# REVIEW OF BASIC DATA IN STATUS OF VOLCANISM STUDIES FOR THE YUCCA MOUNTAIN SITE CHARACTERIZATION PROJECT BY CROWE ET AL., 1995

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*Prepared by*

Brittain E. Hill

Center for Nuclear Waste Regulatory Analyses
San Antonio, Texas

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# 1 INTRODUCTION

The Center for Nuclear Waste Regulatory Analyses (CNWRA) was tasked to perform a scoping review of Chapter 2 in Crowe et al. (1995), to determine if comments raised during the review of the initial draft of this report (Crowe et al., 1993) have been addressed. These comments (Connor et al., 1993) were transmitted to the U.S. Department of Energy (DOE) on August 18, 1993. In addition, the present CNWRA review was to document any new areas of concern regarding Los Alamos National Laboratory (LANL) or DOE volcanism studies in the Yucca Mountain Region (YMR). Chapter 2 was chosen for review because it was purported to contain much of the basic data regarding YMR basaltic volcanism (Crowe et al., 1995, p. 1-6). The current CNWRA review was of the March, 1995 revised version of Crowe et al. (1995).

The introduction to Crowe et al. (1995) states "The purpose of this volcanism status report is to bring a sense of scientific perspective to many questions raised in this Introduction. (p. 1-6)." In addition, this report is supposed to provide "a summary current to the date of publication of the results of a long history of volcanism studies (1978 to early 1994)" and to "present the most current and comprehensive information concerning the geologic record of the YMR. (p. 1-6)." The ensuing comments and concerns regarding the information presented in Crowe et al. (1995) will bring a useful perspective to these statements, which are especially pertinent given planned DOE high-level findings in volcanism during 1996.

# 2 RESPONSES TO COMMENTS IN CONNOR ET AL. (1993)

The individual comments from Connor et al. (1993), regarding specific items in Crowe et al. (1993), are summarized in italicized text. Our understanding of the responses, based on the information provided in Crowe et al. (1995), is given after each comment.

**COMMENT 2.1:** *Many of the dates are incorrectly reported or incorrectly cited.*

Many of the data errors cited in this comment have been either corrected or not reported in Crowe et al. (1995), although some remain. However, apparently new data are reported throughout Chapter 2 without citation, data with citations differ from data in the original reports, and data are inconsistently reported in tables and text in this chapter. Documentation of these errors is contained in Concern 3.

**COMMENT 2.2:** *Reported means and uncertainties do not adequately represent the analytical error associated with the data.*

This comment has not been addressed in Crowe et al. (1995). Large analytical uncertainties are not propagated through statistical calculations, even when data are known to have non-normal distributions (e.g., p. 2-61). For data with more precise determinations, there is no discussion on how dates that are numerically distinct at one sigma uncertainties should be combined to yield an average date that accurately reflects analytical precision and accuracy.

**COMMENT 2.3:** *Analytical information presented in this report and in original references is inadequate to evaluate the precision and accuracy of reported dates.*

This comment is partially addressed in Crowe et al. (1995). Required analytical data for Lathrop Wells $^3He$ dates are reported in Table 2.4, and many useful paleomagnetic data are reported in Table 2.5. There are, however, no data reported for other dating techniques, nor are raw data presented for unpublished reports that are repeatedly cited in Chapter 2. Many critical hypotheses, such as the significance of thermoluminescence and U/Th dates, cannot be evaluated until basic data are presented.

**COMMENT 2.4:** *The ages of Quaternary Crater Flat volcanoes are insufficiently precise to permit the development of robust volcanological models.*

Although a range of dates are available for these volcanoes, many relevant dates are not reported in Crowe et al. (1995). There is no discussion on how the apparent range in analytical precision and accuracy will be used to arrive at an eruption age for these volcanoes. However, probability models have been developed that permit a range of interpretations to be placed on the available geochronology (e.g., Connor and Hill, 1993, 1995). Additional geochronological studies are mentioned in Crowe et al. (1995), but it is not clear how the newer data will be reconciled with existing data.

