Conf-910435--73

CONF-910435--73

DE91 011940

$^{40}Ar/^{39}Ar$ LASER FUSION AND K-Ar AGES FROM LATHROP WELLS, NEVADA, AND CIMA, CALIFORNIA: THE AGE OF THE LATEST VOLCANIC ACTIVITY IN THE YUCCA MOUNTAIN AREA

Brent D. Turrin* and Duane E. Champion,
U.S. Geological Survey
345 Middlefield Road
Menlo Park, CA 94025
(415) 329-5441 (415) 329-4671

*Also affiliated with the
Geochronology Center
Institute of Human Origins
2453 Ridge Road
Berkeley, CA 94709

I. ABSTRACT

K-Ar and $^{40}Ar/^{39}Ar$ ages from the Lathrop Wells volcanic center, Nevada, and from the Cima volcanic field, California, indicate that the recently reported 20-ka age estimate for the Lathrop Wells volcanic center is incorrect. Instead an age of 119±11 to 141±10 ka is indicated for the Lathrop Wells volcanic center. This age corrected is concordant with the ages determined by two independent isotopic geochronometric techniques and with the stratigraphy of surficial deposits in the Yucca Mountain region. In addition, paleomagnetic data and radiometric age data indicate only two volcanic events at the Lathrop Wells volcanic center that are probably closely linked in time, not as many as five as recently reported.

II. INTRODUCTION

Site-characterization studies of the proposed high-level-nuclear-waste repository at Yucca Mountain, Nev., require an evaluation of the potential hazards of possible future volcanic activity.[1,2] Knowledge of the chronology and eruptive volumes of the latest volcanic events in the region is essential for assessing the potential for such events during the required 10^4-yr isolation period. The most recent volcanic activity in the Yucca Mountain area occurred at the Lathrop Wells cinder cone (Figure 1), which is the focus of this study.

Wells et al.[3] suggested that at least three volcanic events have occurred at the Lathrop Wells volcanic center within the past 20 k.y. However, K-Ar, $^{40}Ar/^{39}Ar$, and paleomagnetic studies of the lava flows at the Lathrop Wells[4,5] and Cima volcanic centers indicate that the geomorphic and soil-profile evidence for the 20-ka age of the Lathrop Wells volcanic center is incorrectly calibrated. Furthermore, the results of these studies indicate that the ages of the Lathrop Wells and Cima A volcanic centers are approximately 130 and 119 ka, respectively. Moreover, paleomagnetic analyses of the lava flows and scoria deposits at the Lathrop Wells volcanic center indicate only two eruptive events, not three or more as suggested by Wells et al.[3]

A. Background Information

The Great Basin has been the site of extensive Cenozoic igneous activity that reflects spatial and temporal changes in the tectonic setting of western North America.[6-11] The most recent volcanism within the Great Basin has been dominated by transitional subalkaline (hypersthene normative) to alkaline undersaturated (nepheline normative) mafic lavas associated with crustal rifting.[12-18] K-Ar ages from these fields document intermittent volcanic activity during the past 8 m.y.[1,19-22]

Within the Yucca Mountain-Crater Flat area, several coalesced caldera complexes, associated with bimodal volcanism, were active during the Miocene (14 to 8 Ma).[3,4] Since then, as within the rest of the Great Basin, volcanism has been limited to small, isolated, subalkaline (hypersthene normative) to alkaline, undersaturated (nepheline normative) basaltic centers.[5,6] Radiometric ages from the Yucca Mountain-Crater Flat area indicate five periods of activity within the past 8 m.y.: at 3.8, 3.0-1.0, 0.3, and 0.1 Ma.[23] The recurrence interval for this activity ranges from 0.2 to 2.0 m.y. The most recent volcanic activity in the Yucca Mountain-Crater Flat area occurred at the Lathrop Wells cinder cone (Figure 2).

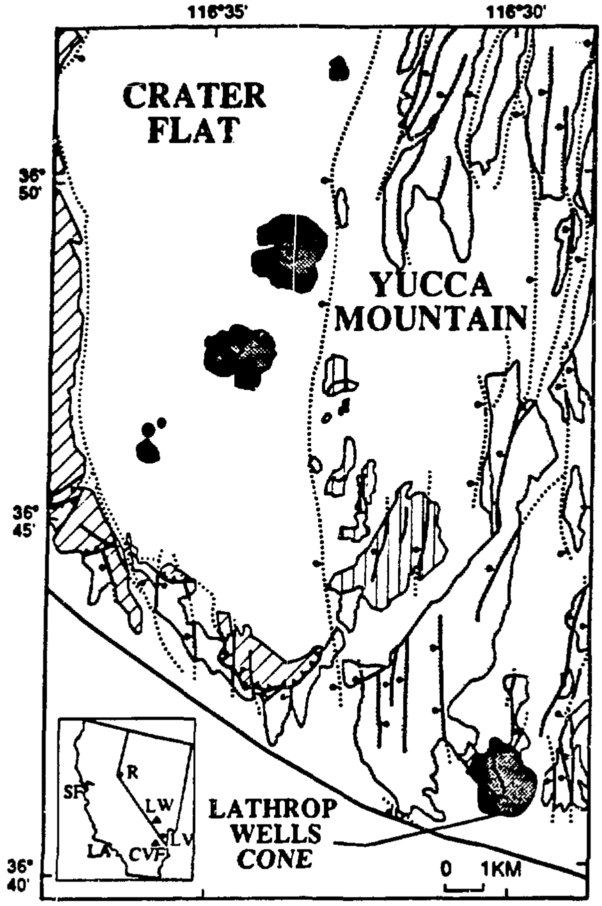

Figure 1
Southwestern Nevada, showing location of the Crater Flat-Yucca Mountain area. Light-gray areas, ash-flow tuffs; diagonal-lined areas, Paleozoic limestone; dark-shaded areas, Quaternary basalt flows and cinders; vertical-lined areas Tertiary basalt flows and cinders; unshaded-areas alluvium. Sawtoothed lines, detachment faults; teeth on upper plate. Inset, LV, Las Vegas; LW, Lathrop Wells; R, Reno; SF, San Francisco; LA, Los Angeles; CVF, Cima volcanic field.

