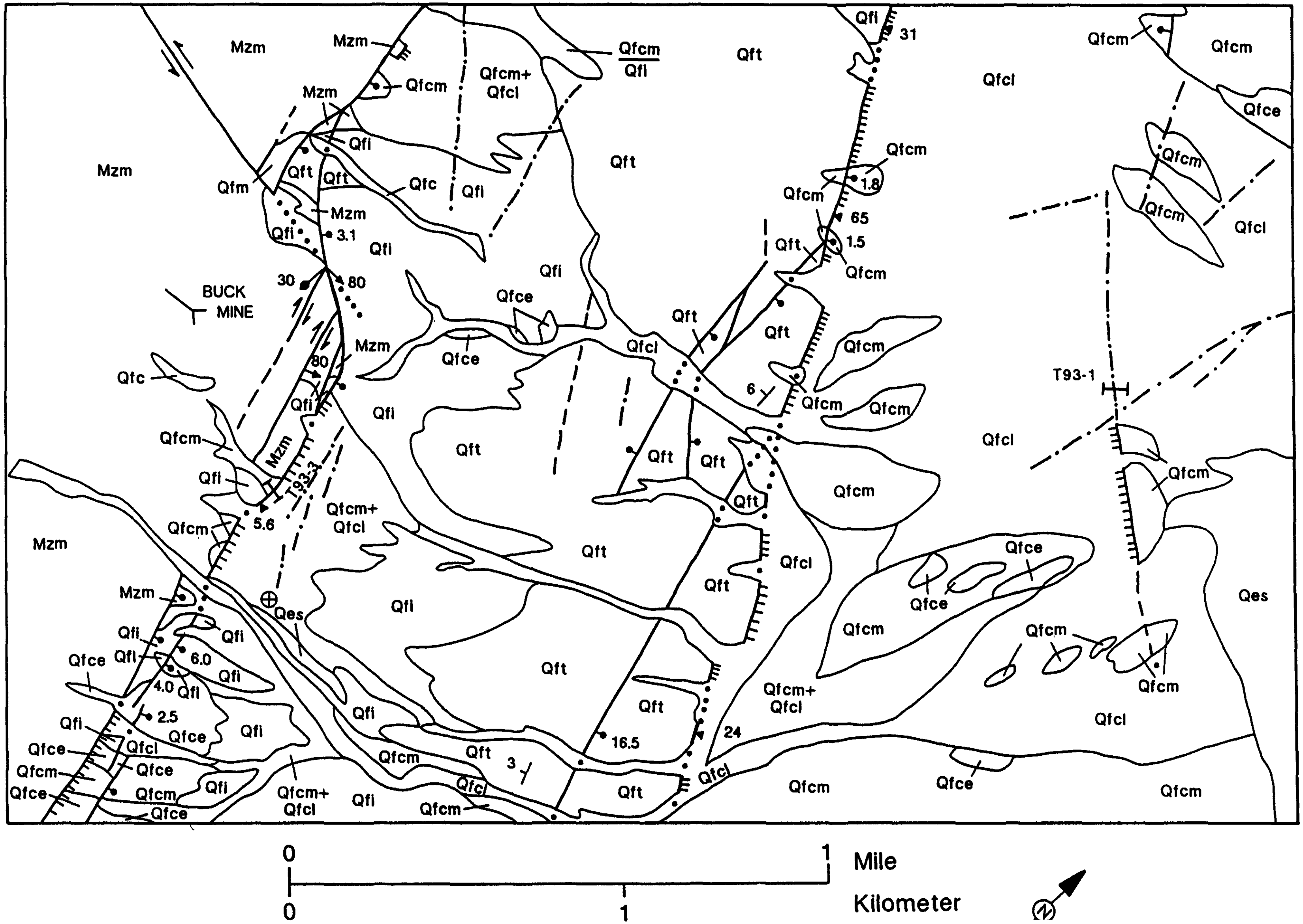


Figure 2a. Geologic map of the area of trenches T93-1 and T93-3 northwest of Oasis, California (fig. 1). Modified from Rehels and others (in press)

