Review of Age - Dating Activity

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Outline

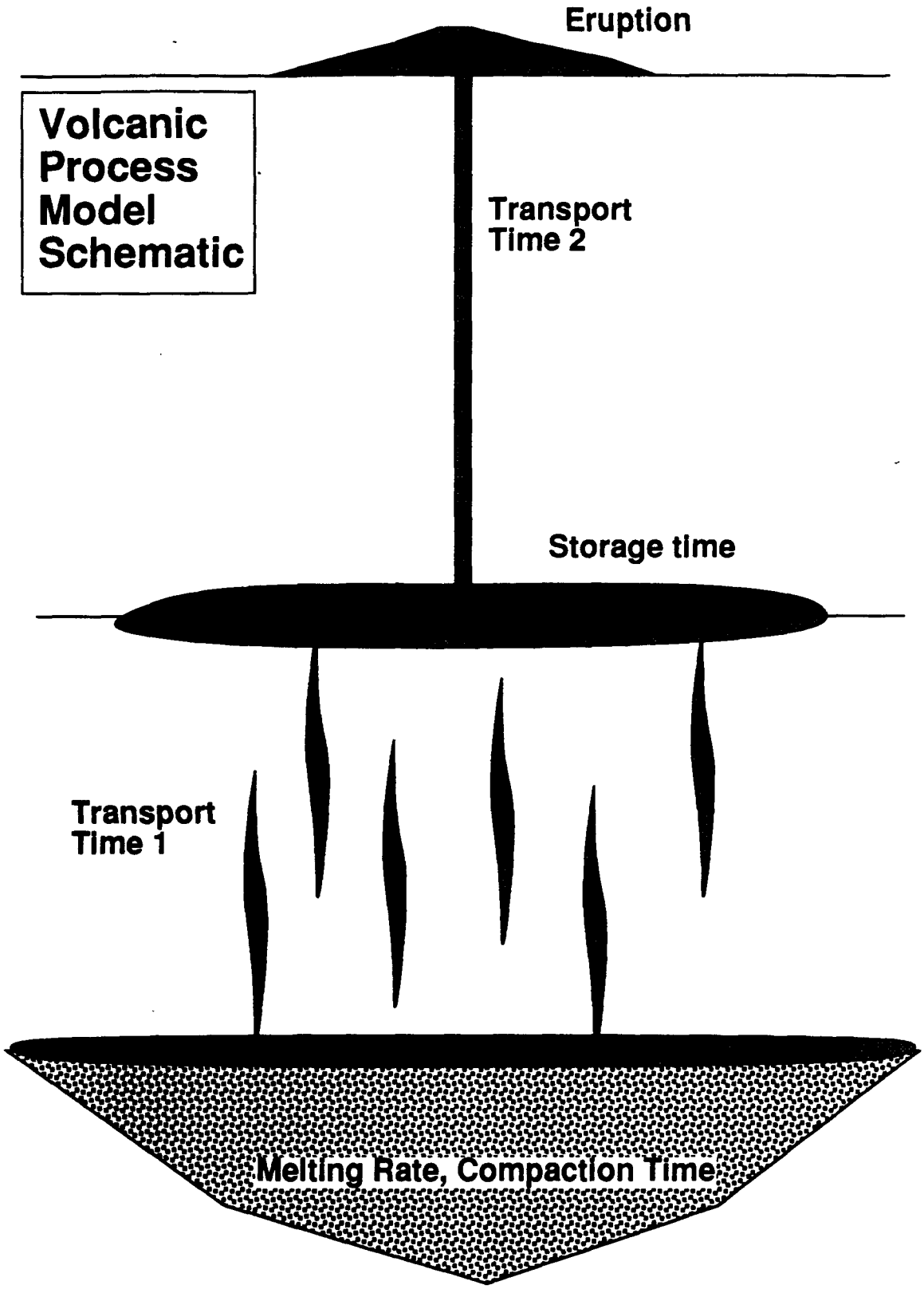
Major components of Volcanism Geochronology Program

- ^{40}Ar - ^{39}Ar Data
- Cosmogenic ^{3}He and ^{21}Ne
- ^{238}U - ^{230}Th Data
- Thermoluminescence data
- Paleomagnetic data
- Summary

Volcanism Geochronology Program

Major components

- **Quantification of relationship between geochronology and hazard**
  - **Sensitivity tests of geochronological interpretations**
  - **Credibility of the geochronology program**


Eruption
Volcanic Process Model Schematic
Transport Time 2
Storage time
Transport Time 1
Melting Rate, Compaction Time

Volcanism Geochronology Program

(Continued)

Geochronological Data

- **Quantitative age information**
  - ^{40}Ar - ^{39}Ar data
  - Cosmogenic ^{3}He - ^{21}Ne data
  - ^{238}U - ^{230}Th data
  - Thermoluminescence data
- **Qualitative age or hazard modifiers**
  - Paleomagnetic direction data
  - Soils stratigraphy and developmental stage data
  - Volcanic stratigraphy data
  - Volcanic geochemistry/eruption rate data

Volcanism Geochronology Program

(Continued)

Synthesis of data and hazard implications

- Volcanic process framework models
- Reconciliation of all geochronological data

Relationship between Geochronology and Volcanic Hazard

Components of the assessment

- Age distribution of volcanism
- Recurrence interval of volcanism
- Spatial distribution of volcanism
  - Needs to be a clear quantification of the relationship between disruption probability and the geochronological results to define the issues that apply to Lathrop Wells and therefore define what is needed in order to "finish"

