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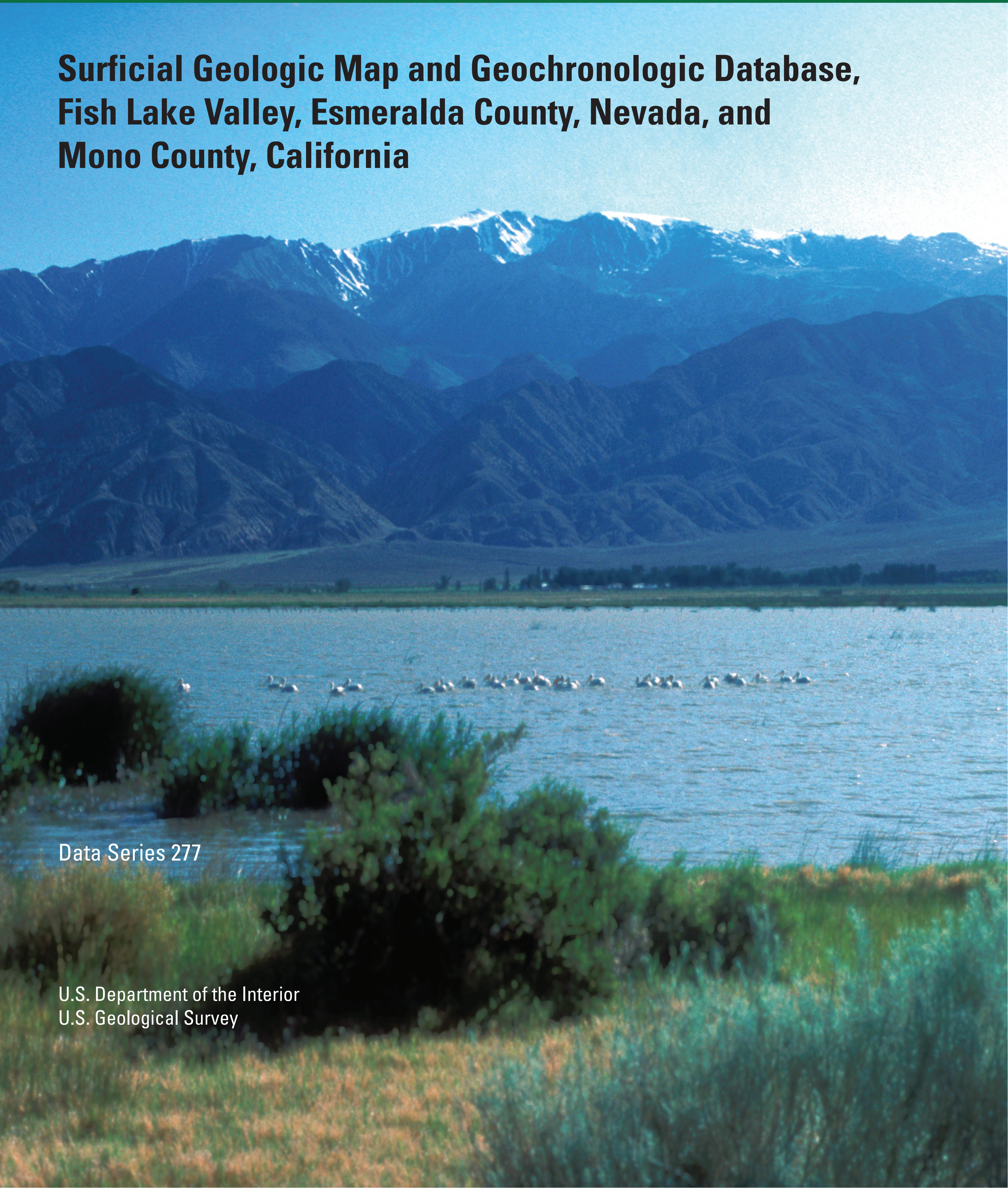
# Surficial Geologic Map and Geochronologic Database, Fish Lake Valley, Esmeralda County, Nevada, and Mono County, California



Data Series 277

U.S. Department of the Interior
U.S. Geological Survey

# Surficial Geologic Map and Geochronologic Database, Fish Lake Valley, Esmeralda County, Nevada, and Mono County, California

By Marith C. Reheis and Debra Block

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FRONT COVER
Range front of the White Mountains in Fish Lake Valley. View to southwest, looking across Fish Lake spring pool (after several wet years) to faulted fans at the mouth of Busher Creek; White Mountain Peak at 14,246 ft (4,342 m) crowns the skyline. Photograph by M.C. Reheis.

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Additional pdf files included on this DVD are accessed by clicking on the hot links here and from the disk directory. These files include a List of Map Units (LOMU), a diagram showing the Correlation of Map Units (COMU), the map symbols explanation, and information on four fault trenches excavated in Fish Lake Valley. This information consists of a descriptive text and color versions of the four trench diagrams (T93-1, T93-2a, T93-2b, and T93-3), which were originally published as U.S. Geological Survey Miscellaneous Field Studies Map MF–2266 (Reheis, 1994).