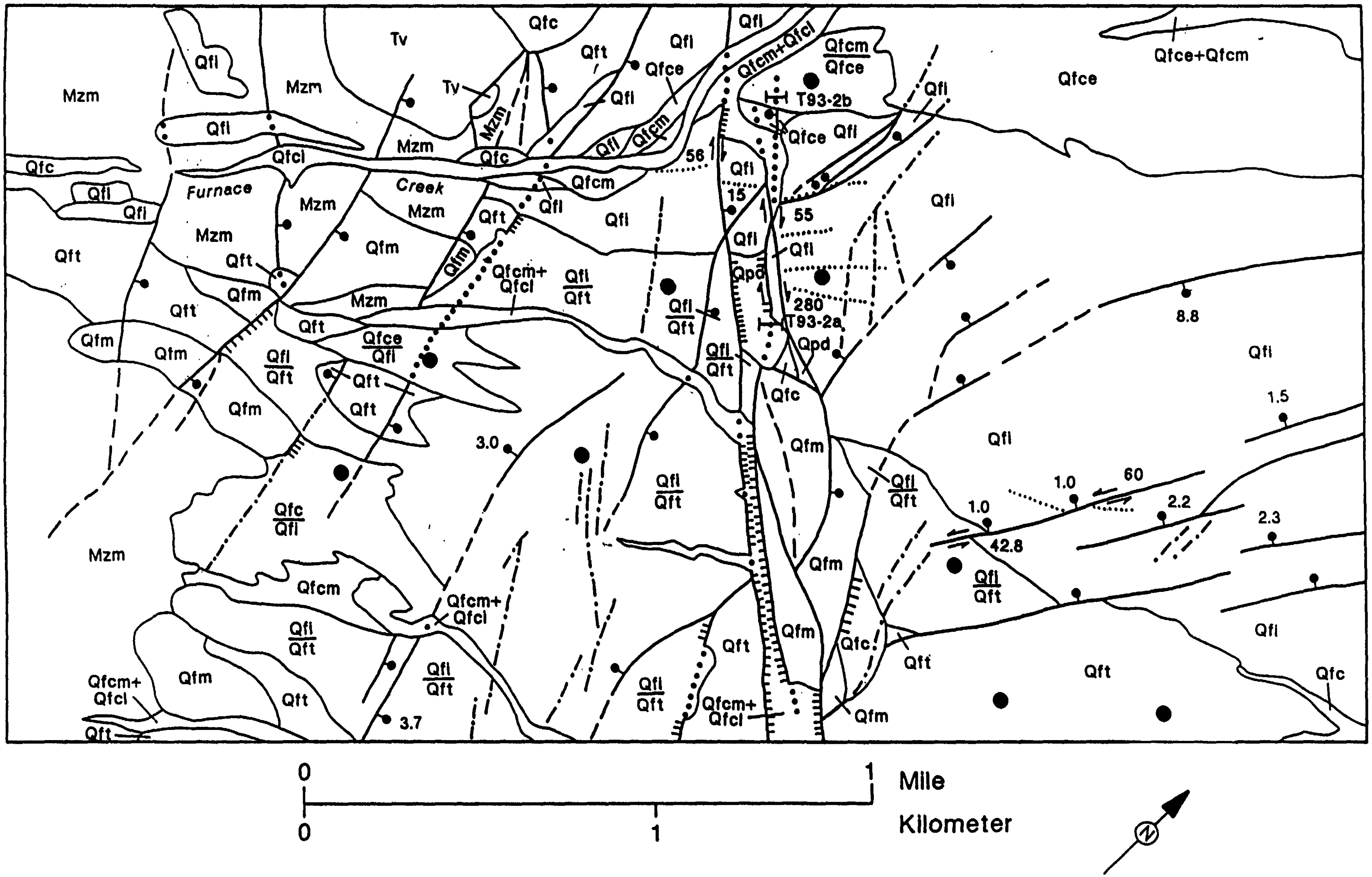


Figure 2b. Geologic map of the area of trenches T93-2a and T93-2b near mouth of Furnace Creek (fig. 1). Modified from Reheis and others (in press).