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^{40}Ar - ^{39}Ar Data

Advantages

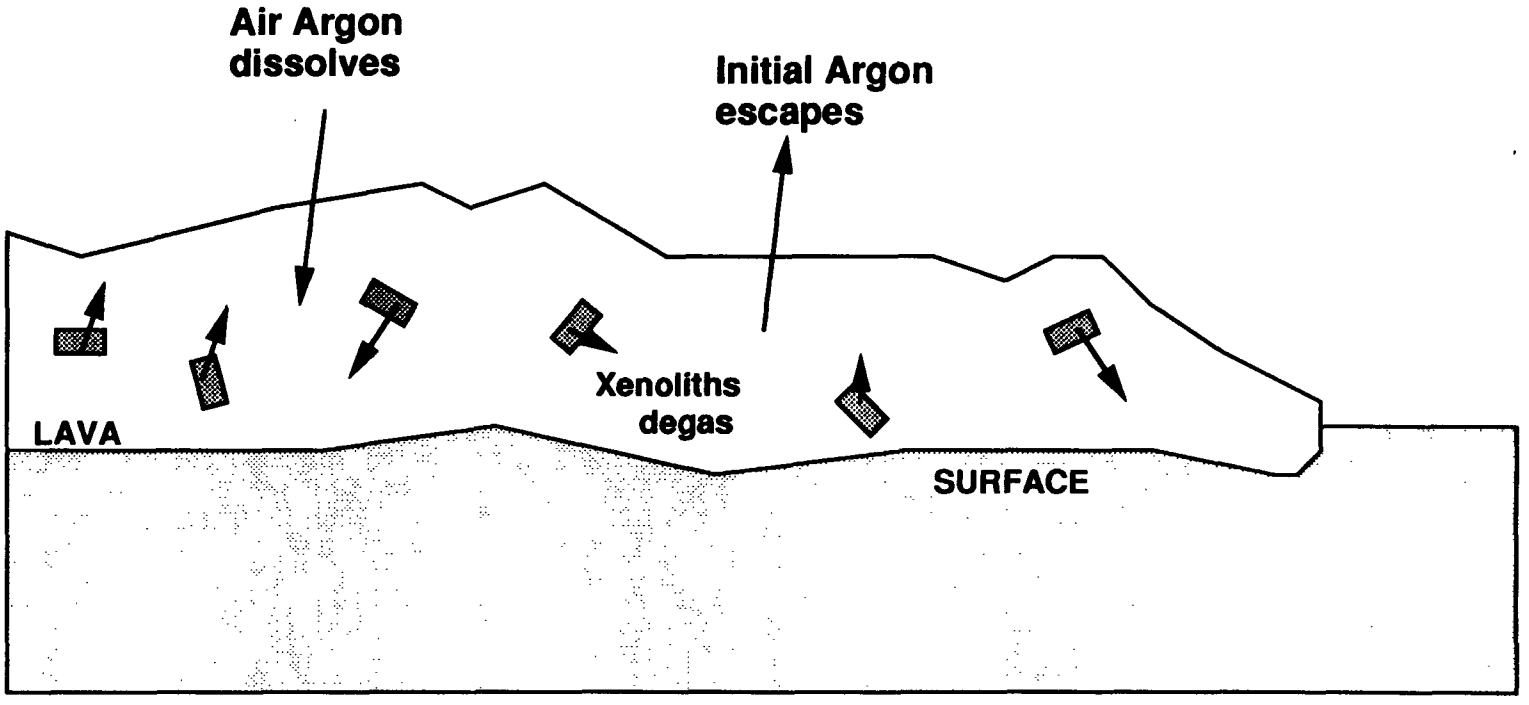
- Has a long history of use
- Has been shown to give "correct" ages in many instances
- Many potential pitfalls have been identified
  Methods for addressing pitfalls are known

^{40}Ar - ^{39}Ar Data

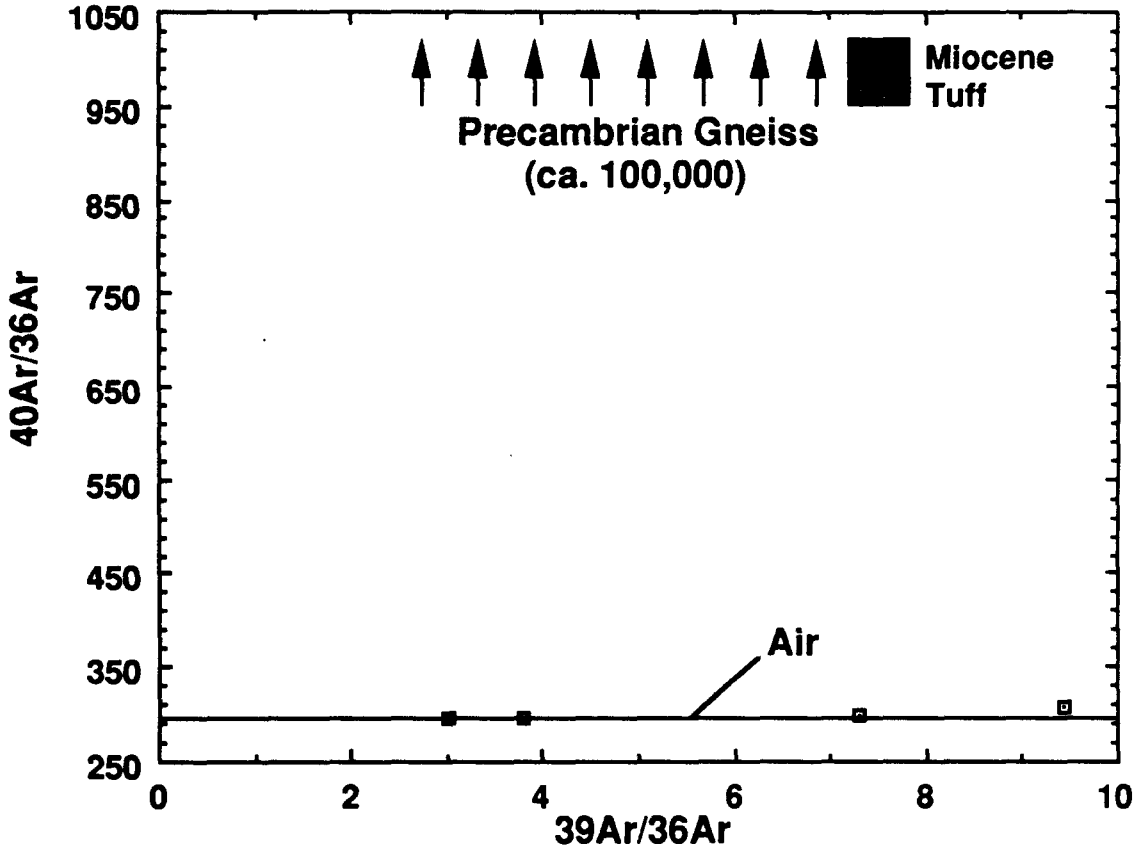
(Continued)