**COMMENT 2.5:** *The Little Cones are considered to be a single vent.*

The concerns outlined in the original comment have not been addressed in Crowe et al. (1995). Reported geochemical, mineralogical, and volcanological distinctions remain between these two vents.

**COMMENT 2.6:** *The Sleeping Butte volcanoes may be contemporaneous with Lathrop Wells volcano.*

This comment is addressed in Crowe et al. (1995). Unpublished data by Champion (1992) and Turrin (1992) indicate that these volcanoes formed around 350 ka. Geochronology studies at these centers are ongoing LANL research tasks, which should be completed by the end of 1995 (Crowe et al., 1995, p. 2-30).

**COMMENT 2.7:** *The mineralogy of the younger post-caldera basalts is not adequately characterized.*

This comment has not been addressed in Crowe et al. (1995).

**COMMENT 2.8:** *There is no discussion in this report of the xenolith content of the Lathrop Wells cinder cone.*

This comment has not been addressed in Crowe et al. (1995).

**COMMENT 2.9:** *The procedure used to calculate volumes of basalts is unclear.*

Although this comment is not addressed specifically in Crowe et al. (1995), the authors state the volume calculations are being revised in 1995 (p. 7-29).

**COMMENT 2.10:** *There are several inconsistencies in the geologic map and stratigraphic relationships at Lathrop Wells.*

Errors on the Lathrop Wells base map have been corrected, and the stratigraphy revised extensively in Crowe et al. (1995). Detailed discussions on the stratigraphic and chronological relationships at Lathrop Wells are not warranted until accurate information regarding unit ages is presented.

**COMMENT 2.11:** *The hypothesis that anomalously old K/Ar dates are due to excess Ar in the system has not been completely tested.*

This comment has not been addressed in Crowe et al. (1995).

**COMMENT 2.12:** *Criticism of the accuracy of $^{36}Cl$ dates by Zreda et al. (1993) appears unwarranted.*

Although sometimes inaccurately reported, the $^{36}Cl$ dates by Zreda et al. (1993) are apparently interpreted as accurate exposure dates by Crowe et al. (1995).

**COMMENT 2.13:** *Published U/Th dates related to the age of Lathrop Wells are not present in this report.*

This comment has not been addressed in Crowe et al. (1995).

**COMMENT 2.14:** *Inadequate data are presented to validate the experimental U/Th disequilibrium dating technique.*

This comment has not been addressed in Crowe et al. (1995). Additional inconsistencies in U/Th dating of Lathrop Wells unit Ql3 further questions the accuracy of the method as applied to Lathrop Wells basalts.

**COMMENT 2.15:** *Reported uncertainties with the $^{3}He$ dates do not accurately represent the analytical uncertainties of this technique.*

This comment is partially addressed in Crowe et al. (1995). The authors indicate that calibration errors with the $^{3}He$ "may be off as much as 30 percent .. for rocks with ages of 100 ka." However, this level of uncertainty is not reported in the data compilation tables reported where errors are typically in the range of 10 percent. The accuracy of the technique in dating 100 ka rocks also is not explained.

**COMMENT 2.16:** *The accuracy of the thermoluminescence dates for the youngest soils at Lathrop Wells has not been determined in sufficient detail to support any conclusion regarding the age of these deposits.*

This comment has not been addressed in Crowe et al. (1995).

**COMMENT 2.17:** *The youngest eruption at Lathrop Wells apparently did not modify the morphology of the cone, yet, based on geomorphology, this unit is related to the approximately 20 ka Black Tank Cone in the Cima Volcanic Field.*

This comment has not been addressed in Crowe et al. (1995).

