Measuring the Age of the Lathrop Wells Volcanic Center at Yucca Mountain

B. Turrin et al. (1) argue that conventional K-Ar and 40Ar/39Ar age determinations and paleomagnetic data provide a definitive age assignment of approximately 136 ka (thousand years ago) to 141 ka for the Lathrop Wells volcanic center with an error of less than 10,000 years. This conclusion is tendered despite replicate age determinations that extend over almost three orders of magnitude. Turrin (1) and other also conclude (2, 3) that the Lathrop Wells volcanic center is a simple monogenic center, and so revert to an earlier interpretation (4, 5) that was made before studies revealed the complexity of the volcanic stratigraphy (6–9).

The geologic map and stratigraphic nomenclature of the Lathrop Wells volcanic center presented by Turrin et al. (1) were extracted and modified without apparent reference to the original publication of these field studies (10). Stratigraphic units separated by soil-bounded unconformities were modified or not accounted for in their interpretation (6, 8). These unconformities indicate a hiatus in eruptive activity of significantly sustained time (at least 10^3 years) and allow the development of soil profiles that are similar to radiocarbon dated soil sequences within arid regions of the southwestern United States (11–14). Without complete stratigraphic sampling, statements regarding the complexity of Lathrop Wells eruptive history offer only an oversimplified stratigraphy. Turrin et al. state that their combined flow and scoria unit Q1/Qsu [(1), figure 1] is younger than the flows and scoria of Q1/Qsu, but they report without any implications a weighted mean of 141 ± 9 ka for the younger rocks and an age of 136 ± 8 ka for the older rocks. In comparison, recently reported thermoluminescence age determination (8) of a buried soil between tephra deposits of their unit Q1s is 9.9 ± 0.7 ka. Cosmogenic 3He age determinations (8) of surface-exposed volcanic bombs of unit Q1s yield ages of 23 ± 4 ka to 44 ± 13 ka. Flows that stratigraphically lie below these tephra and bomb deposits yield a thermoluminescence date of 24.5 ± 2.5 ka for baked soils that underly unit Q1s (8) and yield a cosmogenic 3He date of 64 ± 6 ka on exposed bedrock of unit Q1s (8). The weighted means of the K-Ar and 39Ar/40Ar age determinations have insufficient precision to constrain the age of these late Quaternary volcanic flows and tephra separated by soil-bounded unconformities.

Our major criticism of the K-Ar and 40Ar/39Ar age determinations of the volcanic center made by Turrin et al. is of their method of averaging the age determinations, not of their analytical methods. If the data are compiled as a conventional mean, large 1-sigma errors are obtained that overlap and are consistent with the results of every other chronology method used to assess the age of the Lathrop Wells center (8). The use of a weighted mean gives age assignments with unrealistically small errors, in that the group ages date from 20 ka to 947 ka. Yet Turrin et al. do not explain why the weighted mean might be more reliable than the conventional mean, nor do they test the validity of the weighted mean method. Our specific concerns are as follows:

1) The age determinations are positively skewed with a median larger than the mean, which indicates influence of the mean by older ages.

2) Turrin et al. did not examine the data set with conventional tests for outliers. Evaluation of their data shows that outliers are present where outliers are defined to be more than 1.5 times the interquartile range. The data set is nongaussian, with inclusion of the outliers, and therefore is probably not suitable for description with a weighted mean.

3) Four age determinations were discarded by Turrin et al. in the weighted mean data reduction because of "contamination." No systematic criteria were presented for doing so, and recalibration of the data set (1) with these four age determinations yields significantly older values of the weighted mean with larger uncertainty.

4) The regression plots in (1), figure 2 show the presence of influential cases which should have been identified to check for errors and suitability to the data set. The influential cases could strongly control the y-intercept, the values of which are used by Turrin et al. to argue against the presence of excess Ar.

5) There was no discussion of data errors other than analytical in (1). Because the 40Ar/39Ar analyses were of the matrix of fine-grained basalt (15), there is a possible problem of recoil of 39Ar which could give anomalous older ages (16, 17).

6) Conventional, whole rock K-Ar data are averaged (1) with the 40Ar/39Ar to establish final values for the weighted means. However, the whole rock data are not listed in (1). Thus it is not clear whether the data set belongs to the same population as the 40Ar/39Ar data.

