DEPARTMENT OF THE INTERIOR

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ArAr*

a computer program for reduction of ^{40}Ar-^{39}Ar data

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Introduction

ArAr* is a computer program to reduce ^{40}Ar-^{39}Ar data. Inputs are an irradiation history and sets of raw isotopic analyses. Outputs are tables of input data, corrections, reduced isotopic data and ages, and a series of plots. This report describes the overall logic of the program and program flow, the central data reduction algorithm, the error-propagation algorithm, and an alternate, correlation-diagram approach to age and error calculations that is implemented in ArAr*. Example output, hints concerning use and modification of the program, a partial glossary of variables used in the program, and a listing of the program are included as appendices.

ArAr* is written in Hewlett-Packard BASIC for use on an HP 9845B microcomputer. Much of the structure of the program and the IO routines are a result of the limitations (and strengths) of this particular environment. Input to ArAr* is primarily via data tapes created by program ArTOM*, which controls the mass spectrometer during argon analyses and performs preliminary data reduction. Output from ArAr* is to the screen, the internal printer on the HP 9845, and to an HP plotter, using graphics routines provided by the HP System 45B graphics ROM. As a result of these IO considerations, as well as several non-standard features of HP BASIC, ArAr* is not especially portable. Nonetheless, a copy of ArAr* on a Hewlett-Packard magnetic tape cartridge may be obtained on request from the USGS Reston argon laboratory.

Please Note: We believe that the algorithms used in ArAr* are correct and correctly coded, and that inaccuracies induced by the limited precision of the computer are insignificant. Nonetheless, bugs almost certainly do exist. If you find them, or have suggestions for improvements to ArAr*, please contact the Reston argon lab. You are responsible for the correctness of any calculations you perform with the aid of ArAr*.

If you don't want to read this guide

ArAr* is intended to be self-explanatory. Put the program tape in the right-hand drive, make sure <AUTO ST> is depressed and <PRT ALL> is not, and turn the machine on. At many points you are offered choices: the most common choice (or the choice of preference for the naive user) is given as a default and highlighted on the screen. Press <CONT> for the default.

Program Flow

Main Menu The main menu of ArAr* offers 5 choices:

1 Read an existing irradiation history and reduce data on tape

2 Read an existing irradiation history and reduce data from keyboard

3 Enter a new irradiation history

4 Reduce data from the literature and make plots

5 Go home

Choice 5 ends the program; all other choices return to this main menu.

Choice 1 prompts you to load an irradiation history tape, reads a history from this tape, asks for sample information, and asks for information on the mass spectrometer and extraction line configuration at the time of analysis. You are prompted to load a data tape, asked which data files to read, the files are read, and the program goes to the Calc_n_plot subroutine (described below). You then have the option of reducing further samples from the same irradiation package.

Choice 2 is identical to choice 1, except that analytical data (counts and errors for each isotope for each heating step), time of analysis, and mass spectrometer configuration are entered at the keyboard.

Choice 3 writes an irradiation history file to tape.

Choice 4 allows you to enter published data, recalculate ages and make plots. ArAr* assumes that these data are already corrected for analytical blank, mass discrimination, decay, and products of interfering nuclear reactions. The data may be in moles, cubic centimeters at STP, or any other units which are proportional to moles. Tables are printed assuming input is in moles. Regression fits (discussed below) to such data will be only approximate, as ArAr* will not recognize the strong correlation of errors that is produced by the typical large uncertainty in blank corrections.

Calc_n_plot Choices 1 and 2 take you to the Calc_n_plot subroutine, in which:

(A) Decay factors Dec_{36}, Dec_{37}, and Dec_{39} are calculated for stepwise irradiation, using the formulas given by Dalrymple and others (1981). Because of the limited precision of the computer, this can result in significantly inaccurate decay

factors (e.g. less than 1.0 !). If Dec_{36} and Dec_{39} for any heating step are less than 1.1 they are recalculated assuming continuous irradiation in order to avoid the roundoff errors associated with the stepwise irradiation calculation.

(B) For each heating step, if ^{36}Ar is less than 0.2 counts, it is set to 0.2 counts, so the correction routines do not bomb from division by zero errors. The first heating step is checked for a large ^{37}Ar decay factor (D_{37}, below); if this is greater than 10 or, if ^{37}Ar is less than 100 counts, greater than 4, you are offered the option of setting ^{37}Ar, $^{37}Ar_{measurement\ error}$, and D_{37} to zero for all steps. This can minimize problems associated with multiplying a weak ^{37}Ar signal, with a proportionally large error, by a large decay correction factor.

(C) You are asked if you want to make blank corrections,

(D) you are asked if you want to regress the data for age and initial $^{40}Ar/^{36}Ar$ ratio (see An alternate approach to interpretation: the correlation diagram below),

(E) if indicated, you are asked to enter values for blanks and blank errors

(F) corrections and ages, molar amounts of gas, and errors are calculated,

(G) if so indicated at step (D), the data are regressed and then ages, moles of gas, and age errors are recalculated,

(H) you are asked if you want tables printed; if so, the program goes to the Tables subroutine (see below), during which it tests for and calculates age plateaus.

(I) you are offered the opportunity to re-reduce the data (returning to (C) above)

(J) you may make plots (see below)

(K) you are offered the opportunity to re-reduce and re-plot the data (returning to (C) above)

Choice 4 offers a similar set of options. If you choose to regress literature data for best-fit ages and initial $^{40}Ar/^{36}Ar$ ratios, be aware that the regression routine presupposes a more complete knowledge of

the covariance structure of the data than you are likely to have. The results you get will most probably be only approximate.

Blank_correct subroutine The Blank_correct subroutine is set up to provide a default tube blank of 10 ± 10 counts for each mass, the default furnace (atmospheric) blank specified earlier ('MASS SPECTROMETER CONSTANTS' screen), and a default standard error in the furnace blank of 66.6%. All of these may be changed. If there are many heating steps, not all of the blank information will be visible on the screen at once; however, the arrow keys (top center of the keyboard) can be used to roll the screen to view hidden lines. The default furnace blank of 1 x 10^{-12} moles ^{40}Ar is appropriate for extractions with the RF furnace on the present (Spring 1987) extraction line at Reston.

Tables subroutine The Tables subroutine offers the choice of printing or not printing a matrix indicating the relative importance of each source of error in the age calculation for each heating step. When printing the final data table, the data are tested for age plateaus, and then you are offered the option of calculating average ages for subsets of the data.

Plateaus Analyses are tested for age plateaus by comparing each heating step with all others in the potential plateau. The ages of two steps i and j are considered to be analytically indistinguishable if they differ by less than either

$$1.96 \times \mathrm{sqrt}(\mathrm{age}_i\mathrm{error}^2 + \mathrm{age}_j\mathrm{error}^2)$$

where $\mathrm{age}_n\mathrm{error}$ is the intra-sample precision of step n, or

$$0.00693 \times \frac{F_i + F_j}{2}$$

where F_n is the reduced $^{40}Ar/^{39}Ar$ ratio of step n. If a set of consecutive heating steps have analytically indistinguishable ages and include more than 50% of the $^{39}Ar_k$ released from the sample, they constitute a plateau (Fleck and others, 1977).

