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Photomosaics and Logs of Trenches Associated with Study of West Napa Fault at Ehlers Lane, North of Saint Helena, California

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Pamphlet to accompany
Open-File Report 2022–1002

2022

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

U.S. Geological Survey, Reston, Virginia: 2022

Suggested citation:
Philibosian, B.E., Sickler, R.R., Prentice, C.S., Pickering, A.J., Gannon, P., Broudy, K.N., Mahan, S.A., Titular, J.N., Turner, E.A., Folmar, C., Patterson, S.F., and Bowman, E.E., 2022, Photomosaics and logs associated with study of West Napa Fault at Ehlers Lane, north of Saint Helena, California: U.S. Geological Survey Open-File Report 2022–1002, 1 sheet, pamphlet 8 p., https://doi.org/10.3133/ofr20221002.

ISSN 2331-1258 (online)

Acknowledgments

The National Association of Geoscience Teachers USGS internship program supported seven intern coauthors (P. Gannon, K.N. Broudy, J.N. Titular, E.A. Turner, C. Folmar, S.F. Patterson, and E.E. Bowman) who assisted with field work, sample collection, data processing, drafting, and data synthesis. Belle Philibosian was supported by a Mendenhall Postdoctoral Fellowship. We thank Chris DuRoss, Suzanne Hecker, and Steve DeLong for providing thorough manuscript reviews that led to many improvements. Thanks also to David Schwartz and Steve DeLong for providing trench reviews and logistical support. We are very grateful to Battuello Vineyards and neighboring landowners for allowing this study on their properties and providing background information about the history and local geology of their land.

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Abstract

The West Napa Fault has previously been mapped as extending ~45 kilometers (km) from northern Vallejo to southern Saint Helena, California, dominantly running along the western edge of Napa Valley. A zone of fault strands (some previously unmapped) along a ~15-km section of the fault ruptured during the 2014 magnitude 6.0 South Napa earthquake, illustrating the need for further investigation of this little-studied structure. Based on light detection and ranging (lidar) topography and field examination, the fault zone likely extends an additional 10 km or more northward past Saint Helena. In this vicinity, geomorphology suggests two fault strands, one along the range front and another associated with a line of rounded hills that rise 5–10 meters above the middle of the valley. In 2017, we excavated two trenches across an apparent fault scarp on the east side of one elongate hill near Ehlers Lane north of Saint Helena. Examination of the walls revealed three main sedimentary packages. The oldest package, weakly lithified alluvial fan gravels with local sand and silt layers, is tilted 25°–35° to the west. Overlying these tilted strata are two younger sets of strata. On the west side, underlying the crest of the scarp, are alluvial fan gravels with local sand and silt lenses, potentially tilted a few degrees to the west. On the east side, deposited against the scarp, are much finer grained (dominantly fine sand to silt) subhorizontal fluvial strata, likely overbank deposits from the Napa River. We obtained age control on the two younger units through a combination of radiocarbon, infrared-stimulated luminescence, and obsidian hydration dating, establishing that they are latest Pleistocene to modern in age. Although there are no prominent unconformities within the alluvial fan sediments, sample dating indicates there are two generations, one in the 10–20 thousand year (ka) age range and one in the <3 ka age range. Owing to a general lack of well-defined laterally continuous alluvial fan units, it is difficult to distinguish contacts between the two generations except in the immediate proximity of dated samples. The river sediments approximately span the Holocene. No faults were apparent in either trench, indicating that any fault related to the observed surface deformation has not ruptured to the surface at this site during the Holocene and is likely blind.

Detailed Descriptions of Stratigraphic Units

Trench 2

The northern trench (2) revealed distal river sediments deposited against colluvium-mantled tilted strata at the western end. At the western end of the trench, the river sediments are only coarsely stratified (five discernible units). These sediments are more finely stratified toward the east, differentiating into more than 15 discernible units (with additional underlying layers revealed in a deepened part of the trench). Therefore, we present separate unit descriptions for the west and east ends in the following two tables (tables 1 and 2).

Trench 1

The southern trench (1) revealed a buried ridge of tilted strata, overlain by alluvial fan sediments on its west flank and distal river sediments on its east flank. Individual units within the alluvial fan sediments have limited lateral continuity and most do not directly contact the river sediments, so it is difficult to determine stratigraphic relations between all units. Therefore, we present separate unit descriptions for the west end, middle, and east end of the trench in three tables (tables 3, 4, and 5, respectively).