# Surficial Geologic Map and Geochronologic Database, Fish Lake Valley, Esmeralda County, Nevada, and Mono County, California

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## Introduction

Fish Lake Valley, straddling the border of Nevada and California (fig. 1), was for 8 years (1987–1994) the focus of a mapping project to investigate the history of the Fish Lake Valley fault zone (Reheis, 1991, 1992; Reheis and others, 1993a, 1995). This fault zone is the northern part of the Death Valley fault system (Machette and others, 2001). The initial intent of the project was to use Quaternary mapping techniques to reconstruct fault movement and earthquake history (Sawyer, 1990; Reheis and McKee, 1991; Reheis, 1994; Reheis and Dixon, 1996; Reheis and Sawyer, 1997; Sawyer and Reheis, 1999), but early findings led to extensions of research into other aspects of surficial geology. The discovery of abundant deposits of datable material combined with the valley's unique setting on the east side of the glaciated White Mountains led to important findings in tephrochronology (the study and use of volcanic ashes to date other deposits) (Reheis and others, 1991, 1993b; Sarna-Wojcicki and others, 2005), past climate and its relation to alluvial-fan processes (Gillespie, 1991; Throckmorton and Reheis, 1993; Reheis and others, 1993b), pluvial lake history (Reheis and others, 1996, 2002, 2003), and rates of soil development and formation of pedogenic calcium carbonate (Harden and others, 1991; Slate, 1992, 1996; Pendall and others, 1994). The datable materials studied in Fish Lake Valley include volcanic flows from previous episodes of local volcanism, tephra layers deposited as airfall ash from volcanic eruptions elsewhere in the Western United States, and charcoal, wood, and other organic material, mainly derived from the well-vegetated slopes of the White Mountains and deposited in the valley by debris flows and stream runoff. Preservation of organic matter is rare in desert environments of the southwestern United States, but is relatively common in deposits of late Pleistocene and Holocene age in Fish Lake Valley. Deposits of reworked tephra are the most abundant datable materials in the valley. The tephra layers range in age from a few hundred years to several million years and in thickness from a few millimeters to tens of meters. The valley is a unique repository of volcanic ash from several volcanic centers as much as a thousand kilometers away: Long Valley caldera and the Mono Craters, the southwest Nevada volcanic field, tephra from the Sonoma volcanic field in northern California, Mazama ash and older tephra from the Cascade Range, and the 2-million-year Huckleberry Ridge ash and other tephra layers from the Yellowstone–Snake River plain region.

## Rationale for this Map

The previously published surficial geologic maps of the Fish Lake Valley area (Reheis, 1991, 1992; Reheis and others, 1993a, 1995) included tables of sample numbers, locations, and geochronologic information for tephra, organic material, and volcanic rocks. However, many of the samples collected during the topical studies in the valley are not shown on the maps because they were found and analyzed after maps in the corresponding geographic area had already been published. In addition, the knowledge and interpretation of the Quaternary and Tertiary stratigraphy of the map area evolved over time. Because Fish Lake Valley offers unique perspectives on several aspects of late Cenozoic geologic history in a tectonically and geomorphically active region, we believe that a unified, merged geologic map and geochronologic database published in a digital GIS format will provide a useful tool and springboard for future geologic field studies.

The four separate geologic maps, originally at 1:24,000 scale, were digitally merged and minor edge-matching discrepancies resolved. Locations of all geochronologic samples were digitized and tables of analytical data were linked to these map locations. The glass chemistry of nearly 300 tephra samples from Fish Lake Valley has been analyzed by microprobe at the Tephrochronology Laboratory of the U.S. Geological Survey in Menlo Park, Calif. The chronologic database also includes 84 radiocarbon determinations and 15 conventional potassium-argon ages. Where several dated samples, commonly multiple tephra layers locally interbedded with organic material, are located at a single sample site or closely spaced within a measured section, the samples in the linked database are listed in stratigraphic order. Additional dating methods, including paleomagnetic determination (Reheis and others, 1991; Reheis and Sawyer, 1997; Sarna-Wojcicki and others, 2005), thermoluminescence (Slate, 1992; Reheis and others, 1996), $^{10}$Be accumulation in soils (Reheis and others, 1996), and cosmogenic $^{36}$Cl in boulders (Reheis and others, 1996), were locally applied but are not included in this database. Photographs illustrating the stratigraphy and geomorphology of key localities within Fish Lake Valley are also included in the database.