**COMMENT 2.18:** *Geomorphic characteristics are used to conclude that the age of the main cone at Lathrop Wells is around 40 ka.*

This comment has not been addressed in Crowe et al. (1995), who now follow a more literal interpretation of Wells et al. (1990) that the main cone is no older than 20 ka (p. 2-74). A basic problem remains in that the main cone at Lathrop Wells has a minimum exposure age of 63±7 ka ($^3$He, p. 2-88) or 68±6 ka ($^{36}$Cl, Zreda et al., 1993). However, the Lathrop Wells cone has interpreted geomorphic characteristics that show the cone should be younger than Black Tank cone, which is now thought to be 9-14 ka (Crowe et al., 1995, p. 2-74).

**COMMENT 2.19:** *Some magnetic data presented in this report are missing from figures.*

This comment has been partially addressed in Crowe et al. (1995), where the paleomagnetic data section of Chapter 2 has been expanded significantly. However, not all data are presented in Table 2.5. At least 24 samples and 3 sample sites have been recognized as probably out of place and removed from Table 2.5. Presentation of these missing data would be useful towards evaluating the source of variation within reported units.

**COMMENT 2.20:** *Numerous citations in the text are not referenced, incompletely referenced, or incorrectly referenced.*

A cursory examination of Chapter 2 shows that, as a minimum, the following reference problems still exist:

- Noble et al. (1992) is still incompletely referenced
- Carr et al. (1984) is not in reference list (p. 2-12)
- Ratcliff et al. (1993) is not in reference list (p. 2-15)
- Carr (1974) is not in reference list (p. 2-15)
- Carr (199?) is incorrectly reported (p. 2-92)

# 3 NEW CONCERNS REGARDING BASIC DATA FOR YMR VOLCANOES:

The most basic of all evaluations regarding igneous activity in the YMR is the location and age of volcanoes. Although Crowe et al. (1995) state that "Many review questions and comments about volcanism studies neglect material already covered at length in published volcanism studies (p. 1-8)," this status report cannot be used as an accurate guide to many sources of this basic information on YMR volcanoes, including some of the author's own work. In addition, this report fails to provide a much needed link between the older literature and current stratigraphic and lithologic framework of the YMR. Based on review of Crowe et al. (1995) and other published literature, the following significant concerns exist about basic YMR data.

CONCERN 1: Miocene basaltic rocks of the Yucca Mountain area are inaccurately described. These problems must be addressed in order to accurately evaluate hypotheses regarding the relationship between basaltic magmatism and waning caldera activity:

- Kiwi Mesa basalt has published dates of 9.9±0.4 and 10.0±0.4 Ma (Marvin et al., 1989) that are not reported. In addition, Marvin et al. (1989) report a date of 9.3±0.3 Ma for the rhyolite lava of Shoshone, which apparently locally overlies the Kiwi Mesa basalt (Crowe et al., 1995, p. 2-11).

- Jackass Flats basalt is reported as having dates of 11.0±0.4 Ma and 11.2±0.4 Ma without citation (p. 2-11). Marvin et al. (1989) report dates of 9.6±0.4 and 11.1±0.5 for the basalt of Jackass Flats. They also state the 9.6 Ma date is the more valid age for this unit, based on the greater abundance of radiogenic Ar in the 9.6 Ma sample.

- The youngest basalt on NE Little Skull Mountain was originally mapped by Sargent and Stewart (1971) as correlative with Kiwi Mesa basalt. This uppermost lava was dated 11.2±0.5 Ma and 11.4±0.5 Ma by Marvin et al. (1989), which is inconsistent with a reported age of about 10 Ma for Kiwi Mesa basalt in Marvin et al. (1989). Crowe et al. (1986) report this basalt as correlative with the presumably 9.6±0.4 Ma Jackass Flats basalt. However, Crowe et al. (1995) report a date of 8.4±0.4 Ma for this basalt as inconsistent with the age of correlative basalts at Jackass Flats. Given this range of reported dates, the age of this unit is not clear.

CONCERN 2: At least 4 apparently Miocene basaltic units are not discussed. The distribution of these basalts up to 40 km away from the roughly 11 Ma Timber Mountain caldera system may indicate that the Basalts of the Silicic Episode (BSE) may not represent a unique petrogenetic group as hypothesized, and that at least two major basaltic volcanic centers are present but undetected in the Amargosa Valley area. This is a significant regulatory concern in the context of 10 CFR 60.122(a)(2)(i).