Average ages and errors for plateaus, and for contiguous sets of heating steps for which you choose to calculate an average age, are calculated by first calculating a weighted mean and weighted standard deviation for the reduced $^{40}Ar/^{39}Ar$ ratio F

$$\bar{F} = \frac{\sum F_i w_i}{\sum w_i}$$

$$\bar{F}_{error} = (\sum w_i)^{-1/2}$$

with w_i equal to the inverse of the square of the error in F_i. Errors in F are calculated by the error propagation technique described below; the errors used here reflect uncertainties in inputs 1-11. This best estimate of F, F_{error}, J for the sample, and the error in J are then used to calculate an age and estimated precision.

ArAr* does not calculate errors on total gas ages, as uncertainty in trap current factors and manifold factors makes the precision of sums of analyses from all heating steps potentially very poor.

Plots subroutine The Plots subroutine is largely self-explanatory. Options are to plot an age spectrum with or without a K/Ca plot; an X-Y plot of $^{36}Ar/^{40}Ar$ vs $^{39}Ar/^{40}Ar$; a ternary plot of ^{36}Ar, ^{39}Ar, and ^{40}Ar; or all of these plots. Sample plots are reproduced in Appendix 1.

With the first plot you will be asked to enter a sample name and several lines of labels; these may be up to 50 characters long. Don't use commas. The sample name and all labels will be printed on the age spectrum. The sample name and the first line of labels will be printed on the correlation diagrams. The age spectrum and correlation diagrams offer various options for error bars; note that on the age spectrum the error boxes are 2 standard deviations, whereas all other error bars and polygons are 1 standard deviation. The plotted errors are analytical errors alone (corresponding to uncertainties in inputs 1-9, below).

Algorithm for corrections and age calculation

Five masses --40, 39, 38, 37, and 36-- are measured in each analysis. This gas is the combination of the gas released by the sample, assumed to be all argon, and the analytical blank. For the purposes of data reduction, the blank can be divided into two parts. $Blank_1$, the "furnace blank", is assumed to have no mass 37, no mass 39, and the 40/36 and 38/36 ratios of atmospheric argon. Uncertainties in the 40, 36, and 38 content of $blank_1$ are assumed to be strictly correlated. $Blank_2$ is the "tube blank", composed of all 5 masses with no specified mass ratios and no correlations between uncertainties.

The gas released from the sample is the sum of pre-irradiation ^{40}Ar, ^{38}Ar, and ^{36}Ar; ^{39}Ar produced by irradiation of K, and interfering ^{40}Ar,

^{39}Ar, ^{38}Ar, ^{37}Ar, and ^{36}Ar produced by nuclear reaction with Ca, K, and Cl. To calculate an age we need to know how much ^{40}Ar and ^{36}Ar were present in the sample prior to irradiation ($^{40}Ar'$ and $^{36}Ar_{in}$) and how much ^{39}Ar was produced by the irradiation of K ($^{39}Ar_K$). If we can discern the amount of ^{38}Ar derived from the decay of the ^{38}Cl which was formed by irradiation of chlorine in the sample ($^{38}Ar_{Cl}$), and how much ^{37}Ar was produced by irradiation of calcium ($^{37}Ar_{Ca}$), these can be useful measures of the concentrations of these elements. Minor amounts of the other isotopes of argon are also produced by irradiation of K, Cl, and Ca, and ^{37}Ar and ^{39}Ar will have been lost by radioactive decay since the end of irradiation. The algorithm outlined here calculates corrected isotopic abundances and an age for each heating step.

If blank corrections are specified, the data are corrected

$$^{40}Ar = {}^{40}Ar_{measured} - {}^{40}Ar_{blank2} - {}^{40}Ar_{blank1} \quad (1a)$$

$$^{40}Ar_{err} = \quad (1b)$$

$$sqrt((^{40}Ar_{measurement\ err})^2 + (^{40}Ar_{blank2\ err})^2 + (^{40}Ar_{blank1\ err})^2)$$

and so on. $Blank_2$ is subtracted before passing data to the age function. $Blank_1$ is passed as a parameter to the age function and the correction is made within the age function.

Measurement of atmospheric argon in many mass spectrometers does not reproduce the accepted $^{40}Ar/^{36}Ar$ ratio (295.5) and a correction for mass discrimination must thus be applied to the blank-corrected raw values. ^{37}Ar and ^{39}Ar have been lost by radioactive decay since irradiation. If Ad is the measured atmospheric $^{40}Ar/^{36}Ar$ ratio and D_{37} and D_{39} are the ratios of ^{37}Ar and ^{39}Ar at the end of irradiation to ^{37}Ar and ^{39}Ar at the time of analysis, reduced isotopic amounts corresponding to the amounts present in the sample at the end of irradiation are calculated

$$^{36}Ar_r = {}^{36}Ar \times Ad/295.5 \quad (2a)$$

$$^{37}Ar_r = {}^{37}Ar \times D_{37} \times (1+3x(Ad/295.5-1)/4) \quad (2b)$$

$$^{38}Ar_r = {}^{38}Ar \times (1+2x(Ad/295.5-1)/4) \quad (2c)$$

$$^{39}Ar_r = {}^{39}Ar \times D_{39} \times (1+(Ad/295.5-1)/4) \quad (2d)$$

$$^{40}Ar_r = {}^{40}Ar \qquad (2e)$$

Assuming that production ratios for the various nuclear reactions are known (e.g. Table 8 of Dalrymple and others, 1981), corrections are made for the interfering Ca, K, and Cl-derived isotopes of argon. Simultaneous solution of the equations

$$^{37}Ar_{Ca} = {}^{37}Ar_r - {}^{37}Ar_K \qquad (3)$$

$$^{39}Ar_{Ca} = {}^{37}Ar_{Ca} \times (^{39}Ar_{Ca}/^{37}Ar_{Ca})_{reactor} \qquad (4)$$

$$^{39}Ar_K = {}^{39}Ar_r - {}^{39}Ar_{Ca} \qquad (5)$$

$$^{37}Ar_K = {}^{39}Ar_K \times (^{37}Ar_K/^{39}Ar_K)_{reactor} \qquad (6)$$

yields the equation

$$^{37}Ar_{Ca} = \frac{^{37}Ar_r - (^{37}Ar_K/^{39}Ar_K)_{reactor} \times {}^{39}Ar_r}{1 - (^{37}Ar_K/^{39}Ar_K)_{reactor} \times (^{39}Ar_{Ca}/^{37}Ar_{Ca})_{reactor}} \qquad (7)$$

Equations (4), (5), and (6) are used to calculate $^{39}Ar_{Ca}$, $^{39}Ar_K$, and $^{37}Ar_K$. We then calculate

$$^{36}Ar_{Ca} = {}^{37}Ar_{Ca} \times (^{36}Ar_{Ca}/^{37}Ar_{Ca})_{reactor} \qquad (8)$$

$$^{38}Ar_K = {}^{39}Ar_K \times (^{38}Ar_K/^{39}Ar_K)_{reactor} \qquad (9)$$

$$^{38}Ar_{Ca} = {}^{37}Ar_{Ca} \times (^{38}Ar_{Ca}/^{37}Ar_{Ca})_{reactor} \qquad (10)$$