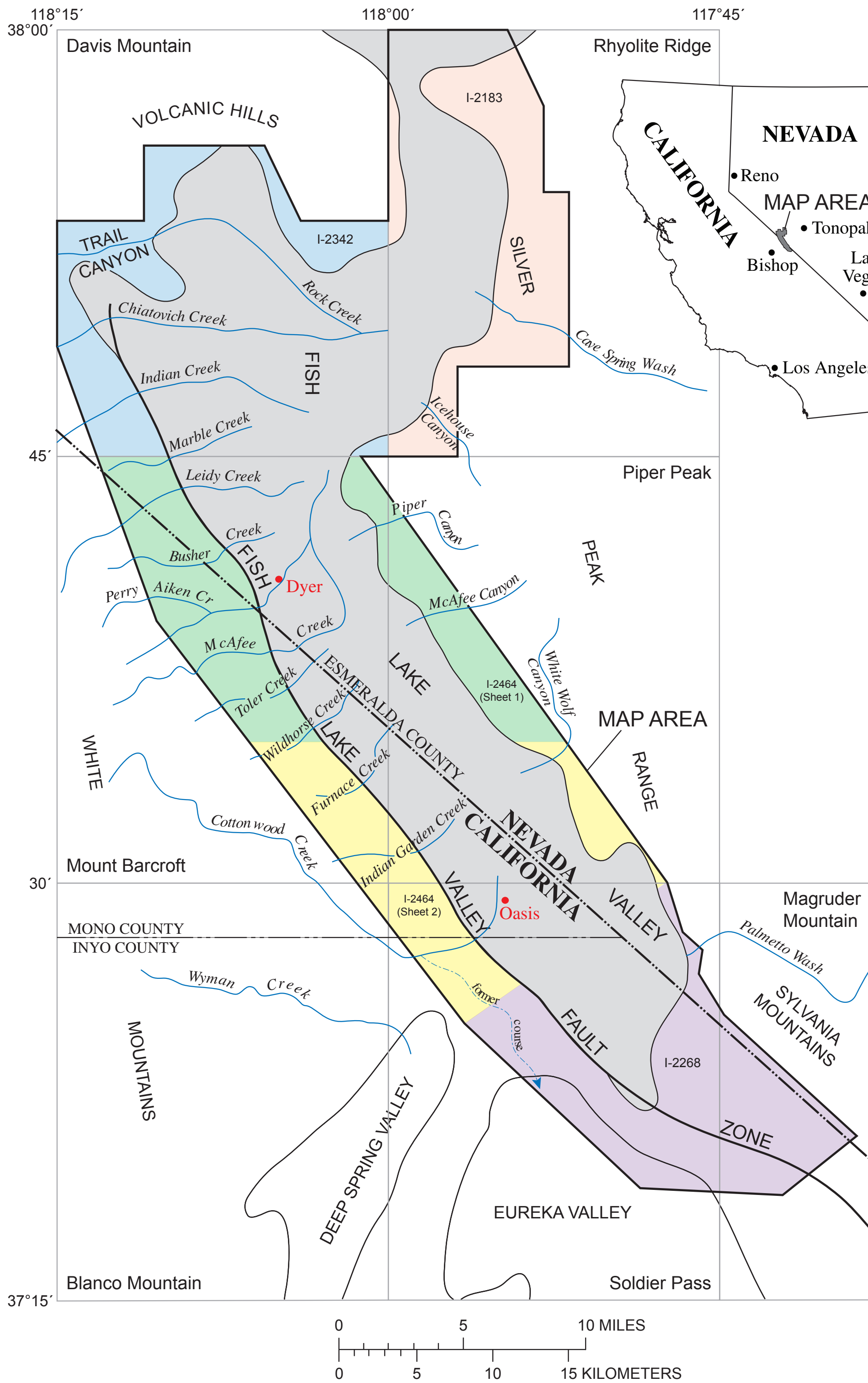


**Figure 1.** Index map showing map area, 15′ quadrangles covering the project area (outlined by heavy line), published U.S. Geological Survey Miscellaneous Investigations Series Maps I–2183 (Reheis, 1991), I–2268 (Reheis, 1992), I–2342 (Reheis and others, 1993a), and I–2464 (Reheis and others, 1995), and major drainages, ranges, and valleys. Alluvial-fan deposits are informally named for Indian, Marble, Leidy, McAfee, and Perry Aiken Creeks and for Trail Canyon. Valley floor is shaded.