- Miocene basaltic rocks are distributed in a roughly 270° sector around the town of Beatty, Nevada, in figure 2.4. These basalts are not discussed in the text or in prior publications. Marvin et al. (1989) report dates of 8.1±0.4 Ma for basalt in the Bullfrog Mountains area, and 10.0±0.4 Ma for latite N of Beatty, which are not discussed in Crowe et al. (1995).

  In addition, 7.5±0.3, 9.0±0.3, and 10.3±0.4 Ma basalts occur on the NE flank of the Funeral and Grapevine Mountains near the California-Nevada border (Marvin et al., 1989). These basalts are temporally and spatially within the range of the BSE province, as currently defined (e.g., Crowe, 1990). Limited geochemical data (Crowe et al., 1986; Milling et al., 1993; Thompson et al., 1993) indicate that these basalts have petrogenetic affinities with YMR basalts, and may be part of the YMR magmatic system. These data are not discussed in Crowe et al. (1995).

- Sargent and Stewart (1971) mapped several small basaltic dikes(?) in the Specter Range. These dikes apparently consist of olivine basalt, which may be correlative with the Kiwi Mesa basalt (nearest known outcrop about 10 km). These basalts have not been discussed and may represent important links to possibly correlative basalts in eastern Amargosa Valley or Mt. Shader Basin.

- Swadley (1983) mapped Tertiary basalt in eastern Amargosa Valley about 3 km SE of the Skeleton Hills. This quartz-phyric basalt may be correlative with similar appearing units in the Skull Mountain area, approximately 20 km N. This basalt has not been discussed.

- At least two shallow reflectors along the AV-1 seismic line are thought to represent buried, areally extensive basalts (Brocher et al., 1993). Reflector "G" is located less than 200 m below the surface and extends for about 4 km. This reflector may be correlative with the quartz-phyric basalt SE of Skeleton Hills mapped by Swadley (1983). However, USGS hydrology wells located about 8 km E of these outcrops intersected at least 20 m of relatively coarse-grained olivine basalt (Johnston, 1968). A similar reflector, "H," extends NE of these wells for at least 5 km.

  Crowe et al. (1986) report two analyses for the basalt in the USGS hydrogeology wells (AM1-15-13, AM1-15-270) and correlate this basalt with the BSE based on composition. However, Crowe et al. (1986) also report similar compositional characteristics (i.e., hypersthene hawaiite) for some Pliocene basalts in Crater Flat. Although these basalts may be older than about 8 Ma, it is possible that they may be as young as Pliocene.

  Thus, at least two basalts with different mineralogies are present in the eastern Amargosa Valley, and may represent Miocene to Pliocene volcanoes. Drilling and seismic reflection surveys indicate these basalts are, in aggregate, at least 10 km long and can thicken to at least 20 m. Aeromagnetic surveys in this area (Langenheim et al., 1993) have failed to detect these basalts using routine exploration techniques. It appears that a major Miocene(?) buried volcanic center has remained present but undetected during YMR site characterization activities.

CONCERN 3: The introduction to this report states "First, we present the most current and comprehensive information concerning the geologic record of the YMR." Although the authors chose to focus on data that were collected under recent Los Alamos YMP quality assurance requirements (p. 2-8), nearly all of the data on YMR Neogene volcanoes was not produced under these requirements. Consequently, information regarding YMR Neogene volcanoes must be obtained from published, high-quality sources. However, significant amounts of published information on basic YMR volcanic features are absent or incorrectly reported in Chapter 2 of Crowe et al. (1995).

Pahute Mesa basalts:

- The <9.4 Ma Spearhead member of the Thirsty Canyon Tuff was renamed the Pahute Mesa Tuff by Noble et al. (1984) to avoid confusion with the 7.50±0.03 Ma Spearhead member of the Stonewall Flat Tuff.