Disadvantages

- Lathrop Wells basalt (in particular) is very young, not K-rich
- Fine-grained basalts often present problems with excess ^{40}Ar and yield anomalously old ages (there is evidence of excess ^{40}Ar in the analyzed samples from Lathrop Wells)



$$\tau_{\text{Ar diffusion}} \approx 10 \text{ to } 100 \ \tau_{\text{thermal diffusion}}$$


1050
950
850
750
650
550
450
350
250
40Ar/36Ar
0
2
4
6
8
10
39Ar/36Ar
Miocene
Tuff
Precambrian Gneiss
(ca. 100,000)
Air

^{40}Ar - ^{39}Ar Data

(Continued)

Comments

- K-Ar conventional and ^{40}Ar - ^{39}Ar laser ages are not reliable at Lathrop Wells because of
  - Probability of excess ^{40}Ar in all samples, combined with small proportions of radiogenic ^{40}Ar
  - Insufficient resolution

- Step-heated whole-rock samples have a better possibility of resolving the correct age because:
  - Achieve separation between radiogenic Ar and air Ar which increases the age resolution
  - Isochron technique should take account of initial ^{40}Ar

- If ^{40}Ar - ^{39}Ar ages are incorrect at Lathrop Wells, they are likely to be a little too old, so they provide an upper bound on the age in any case

^{40}Ar - ^{39}Ar Data

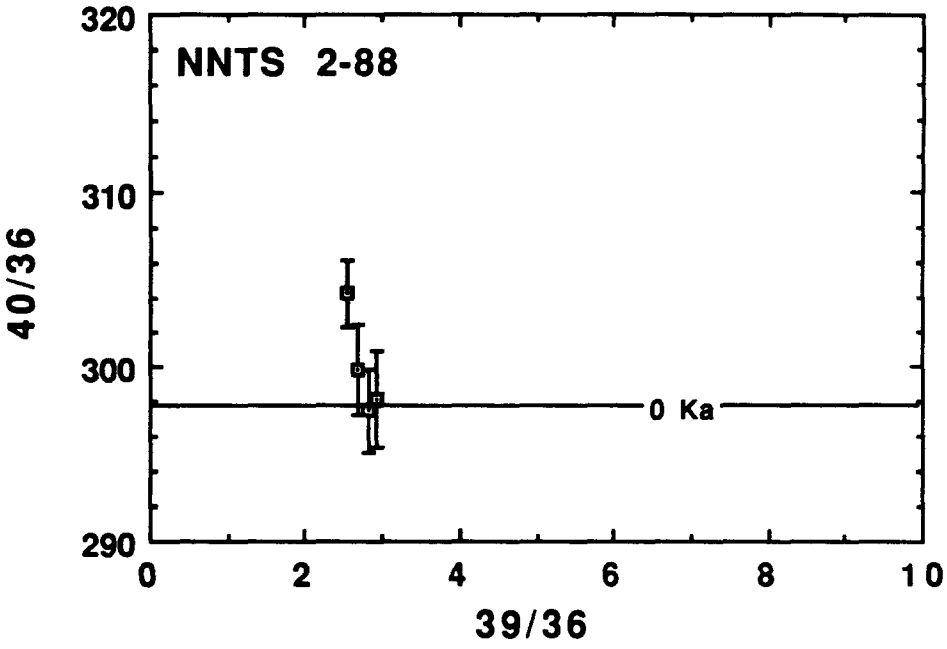
(Continued)

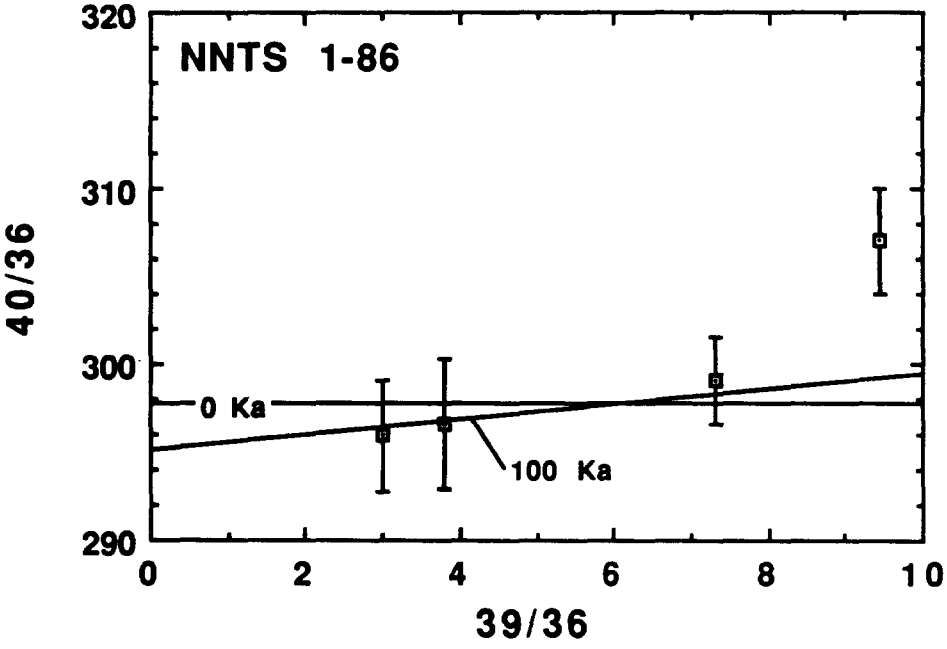
Comments (Continued)