Table 1. Charcoal samples collected from trenches 93-1 (T1 samples) and 93-2a (T2 samples)

[--, not submitted for dating; ##, destroyed by pretreatment or too small to date after pretreatment; AB, treatment by HCl and subsequently NaOH; A, treatment by HCl only (first samples from same stratigraphic level were destroyed by pretreatment). Samples pretreated by T. Stafford and others at Institute of Arctic and Alpine Research (INSTAAR), Boulder, Colorado. Accelerator mass spectrometry (AMS) dating by Lawrence Livermore Laboratory, Livermore, California]

Sample number	Stratigraphic unit	Depth (cm)	Sample size (weight in mg where known)	INSTAAR laboratory number	Pre-treatment	Lawrence Livermore Laboratory number	AMS ^{14}C age
T1-C1	Base of unit B	33	1 large piece (131)	NSRL-1438	AB	CAMS-8259	1,210 ± 70[1]
T1-C16	Base of unit B	34	several small pieces (3.0)	NSRL-1497	AB	CAMS-9413	920 ± 60
T1-C2	Top of unit D	54	1 large piece (193)	NSRL-1430	AB	CAMS-8356	1,230 ± 60
T1-C7	Base of unit E	109	1 medium piece (58)	NSRL-1439	AB	CAMS-8257	1,260 ± 70
T1-C9	Top of unit F	113	5-6 medium pieces (~100)	--	--	--	--
T1-C8	Top of unit F	114	3 medium pieces (~40)	--	--	--	--
T1-C6	Top of unit F	118	1 large piece (102)	NSRL-1440	AB	CAMS-8258	1,200 ± 80
T1-C4	Top of unit F	120	4 medium pieces (~80)	--	--	--	--
T1-C5	Top of unit F	120	several small pieces	--	--	--	--
T1-C3	Base of unit F	134	several pieces (130)	NSRL-1431	AB	CAMS-8357	1,380 ± 60
T1-C10	Basal part of unit G	172	several small pieces (13.9)	NSRL-1432	AB	CAMS-8359	2,870 ± 50
T1-C11	Middle of unit H	191	several small pieces (1.8)	NSRL-1433	AB	##	##
T1-C12	Top of unit K (eroded)	230	many small pieces (17.3)	NSRL-1441	AB	##	##
T1-C13, T1-C14, T1-C15[2]	Middle of unit K Middle of unit K Middle of unit K	232 230 225	many very small pieces (three samples combined[2])	NSRL-1499	AB	CAMS-9414	4,760 ± 70
T2-C11	Bottom of unit A	29	3 small pieces (1.6)	NSRL-1434	AB	CAMS-8350	1,600 ± 60
T2-C6	Upper part of unit D	101	1 small piece (2.8)	NSRL-1435	AB	CAMS-8351	5,620 ± 110
T2-C1, T2-C8, T2-C10[2]	Middle of unit D Top of unit E? Base of unit D	119 178 164	several very small pieces (2.7 for three samples combined[2])	NSRL-1442 NSRL-1436 NSRL-1436	AB	##	##
T2-C2, T2-C3, T2-C4, T2-C7[2]	Upper part of unit S Upper part of unit S Upper part of unit S Upper part of unit S	227 224 238 228	several very small pieces (7.0 for four samples combined[2])	NSRL-1444	A	CAMS-8358	6,320 ± 60
T2-C13	Top of unit G	~205	2 medium pieces (8.9)	NSRL-1437	AB	##	##
T2-C12	Middle of unit G	218	2 small pieces	NSRL-1498	AB	##	##
T2-C9	Upper part of unit S	232	several small pieces (10.1)	NSRL-1443	AB	##	##
T2-C5	Middle of unit S	255	very small piece	--	--	--	--

[1]Age is probably too old, based on age of sample T1-C16 and on surface mapping and correlation of units (table 4); charcoal probably reworked from older beds.

[2]Samples were combined before pretreatment.