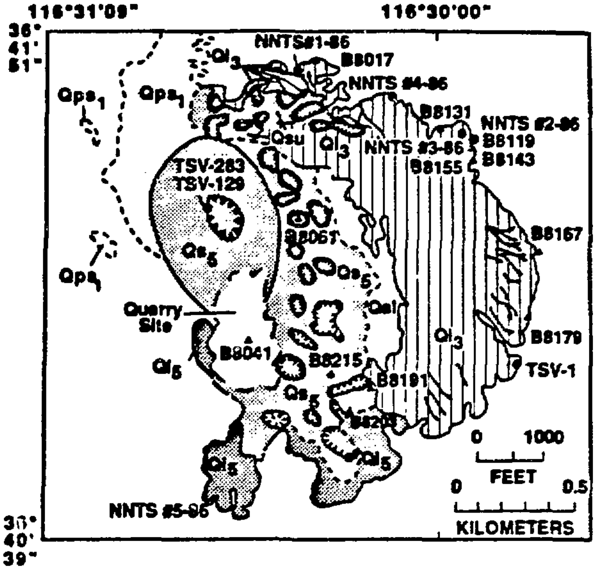

Figure 2
Generalized geologic map of the Lathrop Wells cinder cone and flow complex, showing locations of samples (triangles) for K-Ar and $^{40}Ar/^{39}Ar$ and paleomagnetic studies. Numbers correspond to samples listed in tables 1 and 2. Areas enclosed with hachured lines are scoria mounds composed of welded agglutinate and volcanic bombs; area enclosed with sawtoothed lines is crater at top of main scoria cone. Units: Ql_3, late basaltic lava flows; Ql_5 early basaltic lava flows; Qps_1 pyroclastic base-surge deposits; Qs_5, early scoria deposits; Qsu, undifferentiated scoria deposits, some mounds of which are contemporaneous with unit Ql_3. Unshaded areas, Quaternary alluvium.

The Lathrop Wells cone-and-flow complex overlies Quaternary alluvial sedimentary deposits and Miocene ash-flow and air-fall units of the Paintbrush Tuff. Flows of the Lathrop Wells volcanic center are dense alkali olivine basalt with vesicular tops and bottoms and exhibit block-flow and aa-flow morphologies. The basalt is sparsely porphyritic, with olivine phenocrysts and plagioclase microphenocrysts(?) in a fine-grained groundmass of plagioclase, olivine, clinopyroxene (Ti-augite), opaque minerals (Fe-Ti oxides), interstitial glass, and apatite.

III. $^{40}Ar/^{39}Ar$ DATING STUDIES

A. *Methods*

Samples of whole-rock basalt were coarsely crushed to 0.5- to 1-cm chips, which were then examined for xenolithic contamination. Chips that were apparently contamination free were crushed further, sieved (60 to 100 mesh), and washed. The samples were treated with a 10% HCl solution and a 5% HF solution in an ultrasonic bath for 10 and 5 minutes, respectively, and then rinsed in distilled water in an ultrasonic bath for 5 minutes. From this material, approximately 250 whole-rock grains were picked for irradiation.[a]

After irradiation, the samples were transferred to a copper sample holder and loaded into the extraction system for overnight bakeout at 250°C. All of the $^{40}Ar/^{39}Ar$ analyses are from the total fusion of individual whole-rock grains, approximately 0.3-0.5 mm in size. Fusion was induced by a 6-W continuous Ar-ion laser beam focused to a 2-3-mm spot, applied for 30-60 seconds. The gasses released from the grains were then scrubbed of reactive species, such as CO_2, CO, and N_2, by exposure to a 150°C Zr-Fe-V alloy getter for about 3 minutes. The remaining inert gases, principally Ar, were then admitted to the mass spectrometer, and the argon-isotopic ratios were determined. The mass spectrometer was operated in static mode, using automated data-collection procedures.[b]

B. $^{40}Ar/^{39}$ Results From the Lathrop Wells Volcanic Center

A total of 40 $^{40}Ar/^{39}Ar$ ages from the Lathrop Wells volcanic center yield weighted mean ages[25] of 183±21 ka for unit Ql_3, 138±54 ka for unit Ql_5, and 149±45 ka for unit Qs_5 (Table 1). Isochron and inverse-isochron ages, respectively, of 181±23 and 182±20 ka for unit Ql_3, 100±135 and 100±77 ka, for unit Ql_5, and 193±053 and 193± 49 ka for unit Qs_5 are concordant with the weighted-mean ages. Isochron data from the Lathrop Wells lava flows indicate an initial $^{40}Ar/^{36}Ar$ ratio equivalent to that of atmospheric Ar (295), discounting the presence of excess Ar. However, there is evidence of some xenolith contamination from the underlying rhyolite tuffs (see Table 1); the contaminated samples yield distinctly older ages. Turrin et al.[5] showed that a 0.03% contamination of the basalt by the underlying tuff would add only an additional 0.022 Ma to the age to the Lathrop Wells flow.