## DESCRIPTION OF MAP UNITS

[Combined map symbols (for example, Qfcm+Qfcl) are used where two Quaternary map units are interspersed at such a small scale that separate mapping was impractical. Fractional map symbols (for example, Qes/Qfc) are used where a thin veneer of a younger unit overlies an older unit. Divisions of Pleistocene time are from provisional ages reported in Richmond and Fullerton (1986)]

### VALLEY-FLOOR AND MAINSTREAM ALLUVIAL DEPOSITS

Qa **Modern alluvium (late Holocene)**—Sand, silt, and minor gravel in active stream channels; moderately to poorly sorted and stratified. Thickness probably less than 3 m

Qvf **Valley-fill deposits (Holocene to late middle? Pleistocene)**—Interbedded sand, silt, and clay; commonly alkaline. Massive to well sorted and stratified where exposed. Interfingers with fine gravelly sand and silt (Qfc) at distal edges of alluvial fans; probably consists mainly of distal-fan and some eolian deposits, commonly reworked by overland flow. Locally includes alluvium of Marble Creek (Qfc) and eolian sand (Qes, Qed). Thickness unknown; maximum probably tens of meters

Qbi **Bishop ash bed, fluvially reworked (early middle Pleistocene)**—Pebble- and sand-size tephra; moderately sorted and stratified. Pumice and glass mixed with minor, locally derived sand and gravel. Forms upper part of old alluvial gravel (Qg) in places and is locally interbedded with unit Qfo. Underlies and interfingers with alluvium of McAfee Creek (Qfm) and composes much of unit Qsi (siliceous sinter) in northern Fish Lake Valley. Locally contains bedding and sorting suggesting deposition in large lake (Reheis and others, 1993b). Age is 0.76 Ma (age of Izett and Obradovich, 1994, and Sarna-Wojcicki and others, 2000)

Qg **Old alluvial gravel (early middle Pleistocene to early Pleistocene)**—Gravel and sand; commonly poorly exposed. Where well exposed, unit consists mostly of stratified, poorly to moderately sorted fluvial sand and well-rounded pebble to cobble gravel; weakly consolidated. Clasts commonly pebbles to cobbles, but may be as large as 3 m in diameter. Commonly contains lenses of volcanic ash and tuffaceous sand, ranging in age from approximately 2.0-Ma tuffs of lower Glass Mountain (Sarna-Wojcicki and others, 2005) in northeastern Fish Lake Valley to as young as 0.76-Ma Bishop ash (Reheis, 1991; Reheis and others, 1993b, 1995). In northeastern Fish Lake Valley, contains lenses of older lacustrine deposits (Qlo). Includes unit Qgc (alluvium of Cottonwood Creek) of Reheis and others (1995) and unit QTg of Reheis (1991). Uppermost beds are correlative to alluvium of McAfee Creek (Qfm)

Tg **Old fluvial gravel (late Pliocene)**—Gravel and sand; poorly exposed. Well-rounded clasts commonly pebbles to small boulders. Occurs as lenticular beds as much as 5 m thick interbedded with or underlying andesite flows (Tal) in northwestern Fish Lake Valley. As mapped, includes lag deposits of unknown thickness and possibly different ages that overlie bedrock in small areas north of Middle Creek (unit QTg of Reheis and others, 1993a) and north of Piper Canyon in central Fish Lake Valley (Reheis and others, 1995)

Tsm **Fluvial deposits (early Pliocene)**—Interbedded arkosic conglomerate, sandstone, and minor siltstone; well sorted and stratified, moderately indurated; southern Fish Lake Valley. Commonly contains lenses of volcanic ash and tuffaceous sandstone. Clasts are predominantly quartz monzonite, but locally include basalt and rhyolite. Upper contact marked by upper contact of Nomlaki ash bed (3.4 Ma; Sarna-Wojcicki and others, 1991). Lowest identifiable ash correlated to 5.2-Ma Pinole Tuff and similar tephra layers elsewhere (Reheis and others, 1991). Basal contact is unconformable on rhyolite and basalt flows. Intensity of faulting decreases upward in this unit. Maximum measured thickness 245 m (Reheis, 1992)

Tse **Fluvial deposits (late Miocene)**—Interbedded arkosic gravelly sandstone and sandstone and sandy mudstone. As mapped, includes deposits at mouth of Horse Thief Canyon in southern Fish Lake Valley (Reheis, 1992) and in east-central Fish Lake Valley (unit Ts and that part of unit Tg south of Piper Canyon; Reheis and others, 1995). In Horse Thief Canyon, sediments overlie rhyolite dated about 5.9 Ma and underlie basalt dated about 5.3 Ma (Reheis and Sawyer, 1997) and contain at least 17 different lenses of volcanic ash and tuffaceous siltstone (Reheis, 1992)

### ALLUVIAL-FAN DEPOSITS

Alluvial-fan deposits of Quaternary age in Fish Lake Valley are informally named for the drainages where they are best expressed and (or) dated (summarized in Reheis and others, 1995). These deposits are identified and mapped in other drainages as stratigraphic units on the basis of differences in fan-surface morphology, pavement, desert varnish, soils, and, locally, radiometric ages (see summary table in Reheis and others, 1995). 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 fronts and faults, commonly larger than 2 m in diameter. 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). Contain thin lenses of sand and silt