If we assume that all ^{38}Cl has decayed to ^{38}Ar, a reasonable assumption given the 37 minute half-life of ^{38}Cl and cool-down times of a week or more between irradiation and analysis, simultaneous solution of the equations

$$^{38}Ar_{Cl} = {}^{38}Ar_r - {}^{38}Ar_{in} - {}^{38}Ar_K - {}^{38}Ar_{Ca} \quad (11)$$

$$^{36}Ar_{Cl} = {}^{38}Ar_{Cl} \times (^{36}Cl_{Cl}/^{38}Cl_{Cl})_{reactor} \times (D_{36}-1) \quad (12)$$

$$^{36}Ar_{in} = {}^{36}Ar_r - {}^{36}Ar_{Cl} - {}^{36}Ar_{Ca} \quad (13)$$

$$^{38}Ar_{in} = {}^{36}Ar_{in} * (^{38}Ar/^{36}Ar)_{atm}, \quad (14)$$

with D_{36} the ratio of ^{36}Cl present at the end of irradiation to that present at the time of analysis, yields the equation

$$^{38}Ar_{Cl} = \frac{{}^{38}Ar_r - {}^{38}Ar_{Ca} - {}^{38}Ar_K + (^{38}Ar/^{36}Ar)_{atm} \times (^{36}Ar_r - {}^{36}Ar_{Ca})}{1 - (^{38}Ar/^{36}Ar)_{atm} \times (^{36}Cl_{Cl}/^{38}Cl_{Cl})_{reactor} \times (D_{36}-1)} \quad (15)$$

Equations 12, 13, and 14 are used to calculate $^{36}Ar_{Cl}$, $^{3}Ar_{in}$, and $^{38}Ar_{in}$. $^{40}Ar_K$ and $^{40}Ar'$ are calculated by

$$^{40}Ar_K = {}^{39}Ar_K \times (^{40}Ar_K/^{39}Ar_K)_{reactor} \quad (16)$$

and

$$^{40}Ar' = {}^{40}Ar_r - {}^{40}Ar_K \quad (17)$$

From these reduced values and an assumed initial $^{40}Ar/^{36}Ar$ ratio, ages are calculated with the formula

$$\text{Age} = \frac{1}{\text{lambda}} \times \ln (J \times F + 1) \quad (18)$$

where **lambda** is the half-life of ^{40}K, J is an irradiation parameter (the portion of ^{39}K converted to ^{39}Ar multiplied by the ratio $^{40}K/^{39}K$), and

$$F = \frac{{}^{40}Ar' - {}^{36}Ar_{initial} \times ({}^{40}Ar/{}^{36}Ar)_{initial}}{{}^{39}Ar_K} \qquad (19)$$

All the reduced isotopic values are in counts. To convert counts to moles, we multiply by Cfactor, where

Cfactor = sensitivity x trap-current factor x manifold factor

Error Propagation

As is apparent above, many inputs are required for an age calculation. Uncertainties in calculated ages (and molar quantities) stem from uncertainties in each of the following inputs:

1 $blank_1$ (atmospheric)
2 measured 40 counts (includes non-atmospheric $blank_2$)
3 measured 39 counts "
4 measured 38 counts "
5 measured 37 counts "
6 measured 36 counts "
7 ^{39}Ar decay factor
8 ^{37}Ar decay factor
9 ^{36}Cl decay factor
10 measured atmospheric $^{40}Ar/^{36}Ar$ ratio
11 initial $^{40}Ar/^{36}Ar$
12 the irradiation parameter J
13 $(^{40}Ar_K/^{39}Ar_K)_{reactor}$
14 $(^{38}Ar_K/^{39}Ar_K)_{reactor}$
15 $(^{37}Ar_K/^{39}Ar_K)_{reactor}$
16 $(^{39}Ar_{Ca}/^{37}Ar_{Ca})_{reactor}$
17 $(^{38}Ar_{Ca}/^{37}Ar_{Ca})_{reactor}$
18 $(^{36}Ar_{Ca}/^{37}Ar_{Ca})_{reactor}$
19 $(^{36}Cl_{Cl}/^{38}Cl_{Cl})_{reactor}$
20 initial $^{38}Ar/^{36}Ar$
21 age of the monitor

If we wish to compare ages (or molar quantities) between different heating steps of a single sample, errors in inputs 1 through 9 are the sole sources of imprecision. The remaining inputs are presumably constant within the analyses being compared, and thus do not affect the intra-sample precision. (Note that the magnitudes of these inputs may be poorly known and thus accuracy may be affected.) Comparison between samples within a single irradiation package introduces the possibility of variations in inputs 10-12. Variation in these inputs must be

considered in assessing the precision of intra-package comparisons. The precision of comparisons between irradiation packages will reflect uncertainties in all of the inputs.

The error propagation equation (Taylor, 1982) states that for a function **Age** of several independent variables (**a**, **b**, ...),

$$\text{error\_in\_Age} = \text{sqrt}\left((\text{error\_in\_a} \times \frac{\partial \text{Age}}{\partial a})^2 + (\text{error\_in\_b} \times \frac{\partial \text{Age}}{\partial b})^2 + \ldots \right)$$

Rather than write exact equations for each of the 21 partial derivatives needed to evaluate the error in the age function, I chose to numerically evaluate the partial derivatives $\partial Age/\partial a$. To aide in this differentiation, the input factors for the age function are stored in a matrix **G**, with a corresponding error matrix **E**. Corrections calculated during evaluation of the age function are stored in a corrections matrix **Cor**. In simplified form, the code for evaluating the error in **Age** is

```
100  Error_in_age = 0
110  For n = 1 to Number_of_inputs
120       G(n) = G(n) + E(n)/4          ! G = G plus a little
130       Age1 = FNAge( G(*), Cor(*) )
140       G(n) = G(n) - E(n)/2          ! G = G minus a little
150       Age2 = FNAge( G(*), Cor(*) )
160       G(n) = G(n) + E(n)/4          ! reset G to original value
170       dAge_dn = (Age1 - Age2) / ( E(n)/2 )
180       Error_in_age = Error_in_age + (E(n) * dAge_dn)^2
190  Next n
200  Error_in_age = sqrt(Error_in_age)
```

In practice, ArAr* simultaneously calculates estimated uncertainties of molar amounts, molar ratios, etc. This routine requires 2 x **Number_of_inputs** calls to the **Age** function, resulting in a rather slow calculation (~7 seconds per heating step on the HP 9845B), but the code

is easier to verify and more flexible than would be code for exact differentials.

ArAr* assumes that the standard deviations of inputs 7, 8, 9, 19, and 20 are zero. The standard deviations for inputs 13, 14, 16, 17, and 18 are the errors given by Dalrymple and others (1981). These may be underestimates. The value of input 15 is taken to be 0.0, with a standard error of 0.0023, 100% of the value given by Dalrymple and others (1981), as Larry Snee (oral communication, 1987) found that use of $(^{37}Ar_K/^{39}Ar_K)_{reactor} = 0.0023$ gives negative Ca contents for some high K/Ca samples. If no blank correction is made, the standard deviation of input 1 is set at zero. If the regression option is chosen, the precision of input 11 is that given by the York regression; otherwise, its standard deviation is set to zero.

An alternate approach to interpretation: the correlation diagram

As discussed by Haugerud (in press), two assumptions are implicit in the conventional method of calculating ages from ^{40}Ar-^{39}Ar data (equations 18 and 19, above).

(1) the analysed gas is a mixture of a K-derived component, composed of ^{40}Ar and ^{39}Ar, and a non-K-derived component[1], composed of ^{36}Ar and ^{40}Ar

(2) the non-K-derived component is atmospheric argon

The non-K-derived component can be divided into analytical blank and initial argon--argon present in the sample at the time it formed and(or) closed to argon diffusion.