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Table 1. Descriptions of stratigraphic units and position of unconformities on the west end of trench 2.

Unit symbol	Description or feature
1	Tilled light gray silty soil with rounded pebbles and cobbles, abundant roots, loose and blocky with large soil peds
α	Black-gray clay-rich soil. Upper part is harder, lighter colored, more clay- and silt-rich with more granules and pebbles. Lower part is loose with small soil peds, organic rich, and more friable. Transitions into unit 2 to east
β	Unsorted black-gray, organic-rich silt-sand soil with scattered pebbles and cobbles. Siltier and harder in places, sandier and looser in others. Contains a light gray zone. Likely tilled to 1 meter depth. Cobbles reworked from the unit below are common along base. Differentiates into units 3–8 to east
γ	Dry, hard, light gray medium-coarse sandy silt to silty sand with many pebbles and a few cobbles. Coarser on average than units β and δ. Largely matrix supported, intermittently clast supported. Differentiates into units 9–10.5 to east
δ	Dry, hard, grayish light-brown fine sand and silt with abundant granules and small pebbles. Contains a diffuse coarse layer (coarse sand to pebbly silt with cobbles). Differentiates into units 11–13 to east
–	Buttress unconformity
Col	Colluvium mantle likely derived from underlying layers below angular unconformity. Unsorted loose gray small-medium cobbles and scattered boulders in silty matrix, generally matrix supported; subrounded to rounded clasts generally inclined to the east
–	Angular unconformity
BAU1	Oxidized, hard, light gray clayey silt
BAU2	Oxidized, yellow rounded cobbles and boulders. More cemented than overlying unit. Mainly clast supported. Matrix, where present, is oxidized coarse silty sand. Consistent inclination of cobbles and contacts suggests ~25° westward dip
BAU3	Well-rounded granules and some small pebbles; larger pebbles near base
BAU4	Medium to coarse sand
BAU5	Silt to fine sand with some granules and small pebbles

Table 2. Descriptions of stratigraphic units on the east end of trench 2.

Unit symbol	Description
1	Tilled light gray silty soil with rounded pebbles and cobbles. Abundant roots present. Soil is loose and blocky with large soil peds
2	Pale orange breccia, possibly artificial fill for railroad grade. Color transitions to less yellow and more gray to the west. Locally contains tilled blocks of unit 3
3	Dark gray-brown massive silt with pebbles and granules
4	Layer or stringer of rounded cobbles; intermittent
4a	Brown pebbly silt
5	Coarse sand and granule gravel with yellow and white subangular pebbles. Dark brown silty clay matrix
6	Medium-dark brown silty clay with lenses and scattered clasts of coarser material including white granules, very coarse sand, and pebbles
7	Dominantly white tuff clast-supported granule layer
8	Greenish medium-brown massive silty clay with lenses of coarser material; fewer scattered granules and very coarse sand grains than in unit 6
9	White, gray, and brown clast-supported very coarse sand and white tuff granules with local clay lenses and some iron staining
10	Greenish medium-brown silty clay with few pebbles and granules. Locally layered. Contains charcoal- rich burn horizon at meters 20–22
10.5	White, gray, and red pebbles and scattered cobbles in clay to fine sand matrix; subangular clasts. Fines and pinches out to east
11	Medium brown generally massive silty clay with very abundant pebbles and granules; dry with desiccation cracks
12	Medium-dark brown massive silty clay with scattered granules and pebbles; dry and hard with abundant desiccation cracks
13	Light brown massive silty clay with abundant white and gray pebbles and granules; increasing pebble and cobble content (entrained colluvium) to the west. Granule lenses near top in the eastern part. Hard and slightly damp
13.5	Subrounded medium pebbles to cobbles with matrix that ranges from medium brown silt to coarse sand. Coarser matrix than unit 13
14	Orange-brown massive silty clay with scattered white and gray coarse sand grains, granules, and pebbles. Dry, very hard, and cement-like at top, becomes slightly damp and darkens downward. The lower third of the unit contains more fine sand and pebbles, locally in lenses, and interfingers with unit 15. Sand and pebble content increases toward the west
15	Clast-supported gravel composed of subrounded to well-rounded large pebbles and cobbles in fine sand and silt matrix with granules. Wet and very friable
16	Matrix-supported gravel composed of rounded white granules and pebbles in clay-rich matrix; damp and loose. Contains fewer pebbles and cobbles than the layers above and below; transitions from silty clay matrix with few pebbles to sandy matrix with many pebbles from east to west
16.5	Grayish-blue sandy, silty clay with sparse subrounded cobbles and white pebbles
17	Clast-supported gravel composed of subangular to subrounded pebbles and cobbles in sandy granule matrix; wet and loose at top and well-cemented at base