Qfc **Alluvium of Marble Creek, undivided (late and middle Holocene)**—Deposit thickness and average grain size decrease toward valley axis. Streamcuts at mouths of many creeks along White Mountains and in Willow Wash area to south expose a minimum of 9–13 m of bouldery sediment; in contrast, cores from drill holes in central part of valley show a maximum of 5–9 m of clay, silt, and fine sand lenses (Reheis and others, 1996). Where drainages are incised, Marble Creek deposits underlie inset terraces, but where drainages are not incised they constitute large areas of alluvial fans and bury older deposits. Locally includes small areas of eolian sand (Qes, Qed). Includes colluvium on valley sides. Subdivided into units Qfcl, Qfcm, and Qfce near active faults

Qfcl **Late alluvium of Marble Creek (late Holocene)**—Active stream-channel deposits, recently deposited alluvium, and debris-flow deposits as high as 2.5 m above modern channels on alluvial fans; sparsely vegetated. Unit apparently postdates last fault movement (Sawyer, 1990; Reheis and Sawyer, 1997; Sawyer and Reheis, 1999). Thickness at least 3 m along White Mountains

Qfcm **Middle alluvium of Marble Creek (late Holocene)**—Underlies abandoned surfaces of young alluvial fans. Where incised near range front, surfaces are as much as 6 m higher than modern channels. Fault scarps are as much as 1.8 m high in central part of western Fish Lake Valley (Reheis, 1994; Reheis and others, 1995)

Qfce **Early alluvium of Marble Creek (middle Holocene)**—Underlies abandoned surfaces of young alluvial fans. Where incised near range front, surfaces are as much as 13 m higher than modern channels. Fault scarps in this unit are as much as 3.5 m high

Qfy **Younger alluvium (early Holocene to early late Pleistocene)**—Unit is equivalent in age to alluvium of Leidy Creek (Qfl) and major part of alluvium of Indian Creek (Qfi). Mapped in areas where detailed age resolution is not critical, and (or) where deposits are too small or too poorly preserved for detailed mapping

Qfl **Alluvium of Leidy Creek (early Holocene)**—Where incised near range front, surfaces are as much as 13 m higher than modern channels. Fault scarps in this unit are as much as 12.6 m high

Qfi **Alluvium of Indian Creek (early late Pleistocene)**—Within White Mountains, unit is as much as 50 m thick, but locally thickens to at least 90 m along range-front fault. Indian Creek deposits are extensively faulted; right-lateral offset is as much as 110 m or more, left-lateral offset is as much as 60 m south of Furnace Creek, and normal offset is as much as 90 m (Reheis and Sawyer, 1997)

Qfo **Older alluvium (middle Pleistocene)**—Unit is presumed equivalent in age to alluvium of McAfee Creek (Qfm) and alluvium of Trail Canyon (Qft). Mapped in areas where detailed age resolution is not critical, and (or) where deposits are too small or too poorly preserved for detailed mapping

Qft **Alluvium of Trail Canyon (middle middle Pleistocene)**—Within White Mountains, surfaces measured above modern channels are commonly at the same height to as much as 2 m higher than those of Indian Creek deposits. East of range front, unit is commonly buried beneath younger deposits. As much as 50 m thick within White Mountains but thickens to at least 65 m along fault zone. Cumulative normal offset is as much as 120 m (Reheis and others, 1995). Near Trail Canyon in northeastern Fish Lake Valley, subdivided where elevation difference indicates that units differ in age due to a stream capture (Gillespie, 1991): unit Qfto is mapped along upper Trail Canyon and lies as much as 80 m above Rock Creek, and unit Qfty is mapped along lower Trail Canyon and lies a maximum of 12 m above Rock Creek

Qfty **Younger alluvium of Trail Canyon**—Maximum exposed thickness 12 m

Qfto **Older alluvium of Trail Canyon**—Ranges from as much as 65 m thick where unit Qfto filled a paleovalley (Slate, 1992) to less than 15 m thick (Reheis and others, 1993a)

Qfm **Alluvium of McAfee Creek (early middle Pleistocene)**—Within White Mountains, unit is as much as 50 m thick, but locally much thicker adjacent to fault zone. South of Wildhorse Creek in central Fish Lake Valley, unit forms complexly faulted shutter-ridges. Right-lateral offset is as much as 6 km and vertical offset may exceed 230 m (Reheis and Sawyer, 1997)

Qfp **Alluvium of Perry Aiken Creek (early Pleistocene)**—Crops out as gravel remnants faulted against bedrock on inactive fault strands. Minimum vertical offset across several faults is 305 m. Maximum preserved thickness 55 m

QTf **Old alluvial gravel (early Pleistocene? and late Pliocene?)**—Sandy gravel; mostly poorly exposed. Clasts commonly are pebbles to cobbles but locally are as large as 1 m in a sandy matrix. In Eureka Valley, crops out as rounded hills with slopes blanketed by coarse lag gravel and colluvium; distinguished from unit Qfo by greater dissection and abundance of basalt clasts (Reheis, 1992). Includes one deposit on north side of Wildhorse Creek in central Fish Lake Valley that may be of different age (Reheis and others, 1995)