- The central basalt center has a reported age of 10.4±0.4 Ma. However, Crowe et al. (1983) assigned this age to the western center.

Paiute Ridge basalts:

- Although the paleomagnetic work of Ratcliff et al. (1993) is cited, there is no discussion of the radiometric dates (8.65±0.10, 8.66±0.18, 8.59±0.07 Ma) presented in Ratcliff et al. (1994).

- The basalt of Scarp Canyon was previously defined as the basaltic lavas about 1 km ESE from the main sills of Paiute Ridge (e.g., Crowe, 1990). This lava was dated at 8.7±0.3 Ma (Crowe et al., 1983). In the current report, Scarp Canyon basalt is now used to describe the basaltic dikes about 15 km SSE of Paiute Ridge, near the Nye Canyon basaltic centers. However, the same date (8.7±0.3 Ma) apparently is assigned to this newly defined unit.

Basalt of Yucca Flat:

- Carr (1984) reports basalt in Yucca Flat drill holes UE1h at about 240 m and in nearby UE6d at about 900 m, with about 600 m vertical offset across the Carpetbag Fault. The basalt in UE1h is 32 m thick (Fernald et al., 1975). Similar basalts also are described in lithology logs for UE1j (Fernald et al., 1975). These drill holes are located about 10 km SW of Paiute Ridge. Crowe et al. (1995) report a date of 8.1±0.3 without reference and conclude the basalt is possibly correlative with Paiute Ridge. Although these basalts may be temporally correlative with Paiute Ridge, no information is presented to demonstrate that these basalts do not represent a discrete, previously unrecognized volcanic center.

- This basalt is not located on figure 2.5.

- Fernald et al. (1975) describe basaltic cobbles and gravels in alluvium underlying basaltic lavas in drill holes UE1h and UE1j. The basaltic cobbles do not represent the same lithology as the overlying basalts (Fernald et al., 1975), and may represent another nearby buried volcanic center that has not been discussed.

Nye Canyon basalts:

- Carr (1984) reported basalt in a drill hole located in NW Frenchman Flat at a depth of about 275 m and correlated it with Nye Canyon based on stratigraphic relationships. A new date of 8.6 Ma is presented in Crowe et al. (1995) without citation, indicating it may be correlative with Paiute Ridge or Scarp Canyon as newly defined. Either interpretation gives important information on the areal extent of Miocene volcanic centers, which requires that the age and petrogenetic association of the Frenchman basalt is known.

Amargosa Valley basalts:

- Figure 2.5 is significantly inaccurate. Latitude and longitude tics are unevenly spaced. As a result, the location of the Amargosa Valley anomalies can not be determined correctly. Anomaly "B" is mislocated too far N. The other two anomalies likely represent anomaly "A" of Langenheim et al. (1993). However, Langenheim et al. (1993) recognized three additional anomalies located S of the lower limits of figure 2.5 (C, D, E), which likely represent buried basaltic centers.

- These aeromagnetic anomalies have different polarity directions (Langenheim et al., 1993) and thus represent different age events. Anomalies D, E, and possibly A have positive polarities, whereas B and C have reversed polarities.

Pliocene Crater Flat:

- Unpublished USGS dates are cited without reference.

Buckboard Mesa:

- Unpublished USGS dates are cited without reference.
- Date of 2.7±0.2 Ma from Marvin et al. (1989) is not cited.
- The fissure vent extends SE from Scrugham Peak (Lutton, 1969), not SW as stated.