Table 3. Descriptions of stratigraphic units on the west end of trench 1.

[cm, centimeter]

Unit symbol	Subunit symbol	Description
A3	–	Blocky soil composed of well-rounded cobbles in organic-rich brown-gray silt; friable with soil peds. Bioturbated base forms a weathering horizon on units C1 and C2 with relict blocks of C1 and C2 found within unit A3
A4	–	Yellow well-rounded cobbles in yellow to pale orange cemented matrix with iron staining
C1	–	Pale orange, moderately rounded, poorly sorted, cemented, iron-stained cobble gravel; grades in and out of unit C2. Possibly the uppermost part of unit F with some soil development
C2	–	Dry, hard, massive pebbly clay, silt, and coarse sand with extensive bioturbation and burrowing. Perhaps simply expresses weak soil development in finer parts of unit C1 and (or) top of unit F rather than a distinct stratigraphic unit
Ch	–	Granules to small pebbles in sandy silt matrix fill channels incised into unit F; finer and less cemented than unit F
D	–	Pebbles in silt matrix; matrix supported
E		Upward-fining pebble gravel to fine sand layers present only at far western end of trench
–	E1	Massive, bioturbated fine sand with few pebbles
–	E2	Clast-supported pebble gravel in west; pebble-rich zone in east
–	E3	Clast-supported pebble gravel composed of moderately rounded clasts in silty very coarse sand matrix; weakly bedded and iron stained
F	–	Pale orange, poorly sorted, moderately rounded sandy pebble gravel with significant burrowing and iron staining. Maximum clast size of ~10 cm. Contains cemented finer gravel lenses; becomes more cemented and fines (more sand, fewer cobbles, less rounded clasts) to west on average. Cobble poor and matrix supported at meters 26–29. Similar to unit M but more poorly sorted. Roughly grades into units N and O to east
G	–	Interfingering sand lenses. Upper lens (unit G1) is medium to very coarse sand with pebbles and lower lens (unit G2) is sorted very fine sand
H	–	Pebble gravel, coarser than unit E3; iron stained
I	–	Locally well sorted medium sand with faint and thin coarse sand and pebble interbeds; manganese and iron staining
J	–	Orange-mottled, poorly sorted, subrounded, clast-supported sandy cobble gravel; grades to pebble gravel to west. Loose and iron stained
K	–	Pale orange, poorly sorted pebble and cobble gravel in silty sand matrix; maximum clast size of ~7 cm. Hard and well-cemented
L	–	White-yellow silty fine to coarse sand lenses, the majority of which are massive, well-sorted silty fine sand. Coarse sand, granule, and pebble interbeds present; some lenses exhibit faint laminae and (or) iron staining. Units L1–L4 indicate distinct lenses that dip to either side from center of unit; this may be depositional dip. Interfingers with units J, K, and M
M	–	Gray clast-supported gravel composed of subangular to subrounded pebbles in a coarse sand and granule matrix, friable to weakly cemented. Locally sorted; finer (pebbles in sand) to west, loose clast-supported gravel lenses with void space and very little matrix in east. Manganese staining in east

Age Determination

Three different methods were used to estimate ages of strata: radiocarbon dating, obsidian hydration dating, and luminescence dating. Of these three, radiocarbon dating provides the most precise ages, but can only be performed on samples of organic matter. Organic material (largely charcoal) is plentiful within the river deposits but scarce in the other units. We dated a representative suite of radiocarbon samples from throughout the section of river sediments and every available sample from the other units. Obsidian hydration dating is less precise but is much less expensive than radiocarbon dating. We supplemented the radiocarbon ages by dating every available obsidian sample. However, like organic material, obsidian is plentiful in the river deposits but scarce elsewhere. For the alluvial fan deposits, we rely on luminescence dating, which is the least precise method but can be performed on any fine-grained sediment. We also obtained a series of luminescence dates from the river deposits to verify that ages are consistent among the three methods.