1. Discussion The $^{40}Ar/^{39}Ar$ ages from the Lathrop Wells volcanic center are concordant with the K-Ar ages for the units Ql_5 and Ql_3 of 116±13 ka and 133±10 ka, respectively, obtained by Turrin et al.[5]. We believe that the best estimate for the age of (composite) unit Qs_5/Ql_5 is the combined weighted mean of all the available radiometric ages, which is 119±11 ka. Similarly, we believe that the best estimate for the age of unit Ql_3 is the weighted mean of all the available radiometric ages, or 141±10 ka. From the reported analytical precision of the combined weighted-mean ages for unit Ql_3 and (composite) unit Qs_5/Ql_5, the absolute age difference between these units is no more than 29 ka.[c]

Directions of remanent magnetization from 27 sites at the Lathrop Wells volcanic center indicate two volcanic events;[4,5,26] these two directions have an angular difference of 4.7°. Rates of secular variation of the Earth's magnetic field suggest a minimum age difference of approximately 100 yr for these two events. Therefore, given the above limits for the age differences between unit Ql_3 and (composite) unit Qs_5/Ql_5, the Lathrop Wells volcanic center can be considered a monogenetic (single) volcanic event, for the purposes of volcanic-hazard/risk assessment.

The eruptive products from these two events are spatially separated and not in direct stratigraphic contact; however, the following stratigraphic sequence of volcanic events is inferred from field mapping:[26]

---

[a]In the $^{40}Ar/^{39}Ar$ dating method, separate rock grains are irradiated with fast neutrons to produce the reaction $^{39}K(n,p)^{39}Ar$. After irradiation, samples are heated to fusion. The Ar released during fusion is purified, and then isotopically analyzed with a mass spectrometer. The age is then calculated from the $^{40}Ar/^{39}Ar$ ratio after all interfering Ar-isotopes from atmospheric contamination and undesirable neutron reactions with Ca and K are corrected.[24] Samples for irradiation are encapsulated in aluminum cups and arranged in a known geometry along with mineral standards. The sample package is then put into a cadmium lined 2.5 cm diameter aluminium tube. Then the sample was irradiated 10 minutes at 8 MW in the hydraulic rabbit of the the Los Alamos National Laboratory Omega West reactor

[b]Argon extractions and isotopic analyses were conducted at the Institute of Human Origins, Berkeley Geochronology Center, using a fully automated $^{40}Ar/^{39}Ar$ laser-fusion-micro extraction system. This extraction system is in-line with a Mass Analyzer products MAP 215 extended geometry mass spectrometer. The effective radius of the MAP 215 is 21.5 cm and operates with a mass resolution between 500 to 600. Argon backgrounds for this instrument is typically: $^{40}Ar = \leq 2.0 \times 10^{-12}$ cc (STP); $^{39}Ar = \leq 5.0 \times 10^{-14}$ cc (STP); $^{37}Ar = \leq 7.0 \times 10^{-14}$ cc (STP); $^{36}Ar = \leq 2.0 \times 10^{-14}$ cc (STP). The detection limit is on the order of 1.0×10^{-14} cc (STP).

[c]The 95% confidence interval of 0.029 Ma is obtained from the following equation:

$$C.V. = 1.960*(s^2/n_1+s^2/n_2)^{1/2}$$

(see p. 120, Dalrymple and Lanphere).[27] This value (0.029 Ma) is the minimum difference in age between the two flows that should be detectable at the 95% confidence level.

TABLE 1. $^{40}Ar/^{39}Ar$ Age data from the Lathrop Wells volcanic center (Unit Ql_3)