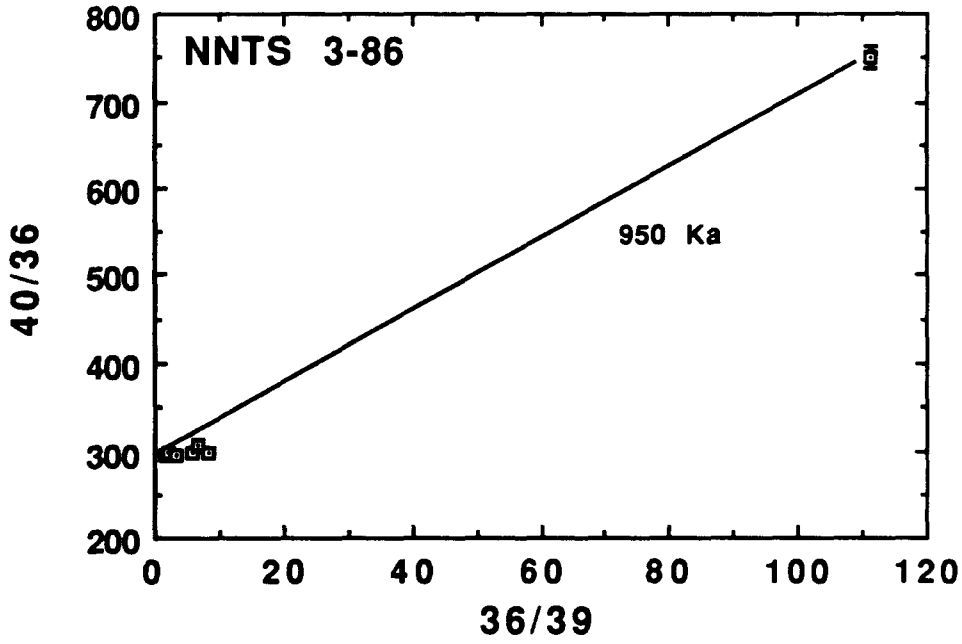
- The ages and age-uncertainties most likely to be reliable are those derived from the Ar-Ar isochron method on step-heated samples

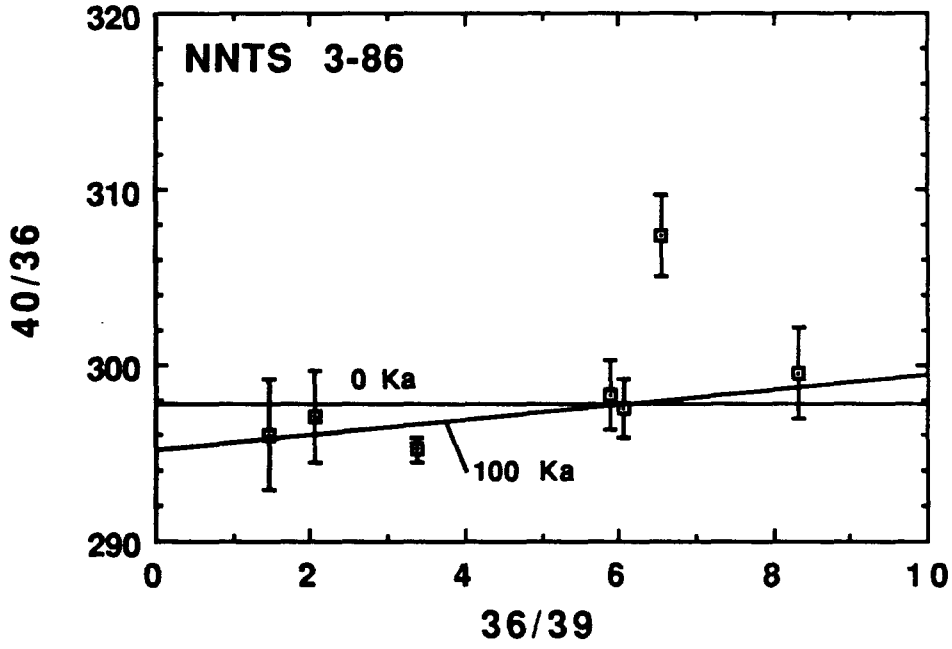
- A more convincing case for the age of Lathrop Wells activity requires more analyses, concentrating on
  - Mineral separates
  - Tuff inclusions