Radiocarbon Ages

The radiocarbon dating method measures the ratio of the radioactive isotope of carbon (^{14}C) to the stable isotopes ^{13}C and ^{12}C in a sample of dead organic matter. This determines the time elapsed since the sample of living tissue died. This age of death may therefore be significantly older than the age of deposition of the unit in which the sample is found, particularly if the samples are charcoal, which can have a long period of surface residence and transport before final deposition. All samples of organic matter found in the Ehlers Lane trenches are charcoal (table 6).

Obsidian Hydration Analysis

Over time, the outer surface of an obsidian clast reacts with water in the environment to form a hydrate rind or band. The band thickness increases with time, so the age of the clast surface can be determined from the band thickness (measured using microscopy) and a known band growth rate. The latter

Table 4. Descriptions of stratigraphic units and position of unconformities in the middle of trench 1.

[mm, millimeter]

Unit symbol	Description
A1	Modern soil A horizon; unsorted silt and sand with some pebbles and cobbles
A2	Unsorted silt to coarse sand with few pebbles and cobbles
A3	Blocky soil composed of well-rounded cobbles in organic-rich brown-gray silt; friable with soil peds
N	In-place remnants of well-cemented gravel composed of unsorted silt, sand, pebbles, and few cobbles, surrounded by bioturbation and burrows. Finer than and interfingering with or below unit F
O	Pebbly unsorted silty sand with few cobbles; extensive bioturbation and burrowing
P	Dry, very hard, cemented, poorly sorted, massive pebble and cobble gravel with coarse sand and granule matrix; fines upward to pebbly medium-coarse sand on south wall. Appears to grade into unit U to the east
Q	Pebbly coarse sand
R	Dry pebble gravel with matrix of silty very coarse sand and granules. Contains medium-coarse sand lenses and cobble layer along base. Crude bedding and manganese staining
S	Pebble to cobble gravel, similar to and grades into unit K to west
T	Gray pebble gravel, finer than unit S, similar to and possibly grades into unit M to west
–	Angular unconformity
BAU10	Massive pebble and cobble gravel; finer layer at top
BAU11	Layered coarse sand, small pebble gravel, and medium sand fill channel incised into unit BAU12
BAU12	Interbedded distinct layers of silt, silty medium sand, coarse sand, and granule to pebble gravel with crossbedding and laminae. Clear westward dip of ~30°
BAU13	Massive pebble and cobble gravel with loose very coarse sand and granule matrix. Mostly clast supported, locally matrix supported; crude orientation of clasts and indistinct bedding at 1-meter scale suggests westward dip. Iron and manganese staining
BAU14	Yellow-orange mottled massive silty fine sand; fines upward. Dry and hard with in situ burrows, subvertical weathering fabric, and iron staining. Contains 3–5 mm thick planar gray clay layer
BAU15	Clast-supported pebble and cobble gravel exhibiting clast orientation that suggests westward dip

Table 5. Descriptions of stratigraphic units and position of unconformities on the east end of trench 1.

[cm, centimeter]

Unit symbol	Subunit symbol	Description or feature
A1	–	Modern soil A horizon; organic-rich, loose pebbly sand and silt with soil peds
B	–	Massive sandy silt with scattered pebbles; most pebbles are subrounded with weathering rinds
–	B1	Dark brown, organic-rich, dry, hard, massive pebbly sand and silt with abundant roots and desiccation cracks
–	B2	Ashen gray to light brown massive sandy silt with scattered pebbles as large as 4 cm in diameter. Dry and hard with scattered roots and some granule lenses; becomes less distinct to west
–	B3	Thin lens of gray silt with scattered granules
–	B4	Gray-mottled medium brown massive sandy silt. Dry and hard with numerous desiccation cracks, many vertical gleyed zones, fewer pockets of granules than unit B2, and many weathered pebbles as large as 5 cm in diameter
–	B5	Orange-mottled to yellow-brown massive clayey silt with scattered pebbles; finer than the rest of unit B. Slightly damp with subvertical weathering fabric
U	–	Cobble colluvium mantle likely derived from underlying layers below angular unconformity. Largely clast supported; becomes finer and supported in brown matrix to east. Interfingers with base of unit B4 and unit B5 to east
V	–	Orange-tinged pebbly sand-silt colluvium, likely derived from unit BAU14. Transitions from clast supported to matrix supported from bottom to top. Interfingers with unit B5 to east
–	–	Angular unconformity