Assumption (1) is unavoidable. Assumption (2) is reasonable, if the non-K-derived component is all analytical blank (but this is rarely the case) and the blank is entirely atmospheric, or your sample formed and(or) closed to argon diffusion while saturated with atmospheric argon, (e.g. biotite from an air-fall tuff). If your sample is from a metamorphic rock or a deep-seated igneous rock, assumption (2) is quite possibly wrong. With high-quality step-heating data it is possible to test these assumptions, and if (1) appears correct, identify the initial argon composition.

To do this, we analyze the blank-corrected data on an ^{40}Ar-^{39}Ar-^{36}Ar isotope correlation diagram (Figure 1). If the data define a mixing

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[1] That is, not derived from radioactive decay or irradiation of K in the sample. Ultimately most of this Ar is derived from decay of ^{40}K.

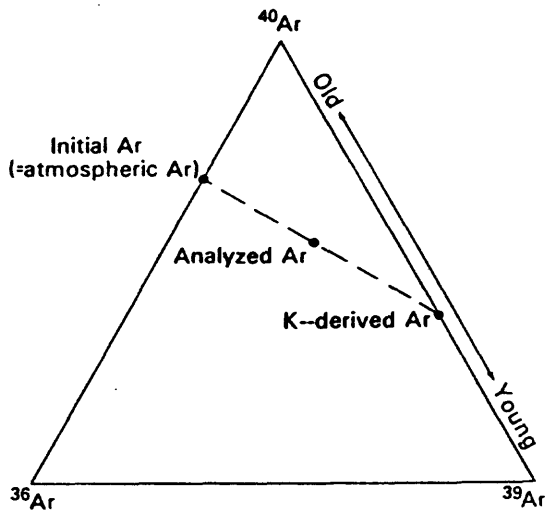

Figure 1. Ternary ^{40}Ar-^{39}Ar-^{36}Ar isotope correlation diagram. Diagram illustrates the assumptions inherent in calculation of a K-Ar age from analytical data: (1) analyzed argon is assumed to be a two-component mixture of initial and radiogenic argon, and (2) usually it is assumed that initial argon is atmospheric.

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line, assumption (1) is justified. On the correlation diagram, the intersection of this mixing line with the line $^{39}Ar = 0$ gives the initial argon composition. The intersection of the mixing line with the line $^{36}Ar = 0$ gives the reduced $^{40}Ar/^{39}Ar$ ratio F needed to calculate an age (equation 18).

ArAr* draws two kinds of isotope correlation diagrams (Appendix 1). One, a ternary diagram with vertices of air Ar, ^{40}Ar, and an arbitrarily chosen ^{40}Ar-^{39}Ar mixture, is helpful for understanding argon systematics, as the effects of possible gas mixing and isotopic re-equilibration are easily visualized, following the rules familiar to many of us from our salad days when we used ternary diagrams to study igneous petrology. The other diagram is a more conventional x-y plot of $^{36}Ar/^{40}Ar$ vs $^{39}Ar/^{40}Ar$.

ArAr* also provides a regression routine to calculate best-fit lines to the data points as they appear on the $^{36}Ar/^{40}Ar$ vs $^{39}Ar/^{40}Ar$ x-y plot. This is York's (1969) regression treatment for data having errors in both X and Y with (variably) correlated errors. Correlation coefficients R are calculated with the formula given by Roddick and others (1980, their Appendix 2):

$$R = \frac{\left(1 - \frac{^{40}Ar'}{295.5\ ^{36}Ar_{in}}\right) \times \left(\frac{^{40}Ar_{blank1\ error}}{^{40}Ar}\right)^2 + \left(\frac{^{40}Ar_{measurement\ error}}{^{40}Ar}\right)^2}{(^{36}Ar/^{40}Ar)_{error}\ (^{39}Ar/^{40}Ar)_{error}}$$

$(^{36}Ar/^{40}Ar)_{error}$ and $(^{39}Ar/^{40}/Ar)_{error}$ are calculated using the numerical approach outlined above.

To use the isotope-correlation approach to define initial ratio and an age, answer Y when asked if you wish to regress the data for the initial $^{40}Ar/^{36}Ar$ ratio. After performing a preliminary age and error calculation, ArAr*

(A) calculates X, Y, their individual errors, and error correlation coefficients for the $^{36}Ar/^{40}Ar$ vs $^{39}Ar/^{40}Ar$ x-y plot,

(B) sends these values to subprogram York which iterates to find the slope of the regression line. If this is the first pass through the regression routine, the program goes to (C), else it skips to (E).

(C) draws the X-Y plot on the screen, with individual data points labelled (A, B, C, ...) in order, draws 1 standard deviation error bars, draws the best-fit line for all the data points, and dumps this plot to the internal printer

(D) prints a list of the relative weights of X and Y, their error correlation coefficient R, and the residual (a measure of how far a point is from the regression line) for each heating step.

(E) prints parameters for the best-fit line, the fit parameters SUMS and MSWD (= SUMS/(n-2)), best values for $(^{40}Ar/^{36}Ar)_{initial}$, F, and age, all with standard errors. The error in age includes the effects of uncertainty in J.

(F) asks if you wish to delete any points and re-regress the data. If yes, you are prompted to enter a list of letters corresponding to the data points you want deleted, and the program goes to (B) above. If no, you procede to

(G) recalculate the ages and errors for each heating step, using the most recently calculated $(^{40}Ar/^{36}Ar)_{initial}$ and its uncertainty.

The radiogenic yields, F, and ages printed in the tables will all reflect the initial ratio defined by the regression. The final table will also report a total-gas age for $(^{40}Ar/^{36}Ar)_{initial} = 295.5$, and two age spectra may be drawn: one for the regressed initial ratio; the other, with a different pen, for an atmospheric initial ratio.

Errors in F and initial ratio are correlated. ArAr* does not consider this correlation when calculating the average age and error in age for a

plateau or a specified set of heating steps. The estimated sample F and F error returned by the York regression do include the effect of this correlation, and thus the age and estimated precision calculated by the isotope correlation approach are better measures of a preferred sample age.

IF YOU HAVE NON-ATMOSPHERIC ARGON IN YOUR SAMPLE YOU BETTER MAKE BLANK CORRECTIONS. IF THE BLANKS ARE AT ALL SIGNIFICANT, BOTH THE AGE AND THE INITIAL RATIO MAY BE POORLY CONSTRAINED. IF SO, TOO BAD. YOU NEED BETTER DATA.

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Appendix 1. Example output

The tables and graphs on the following pages are typical output from ArAr*. They were produced with the following choices:

Main menu: 1

Blank correction: Yes. Used default blanks

Regress for initial ratio: Yes

Delete points and repeat regression: No

Print tables: Yes

Printout of importance of various sources of error: Yes

Calculate average age for group of steps: No

Make plots: Yes

Plot choices: 1 (all plots)

Error polygons on ternary: No

Air-error lines on ternary: Yes

Regression line on ternary: No

Change minimum F: Yes (to 8.0)