Tsl **Alluvial-fan, fluvial, and lacustrine deposits (late Pliocene)**—Interbedded sandy gravel, sand, silt, and clay; moderately to weakly indurated. Contains numerous rhyolitic tephra layers (Reheis, 1991, 1992; Reheis and others, 1993b; Sarna-Wojcicki and others, 2005). In northeastern Fish Lake Valley, conformably underlies and locally interfingers with basal part of unit Qg (old alluvial gravel). Conglomerate beds dominate upper third of unit near front of Silver Peak Range, whereas lacustrine mud and sand dominate lower third of unit to west (the latter equivalent to unit Tl in southern Fish Lake Valley). Maximum measured thickness 670 m (Robinson and others, 1976). In southernmost Fish Lake Valley, predominantly gravel and sand as much as 290 m thick (Reheis and others, 1991)

Tf **Alluvial-fan deposits (late Miocene)**—Intermixed and interbedded gravel, sand, silt, and clay; moderately to strongly indurated. Mapped only southwest of Fish Lake Valley fault zone in area of Horse Thief Hills. Along crest and flank of hills, unit is chiefly angular boulders of quartzite lagged on slopes; elsewhere, lithology depends on proximity to bedrock sources. Adjacent to faults, unit is a matrix-poor breccia with clasts as much as 4 m long (Reheis and Sawyer, 1997). Near Eureka Valley, grades laterally to round-pebble conglomerate. Contains thin rhyolite flows as old as 8.4 Ma near base and overlain by rhyolite and basalt as young as 6.3 Ma (Reheis, 1992; Reheis and Sawyer, 1997). Thickness varies greatly; maximum measured thickness 125 m

## PALUDAL, PONDED, AND LACUSTRINE DEPOSITS

Qm **Marsh deposits (Holocene and late Pleistocene)**—Fine sand, silt, and clay; massive to well sorted and stratified. Locally contains beds of peat and organic silt. Dry surfaces are commonly encrusted with salt. Mapped in areas of spring discharge and high ground-water table in east-central part of Fish Lake Valley. Poorly exposed; thickness 5–6 m based on coring (FLV-1, -2, and -7; Throckmorton and Reheis, 1993; Reheis and others, 1996)

Qpd **Ponded deposits (Holocene and late Pleistocene)**—Silt and minor sand and pebbly sand; interfinger laterally with sandy to gravelly alluvial-fan deposits. Locally contain tephra layers and one site contains gastropods in calcareous, sandy silt indicating deposition in poorly drained or standing-water conditions. Accumulated when drainages were blocked either by shutterridges along active faults or by landslides

Qp **Playa deposits (Holocene and late Pleistocene?)**—Silt and clay; massive to well stratified. Commonly flooded during the spring and during and after high rainfall events. Probably interbedded at depth with fine alluvium of adjacent alluvial fans. Thickness probably several meters. Much thicker deposits underlying large playa in northeastern Fish Lake Valley contain abundant salts and were locally mined for ulexite (Spurr, 1906)

Qly **Younger lacustrine deposits (late Pleistocene)—**Fine gravel and sand; well sorted and stratified; crossbeds dip as much as 15°. Occurs in northeastern corner of map area where arcuate beach ridges mark high stand of pluvial lake in Columbus Salt Marsh north of map area; high stand at about 17 ka was at about 1,402 m (Reheis and others, 2002, 2003). Thickness at least 2.5 m

Qlo **Older lacustrine deposits (middle to early Pleistocene)**—Sand and granule to pebble gravel; well sorted and stratified. Locally derived volcanic and sedimentary material commonly mixed with volcanic glass shards and pumice. Crops out in northeastern part of valley; represents near-shore and beach deposits of former pluvial lake occupying Fish Lake Valley. Uppermost older lacustrine deposits consist primarily of reworked 0.76-Ma Bishop ash; lower deposits locally contain reworked glass and pumice of the younger tuffs of Glass Mountain (Reheis and others, 1993b; Sarna-Wojcicki and others, 2005). Unit locally includes interfingering alluvial deposits (Qg) indicative of an oscillating lake level. Unit is thickest (8 m or more) adjacent to Emigrant Peak fault zone; thins rapidly and pinches out within 1 km east of main active fault

Tl **Lacustrine deposits (late Pliocene)—**Swelling, gypsiferous mud, silt, and minor sand; well sorted and stratified. Contains lenses of altered fine volcanic ash. Mapped in southern Fish Lake Valley where it conformably overlies unit Tsm; as much as 145 m thick and ranges in age from about 3.4 to 2.8 Ma (Reheis and others, 1991; Sarna-Wojcicki and others, 2005). Correlative with lacustrine deposits in upper part of unit Tsl in northeastern Fish Lake Valley