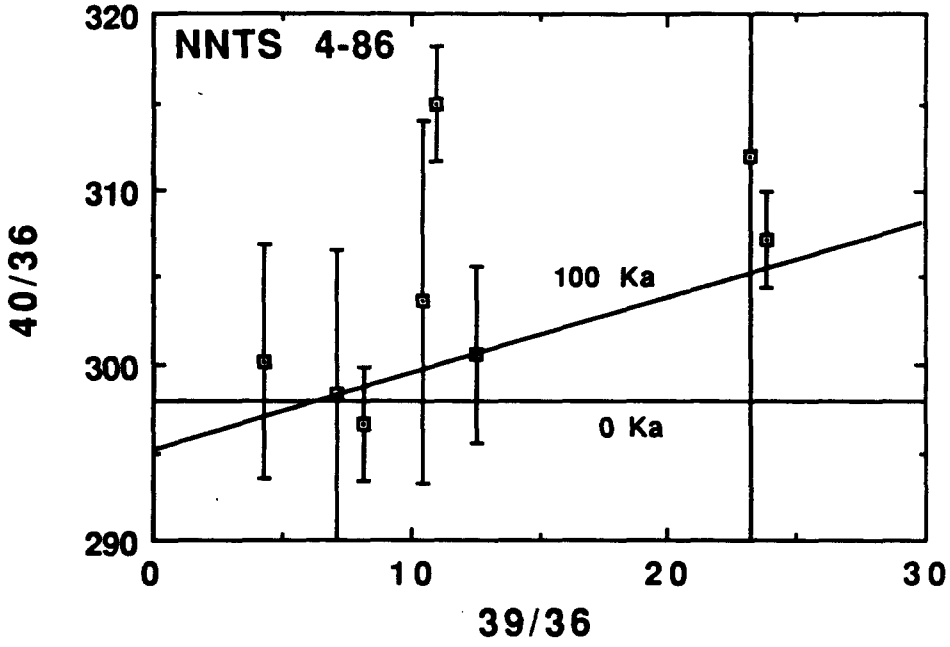
- If duration of Lathrop Wells activity is less than 50 ka, it is unlikely that age differences can be confidently established by this method