1-sigma error bars on 39/40 - 36/40 correlation plot: Yes

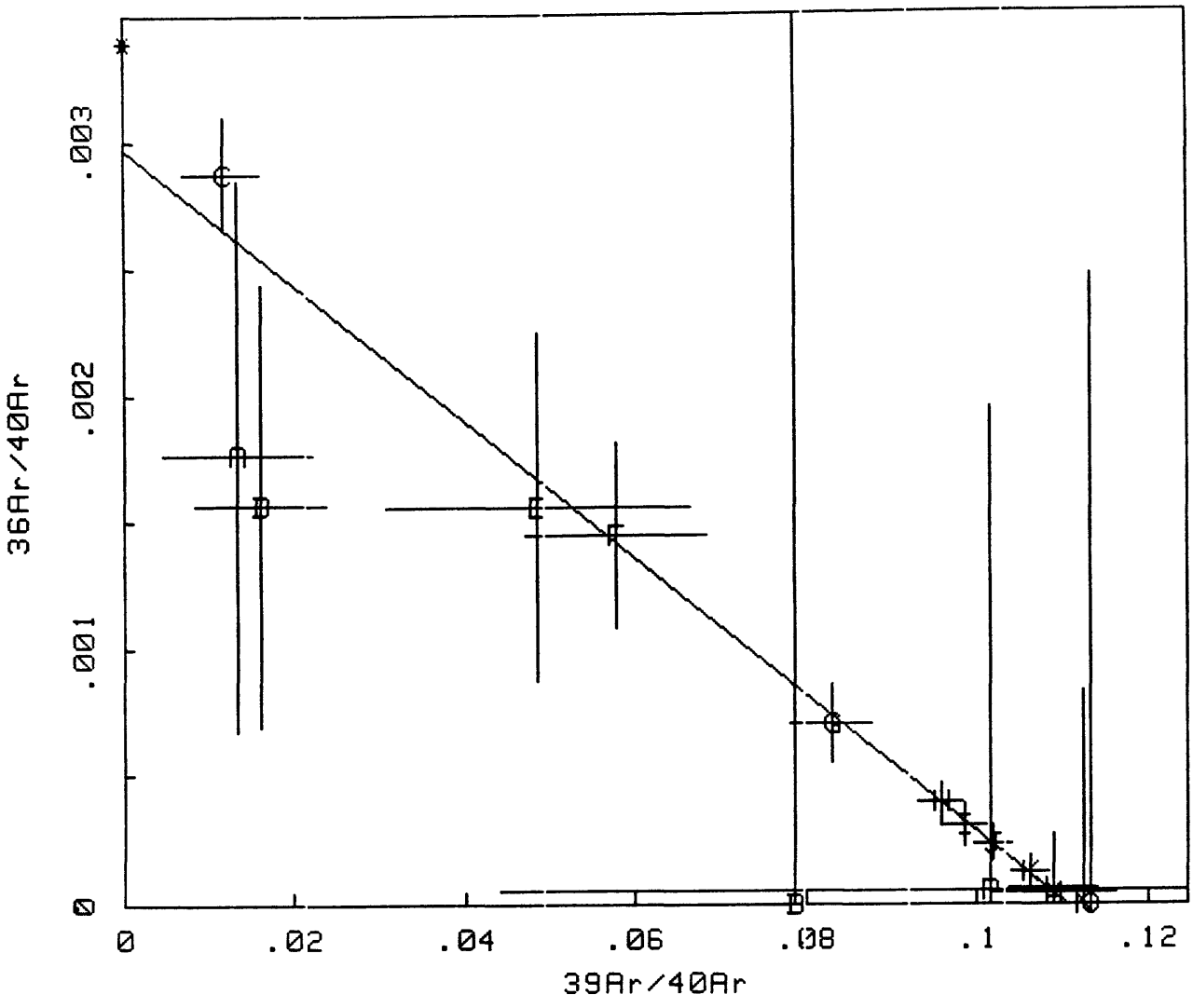
Regression line on 39/40 - 36/40 correlation plot: Yes

2-sigma error boxes on age spectrum: Yes

Plot age spectrum for 40Ar/36Ar initial = 295.5: No
(if plots are not going to be reproduced in black and white, default yes responses to this and the following question--Plot age spectrum for regressed initial 40Ar/36Ar--are recommended)

Plot K/Ca: Yes

v 2/17/88 , sample RH85-F18a HORNBLENDE RD40:5-6



16 points regressed out of 16
Mean X = .101E+00 Mean Y = .264E-03 Slope = -.269E-01 ± .168E-02
36/40 = .297E-02 ± .169E-03 39/40 = .111E+00 ± .800E-03
Fit parameters: SUMS = 3.761 MSWD = .269
40Ar/36Ar = 336.89 ± 19.23 F = 9.048 ± .066 AGE = 86.36 ± .74 Ma

A	450C	WT X =	.13E+05	WT Y =	.86E+06	R =	-.24E+00	Residual =	.66E+00
B	650C	WT X =	.17E+05	WT Y =	.13E+07	R =	-.33E+00	Residual =	.14E+01
C	750C	WT X =	.51E+05	WT Y =	.20E+08	R =	-.35E+00	Residual =	.11E+01
D	850C	WT X =	.21E+02	WT Y =	.82E+04	R =	-.28E-01	Residual =	.47E-02
E	950C	WT X =	.31E+04	WT Y =	.22E+07	R =	-.40E+00	Residual =	.24E-01
F	1000C	WT X =	.88E+04	WT Y =	.77E+07	R =	-.60E+00	Residual =	.16E-01
G	1050C	WT X =	.44E+05	WT Y =	.42E+08	R =	-.84E+00	Residual =	.20E+00
H	1100C	WT X =	.16E+06	WT Y =	.16E+09	R =	-.92E+00	Residual =	.83E-02
I	1150C	WT X =	.15E+06	WT Y =	.15E+09	R =	-.92E+00	Residual =	.24E+00
J	1200C	WT X =	.21E+06	WT Y =	.22E+09	R =	-.93E+00	Residual =	.21E-01
K	1250C	WT X =	.20E+06	WT Y =	.21E+09	R =	-.93E+00	Residual =	.12E+00
L	1300C	WT X =	.38E+05	WT Y =	.40E+08	R =	-.86E+00	Residual =	.18E-01
M	1350C	WT X =	.19E+05	WT Y =	.20E+08	R =	-.82E+00	Residual =	.36E-03
N	1400C	WT X =	.14E+04	WT Y =	.14E+07	R =	-.52E+00	Residual =	.48E-02
O	1450C	WT X =	.13E+03	WT Y =	.16E+06	R =	-.22E+00	Residual =	.77E-03
P	1550C	WT X =	.30E+03	WT Y =	.28E+06	R =	-.29E+00	Residual =	.80E-02