## SPRING DEPOSITS

Qst **Travertine (Holocene to late middle? Pleistocene)**—Slabby, massively bedded sandy limestone and loose to weakly indurated sand in northeast corner of map area. Active springs and seeps are surrounded by well-sorted, massive eolian sand, which lies on tops or flanks of cemented travertine mounds. In arroyos, layers of travertine underlie Holocene alluvium and extend northward from spring mounds. Deposits probably formed by voluminous spring discharge from Fish Lake Valley into Columbus Salt Marsh to the north during pluvial episodes

Qsi **Silicified sandstone and siliceous sinter (early middle Pleistocene)—**Interbedded fine- to medium-grained sandstone, amorphous and opaline silica, and minor conglomerate; well sorted and stratified; lenticular. Sand grains are mainly pumice and volcanic glass shards, cemented by light-gray opaque silica; some beds slightly to moderately calcareous. Silica deposits are finely laminated amorphous to opaline silica that breaks conchoidally; contain abundant volcanic glass shards that exhibit graded bedding. Uppermost part of unit is silica- and carbonate-cemented, poorly sorted conglomerate consisting of granule- to pebble-size subangular pumice clasts admixed with locally derived rhyolite and basalt clasts. Pumice and glass is correlated with 0.76-Ma Bishop ash. Deposited in north-central part of valley by siliceous hot springs that apparently were active during deposition of near-shore and beach sediments of a pluvial lake corresponding to uppermost older lacustrine deposits (Qlo) (Reheis and others, 1993b; Reheis and others, 2002)

EOLIAN DEPOSITS

Qed **Dune sand (Holocene)**—Fine to medium quartz sand and variable amounts of lithic grains; well sorted. Forms barchan and coppice dunes, mostly stabilized by vegetation, on east side of Fish Lake Valley. Commonly overlies Holocene fan alluvium (Qfc) or Pleistocene and Holocene valley-fill deposits (Qvf). Locally includes small areas of sheet sand (Qes). Mapped only where greater than 0.5 m thick; thickness usually less than 4 m

Qes **Sheet sand (Holocene)**—Fine to medium sand; well sorted, silty. Forms thin sheets surrounding dunes, and commonly overlies Holocene fan alluvium (Qfc) or Pleistocene and Holocene valley-fill deposits (Qvf). Consists largely of eolian sand reworked by fluvial processes. Locally includes small areas of dune sand (Qed). Thickness usually less than 1 m

MASS-WASTING DEPOSITS

Qls **Landslide deposits (Holocene and Pleistocene)**—Mostly blocks of Precambrian, Mesozoic, and Tertiary rocks that have been moved downslope mainly by slumping and earthflow and mixed with finer sediments. May include coherent glide blocks. North of Perry Aiken Creek, unit consists of remobilized alluvial-fan deposits (Qfi and Qft) adjacent to major fault scarp; landslide possibly triggered by earthquake event. North of Busher Creek, landslide deposits of at least two ages are preserved. Unit characterized by hummocky terrain except where deeply dissected; younger landslides are bounded upslope by crescentic headwall scarps and downslope by lobate toes. Maximum thickness probably tens of meters

Qc **Colluvial deposits (Holocene and Pleistocene)**—Blocks of basalt that have been moved downslope by rockfall and sliding on steep slopes and mixed with finer sediments. Mainly occurs as aprons and sheets overlying Miocene fluvial deposits (Tse)

GLACIAL DEPOSITS

Qt **Glacial till(?) (middle? Pleistocene)**—Gravel clasts as large as boulders in a gray sandy matrix; unsorted and unstratified. Clasts are predominantly granitic and hence probably not derived from upslope bedrock of mainly Precambrian sedimentary rocks. Crops out only on south side of Indian Creek canyon. Overlies reddish diamicton (Qls), which is crudely stratified and contains unsorted, angular clasts of Precambrian sedimentary rocks and Mesozoic granitic rocks in a mud matrix. At least 15 m thick; top of deposit about 170 m above Indian Creek

BEDROCK UNITS

Descriptions of bedrock units on this map of Fish Lake Valley are mostly summarized, and contacts with other bedrock units are modified, from previous geologic maps: McKee and Nelson (1967), Krauskopf (1971), Robinson and Crowder (1973), Stewart and others (1974), Robinson and others (1976), and McKee (1985). Because these authors varied in how they mapped the igneous intrusive rocks, some overlap may exist among these units within the present map

Tal **Andesite of Davis Mountain (late Pliocene)**—Medium gray; in part flow banded and platy. Locally underlain by, or contains beds of, fluvial gravel and sand (Tg). Mapped only in northwestern Fish Lake Valley. Whole-rock K-Ar ages are as old as 3.9 Ma but mainly range from 3.0 to 3.2 Ma. Thickness usually 35–50 m but may be as thick as 245 m on Davis Mountain. Andesite flows were apparently emplaced during motion on northwest-trending faults that have not been active in the Pleistocene (Reheis and others, 1993a; Reheis and Sawyer, 1997; previously mapped as unit Ta)