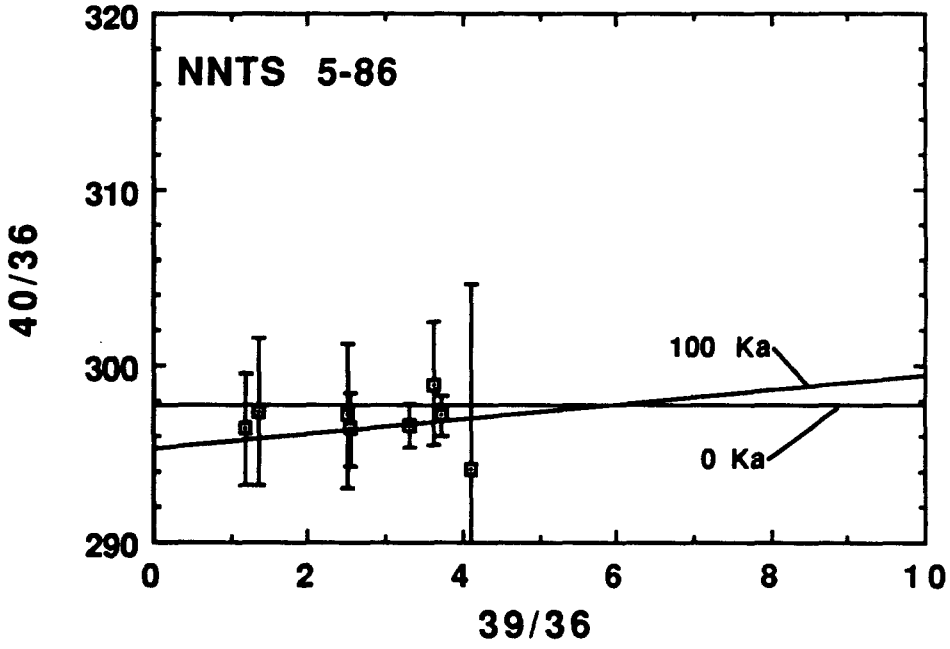

NNTS 2-88
320
310
300
290
40/36
0 Ka
0
2
4
6
8
10
39/36

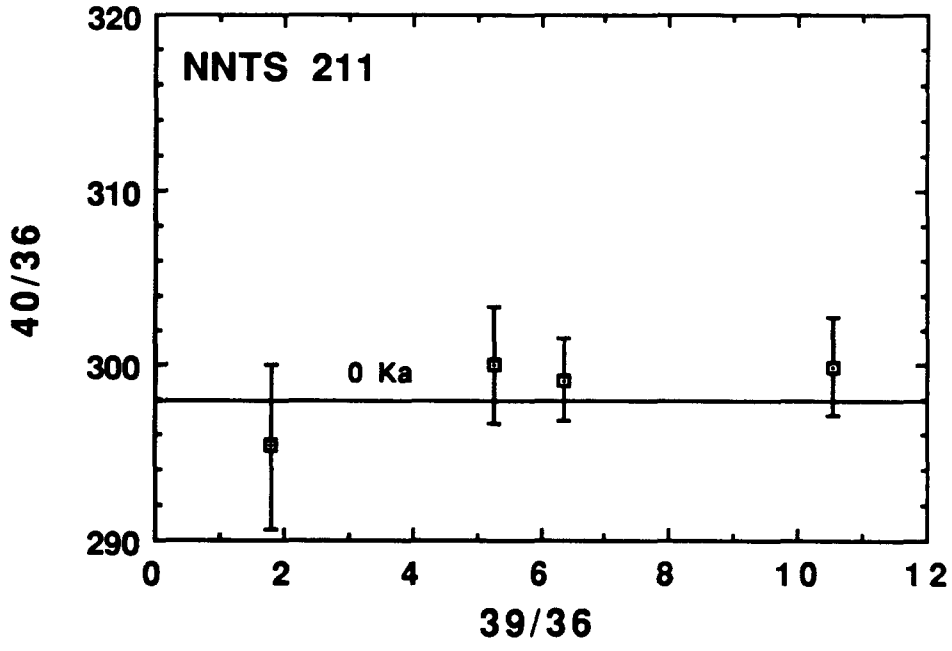

NNTS 1-86
320
310
300
290
40/36
0 Ka
100 Ka
0
2
4
6
8
10
39/36

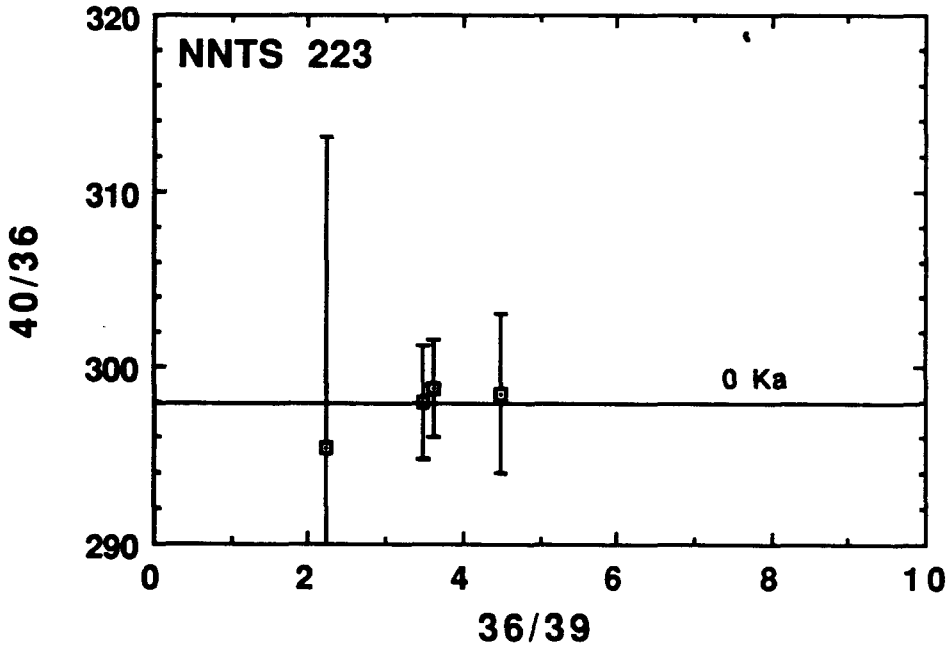

NNTS 3-86
950 Ka
40/36
36/39
800
700
600
500
400
300
200
0
20
40
60
80
100
120


NNTS 3-86
0 Ka
100 Ka
40/36
36/39
320
310
300
290
0
2
4
6
8
10


NNTS 4-86
320
310
300
290
40/36
100 Ka
0 Ka
0
10
20
30
39/36


NNTS 5-86
320
310
300
290
40/36
100 Ka
0 Ka
0
2
4
6
8
10
39/36


NNTS 211
320
310
300
290
40/36
0 Ka
0
2
4
6
8
10
12
39/36


NNTS 223
320
310
300
290
40/36
0 Ka
0
2
4
6
8
10
36/39

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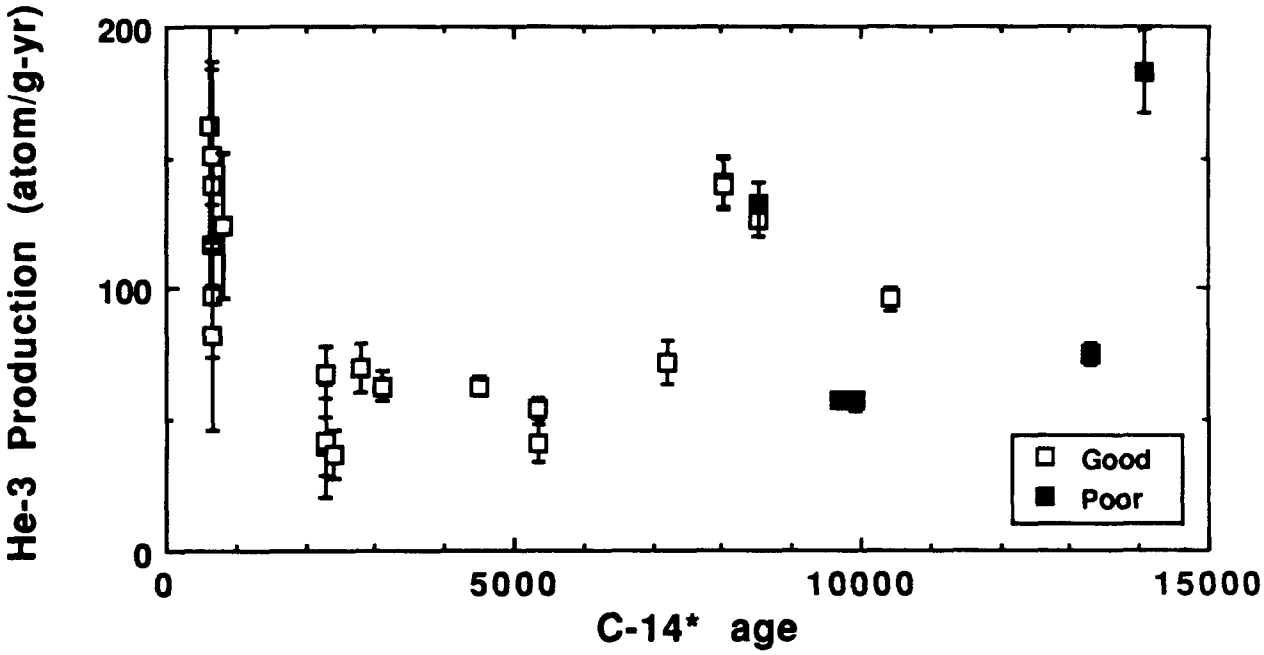
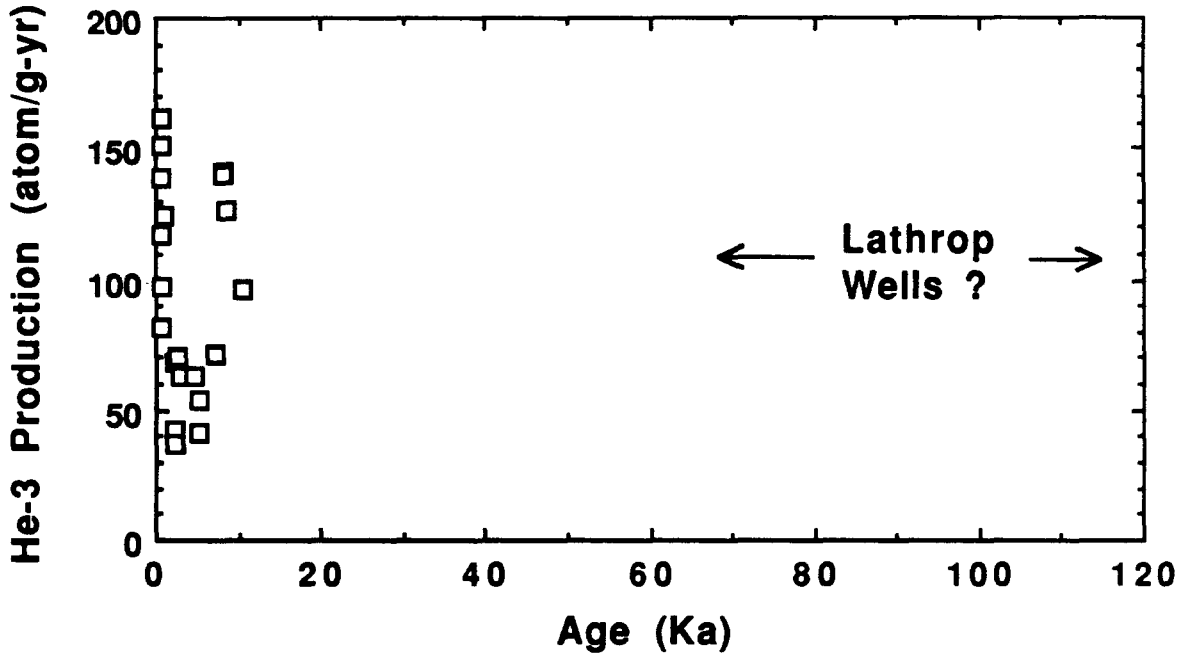
Cosmogenic ^{3}He and ^{21}Ne