Table 2. Tephra samples collected from trenches 93-1 (O-series numbers) and 93-2a (FC-series numbers)

Sample number	Stratigraphic unit	Depth below surface (cm)	Description	Tentative correlation[1]
FLV-220-O	Top of D	51	Clean, fine-sand- and silt-sized shards. Locally reworked into finely laminated ashy silt layers; lies on and locally incorporated into buried Av horizon at top of unit D. Where sampled, lens was 1-2 cm thick and 40 cm long	Mono Craters(?)
FLV-221-O	Base of G	180	Reworked, dirty, about 50 percent shards mixed with fine sand and silt. Thinly laminated, locally crossbedded. Where sampled, lens was as much as 3 cm thick and 35 cm long	Mono Craters(?)
FLV-222-O	Contact of E and G	122	Reworked, very dirty, less than 25 percent shards mixed with fine sand and silt in lenses as much as 3 cm thick and 100 cm long. Overlies buried soil at top of unit G and underlies coppice dune.	Mono Craters(?)
FLV-224-FC	Upper part of S	234	Reworked, very dirty, <10% silt- to fine-sand-sized shards mixed with silt. Presumed same as FLV-226-FC on the basis of depth below surface; not submitted for analysis	Mazama ash[2] or Mono Craters(?)
FLV-225-FC	Middle of S	255	Clean, silt-sized shards. Lens about 2 mm thick and 20 cm long in section 15S3	Mazama(?) ash
FLV-226-FC	Upper part of S	233	Reworked, dirty, about 50 percent fine-sand-sized shards mixed with silt. Small pod in section 14S3	Mazama ash or Mono Craters(?)
FLV-227-FC	Contact of A and B	29	Reworked, very dirty, less than 25 percent silt- to fine-sand-sized shards mixed with silt. One grain thick and 25 cm long in sections 10-11S1	Mono Craters(?)

[1]Analyses by A.M. Sarna-Wojcicki and others in progress; tentative correlations based on soil and surficial properties of mapping units containing previously identified tephra deposits (figs. 2a and 2b; Reheis and others, in press).

[2]Mazama ash (A.M. Sarna-Wojcicki, written commun., 1990) found at about 225 cm depth in hand-auger hole located about 50 m south of trench.

Table 3. Field descriptions of soil profiles in trenches 1 (T1 series numbers) and 3 (T3 series numbers)

[Color column gives Munsell soil colors. Second line under color columns reports carbonate colors of clast coats; number not preceded by hue has the same hue as preceding color. Descriptions follow guidelines of Guthrie and Witty (1982) and Birkeland (1984), except for "v", which denotes vesicular porosity, "j", which denotes incipient character of soil property denoted by preceding letter (for example, Bwj), and carbonate stage "I-", which denotes a very small amount of pedogenic $CaCO_3$. ?, particle size not measured in laboratory or uncertain due to silica cementation; 0, not present]

Profile number (unit)	Horizon	Depth (cm) below surface	Color		Texture[1]	Structure[2]		Consistence		Clay films[5]	Gravel content (percent)	$CaCO_3$ stage	$CaCO_3$ descriptions and other comments
			dry	moist		primary	secondary	dry[3]	wet[4]				
T1-S1 (unit D)	Ab1	50-53	10YR7/2	10YR6/3	SL-	1fsbk	sg	so	so po	0	0	0	No visible $CaCO_3$; weakly effervescent in HCl acid
	Avb1	53-56	2.5Y8/2	2.5Y6/3	fSL	2f-msbk		so	ss ps	0	0	I-	Few scattered small spots
	2Bk1b1	56-75	2.5Y7/3	2.5Y6/3	SL-	2m-cosbk		sh	vss po	0	0	I	Common thin filaments
(unit E)	3Bk2b1	75-107	10YR7/2	10YR6/3	LS	massive	1f-cosbk	sh	so po	0	0	I	Common thin filaments
(unit F)	4Bk3b1	107-125	2.5Y7/2	2.5Y6/2	S	sg		lo-so	so po	0	0	I-	Few thin filaments
T1-S2 (unit G)	Avb2	135-140	2.5Y8/1	2.5Y6/3	fSL	2fsbk		so	so po	0	0	0	Locally few small spots belonging to soil above
	Bwkb2	140-149	10YR7/3	10YR6/3	SL	2f-msbk		sh	ss vps	v1npo	0	I-	Few small spots and filaments, in part belonging to soil above
	2Bk1b2	149-165	10YR7/3	10YR7/3	SL	2m-cosbk		sh	ss ps	0	0	I	Abundant small spots concentrated in fine-grained lenses
	2Bk2b2	165-192	2.5Y8/2	2.5Y7/2	LS	sg		lo	so po	0	0	0	Rare small spots
T3-S1a (unit C-D)	A	0-8	10YR7/2	10YR4/3	LS	2m-cosbk		so	so po	0	10	0	Locally has vesicular pores
	Bw	8-15	10YR7/2	10YR5/3	S+	1f-msbk		so	so po	0	10	0	
	Bk1	15-28	2.5Y7/2 10YR7/3, 8/1, 8/3	10YR5/2	S	1f-msbk		lo-so	so po	0	10	I-	Small patches on some clasts
	Bk2	28-75	2.5Y7/2 2.5Y7/2, 8/1, 8/2	2.5Y5/3	S	sg		lo	so po	0	10	I	Small patches on most clasts
T3-S1b (unit H)	2Bkmqb	75-118	7.5YR8/ 2.5Y8/1, 8/2; 10YR8/2	10YR6/4	S	massive	2mpl	h-vh	so po	0	30	III	Platy, massively cemented layers and less cemented lenses
	2Bkb	118-145+	2.5Y7/3 2.5Y7/2, 8/2; 10YR8/2	2.5Y5/3	S	sg	massive	lo-h	so po	0	30	II	Variable cementation