L#	Sample	$^{40}Ar/^{39}Ar$	$^{37}Ar/^{39}Ar$	$^{36}Ar/^{39}Ar$	$^{40}Ar^*/^{39}Ar$	% $^{40}Ar^*$	$^{36}Ar_{Ca}$	$^{39}Ar_{Ca}$	Age±1σ (Ma)
				Flow Unit Ql_3					
1554-01	NNTS #1-86	40.939	1.7407	0.1369	0.6294	1.5	0.34	0.024	0.143±0.088
1554-02	NNTS #1-86	32.546	1.8868	0.1060	1.3692	4.2	0.48	0.26	0.311±0.078
1554-03	NNTS #1-86	98.908	1.8207	0.3342	0.2910	0.3	0.15	0.25	0.066±0.216
1554-04	NNTS #1-86	78.306	1.6280	0.2640	0.4112	0.5	0.17	0.23	0.093±0.212
Arithmetic mean:		0.153 ± 0.110	SEM:	±0.055					
Weighted mean:		0.217 ± 0.054							
$^{40}Ar/^{36}Ar$ vs $^{39}Ar/^{36}Ar$ isochron age:			0.351 ± 0.090	MSWD: 1.4	$^{40}Ar/^{36}Ar_i$: 291.2 ± 2.3				
$^{36}Ar/^{40}Ar$ vs $^{39}Ar/^{40}Ar$ isochron age:			0.354 ± 0.083	MSWD: 1.4	$^{40}Ar/^{36}Ar_i$: 291.2 ± 2.3				
1561-01	NNTS 2-88	111.8408	1.7041	0.3730	1.7409	1.6	0.12	0.12	0.392±0.215
1561-02	NNTS 2-88	105.3083	1.7763	0.3539	0.8614	0.8	0.14	0.13	0.194±0.186
1561-04	NNTS 2-88	101.6739	1.6126	0.3406	1.1622	1.1	0.13	0.12	0.261±0.232
Arithmetic mean:		0.282 ± 0.101	SEM:	±0.058					
Weighted mean:		0.274 ± 0.120							
$^{40}Ar/^{36}Ar$ vs $^{39}Ar/^{36}Ar$ isochron age:			-1.25 ± 2.00	MSWD: 0.79	$^{40}Ar/^{36}Ar_i$: 314.4 ± 25				
$^{36}Ar/^{40}Ar$ vs $^{39}Ar/^{40}Ar$ isochron age:			-1.25 ± 1.19	MSWD: 0.79	$^{40}Ar/^{36}Ar_i$: 314.4 ± 25				
1553-01	NNTS #3-86	144.06	1.5909	0.4851	0.8317	0.6	0.09	0.12	0.187±0.243
1553-02	NNTS #3-86	200.13	1.7230	0.6761	0.4884	0.2	0.07	0.13	0.110±0.327
1553-03	NNTS #3-86	87.367	1.7964	0.2955	0.1875	0.2	0.16	0.13	0.042±0.185
1553-04	NNTS #3-86	50.708	1.8269	0.1699	0.6425	1.3	0.29	0.13	0.145±0.088
1553-11	NNTS 3-86	35.947	1.8698	0.1200	0.6394	1.8	0.42	0.14	0.144±0.084
1553-13	NNTS 3-86	49.092	1.9398	0.1647	0.5612	1.1	0.32	0.14	0.126±0.082
Arithmetic mean:		0.126 ± 0.048	SEM:	±0.020					
Weighted mean:		0.133 ± 0.046							
$^{40}Ar/^{36}Ar$ vs $^{39}Ar/^{36}Ar$ isochron age:			0.142 ± 0.057	MSWD: 0.39	$^{40}Ar/^{36}Ar_i$: 295.4 ± 0.9				
$^{36}Ar/^{40}Ar$ vs $^{39}Ar/^{40}Ar$ isochron age:			0.147 ± 0.052	MSWD: 0.39	$^{40}Ar/^{36}Ar_i$: 295.4 ± 0.9				
1552-01	NNTS 4-86	12.901	1.8683	0.0416	0.7661	5.9	1.21	0.14	0.172±0.039
1552-02	NNTS 4-86	36.488	1.7906	0.1225	0.4391	1.2	0.39	0.13	0.099±0.196
1552-04	NNTS 4-86	13.417	1.7257	0.0427	0.9372	7	1.09	0.13	0.211±0.041
1557-01	NNTS #4-86	29.148	1.0829	0.0963	0.7826	2.7	0.3	0.15	0.177±0.212
1557-02	NNTS #4-86	24.048	1.0834	0.0795	0.6506	2.7	0.37	0.15	0.147±0.134
1557-03	NNTS #4-86	69.949	1.3375	0.2327	1.3022	1.9	0.15	0.19	0.294±0.379
155, 04	NNTS #4-86	42.058	0.8296	0.1409	0.4958	1.2	0.16	0.12	0.112±0.282
Arithmetic mean:		0.173 ± 0.066	SEM:	±0.025					
Weighted mean:		0.187 ± 0.027							
$^{40}Ar/^{36}Ar$ vs $^{39}Ar/^{36}Ar$ isochron age:			0.175 ± 0.034	MSWD: 0.85	$^{40}Ar/^{36}Ar_i$: 295.8 ± 1.7				
$^{36}Ar/^{40}Ar$ vs $^{39}Ar/^{40}Ar$ isochron age:			0.175 ± 0.032	MSWD: 0.85	$^{40}Ar/^{36}Ar_i$: 295.9 ± 1.7				
•Arithmetic mean:		**0.171 ± 0.087**							
•SEM:		**± 0.020**							
•Weighted mean:		**0.183 ± 0.021**							
•$^{40}Ar/^{36}Ar$ vs $^{39}Ar/^{36}Ar$ isochron age:			***0.181 ± 0.023***		**MSWD: 0.96**		**$^{40}Ar/^{36}Ar_i$: 295.3 ± 0.5**		
•$^{36}Ar/^{40}Ar$ vs $^{39}Ar/^{40}Ar$ isochron age:			**0.182 ± 0.020**		**MSWD: ^97**		**$^{40}Ar/^{36}Ar_i$: 295.3 ± 0.5**		
Comtaminated Samples									
1553-12	*NNTS 3-86*	*6.7560*	*0.3146*	*0.0087*	*4.2112*	*62.3*	*0.97*	*0.02*	*0.947±0.024*
1553-10	*NNTS 3-86*	*47.0300*	*1.8546*	*0.1529*	*2.0101*	*4.3*	*0.33*	*0.014*	*0.452±0.086*
-1552-03	*NNTS 4-86*	*28.6602*	*1.8936*	*0.0907*	*1.9989*	*7*	*0.56*	*0.14*	*0.450±0.073*
1561-03	*NNTS 2-88*	*118.9615*	*1.7781*	*0.3914*	*3.4504*	*2.9*	*0.12*	*0.13*	*0.776±0.162*

•Values calculated from all data except those that shown in italics; J = 0.000125; $^{36}Ar_{Ca}/^{37}Ar_{Ca}$ = 0.000269; $^{39}Ar_{Ca}/^{37}Ar_{Ca}$ = 0.000729; $^{40}Ar_K/^{39}Ar_K$ = 0.002

1) Formation of a northwest-trending fissure complex composed of local vents of irregular scoria mounds and agglutinate (unit Qs_5, figure 2), accompanied by eruption of small-volume block and aa flows (unit Ql_5, figure 2). The last phases of this eruption produced the main scoria cone.

2) Subsequent volcanic activity along a small, east-west-trending fissure system, producing a lava flow (unit Ql_3, figure 2) that flowed to the east and south around the older flow-and-vent complex.