Quaternary Crater Flat:

- Little Cones: 0.77±0.04 Ma date from Smith et al. (1990) and Faulds et al. (1994) not reported. Date of 0.904±0.011 Ma from Heizler (1994) not reported.
- Red Cone: Dates of 0.84±0.15 and 1.07±0.34 Ma are reported in text (p. 2-23) but not included in Table 2.2. Date of 1.53±0.31 is attributed to Sinnock and Easterling (1983) in text (p. 2-22) but is attributed to USGS (Carr) in Table 2.2.
- Black Cone: Dates of 1.09±0.12 and 0.71±0.06 from Smith et al. (1990) and Faulds et al. (1994) not reported. Date of 1.05±0.08 is shown in Table 2.1 but not reported in text (p. 2-23) or in Table 2.2.
- Northern Cone: Date of 1.05±0.07 Ma from Smith et al. (1990) and 1.09±0.07 Ma from Faulds et al. (1994) not reported.
- Wells et al. (1990) discussed differences in the degree of soil development on Red Cone and Black Cone lavas, which they interpret to represent significant differences in time between the formation of these two volcanoes. Although Wells et al. (1990) is cited in other parts of this discussion, this important relationship is not discussed.

Sleeping Butte:

- Dates of 0.21±0.13 and 0.22±0.10 Ma were reported in Crowe and Perry (1991) for Little Black Peak yet are not cited in Crowe et al. (1995).
- Turrin (1992) only presented dates for Hidden Cone (0.38±0.02 by Ar/Ar and 0.37±0.07 by K/Ar), not for both Sleeping Butte centers. Champion (1992) discussed 14 Little Black Peak and 12 Hidden Cone K/Ar dates, which he averaged to a single episode of volcanism at 0.353 Ma. Crowe and Perry (1991) report a date of 0.32±0.20 for Hidden Cone, which is not cited in Crowe et al. (1995).

Lathrop Wells:

- The sources of many dates reported in this section are unknown, to the extent that new dates cannot be distinguished from previously reported data. Some dates continue to be reported inaccurately. There is no translation provided for dates using the pre-1995 general stratigraphy (e.g., Ql5 is now Ql1a-1d). Until basic geological data are reported completely and accurately, evaluation of hypotheses based on these data is not warranted.

- What are the correct $^3$He dates for unit Ql1a?
  Poths et al. (1994), Ql1a: 81±7, 84±7, 87±6, 82±5, 81±6, 85±5 ka.
  Text (p. 2-40) Ql1a: 81±7, 81±9, 87±6, 82±5, 81±7, 85±5 ka.
  Table 2.4 (p. 2-70), Ql1a: 87±7, 81±9, 78±8, 85±6, 87±6, 82±5, 81±7, 85±5 ka.
  Table 2.6 (p. 2-87), Ql1a: 81±7, 87±6, 82±5, 81±7, 85±5 ka.

- This report lists $^3$He exposure dates of 76±7 ka for Qs1d, and 88±8, 61±8 ka for Q1b. However, Poths and Crowe (1992) report dates of 64±6 and 59±6 ka for old unit Ql5 (i.e., Ql1). These dates are not reported for any Ql1 unit in Crowe et al. (1995).

- The $^{36}$Cl age for unit Ql1a (p. 2-40) from Zreda et al. (1993) is actually the mean and 1 standard deviation of 5 dates: 93±7.2, 73±6.8, 81±5.4, 77±6.0, 79±6.1 ka. Assuming the $^{36}$Cl data in Table 2.6 is from Zreda et al. (1993), the dates for unit Ql1a are incorrectly assigned; these 4 dates are from volcanic bombs collected on the western Qs2 fall deposit, not the Ql1a lavas as stated. The Ql1a lava $^{36}$Cl dates are not reported in Table 2.6.

- Turrin et al. (1991) reported a K/Ar date of 116±13 ka for unit Ql1a (i.e., Ql5), not Qs1b as stated (p. 2-41); Turrin et al. (1991) clearly distinguished between Ql5 (i.e., Ql1a) and Qs5 (i.e., Qs1b). Turrin et al. (1991) did not publish a date of 214±86 ka for unit Qs1b as stated (p. 2-41).

- Units Qs2 and Ql2 are not subdivided in figure 2.12 as stated, creating difficulty in following the arguments outlined in the text.