Table 3. Field descriptions of soil profiles in trenches 1 (T1-series numbers) and 3 (T3-series numbers)--Continued

Profile number (unit)	Horizon	Depth (cm) below surface	Color		Tex-ture[1]	Structure[2]		Consistence		Clay films[5]	Gravel content (percent)	$CaCO_3$ stage	$CaCO_3$ descriptions and other comments
			dry	moist		primary	secondary	dry[3]	wet[4]				
T3-S2a (unit C)	Ab1	20-27	10YR7/3	10YR5/3	S+	2f-msbk		so	so po	0	30	0	Locally has vesicular pores
	Bwjb1	27-38	10YR7/2	10YR5/3	S	1f-msbk		lo-so	so po	0	30	0	
	Bk1b1	38-60	10YR7/2 2.5Y7/2;	10YR5/3 10YR8/0, 8/2	S	sg		lo	so po	0	30	I-	Small patches on some clasts
	Bk2b1	60-94	2.5Y7/2 2.5Y8/1, 8/2	2.5Y6/2	S	sg		lo	so po	0	50	I	Small patches on many clasts
(unit D)	2Bk3b1	94-204	2.5Y7/2 10YR8/1, 8/2, 8/3	2.5Y6/2	S	sg		lo	so po	0	30	I-	Small patches on some clasts
T3-S2b (unit F)	3Bwkb2	204-225	10YR7/3 2.5Y7/2;	10YR5/4 10YR8/1, 8/3	LS	1f-msbk		lo-so	so po	0	40	I	Small patches on most clasts; effervesces strongly in HCl
	3Bkb2	225-295	10YR6/4 2.5Y8/1, 8/2; 10YR7/0, 7/2, 8/2	10YR5/4	LS	sg	massive	lo-sh	so po	0	40	I-	Small patches on some clasts; effervesces weakly in HCl throughout deposit
T3-S2c (unit H)	4Btkqjb3	295-305	10YR6/4 10YR7/2, 8/2, 8/3	7.5YR4/4	SL?	3m-cosbk		vh	so vps	2npo, 2npf	30?	I	Induration partly due to pedogenic silica?
	4Btkqb3	305-321+	10YR6/4 10YR7/2, 8/1, 8/2	7/5YR4/4	SL	3m-cosbk		vh	vss vps	2npo 1npf	30?	II	Induration partly due to pedogenic silica

[1]Texture abbreviations: f, fine; S, sand; LS, loamy sand; SL, sandy loam. Symbols "+" and "-" indicate sample has maximum or minimum amounts of clay, respectively, for the textural class shown.

[2]Structure abbreviations: grade (strength)--1, 2, 3; size--f, fine; m, medium; co, coarse; type--m, massive; sg, single grain; sbk, subangular blocky; pl, platey.