TABLE 1. continued (Unit Ql_5 and Unit Qs_5)

L#	Sample	$^{40}Ar/^{39}Ar$	$^{37}Ar/^{39}Ar$	$^{36}Ar/^{39}Ar$	$^{40}Ar^{*}/^{39}Ar$	% $^{40}Ar^{*}$	$^{36}Ar_{Ca}$	$^{39}Ar_{Ca}$	Age ±1σ (Ma)
Flow Unit Ql_5									
1555-10	NNTS 5-86	89.8753	1.8679	0.303	0.4987	0.6	0.17	0.14	0.112±0.090
1555-11	NNTS 5-86	116.1837	1.8053	0.3921	0.4739	0.4	0.12	0.13	0.107±0.155
1555-12	NNTS 5-86	247.2218	1.8554	0.8336	1.0458	0.4	0.06	0.14	0.235±0.521
1555-13	NNTS 5-86	82.8124	1.7724	0.2773	1.0111	1.2	0.17	0.13	0.228±0.200
1555-01	NNTS 5-86	119.1635	1.6254	0.4012	0.7398	0.6	0.11	0.23	0.168±0.318
1555-02	NNTS 5-86	71.7858	1.7913	0.2437	-0.0886	-0.1	0.20	0.25	-0.020±0.263
1555-03	NNTS 5-86	221.2334	1.4189	0.7436	1.6251	0.7	0.05	0.02	0.368±0.644
1555-04	NNTS 5-86	79.6465	1.6652	0.2675	0.7251	0.9	0.17	0.23	0.164±0.089

Arithmetic mean 0.170 ± 0.114
SEM ± 0.040
Weighted Ave. 0.138 ± 0.054
$^{40}Ar/^{36}Ar$ vs $^{39}Ar/^{36}Ar$ isochron age: 0.100 ± 0.135 MSWD: 0.22 $^{40}Ar/^{36}Ar_i$: 296.2 ± 1.7
$^{36}Ar/^{40}Ar$ vs $^{39}Ar/^{40}Ar$ isochron age: 0.100 ± 0.077 MSWD: 0.22 $^{40}Ar/^{36}Ar_i$: 296.2 ± 1.7

L#	Sample	$^{40}Ar/^{39}Ar$	$^{37}Ar/^{39}Ar$	$^{36}Ar/^{39}Ar$	$^{40}Ar^{*}/^{39}Ar$	% $^{40}Ar^{*}$	$^{36}Ar_{Ca}$	$^{39}Ar_{Ca}$	Age ±1σ (Ma)
Scoria Unit Qs_5									
1569-01	223-1	132.6036	1.5995	0.4491	0.0326	0.0	0.10	0.12	0.007±0.374
1569-02	223-1	85.5278	1.5849	0.2873	0.7548	0.9	0.15	0.12	0.170±0.180
1569-03	223-1	66.2619	1.6591	0.2224	0.6693	1.0	0.02	0.12	0.151±0.197
1569-04	223-1	82.4773	1.5316	0.2761	1.0136	1.2	0.15	0.11	0.228±0.165

Arithmetic mean 0.139 ± 0.094
SEM ± 0.047
Weighted Ave. 0.175 ± 0.100
$^{40}Ar/^{36}Ar$ vs $^{39}Ar/^{36}Ar$ isochron age: 0.243 ± 0.298 MSWD: 0.34 $^{40}Ar/^{36}Ar_i$: 294.3 ± 4.9
$^{36}Ar/^{40}Ar$ vs $^{39}Ar/^{40}Ar$ isochron age: 0.243 ± 0.209 MSWD: 0.34 $^{40}Ar/^{36}Ar_i$: 294.3 ± 5.0

L#	Sample	$^{40}Ar/^{39}Ar$	$^{37}Ar/^{39}Ar$	$^{36}Ar/^{39}Ar$	$^{40}Ar^{*}/^{39}Ar$	% $^{40}Ar^{*}$	$^{36}Ar_{Ca}$	$^{39}Ar_{Ca}$	Age ±1σ (Ma)
1557-10	211-1	28.4922	1.311	0.0947	0.619	2.2	0.37	0.1	0.139±0.081
1557-11	211-1	56.9906	1.1536	0.1904	0.8074	1.4	0.16	0.08	0.182±0.125
1557-12	211-1	164.499	1.4253	0.5568	0.0878	0.1	0.07	0.10	0.020±0.285
1557-13	211-1	46.9586	1.3372	0.1572	0.6138	1.3	0.23	0.10	0.138±0.080

Arithmetic mean 0.120 ± 0.070
SEM ± 0.035
Weighted Ave. 0.142 ± 0.051
$^{40}Ar/^{36}Ar$ vs $^{39}Ar/^{36}Ar$ isochron age: 0.185 ± 0.054 MSWD: 0.21 $^{40}Ar/^{36}Ar_i$: 294.2 ± 0.9
$^{36}Ar/^{40}Ar$ vs $^{39}Ar/^{40}Ar$ isochron age: 0.185 ± 0.054 MSWD: 0.21 $^{40}Ar/^{36}Ar_i$: 294.2 ± 0.9

Arithmetic mean 0.129 ± 0.077
SEM ± 0.027
Weighted Ave. 0.149 ± 0.045
$^{40}Ar/^{36}Ar$ vs $^{39}Ar/^{36}Ar$ isochron age: 0.193 ± 0.053 MSWD: 0.37 $^{40}Ar/^{36}Ar_i$: 294.3 ± 0.8
$^{36}Ar/^{40}Ar$ vs $^{39}Ar/^{40}Ar$ isochron age: 0.193 ± 0.049 MSWD: 0.34 $^{40}Ar/^{36}Ar_i$: 294.4 ± 0.9