depends on obsidian composition and burial environment and has been empirically calibrated for Napa Valley's Glass Mountain obsidian using samples of independently known age (for example, Carpenter and Mikkelsen, 2005). Using X-ray diffraction analysis, all obsidian samples collected at the Ehlers Lane site were determined to be consistent with a Napa Valley Glass Mountain source (unsurprising as Glass Mountain is only a few kilometers from the Ehlers Lane site). As with radiocarbon samples, the age of the clast could be substantially older than the age of deposition. The surface ages on obsidian debitage (human-worked flakes) are likely closer to the age of deposition than the surface ages on naturally eroded clasts. Obsidian hydration ages for the Ehlers Lane site are given in table 7.

Infrared-Stimulated Luminescence

Buried sediments trap electrons that are emitted by decay of local radioactive elements. Light exposure releases these trapped electrons within seconds to minutes. Luminescence dating works by measuring the stored luminescence in mineral grains of quartz or potassium feldspar under controlled conditions in the laboratory, then taking that result divided by the isotopic decay of known radioactive minerals that generate the luminescence. Visible light is used on quartz grains whereas infrared wavelengths are used on feldspar grains. Our samples had very little quartz, so we used infrared-stimulated luminescence dating on the feldspars (table 8).

Table 6. Radiocarbon analysis results for Ehlers Lane site samples, Saint Helena, California.

[USGS, U.S. Geological Survey; ‰, per mil; NIST, National Institute of Standards and Technology; SRM, standard reference material; µg, microgram]

Sample	USGS no.[1]	Material	Pretreatment[2]	F ^{14}C ±2σ[3]	^{14}C age ±2σ[4]	Trench	Stratigraphic unit[5]
Nm-10C-a-ch	1299	Charcoal	ABA	0.6806±0.0036	3,090±40	2	6
Sm-16D-a-ch	1300	Charcoal	ABA	0.6940±0.0038	2,935±40	2	9
Sm33D-a-ch	1301	Charcoal	ABA	0.6941±0.0038	2,935±40	2	δ top (≈11)
Sm9E-a-ch	1302[6]	Charcoal	ABA	0.6219±0.0036	3,815±50	2	12
Sm15G-a-ch	1303	Charcoal	ABA	0.3719±0.0030	7,945±70	2	14 top
Sm17K-a-ch	1304	Charcoal	ABA	0.3077±0.0036	9,470±90	2	14 base
Sm11J-b-ch	1305	Charcoal	ABA	0.3180±0.0026	9,205±70	2	14 base
Nm9J-a-ch	1342[6]	Charcoal	ABA	0.3323±0.0036	8,850±90	2	15–16
Sm10J-a-ch	1341	Charcoal	ABA	0.2659±0.0032	10,640±100	2	16
S-G7-b-ch	1297	Charcoal	ABA	0.9295±0.0050	585±40	1 east	B1 (in situ)
S-G7-a-ch	1296	Charcoal	ABA	0.9157±0.0046	705±40	1 east	B1
S-H1-a-ch	1294	Not enough carbon for analysis				1 east	B2
S-I3-a-ch	1295	Not enough carbon for analysis				1 east	B4 top
S-L0-a-ch	1293[6]	Charcoal	ABA	0.3347±0.0032	8,790±80	1 east	B4 base
N-L4-a-ch	1292	Not enough carbon for analysis				1 east	B5
N-C29-a-ch	1289	Charcoal	ABA	0.0066±0.0022	40,300±2,800	1 west	C2 (fossil fuel?)
N-C25-b-ch	1290	Charcoal	ABA	0.9509±0.0050	405±40	1 west	C2 base
S-E28-b-ch	1298	Not enough carbon for analysis				1 west	L1
N-G23-a-ch	1291	Not enough carbon for analysis				1 west	M top

[1] Unique identifier for each radiocarbon analysis in the USGS Radiocarbon Laboratory. Analyses were performed by Jeff Pigati and Jeff Honke. Reporting follows standards established by Stuiver and Polach (1977) and van der Plicht and Hogg (2006).