[3]Dry-consistence abbreviations: lo, loose; so, soft; sh, slightly hard; h, hard; vh, very hard.

[4]Wet-consistence abbreviations: stickiness--so, nonsticky; vss, very slightly sticky; ss, slightly sticky; plasticity--po, nonplastic; vps, very slightly plastic; ps, slightly plastic.

[5]Clay-film abbreviations: abundance--v1, 1, 2, 3; thickness--n, thin; location--po, pore; pf, ped face.

Table 4. Tentative correlation of map units with trench units based on soil properties (table 3) and radiocarbon ages (table 1)

[--, not present; ?, correlation uncertain]

Map unit	Age range (in ka) (Reheis and others, 1993, and in press)	Trench units			
		Trench 1	Trench 2a	Trench 2b	Trench 3
Qfcl	0.11-0.75	A, B, and C	--	--	A, FC6, and B
Qfcm	1.1-1.7	D, E, and F	--	A and B	C, FC5, and FC4
Qfce	1.9-5.7	G, H, I, J, and K	--	C	FC3, D, and E
Qfl	6.2-10	--	--	--	FC2?, F?, FC1?, and G?
Qfi	50-125	--	J	--	H
Qpd	0-10(?)	--	A through I and S	--	--

Table 5. Laboratory data for soil samples collected in trenches 93-1 (T1 series numbers) and 93-3 (T3 series numbers)

[--, no data]

Profile number (unit)	Horizon	Depth (cm) below surface	pH (1:1 H_2O)	Content (percent) Organic matter	$CaCO_3$	Sand	Silt	Clay
T1-S1	Ab1	50-53	9.95	0.35	1.81	63.50	31.49	5.01
(unit D)	Avb1	53-56	10.20	0.18	1.63	53.10	38.59	8.31
	2Bk1b1	56-75	10.15	0.17	1.09	66.83	24.85	8.32
(unit E)	3Bk2b1	75-107	10.00	0.12	0.88	81.09	12.64	6.27
(unit F)	4Bk3b1	107-125	9.00	0.07	0.83	84.15	11.62	4.23
T1-S2	Avb2	135-140	9.55	0.07	2.01	61.36	33.64	5.00
(unit G)	Bwkb2	140-149	9.70	0.09	2.43	69.71	18.39	11.90
	2Bk1b2	149-165	9.80	0.05	1.62	67.97	23.36	8.67
	2Bk2b2	165-192	9.90	0.03	1.19	85.43	9.52	5.05
T3-S1a	A	0-8	8.40	0.15	0.34	83.05	12.97	3.98
(unit C-D)	Bw	8-15	8.20	0.11	0.39	85.01	10.90	4.09
	Bk1	15-28	8.15	0.14	0.76	86.58	9.79	3.63
	Bk2	28-75	8.25	0.13	1.45	89.48	7.56	2.96
T3-S1b	2Bkmqb	75-118	8.35	0.30	12.68	90.55	6.53	2.92
(unit H)	2Bkb	118-145+	8.40	0.08	1.61	91.03	7.39	1.58
T3-S2a	Ab1	20-27	--	--	--	--	--	--
(unit C)	Bwjb1	27-38	8.15	0.18	0.60	87.09	10.03	2.88
	Bk1b1	38-60	8.15	0.17	0.86	89.71	7.21	3.08
	Bk2b1	60-94	8.25	0.09	1.16	89.21	7.57	3.22
(unit D)	2Bk3b1	94-204	8.15	0.06	1.28	90.48	6.77	2.75
T3-S2b	3Bwkb2	204-225	8.50	0.13	2.67	82.96	13.34	3.70
(unit F)	3Bkb2	225-295	8.30	0.11	2.41	81.67	14.22	4.11
T3-S2c	4Btkqjb3	295-305	8.20	0.11	1.96	81.42[1]	15.33[1]	3.25[1]
(unit H)	4Btkqb3	305-321+	8.20	0.12	1.88	74.39	13.05	12.56

[1]Particle size is thought to be too coarse because amorphous silica was not removed before measurement; particle-size distribution should resemble (or be finer grained than) that of the horizon below.