*Arithmetic mean 0.150 ± 0.096
*SEM ± 0.058
*Weighted mean 0.144 ± 0.035
*$^{40}Ar/^{36}Ar$ vs $^{39}Ar/^{36}Ar$ isochron age: 0.150 ± 0.048 MSWD: 0.75 $^{40}Ar/^{36}Ar_i$: 295.1 ± 0.7
*$^{36}Ar/^{40}Ar$ vs $^{39}Ar/^{40}Ar$ isochron age: 0.151 ± 0.033 MSWD: 0.75 $^{40}Ar/^{36}Ar_i$: 295.1 ± 0.7

On the basis of cinder-cone morphology and soil-stratigraphic studies, it was recently suggested that three additional volcanic events have occurred at the Lathrop Wells volcanic center within the past 20 ka.[3] This assertion is based on three experimental radiocarbon ages on rock varnish from the Cima A cone (Black Tank Wash cone)[28,29] in the Cima volcanic field, Calif., and on a one-to-one geomorphic comparison of the Lathrop Wells cone with the Cima A cone.

The evidence cited for three additional volcanic events at Lathrop Wells is found in deposits of eolian sand and silt and lapilli-size tephra, supported by a matrix of eolian sand and silt. These deposits occur immediately adjacent to the main cinder cone and overlie unit Qs_5. An alternative interpretation, proposed here and by Turrin et al.,[4,5] is that these deposits are not volcanogenic in origin but are cone-apron deposits derived from the nearby cone slope. Moreover, the

TABLE 2: $^{40}Ar/^{39}Ar$ data from the Cima A flow

L #	Sample #	$^{40}Ar/^{39}Ar$	$^{37}Ar/^{39}Ar$	$^{26}Ar/^{39}Ar$	$^{40}Ar^{*}/^{39}Ar$	%$^{40}Ar^{*}$	Age±1σ (Ma)
2713-01	Cima A	85.3992	2.0410	0.2872	0.7094	0.8	0.149±0.305
2713-02	Cima A	35.5368	0.8002	0.1177	0.8211	2.3	0.172±0.281
Arithmetic mean		0.160±0.017					
SEM:		±0.012					
Weighted mean:		0.161±0.207					
2714-01	Cima A	27.0856	2.0160	0.0898	0.7264	2.7	0.152±0.090
2714-02	Cima A	39.2833	2.0136	0.1322	0.3884	1.0	0.081±0.208
2714-03	Cima A	23.7434	1.9917	0.0788	0.6041	2.5	0.127±0.124
2714-04	Cima A	22.5236	2.0924	0.0752	0.4784	2.1	0.100±0.125
Arithmetic mean		0.115±0.031					
SEM:		±0.015					
Weighted mean:		0.128±0.060					
2715-01	Cima A	39.4443	3.9410	0.1321	0.7382	1.9	0.155±0.500
2715-02	Cima A	33.8861	3.2356	0.1105	1.5086	4.4	0.316±0.250
2715-03	Cima A	38.1402	2.1275	0.1281	0.4591	1.2	0.096±0.078
2715-04	Cima A	29.0807	1.9724	0.0975	0.4232	1.5	0.089±0.244
Arithmetic mean		0.164±0.106					
SEM:		±0.053					
Weighted mean:		0.114±0.070					
2716-04	Cima A	29.8937	2.2375	0.0999	0.5429	1.8	0.114±0.409
2716-05	Cima A	22.3883	1.5900	0.0745	0.5059	2.3	0.106±0.071
Arithmetic mean		0.110±0.005					
SEM:		±0.004					
Weighted mean:		0.106±0.070					
*Arithmetic mean		0.138±0.063					
*SEM:		±0.018					
*Weighted mean:		0.119±0.038					

*$^{40}Ar/^{36}Ar$ versus $^{39}Ar/^{36}Ar$ isochron age: 0.114±0.099; MSWD: 0.1; $^{40}Ar/^{36}Ar_I$: 295.7±4.5

*$^{36}Ar/^{40}Ar$ versus $^{39}Ar/^{40}Ar$ isochron age: 0.114±0.067; MSWD: 0.1; $^{40}Ar/^{36}Ar_I$: 295.7±4.5

*Values calculated from all data; J=0.000125; $^{36}Ar_{Ca}/^{37}Ar_{Ca}$=0.000269; $^{39}Ar_{Ca}/^{37}Ar_{Ca}$=0.000729; $^{40}Ar_K/^{39}Ar_K$=0.002. The reference standard is mmhb, using an age of 520.4 Ma.

20-ka age suggested by Wells et al.[3] is not supported by the K-Ar and $^{40}Ar/^{39}Ar$ data from Lathrop Wells; instead, an age of 119 ± 11 to 141 ± 10 ka is indicated for the Lathrop Well volcanic center.[4]

In addition, recent paleomagnetic and $^{40}Ar/^{39}Ar$ studies of the Cima volcanic field suggest that the 20-ka age estimate for Lathrop Wells is incorrect. A flow in the Cima volcanic field, the Cima I flow, which has been well dated by the K-Ar method at 110 ± 10 ka,[19,d] has the same direction of remanent magnetization as the Cima A flow. This shared direction is unusual in that it has a very shallow inclination and somewhat easterly declination relative to the Earth's average dipole direction; Using the statistical analyses of Bogue and Coe[30] the direction of remanent magnetization of both the A and I cones indicate that the probability of A and I being random events in time is 2 parts in 10^4, strongly suggesting that the Cima A and I events are similar in age. If, as the paleomagnetic data indicate, the Cima A and I cones are similar in age; then the age of the Cima A flow should also be approximately 100 ka. A total of 12 $^{40}Ar/^{39}Ar$ ages were determined on the Cima A flow to test this model.