RH85-F18a HORNBLENDE RD40:5-6

R A W D A T A

FILE	TEMP	40Ar	39Ar	38Ar	37Ar	36Ar	TRAP CURRENT	MANIFOLD OPTION
9659:T	450	204734	1414	2646	3231	534	200	ALL
	±	90	7	79	11	14		
furnace blank 40Ar		100000±	66667					
9660:T	650	243565	2345	1111	4078	574	200	ALL
	±	77	6	33	12	13		
furnace blank 40Ar		100000±	66667					
9661:T	750	278310	2101	560	4059	862	200	ALL
	±	121	12	28	15	16		
furnace blank 40Ar		100000±	66667					
9662:T	850	132781	2597	470	4713	331	200	ALL
	±	89	10	47	18	8		
furnace blank 40Ar		100000±	66667					
9663:T	950	283112	8935	1879	23401	647	200	ALL
	±	164	20	56	16	15		
furnace blank 40Ar		100000±	66667					
9664:T	1000	463654	21129	4691	64173	911	200	ALL
	±	6	14	47	57	16		
furnace blank 40Ar		100000±	66667					
9665:T	1050	1265336	96998	21656	300731	1343	200	ALL
	±	136	99	65	383	5		
furnace blank 40Ar		100000±	66667					
9666:T	1100	2666655	246502	52953	743675	1789	200	ALL
	±	1783	145	159	322	18		
furnace blank 40Ar		100000±	66667					
9667:T	1150	2664729	253323	53694	761537	1579	200	ALL
	±	1665	23	161	165	6		
furnace blank 40Ar		100000±	66667					
9668:T	1200	3214086	318495	66120	951536	1627	200	ALL
	±	2989	276	198	367	20		
furnace blank 40Ar		100000±	66667					
9669:T	1250	3283172	339269	69101	995138	1319	200	ALL
	±	940	317	207	359	19		
furnace blank 40Ar		100000±	66667					
9670:T	1300	1508952	153757	31176	445267	688	200	ALL
	±	1611	140	94	56	19		
furnace blank 40Ar		100000±	66667					
9671:T	1350	1100292	109372	21887	314642	575	200	ALL
	±	695	29	66	47	13		
furnace blank 40Ar		100000±	66667					
9672:T	1400	379029	31478	6361	90687	381	200	ALL
	±	313	24	32	48	13		
furnace blank 40Ar		100000±	66667					
9673:T	1450	204919	11939	2488	34364	329	200	ALL
	±	121	17	75	30	14		
furnace blank 40Ar		100000±	66667					
9674:T	1550	220481	12288	2548	35298	375	200	ALL
	±	202	2	76	22	6		
furnace blank 40Ar		100000±	66667					

38Ar errors assigned from experience, rest calculated from regression statistics
Raw counts and errors do not include blank corrections. Blanks include indicated amount of air 40Ar, with corresponding 38Ar and 36Ar, as well as the following tube blank:
mass 40:10+10 mass 39:10+10 mass 38:10+10 mass 37:10+10 mass 36:10+10

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RH85-F18a HORNBLENDE RD40:5-6

C O R R E C T I O N S

TEMP °C	39Ar Decay	37Ar Decay	-----K-derived---- 40Ar	38Ar	37Ar	----Ca-derived---- 39Ar	38Ar	36Ar	Cl-der 36Ar	Initial 38Ar
450	0	3851	8	19	0	5	0	2	0	34
650	1	4865	13	31	0	6	0	2	0	42
750	1	4848	12	28	0	6	0	2	0	96
850	1	5634	15	35	0	7	0	3	0	-4
950	3	28006	51	119	0	35	2	14	0	53
1000	6	76887	120	282	0	95	4	37	0	99
1050	28	373859	549	1295	0	455	21	179	2	153
1100	70	892966	1395	3292	0	1104	52	433	4	189
1150	72	915242	1434	3383	0	1131	53	444	4	147
1200	90	1144796	1803	4254	0	1414	67	555	5	135
1250	96	1198698	1921	4531	0	1480	70	581	5	73
1300	44	536914	871	2054	0	663	31	260	2	15
1350	31	379745	619	1461	0	468	22	184	2	8
1400	9	109567	178	420	0	135	6	53	0	-4
1450	3	41562	68	159	0	51	2	20	0	-7
1550	4	42740	70	164	0	53	2	21	0	1

All values in counts, corrected for mass discrimination

	TEMP C	% TOT 39Ar	RAD YIELD	APP K/Ca	APP K/Cl	F	AGE (Ma)		precision intra-sample	intra-package	inter-package
A	450	.1	40.7	.10	1	30.410	275.19	±	67.07	70.37	70.38
B	650	.1	47.3	.14	5	29.152	264.60	±	40.05	43.01	43.02
C	750	.1	3.2	.12	9	2.703	26.23	±	53.45	70.20	70.20
D	850	.2	100.0	.13	17	15.370	144.33	±	36.69	36.72	36.73
E	950	.6	47.4	.09	12	9.756	92.94	±	11.92	13.23	13.24
F	1000	1.3	51.1	.08	11	8.833	84.34	±	5.08	6.79	6.80
G	1050	6.0	76.3	.07	11	9.201	87.78	±	1.00	1.87	1.92
H	1100	15.3	86.8	.08	12	9.059	86.45	±	.46	.97	1.06
I	1150	15.7	89.7	.08	12	9.102	86.86	±	.39	.80	.91
J	1200	19.8	92.2	.08	12	9.036	86.24	±	.38	.70	.82
K	1250	21.0	95.9	.08	13	9.020	86.09	±	.34	.58	.72
L	1300	9.5	98.1	.08	13	9.015	86.05	±	.74	.86	.96
M	1350	6.8	98.6	.08	13	9.041	86.29	±	.95	1.05	1.13
N	1400	2.0	100.0	.08	13	9.115	86.98	±	3.31	3.34	3.37
O	1450	.7	100.0	.08	13	9.934	94.59	±	8.76	8.79	8.80
P	1550	.8	98.2	.08	13	9.664	92.08	±	7.88	7.89	7.90

Precisions are 1 sigma, measured in Ma. Measured 40/36 atm = 296.5 ±.5
J = 0.005419 ± 0.50% (intra-package) ± 0.50% (inter-package)
Trap current factors- 40: 9.3 100: 4.56 200: 1
Manifold factors- ALL: 1 SPLIT 1: 3.6 SPLIT 2: 12.96 SPLIT 3: 46.656
Sensitivity = 1.000E-17 Detection limit = 40 counts
Data reduced assuming initial 40/36 = 336.89 ± 19.23

RH85-F18a HORNBLENDE RD40:5-6

Relative importance of various sources of error in age, normalized to inter-package error = 1000

Furnace blnk	667	652	398	833	571	390	232	119	152	119	135	373	527	717	722	848
Raw 40	0	0	0	0	0	0	0	4	5	12	1	11	3	1	0	0
Raw 39	1	1	0	0	0	0	2	2	0	8	12	6	0	0	0	0
Raw 38	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Raw 37	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Raw 36	240	214	182	165	239	166	37	65	26	73	77	210	184	249	267	144
39 Decay cor	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
37 decay cor	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
36Cl decay	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
40/36 in	91	132	420	1	187	436	627	484	376	249	81	9	4	1	5	0
Mass discrim	0	0	0	0	0	1	2	3	4	4	4	2	1	0	0	0
intra-pkg J	0	1	0	0	1	4	50	160	218	266	342	193	139	16	3	3
K4039 reac	0	0	0	0	0	0	0	1	2	2	3	2	1	0	0	0
K3839 reac	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
K3739 reac	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Ca3937 reac	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Ca3837 reac	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Ca3637 reac	0	0	0	0	0	0	0	1	2	2	2	1	1	0	0	0
Cl3638 reac	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
init Ar3836	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
monitor age	0	1	0	0	1	4	50	160	218	266	342	193	139	16	3	3

Intra-sample error includes effects of Furnace blnk to 36Cl Decay errors (first 9) inclusive; intra-package error also includes effects of error in initial 40/36 ratio and mass discrimination and intra-package uncertainty in J; interpackage error includes effects of all sources of uncertainty.
Uncertainties in decay corrections and initial 38/36 ratio are assumed to be 0.
Uncertainties in tube blank are included in uncertainties in raw counts.