[2] Chemical pretreatment protocol applied to the sample. ABA, acid-base-acid; HCl, hydrochloric acid leach.

[3] Activity ratio of ^{14}C corrected for isotopic fractionation and normalized to a δ^{13}C value of −25‰. By convention, the modern reference standard is defined as 95 percent of the ^{14}C activity of NIST Oxalic Acid I (SRM 4990C). Uncertainty is given at the 2σ level.

[4] Conventional (uncalibrated) radiocarbon age, based on the Libby half-life of 5,568 years, where 0 years before present is 1950 A.D. Uncertainty is given at the 2σ level.

[5] Samples are listed in stratigraphic order within each of the stratigraphic sections (trench 2, trench 1 east, trench 1 west).

[6] Sample yielded <300 µg of carbon. We recommend this result be viewed with caution.

Table 7. Obsidian hydration analysis results for Ehlers Lane site samples, Saint Helena, California.

[µm, micrometer; max., maximum; m, meter]

Sample	Far Western ID	Origer lab ID	Notes	Provenance[1]	Clast type[2]	Band thickness[3] (µm)	Max. band thickness[3] (µm)	Corrected thickness[3] (µm)	Corrected age[4]	Trench	Stratigraphic unit[5]
Sm9D-a-ob	26426	OOL-1109-33	Broke in field	Unknown	Worked	4.4		4.0	2,454±300	2	9
Nm10D-a-ob	26407	OOL-1109-15		Glass Mountain	Worked	4.6		4.2	2,706±300	2	9
Nm36B-a-ob	26421	OOL-1109-28		Glass Mountain	Worked	4.0		3.7	2,100±300	2	γ (≈10.5)
Nm37C-a-ob	26423	OOL-1109-30		Glass Mountain	Worked	4.2		3.8	2,215±300	2	γ (≈10.5)
Nm22D-a-ob	26420	OOL-1109-27		Glass Mountain	Worked	5.0		4.6	3,246±600	2	10.5
Nm21D-a-ob	26419	OOL-1109-26	Sample taken from broken surface	Glass Mountain	Worked	5.3		4.9	3,683±600	2	10.5
Nm36D-a-ob	26422	OOL-1109-29		Glass Mountain	Worked	5.6		5.1	3,990±600	2	δ top (≈11)
Sm10E-a-ob	26428	OOL-1109-35		Glass Mountain	Worked	5.1		4.7	3,389±600	2	11
Sm15E-a-ob	26435	OOL-1109-42	Weathered	Glass Mountain	Worked	Variable	4.8	4.4	2,970±300	2	11
Nm20D-a-ob	26416	OOL-1109-24	Weathered	Glass Mountain	Natural	Variable	8.0	7.3	8,175±600	2	11
Sm2E-a-ob	26425	OOL-1109-32		Glass Mountain	Worked	6.8		6.2	5,897±600	2	11–12
Nm12E-a-ob	26413	OOL-1109-21		Glass Mountain	Worked	6.8		6.2	5,897±600	2	12
Nm16F-a-ob	26414	OOL-1109-22	Weathered	Glass Mountain	Worked	6.6		6.0	5,522±600	2	13
Sm18F-a-ob	26437	OOL-1109-44	Weathered	Glass Mountain	Natural	Variable	117	103.4	1,640,085	2	13
Nm10I-a-ob	26410	OOL-1109-18		Glass Mountain	Natural	11.5		10.5	16,912	2	14 middle
Nm10H-a-ob	26409	OOL-1109-17	Weathered	Glass Mountain	Natural	Variable	114	100.7	1,555,551	2	14 middle
Nm8I-a-ob	26406	OOL-1109-14		Glass Mountain	Worked	7.4		6.8	7,093±600	2	14 base
Nm17J-a-ob	26415	OOL-1109-23	Weathered	Glass Mountain	Natural	Variable	55	48.6	362,325	2	14 base
Sm12J-b-ob	26433	OOL-1109-40	Weathered	Glass Mountain	Natural	Variable	72	63.6	620,497	2	14 base
Sm14K-a-ob	26434	OOL-1109-41	Weathered	Glass Mountain	Natural	Variable	73	64.5	638,182	2	14 base
Nm11J-a-ob	26412	OOL-1109-20	Weathered	Glass Mountain	Natural	Variable	84	74.2	844,565	2	14 base
Sm11J-a-ob	26430	OOL-1109-37	Weathered	Glass Mountain	Natural	~80		75.2	867,483	2	15
Sm11J-c-ob	26431	OOL-1109-38	Weathered	Glass Mountain	Natural	~80		75.2	867,483	2	15
Sm9J-a-ob	26427	OOL-1109-34	Weathered	Glass Mountain	Natural	Variable	53	46.8	335,983	2	16
N-G3-a-ob	26397	OOL-1109-5	Weathered	Glass Mountain	Probably worked	Variable	5.3	4.9	3,683±600	1 east	B1
S-G0-a-ob	26401	OOL-1109-9	Weathered	Glass Mountain	Worked	Variable	5.8	5.3	4,309±600	1 east	B1
N-G1-a-ob	26396	OOL-1109-4		Glass Mountain	Possibly worked	6.5		6.0	5,522±600	1 east	B1
S-G4-b-ob	26403	OOL-1109-11	Weathered	Glass Mountain	Worked	Variable	7.3	6.7	6,886±600	1 east	B1
S-G4-a-ob	26402	OOL-1109-10	Weathered	Glass Mountain	Probably worked	Variable	7.8	7.1	7,733±600	1 east	B1
S-G5-a-ob	26404	OOL-1109-12	Weathered; broke in field	Glass Mountain	Worked	Variable	3.9	3.6	1,988±300	1 east	B1-B4 border
N-F6-b-ob	26395	OOL-1109-3	Weathered; broke in field	Unknown	Worked	Variable	5.8	5.3	4,309±600	1 east	B4 top
A	26439	OOL-1109-46	Weathered	Glass Mountain	Worked	Variable	3.8	3.5	1,879±300	1 east	2–2.5 m depth (B4?)
N-C21-a-ob	26393	OOL-1109-1		Glass Mountain	Worked	3.1		2.8	1,203±300	1 west	F? top
N-D28-a-ob	26394	OOL-1109-2		Glass Mountain	Worked	4.0		3.7	2,100±300	1 west	F
S-F24-a-ob	26400	OOL-1109-8	Weathered	Glass Mountain	Natural	Variable	4.7	4.3	2,836±300	1 west	K