C. $^{40}Ar/^{39}Ar$ Results From the Cima A flow

A weighted-mean age of 119 ± 28 ka was obtained from the 12 $^{40}Ar/^{39}Ar$ analyses (Table 2). Isochron and inverse-isochron ages of 114±99 and 114±67 ka, respectively, are concordant with the weighted-mean age (Table 2). Isochron data from the Cima A lava flows indicate an initial $^{40}Ar/^{36}Ar$ ratio equivalent to that of atmospheric Ar, discounting the presence of excess Ar.

---

[d] The K-Ar ages on the Cima I cone flows are; 130 ± 30, 140 ± 40, 60 ± 30 90 ± 70, and 130 ± 60 ka. These ages yield and weighted-mean of 110 ± 10 ka.

1. Discussion. The above-mentioned data indicate that the geomorphic and soil-profile evidence for the 20-ka age of the Lathrop Wells volcanic center is incorrectly calibrated. In addition, other sources of radiometric data support the K-Ar and $^{40}Ar/^{39}ArAr$ age of 120 to 140 ka for the Lathrop Wells volcanic center:

1. Uranium-thorium ages on alluvial deposits that contain primary and reworked cinders, 3 to 4 km northwest of the Lathrop Wells volcanic center and aligned with the direction of elongation of the cinder cone. These ages require that the cinders were deposited between 240 ± 30 and 145 ± 25 ka.[31,32]

2. An uranium-thorium age of 150 (-30/+40) ka on the Lathrop Wells lava flows (Mike Morrel, written and oral communication).

3. ^{36}Cl surface-exposure ages on volcanic bombs, which are minimum ages because of spalation of the volcanic bomb's original surface. These ages indicate that the volcanic activity preceded 105-69 ka (Fred Phillips, oral communication).

IV. CONCLUSIONS

In conclusion, paleomagnetic data indicate only two volcanic events at the Lathrop Wells volcanic center that are probably closely linked in time. The combined weighted-means of the K-Ar and $^{40}Ar/^{39}Ar$ ages indicate that these two volcanic events occurred at 119±11 to 141±10 ka. For the purpose of volcanic-hazard/risk assessment, Lathrop Wells can be considered a monogenetic (single) volcanic event, which occurred 130 ka. This age for the Lathrop Wells volcanic center is concordant with the ages determined by two independent isotopic geochronometers and with the chronology and stratigraphy of the surficial deposits in the Yucca Mountain region. The 20-ka age for the Lathrop Wells volcanic center, obtained by Wells et al.[3] on the basis of geomorphic and soil-profile evidence, apparently is incorrectly calibrated.

V. REFERENCES

1. B.M. CROWE and W.J. CARR, "Preliminary assessment of the risk of volcanism at a proposed nuclear waste repository in the southern Great Basin" *U.S. Geol. Sur. O-F Rept. 80-357*, 15.(1980).

2. B.M. CROWE, S. SELF, D. VANIMAN, R. Amos, and F. PERRY, "Aspects of potential magmatic disruption of a high level radioactive waste repository in southern Nevada" *Jour. of Geol., 91*, 259-276.(1983)

3. S.G. WELLS, L.D. McFADDEN, C.E. RENAULT, and B.M. CROWE, "Geomorphic assessment of late Quaternary volcanism in the Yucca Mountain area, southern Nevada: Implications for the proposed high-level radioactive waste repository" *Geol., 18*, 549-553.(1990).

4. B.D. TURRIN, D.E. CHAMPION, and R.J. FLECK, "$^{40}Ar/^{39}Ar$ laser-fusion ages from the Lathrop Wells volcanic center: Implications for volcanic hazards at the Yucca Mountain radioactive waste repository site, southwestern Nevada" (in press).

5. B.D.TURRIN, D.E CHAMPION, R.J. FLECK, G.H. CURTIS, R.E. DRAKE, 1990, "K-Ar ages and paleomagnetic directions from the Lathrop Wells volcanic center, southwestern Nevada: No evidence for polycyclic volcanism" *U.S. Geol. Surv. Bull.* (in press).

6. R.L. ARMSTRONG, E.B. EKREN, E.H. McKEE, and D.C. NOBLE, "Space-time relations of Cenozoic silicic volcanism in the Great Basin of the western United States" *Amer. Jour. Sci. 267*, 478-490.(1969).

7. E.H. McKEE, "Tertiary igneous chronology of the Great Basin of the western United States; implications for tectonic models" *Geol. Soc. Amer. Bull. 82*, 3497-3502 (1971).

8. R.L. CHRISTIANSEN, and P.W. Lipman, "Cenozoic volcanism and plate tectonic evolution of the western United States. II. Late Cenozoic: *Philos. Trans. of the Royal Soc. of Lond, Series A. 271*, 249-284.(1972).

9. P.W. LIPMAN, H.J. PROSTKA, and R.L. CHRISTIANSEN, "Cenozoic volcanism and Plate-tectonic evolution of the Western United States. I. Early and Middle Cenozoic" *Philos. Trans. of the Royal Soc. of Lond, Series A. 271*, 217-248 (1972).

10. D.C. NOBLE, "Some observations on the Cenozoic volcano-tectonic evolution of the Great Basin, western United States" *Earth Plan. Sci. Lett., 17*, 142-150 1972.