- What are the correct $^3$He dates for unit Ql2a?
  Poths et al. (1994), Ql2a: 82±9, 88±6, 82±5 ka.
  Text (p. 2-45) Ql2a: 82±9, 88±7, 82±4, 100±9 ka.
  Table 2.4 (p. 2-70), Ql2a: 82±9, 92±11, 84±6, 82±4, 100±9 ka.
  Table 2.6 (p. 2-87), Ql2a: 82±9, 88±8, 82±4 ka. Date of 100±9 ka assigned to Ql1c.
  Poths and Crowe (1992), old unit Ql3 (i.e., Ql2): 65±7, 73±9 ka dates not reported.

- Turrin et al. (1991) report a K/Ar date of 133±10 ka for old unit Ql3 (i.e., Ql2), which does not agree with the values reported (p. 2-45) from Turrin et al. (in press). The $^{40}$Ar/$^{39}$Ar dates of 217±54 (incorrectly shown as 217±64, p. 2-45) weighted mean and 153±110 ka mean from Turrin et al. (1991) are incorrectly assigned to unit Ql2a. Careful examination of the sample location maps in Turrin et al. (1991) and Turrin and Champion (1991) shows these dates are from unit Ql3 under the revised stratigraphy, not Ql2a. This is also incorrectly reported in Table 2.6.

- Turrin et al. (1992) also report a plateau $^{40}Ar/^{39}Ar$ date of 149±19 ka for this sample, which is not in close agreement with cosmogenic $^{3}He$ dates (p. 2-47).

- The 24.5±2.5 ka thermoluminescence date of baked sediments underlying Ql2a (p. 2-47) remains a serious problem regarding accuracy of this dating technique as applied to the geological conditions at Lathrop Wells. It is troublesome that although this date was first presented in Crowe et al. (1992) as problematic, there apparently has been no reported progress towards resolving this problem. However, TL dates are assumed accurate in other sections of Chapter 2.

- What are the correct $^{3}He$ dates for unit Qs3?
  Poths et al. (1994), Qs3: 30±5, 35±5, 36±5, 43±3, 57±7 ka.
  Text (p. 2-52) Qs3: 29±5, 35±5, 36±5, 43±3, 56±7 ka.
  Table 2.4 (p. 2-70), Qs3: 28±4, 31±6, 35±4, 36±5, 43±3, 50±7, 63±7 ka.
  Table 2.6 (p. 2-87), Qs3: 29±5, 35±5, 35±5, 43±3, 56±7 ka.
  Poths and Crowe (1992), old Qs1 (i.e., Qs3): 22±4, 28±4, 44±6 ka.

- Although Turrin and Champion (1991) do not present K/Ar dates for Qs3 summit samples TSV-283 and TSV-129 (p. 2-53), these data are reported in Marvin et al. (1989):
  TSV-283: 230±40 ka, 3 percent radiogenic Ar (Ar*).
  TSV-129: 300±100 ka, 25 percent Ar*.

  Although it is easy to disregard a K/Ar date with only 3 percent Ar*, a K/Ar date with 25 percent Ar* is generally considered accurate within the limits of reported precision (e.g., Dalrymple and Lanphere, 1969). There is a recurring theme at Lathrop Wells: conventional K/Ar and Ar/Ar dates are somewhat to significantly older that cosmogenic exposure dates on the same units. This relationship may seriously question the accuracy of exposure dates in representing eruptive events.

- What are the correct $^{3}He$ dates for unit Ql3?
  Poths et al. (1994), Ql3: 61±6, 100±9 ka.
  Text (p. 2-54) Ql3: 67±6, 53±7, 100±9 ka.
  Table 2.4 (p. 2-71), Ql3: 67±6, 53±7 ka.
  Table 2.6 (p. 2-87), Ql3: 67±6, 53±7 ka.
  Poths and Crowe (1992): Cannot correlate old unit Ql4 with new unit Ql3. However, youngest lava dates are in Ql4 (48±5, >49), which may be correlative.