Advantages

- Good age resolution, ca. 10-20 Kyr
- He loss problems for olivine not demonstrated to be a significant problem for sub-100 Kyr ages
- A check is derived with ^{3}He and ^{21}Ne

From Kurz et al. (1990)





Cosmogenic ^{3}He and ^{21}Ne

(Continued)

Disadvantages

- Production rates are uncertain due to secular variations in the cosmic-ray shielding of the earth's surface by the geomagnetic field
- There is possibility of unanticipated complications. Previous applications for dating volcanic events are limited
- There is some possibility of burial by sand dunes or ash at Lathrop Wells

Cosmogenic ^{3}He and ^{21}Ne

(Continued)

Comments

- Variations and uncertainties in geomagnetic shielding corrections can be estimated and included in overall age uncertainty estimations
- Calibrations of the method in the 0 - 20 ka range (where there is some information on secular variation of production rate) are not sufficient to guarantee a correct age at 50 - 100 ka (where there is no information)
- Limits can be placed on burial and erosion corrections
- This method will most likely give minimum ages; in combination with Ar-Ar, could bracket the age

Cosmogenic ^{3}He and ^{21}Ne

(Continued)

Comments (Continued)

- This method has the best possibility of resolving age differences between units at Lathrop Wells. Production rate issues will be less important for age *differences*
- Still insufficient data from Lathrop Wells to make a strong case for the age; or for age differences
- ^{21}Ne results would be useful

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^{238}U - ^{230}Th Data

Advantages

- Potentially good age resolution
- Basis of the method is straightforward
  - Decay constants are well known
  - Expect systematic behavior

^{238}U - ^{230}Th Data

(Continued)

Disadvantages

- Minimal U/Th fractionation in minerals makes age resolution less than optimal
- Previous applications are few; pitfalls may exist

^{238}U - ^{230}Th Data

(Continued)

Comments:

- Possibility of $^{234}U/^{238}U$ variations not accounted for; particularly for samples with minimal U/Th variability this may be critical. Also need to know how well $^{234}U/^{238}U$ is determined
- U-Th ages should not be biased either high or low

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Thermoluminescence Data

Advantages

- Potentially good age resolution down to sub-10 Kyr

Disadvantages

- Mechanism by which age is recorded in silicates is only qualitatively known
  - Discrepancies can be explained only in retrospect
  - Each sample must be separately evaluated for retentivity
- Method is still in a developmental stage

Thermoluminescence Data

(Continued)

Comments

- Although there have been some successes dating Holocene samples, there is minimal indication that the method will yield reliable ages in the 50 - 200 Kyr range