11. P.W. LIPMAN, "Cenozoic volcanism in the Western United States: Implications for continental tectonics", *in Studies in geophysics: Continental tectonics* Wash., D.C., Natil. Acad. Press, 161-174 (1980).

12 W.P. LEEMAN and J.W. RODGERS, "Late Cenozoic alkali-olivine basalts of the Basin-Range Province, U.S.A." *Contrib. to Min. Petr., 25, 1,* 1-24.(1970).

13. R.G. LUEDKE AND R.L. SMITH, "Map showing distribution, composition, and age of Late Cenozoic volcanic centers in Arizona and New Mexico" *U.S.G.S. Misc. Geol. Inv. Series Map, I-1091-A,* scale 1:1,000,000 (1978a).

14. R.G. LUEDKE AND R.L. SMITH, "Map showing distribution, composition, and age of Late Cenozoic volcanic centers in Colorado, Utah, and Southwestern Wyoming" *U.S.G.S. Misc. Geol. Inv. Series Map, I-1091-B,* scale 1:1,000,000 (1978b)

15. R.G. LUEDKE AND R.L. SMITH, "Map showing distribution, composition, and age of Late Cenozoic volcanic centers in California and Nevada" *U.S.G.S. Misc. Geol. Inv. Series Map, I-1091-C,* scale 1:1,000,000 (1981).

16. R.G. LUEDKE AND R.L. SMITH, "Map showing distribution, composition, and age of Late Cenozoic volcanic centers in Oregon and Washington" *U.S.G.S. Misc. Geol. Inv. Series Map, I-1091-D,* scale 1:1,000,000 (1982).

17. R.G. LUEDKE AND R.L. SMITH, "Map showing distribution, composition, and age of Late Cenozoic volcanic centers in Idaho, Western Montana, West-Central South Dakota, and Northwestern Wyoming" *U.S.G.S. Misc. Geol. Inv. Series Map, I-1091-A,* scale 1:1,000,000 (1983).

18. E.H. McKEE and D.C. NOBLE, "Tectonic and magmatic development of the Great Basin of western United States during late Cenozoic time" *Mod. Geol., 10,* 39-49 (1986).

19. B.D. TURRIN, J.C. DOHRENWEND, R.E. DRAKE, and G.H. CURTIS, "K-Ar ages from the Cima volcanic field, eastern Mojave desert, California" *Isoch./West, .44,* 9-16 (1985).

20. B.D. TURRIN, J.C. DOHRENWEND, "K-Ar ages of basaltic volcanism in the Lunar Crater volcanic field, northern Nye County, Nevada: Implications for Quaternary tectonism in the central Great Basin" *Geol. Soc. Amer. Abst. Prog.,16, 6,* 679 (1984).

21. B.D. TURRIN, P.R. RENNE, and J.C. DOHRENWEND, "Temporal trends in the chemical evolution of Megacryst bearing, subalkaline-alkaline basaltic lavas from the Lunar Crater volcanic field, Nye County, Nevada" *Geol. Soc. Amer. Abst. Prog.,17, 6,* 414 (1985).

22. B.D. TURRIN, and A. GILLESPIE, "K/Ar ages of basaltic volcanism of the Big Pine volcanic field, California: Implications for glacial stratigraphy and neotectonics of the Sierra Nevada" *Geol. Soc. Amer. Abst. Prog.,18, 6,* (1986).

23. B.D. TURRIN unpublished data.

24. N.R. BRENTON "Corrections for interfering isotopes in the $^{40}Ar/^{39}Ar$ dating method" *Earth Plan. Sci. Let., 8, 427-433* (1971).

25. J.R. TAYLOR *An introduction of error analysis, the study of uncertainties in physical measurements* Oxford Univ. Press (1982)

26. B.M. CROWE, C. HARRINGTON , L.D., McFADDEN, F.V. PERRY, S.G.WELLS, B.D. TURRIN, D.E. CHAMPION "Preliminary Geologic Map of the Lathrop Wells Volcanic Center" *LA-UR-44-4155* Los Alamos Natl .Lab. (1988)

27. G.B. DALRYMPLE and M.A. LANPHERE *Potassium-argon dating* W. H. Freeman Co San Fran. (1969)

28. R.I. DORN "Geomorphological interpretation of rock varnish inthe Mojave Desert", *in Dohrenwend, J. C., ed., Surficial geology of the eastern Mojave Desert, California Geol. Soc. Amer* Ann. Mtg Guidebook, Reno, Nevada, (1984)

29. R.I. DORN, D.B.BAMFORTH, T.A. CAHILL, J.C. DOHRENWEND, B.D. TURRIN, D.J. DONAHUE, A.J.T. JULL, A. LONG, M.E. MACKO, E.B. WEIL, D.S. WHITLEY, and T.H. ZABEL, "Cation-ratio and accelerator radiocarbon dating of rock varnish on Mojave artifacts and landforms," *Sci., 231,* 830-833.(1986)

30 S.W. BOGUE and R.S. COE, "Paleomagnetic correlation of Columbia River basalt flows using secular vartion," *Jour. Geophys. Res., 86,* 11883-11897 (1981).

31. W.C.SWADLEY, D.L. HOOVER, AND J.N. ROSHOLT, "Preliminary report on Late Cenozoic faulting and stratigraphy in the vicinity of Yucca Mountain, Nye County, Nevada" *U.S.G.S. O-F Rpt 84-788,* (1984).

32. B.J SZABO. W.J. CARR, AND W.C. GOTTSCHALL, "Uranium-thorium dating of Quaternary carbonate accumulations in the Nevada Test Site region, southern Nevada," *U.S.G.S. O-F Rpt 81-119,* 35 (1981).