We conclude that the reduction of the data set of Turrin et al. with a weighted mean method is unsupported at best and may be invalid if all sources of variance in the data set are not analytical. Their conclusion that the soil and geomorphic studies of the Lathrop Wells center are miscalibrated is not supported by the data.

Turrin et al. argue that an angular difference of 4.7° between mean directions of remanent magnetization indicates that the dates of Lathrop Wells eruptive events differ by 100 years. However, angular differences between two paleomagnetic data sets can only be used at best to infer a minimum age between stratigraphic units. The geomagnetic field at Lathrop Wells could have occupied the observed directions numerous times during the Quaternary and thus could equally represent eruptions separated by 100, 10,000, 100,000 years, or 1 million years (Ma). For example, Champion (3) notes that the flow mean paleomagnetic directions from adjacent 3.7 Ma and 1.1 Ma flows in Crater Flat are "similar . . . but cannot be confused because they have different K-Ar ages and stratigraphic positions." Turrin et al. rely on these stratigraphic relations in neighboring Crater Flat, but not at Lathrop Wells (6–8).

The conclusion (1) that the paleomagnetic data of Q1s scoria and Q1f flows fall into only two statistically distinguishable groups is unfounded. First, Turrin et al. apparently did not sample or analyze several mapped units. Their paleomagnetic record is incomplete (1–3, 18), and thus their conclusions are premature. Second, the paleomagnetic data for the 27 sites with flows and spatter and for the 40 core samples from the scoria cone rim are not presented in (1) or in their supporting papers (2, 3, 18). These data are necessary to assess confidently the statistical validity of their proposed field magnetic groups. Third, on the basis of matching directions of remanent magnetization, Turrin et al. infer (1) that all scoria and spatter deposits of unit Q1s have the same direction as the main scoria cone, but do not note that this conclusion requires the rejection of paleomagnetic data. One-third of 16 reported samples from bombs of the main scoria cone unit (unit Q1s) were rejected because discordant directions of remanent magnetization revealed apparent "cone slope slumping" (18). These rejected data contradict their statement (1) that 40 core samples from "bedded" bombs on the rim yield a direction "identical" to that of the flanking spatter cone. Fourth, the conclusion that the Lathrop Wells has a simple eruptive history (1) apparently contradicts an earlier interpretation by Turrin et al. that the center is polycyclic with "a more complex volcanic history than previously thought" (18). This interpretation is based on K-Ar data not presented in (1) and paleomagnetic data that indicate a minimum of 100
years between eruptions.

A simple eruptive history, together with an older age of the most recent volcanic activity in the region, could justify an assessment of decreased volcanic risk for Yucca Mountain. The polycyclic model, by contrast, requires the consideration of possible additional eruptions within the 10,000-year isolation period required for a potential radioactive waste repository. The latter model could lead to an assessment of increased potential of dispersal of such waste to the environment should a future volcanic eruption compromise the site.

Finally, the simplified volcanic history of Turrin et al. (1) apparently was not tested by geochemical studies. Recent studies by Perry and Crowe (9, 19) at Lathrop Wells center demonstrate that geochemical variations between the main scoria cone and flanking spatter deposits could not result from fractional crystallization of a single magma batch of mixing of separate batches. They conclude (9, 19) that the geochemical data are consistent with the interpretation that separate magma batches formed a complex polycyclic volcano characterized by scoria and spatter deposits that were separated in time by a prolonged hiatus in eruptive activity (6).

S. G. Wells
Department of Earth Sciences-036,
University of California,
Riverside, CA 92521

B. M. Crowe
EES-13, Los Alamos National Laboratory,
Las Vegas, NV 89109

L. D. McFadden
Department of Geology,
University of New Mexico,
Albuquerque, NM 87131

REFERENCES


Fig. 1. Grain size distribution curve for scoria and cone-apron deposits from the Lathrop Wells volcanic center. Solid black lines and solid circles are grain size distribution curves of scoria and lapilli from the main cinder cone. Dashed and dotted lines show the grain-size distribution curves of the "tephra" deposits of Wells et al. (4). Dashed lines and solid circles indicate scoria and lapilli. Dotted lines and open circles indicate quartzofeldspathic eolian sand and silt.
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