- TL ages can be regarded as minimum ages

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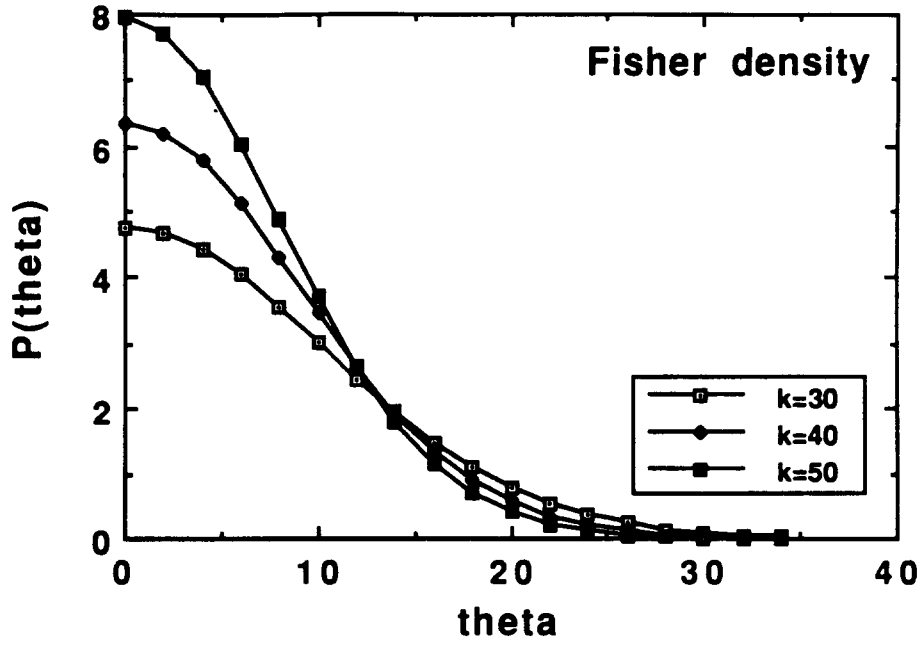
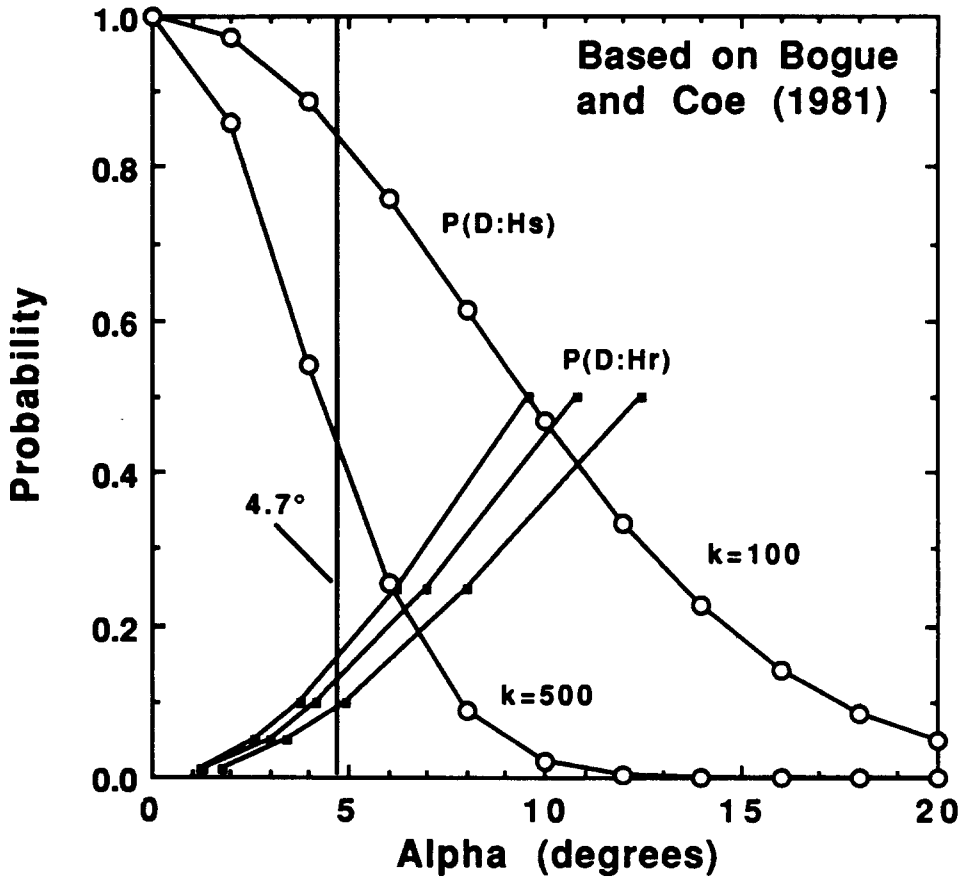
Paleomagnetic Data

Comments

- Useful as a stratigraphic tool, particularly in continuous (buried) lava sequences like in Hawaii.
  - Small flow-to-flow changes in direction imply closeness in time; large change suggests hiatus
- Evaluation of "proximity in time" of different volcanic events using these data should be treated carefully. Lathrop Wells data, as reported by Turrin et al., indicate two directions separated by 4.7° This result should be interpreted in light of the following observations:
  - Typical SV rate is 1° per century (Holcomb et al., 1986)
  - Typical cinder cone eruption events last less than one year (Turrin et al., 1992)
  - There are few data for comparison on flow sequences where the age is as great as 100 Ka and the flows are not buried, as at Lathrop Wells


Fisher density
P(theta)
theta
k=30
k=40
k=50
0
2
4
6
8
0
10
20
30
40


Based on Bogue
and Coe (1981)
Probability
Alpha (degrees)
P(D:Hs)
P(D:Hr)
4.7°
k=100
k=500
0.0
0.2
0.4
0.6
0.8
1.0
0
5
10
15
20

Geologic Relationships and Stratigraphy

- Geologic characterization of the Lathrop Wells site is critical to the evaluation of geochronological data
- Soils data are useful as enrichment of volcanic stratigraphy information
- Geochemical data are useful as modifiers regarding effusion rates and for assessing the continuity of activity at individual centers.
  - Will need to be reconciled with magmatic process models

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Summary

Credibility

- Discrepancies between data sets can be rationalized and still result in a credible hazard assessment.
- Conflicts between investigators can call into question whether any useful information about age is in hand and could lead to a conclusion of ignorance implying that hazard cannot be satisfactorily estimated.
- Public posturing by investigators is presently more of a problem than the geochronological data and probability calculations

Summary

(Continued)

State of the investigations at Lathrop Wells

Existing data indicate

- Activity at Lathrop Wells is older than 65 ka and not older than ca. 150 ka
- At least two eruptive events occurred at the same locality and were separated in time sufficiently (at least hundreds of years) that they need to be considered as two separate events

Data insufficient to

- Rule out events younger than 65 ka and older than 150 ka
- Rule out the possibility of more than two events
- Define the time interval between events

Summary

(Continued)

Systematic investigations keyed to geologic/ stratigraphic models focussing on $^{40}Ar/^{39}Ar$ and ^{3}He-^{21}Ne are likely to allow these issues to be addressed, assuming this effort is warranted by the probability model calculations