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RH85-F18a HORNBLENDE RD40:5-6

J = 0.005419 ± 0.50% SAMPLE WT = 1.0011 g

TEMP C	Initial & radiogenic 40Ar	Potassium derived 39Ar	Chlorine derived 38Ar	Calcium derived 37Ar	Initial 36Ar	AGE* in Ma	**
450	1.047E-12	1.401E-14	2.593E-14	7.078E-14	1.844E-15	275.19 ±	70.37
650	1.435E-12	2.331E-14	1.050E-14	8.944E-14	2.243E-15	264.60 ±	43.01
750	1.783E-12	2.087E-14	5.547E-15	8.907E-14	5.125E-15	26.23 ±	70.20
850	3.276E-13	2.583E-14	3.589E-15	1.035E-13	***	144.33 ±	36.72
950	1.831E-12	8.901E-14	1.741E-14	5.152E-13	2.856E-15	92.94 ±	13.23
1000	3.635E-12	2.105E-13	4.438E-14	1.414E-12	5.272E-15	84.34 ±	6.79
1050	1.165E-11	9.664E-13	2.046E-13	6.763E-12	8.179E-15	87.78 ±	1.87
1100	2.565E-11	2.457E-12	4.982E-13	1.641E-11	1.009E-14	86.45 ±	.97
1150	2.563E-11	2.525E-12	5.042E-13	1.681E-11	7.875E-15	86.86 ±	.80
1200	3.112E-11	3.174E-12	6.198E-13	2.102E-11	7.238E-15	86.24 ±	.70
1250	3.181E-11	3.382E-12	6.462E-13	2.199E-11	3.885E-15	86.09 ±	.58
1300	1.408E-11	1.533E-12	2.909E-13	9.847E-12	7.837E-16	86.05 ±	.86
1350	9.997E-12	1.090E-12	2.038E-13	6.961E-12	4.170E-16	86.29 ±	1.05
1400	2.788E-12	3.137E-13	5.868E-14	2.007E-12	***	86.98 ±	3.34
1450	1.048E-12	1.189E-13	2.250E-14	7.610E-13	***	94.59 ±	8.79
1550	1.204E-12	1.224E-13	2.313E-14	7.821E-13	***	92.08 ±	7.89
TOTAL GAS	1.650E-10	1.606E-11	3.179E-12	1.056E-10	5.587E-14	86.86	
		assuming 40Ar/36Ar initial = 295.5				88.20	

99.8% of gas on plateau, steps 750 through 1550 PLATEAU AGE = 86.31 ± .49

Note: all gas quantities are in moles. Corrected for analytical blank.
* Ages calculated assuming initial 40Ar/36Ar = 336.9 ± 19.2
** 1-sigma precision estimates are for intra-irradiation package reproducibility.
*** below detection limit