[1] Provenance was established through X-ray fluorescence trace-element composition analysis by Lucas Martindale Johnson at Far Western Anthropological Research Group (sample IDs in column 2). Provenance is considered unknown for two samples <4 mm thick, but results are still consistent with a Napa Valley Glass Mountain source.

[2] Worked clasts bear signs of shaping by humans whereas natural clasts appear to have formed via geologic processes.

[3] Hydration band thickness and age analyses were performed at Origer's Obsidian Laboratory (Tom Origer & Associates; sample IDs in column 3). For clasts with variable hydration band thickness, we assume the variability is caused by weathering and we use the maximum observed band thickness to determine the age. Corrected thickness indicates equivalent thickness after accounting for ambient temperature and burial depth.

[4] Age uncertainties were estimated based on scatter around the calibration curve from Carpenter and Mikkelsen (2005). Uncertainties were not assigned for ages >10 kilo-annums (ka), as no calibration data exist for that part of the hydration curve.

[5] Samples are listed in stratigraphic order within each of the stratigraphic sections (trench 2, trench 1 east, trench 1 west).

Table 8. Feldspar infrared-stimulated luminescence (IRSL) analysis results for Ehlers Lane site samples, Saint Helena, California.

[Analyses were performed by coauthor Shannon Mahan at the USGS Luminescence Dating Laboratory. cm, centimeter; Gy, gray; Gy/ka, gray per thousand years; ppm, part per million; %, percent; yr, year; -, not applicable]