- What is the correct U/Th date for unit Ql3?
  Text (p. 2-54): 125 +20 -15 (1$\sigma$) ka
  Text (p. 2-67): 125 +45 -30 (1$\sigma$) ka
  Table 2-6 (p. 2-88): 125 +35 -30 ka

- A date of 150±40 ka was reported in Crowe et al. (1992), not 140±40 as reported on p. 2-67. Apparently these data were used in the second dating of sample Ql3b (LW-89-3-21-2?) along with additional data points, giving a reported date of 125 +45 -30 ka (p. 2-67). However, significant differences exist between "mag" and "wr" measurements for samples Ql3b-1 and Ql3b-2. Although small precision errors are shown, there is no discussion of the apparent lack of accuracy in these measurements.

- Information presented by Perry (1995) showed a date of 49.5 +16.9 -14.6 ka for sample LW-89-3-21-2. This date also is reported by Murrell et al. (1995), who indicate that olivine phenocrysts in correlative unit Qs3 are zoned and may represent a mixed population. It is not clear why these data are not in the March 1995 revision of Crowe et al. (1995), as was indicated by Perry at the February 1995 Geomatrix meeting. The large variations in geochemical abundances for the 3 different analyses of the same Ql3 sample and the apparent olivine zonation seriously questions the accuracy of the reported dates as ages of a volcanic eruption.

Direct and Indirect Dating Methods:

- Turrin et al. (1991) or Turrin and Champion (1991) are frequently cited as data sources for K/Ar dates. With the exception of mean dates of 116±13 and 133±10 ka, no K/Ar dates are presented in these reports.

- K/Ar dates of 214±86 are cited as invalid dates for unit Qs1b and Ql1a in Table 2.6 (p. 2-87), yet there is no indication on the source of these dates nor why they are invalid.

- A K/Ar date of 139±68 is cited in Table 2.6 (p. 2-87) for unit Ql2a, yet the source of this date is not cited in the table or the text.

- K/Ar data from Sinnock and Easterling (1983) is dismissed as having "generally large analytical errors for individual measurements, and poor reproducibility between analytical laboratories (p. 2-60)." However, laboratories A and C have reproducibilities and individual measurements of analytical error (10-20 percent) that are generally regarded as acceptable for K/Ar determinations on young, low-K basalt. Given the number of developmental, indirect dating techniques used in Crowe et al. (1995), the basis for discarding direct dates using standard techniques should be discussed in more detail.

- Additional K/Ar dates from Marvin et al. (1973), Vaniman and Crowe (1981), Vaniman et al. (1982), and Marvin et al. (1989) are absent from this section.

- Turrin et al. (1992) report Ar/Ar step-heating dates of 142±19 ka (plateau), 107±33 ka (isochron) and 107±30 ka (inverse isochron), not 104, 123, and 122 ka as cited (p. 2-64).

- The small degree of U/Th fractionation "appears to be a characteristic of the minerals themselves, not a reflection of poor physical separation of phases (p. 2-67)." Perry (1995) shows that groundmass(?) pyroxene strongly affects the isochron. However, this phase has not been reported in the two previous analyses of unit Ql3, which seriously questions the accuracy in obtaining reasonably pure mineral separates for U/Th analyses.

- Conventional K/Ar and Ar/Ar dates are concluded to be skewed towards older ages and should be viewed as maximum ages at best (p. 2-66). However, these same data are cited as supporting U/Th ages as reliable (p. 2-68).

- Variations in $^3$He dates on the main cone "directly reflects the erosional instability of the scoria surfaces (p. 2-69)." However, a "generally undisputed observation of the characteristics of the main cone of Lathrop Wells center is the absence of cone-slope erosion and formation of a cone-slope apron (p. 2-58)." It appears that data are in direct contradiction of assumptions based on observation.

- Thermoluminescence dates for Lathrop Wells were considered "preliminary" in Crowe et al. (1992) and Crowe et al. (1993), and are still considered "preliminary" (p. 2-73). No apparent progress has been made towards evaluating the accuracy of these dates, in spite of recognized inaccuracies in the technique (e.g., p. 2-47, 2-73).

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