Tb **Basalt, undivided (Pliocene and Miocene)**—Olivine basalt, locally scoriaceous. Mapped on east side of Fish Lake Valley. Elsewhere subdivided as follows into units Tbe and Tbl where age is known or can be inferred

Tbl **Late basalt (Pliocene)**—Black to dark-gray olivine basalt; includes one outcrop of andesite in Eureka Valley. Overlies unit Tse on east side of Fish Lake Valley, where age is about 4.8 Ma (Robinson and others, 1968), and also in Eureka Valley (previously mapped as unit QTb by Reheis, 1992), where age is 5.3 Ma (Reheis and Sawyer, 1997)

Tbe **Early basalt (late Miocene)**—Olivine basalt. Overlies rhyolite of unit Tre and Mesozoic rocks (Jmb and Mzm) in White Mountains. Generally caps high divides but locally occurs in valley bottoms (for example, in upper Iron Creek) as probable volcanic necks. West of map area in White Mountains and Deep Springs Valley, covers large remnants of erosion surface cut on Mesozoic igneous rocks. Also overlies rhyolite in Willow Wash where mapped as unit Tve (rhyolite and basalt, undivided). Age is between 11.5 and 10.8 Ma (Dalrymple, 1963; Robinson and others, 1968; Reheis and McKee, 1991)

Tae **Andesite (late Miocene)**—Dark-gray, porphyritic vesicular andesite. Age about 6 Ma based on relations to dated tuffs (Stewart and others, 1974). Shown only on east-central edge of map area (previously called unit Ta by Reheis and others, 1995). Contacts modified from Krauskopf (1971) and Stewart and others (1974)

Tr **Rhyolite, undivided (Miocene)**—Rhyolitic, welded and unwelded ash-flow tuffs. Subdivided as follows into units Tre and Trl where age is known

Trl **Late rhyolite (late Miocene)**—White to tan lapilli and vitric tuff. On east side of Fish Lake Valley, derived from Silver Peak volcanic center to east. Locally includes rhyolite flows and intrusive rocks. Age 6. 1 Ma (Robinson and others, 1968). Contacts modified from Krauskopf (1971) and Stewart and others (1974). In Eureka Valley, source of rhyolite is unknown. There, rhyolite previously mapped as unit Tr (Reheis, 1992) is interbedded with Miocene alluvial-fan deposits (Tf) and basalt (Tvl); ages range from 8.4 to 6.9 Ma (summarized in Reheis and Sawyer, 1997)

Tre **Early rhyolite (late middle and late Miocene)**—White, gray, pink, and buff vitric tuff; in part welded. Underlies basalt (Tbe) on erosion surfaces in White Mountains and Deep Springs Valley. Also underlies basalt in Willow Wash where mapped as unit Tve (rhyolite and basalt, undivided). Age is between about 15 Ma and 11.2 Ma (Dalrymple, 1963; Reheis and Sawyer, 1997)

Tvl **Rhyolite and basalt, undivided (early Pliocene and late Miocene)**

Tve **Rhyolite and basalt, undivided (late middle and late Miocene)**

Tu **Tertiary rocks, undivided (Pliocene and Miocene)**—Fluvial and lacustrine sedimentary rocks and volcanic rocks, including rhyolite, latite, basalt, and andesite. Mapped only in northern Fish Lake Valley

Mzm **Mesozoic intrusive rocks, undivided (Cretaceous and Jurassic)**—Includes adamellite, quartz monzonite, and granodiorite

Jmb **Quartz monzonite of Beer Creek (Jurassic)**—Medium- to coarse-grained porphyritic quartz monzonite. Contains large dioritic inclusions. From Wildhorse Creek south to Cottonwood Creek in the White Mountains, includes Cretaceous intrusive rocks variously mapped as quartz monzonite, adamellite, and aplite

Jmj **Hornblende-augite monzonite of Joshua Flat (Jurassic)**—Medium-grained, hornblende-, biotite-, and locally augite-bearing monzonite to quartz monzonite. Includes small areas of medium-grained, augite- and olivine-bearing monzonite

Pzr **Paleozoic rocks, undivided (Ordovician and Cambrian)**—Includes Middle and Lower Ordovician Palmetto Formation (shale, chert, and minor limestone, quartzite, and slate) and Lower Cambrian Harkless and Poleta Formations (siliceous siltstone and quartzite, shale, and limestone)

TPzu **Tertiary and Paleozoic rocks, undivided**—Shown in northern part of map area where erosional remnants of Tertiary rocks overlie Paleozoic rocks

€Zs **Sedimentary rocks (Cambrian and Late Proterozoic)**—Quartzite, siltstone, shale, limestone, dolomite, and metamorphic equivalents of Late Proterozoic and Lower Cambrian Deep Springs Formation, Reed Dolomite, and Wyman Formation. In northern White Mountains, includes biotite schist and marble mapped as Lower Cambrian Harkless Formation(?)

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