Sample	Depth (cm)	Water content (%)[1]	K (%)[2]	U (ppm)[2]	Th (ppm)[2]	Total dose (Gy/ka)[3]	Equivalent dose (Gy)	n[4]	Scatter[5]	Age (yr)[6]	Age model[7]	Trench	Stratigraphic unit[8]
Nm26C-OSL	85	7 (49)	1.12±0.04	3.11±0.24	6.23±0.26	3.61±0.11	12.9±1.6	5 (24)	102%	3,570±920	MAM	2	6
							36±9.6	16 (24)		9,970±5,360	CAM		
Nm26F-OSL	260	12 (37)	1.22±0.04	2.88±0.22	7.45±0.30	3.82±0.11	17.2±2.8	7 (25)	77%	4,500±1,500	MAM	2	14 top
							39.5±6.4	24 (25)		10,340±3,400	CAM		
Nm18K-OSL	485	16 (34)	1.36±0.04	2.67±0.20	6.91±0.33	3.77±0.12	20.6±1.3	12 (25)	55%	5,670±800	MAM	2	14 base
							32.2±3.9	22 (25)		8,870±2,200	CAM		
N-L2-OSL	330	14 (44)	1.17±0.04	2.91±0.19	7.74±0.27	3.75±0.10	48.4±3.9	6 (20)	27%	13,560±2,300	MAM	1 east	B5
							67.5±4.7	19 (20)		18,910±2,820	CAM		
N-B36-OSL	130	8 (40)	0.87±0.04	2.8±0.21	8.86±0.31	3.71±0.10	42.1±4.1	6 (30)	30%	11,320±2,300	MAM	1 west	D
							67.4±4.4	26 (30)		18,170±2,580	CAM		
S-E23-OSL	185	6 (32)	1.47±0.09	2.30±0.19	9.90±0.80	4.19±0.23	54.5±6.2	7 (25)	36%	12,990±3,280	MAM	1 west	G2
							89.4±6.8	25 (26)		21,310±4,000	CAM		
S-E28-OSL	220	7 (45)	1.63±0.19	3.20±0.19	8.49±0.33	4.46±0.11	50±6.4	6 (20)	33%	11,210±2,920	MAM	1 west	L1
							76.3±6.4	17 (20)		17,110±3,000	CAM		
N-F29-OSL	285	13 (70)	1.58±0.06	2.83±0.22	8.13±0.61	3.95±0.18	47.3±6.3	4 (20)	39%	11,970±3,360	MAM	1 west	L4
							77.5±8.1	17 (20)		19,620±4,460	CAM		
S-G21-OSL	280	12 (37)	1.85±0.04	3.19±0.22	9.17±0.31	4.84±0.12	50±5.6	4 (24)	44%	10,330±2,380	MAM	1 west	M or S base
							94±10	20 (24)		19,420±4,220	CAM		
S-H14-OSL	250	17 (31)	1.21±0.06	3.13±0.23	8.03±0.47	4.07±0.16	>440	10 (10)	26%	>108,000	-	1 west	BAU12
N-K7-OSL[9]	310	7 (43)	1.45±0.06	3.84±0.25	9.55±0.61	4.74±0.19	-	-	-	-	-	1 west	BAU14

[1] Field moisture; figures in parentheses indicate the complete sample saturation percentage. Ages calculated using 20 percent of the saturated moisture (that is, 7 (45) = 45×0.20 = 9).

[2] Analyses obtained using high-resolution gamma spectrometry (using a high purity germanium detector).

[3] Includes cosmic doses and attenuation with depth calculated using the methods of Prescott and Hutton (1994). Cosmic doses were about 0.17–0.30 Gy/ka.

[4] Number of replicated equivalent dose (DE) estimates used to calculate the total. Figures in parentheses indicate total number of measurements included in calculating the represented DE and age analyzed via single aliquot regeneration on feldspar grains.

[5] Defined as overdispersion of the DE values. Obtained using the R software program (R Core Team, 2020). Values >30 percent are considered to be poorly bleached or mixed sediments indicating that the minimum age model may be more appropriate than the central age model.

[6] Age for fine-grained 90–250-micrometer-sized K-feldspar (infrared stimulation with the sample heated to 160 °C and again at 230 °C; no anomalous fade). Exponential plus linear fit used on DE; uncertainty is given at the 2σ level.

[7] MAM, minimum age model; CAM, central age model.

[8] Samples are listed in stratigraphic order within each of the stratigraphic sections (trench 2, trench 1 east, trench 1 west).

[9] Analysis was halted on sample N-K7-OSL after obtaining the results from sample S-H14-OSL. The latter is stratigraphically above N-K7-OSL so N-K7-OSL can also be assumed to be beyond the range of IRSL dating.

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