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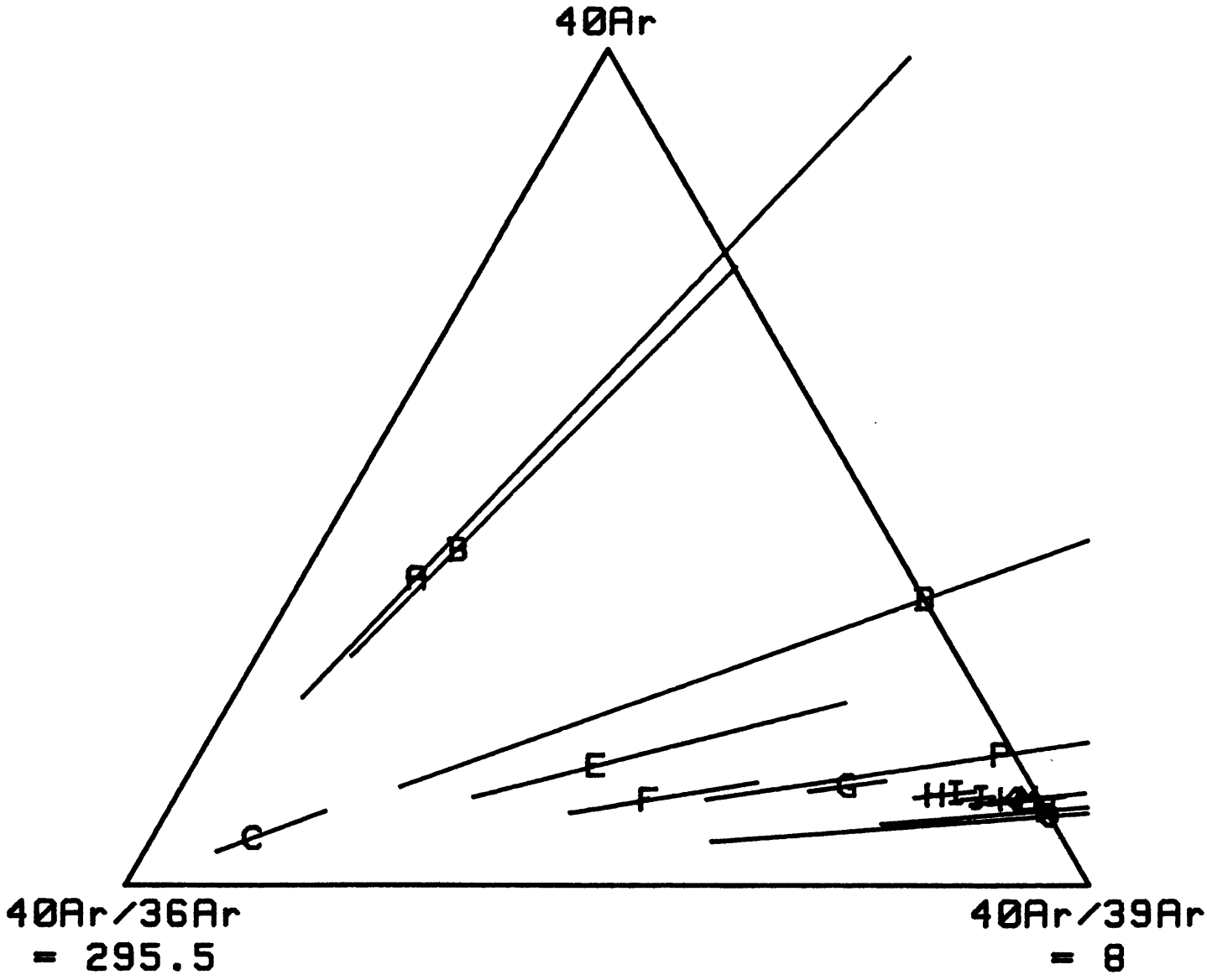
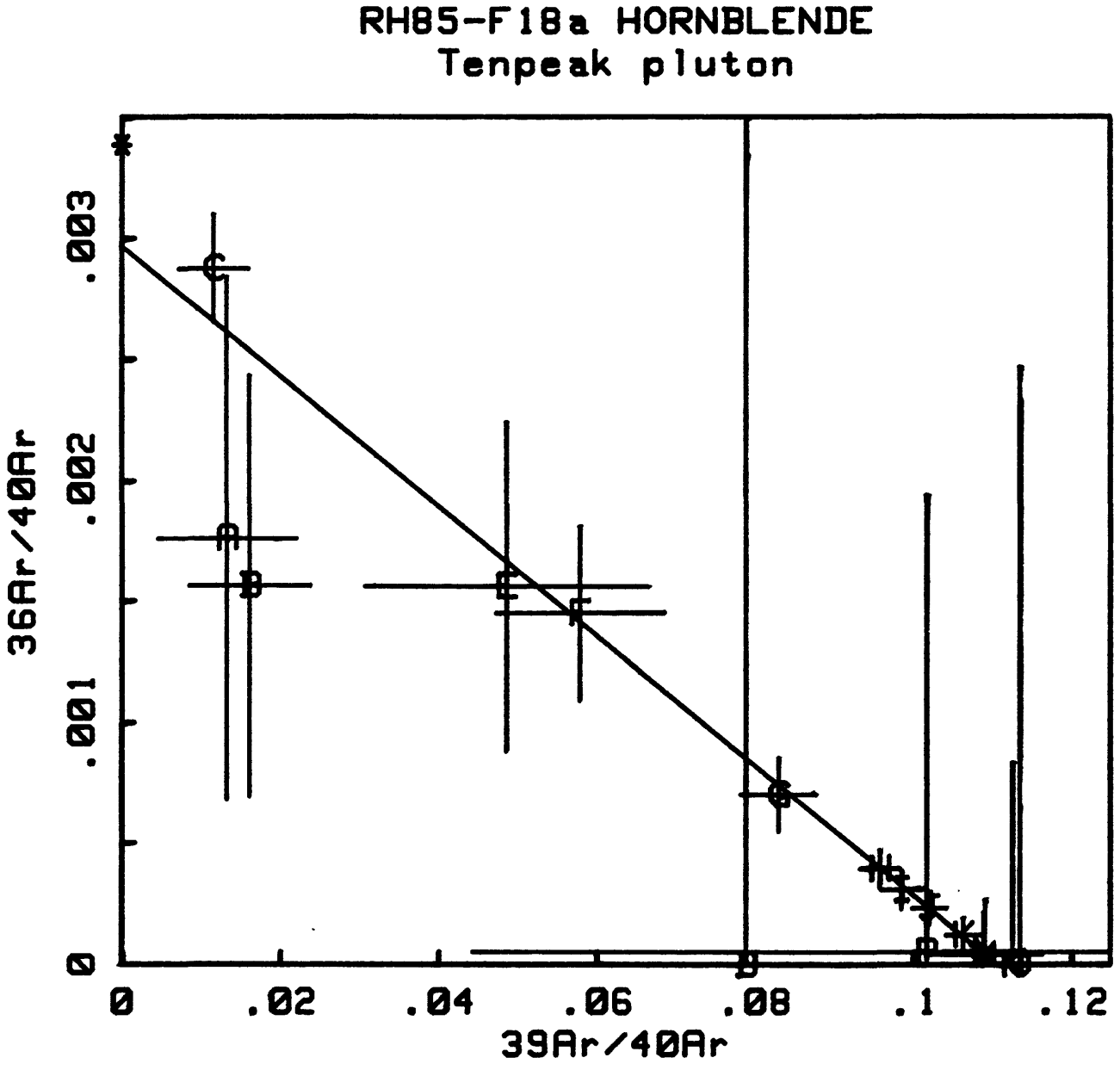
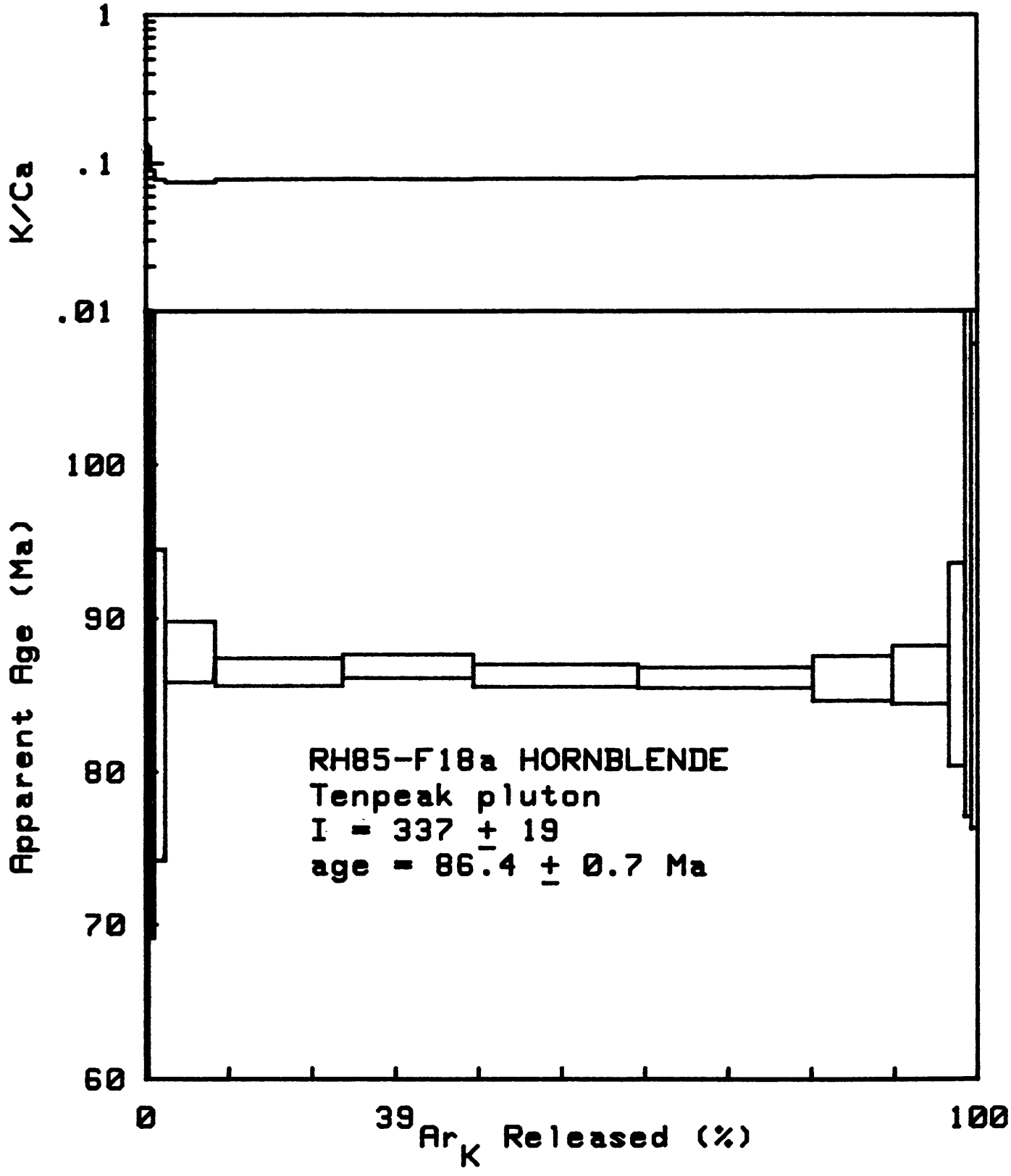


RH85-F18a HORNBLENDE
Tenpeak pluton
I = 337 ± 19
age = 86.4 ± 0.7 Ma

v 2/17/88 RH85-F18a HORNBLENDE RD40:5-6



v 2/17/88 RH85-F18a HORNBLENDE RD40:5-6



v 2/17/88 RH85-F18a HORNBLENDE RD40:5-6 (40/36in = 336.9)

Appendix 2. Hints for use and modification of ArAr*

The HP 9845B has a rather elaborate keyboard, with three varieties of ENTER key: <CONT>, <STORE>, and <EXECUTE>. Input to the program must be ended by <CONT>. If you press <STORE> or <EXECUTE>, you will get an error message or your input repeated. Never fear, if you press <CONT> the program will in most cases procede normally.

As is the case with most computers, you cannot harm the HP 9845B by anything you type on it. At worst you might enter a infinite loop, or corrupt the program in memory. If you fear this has happened, turn the machine off (switch on the right-hand side of computer), put the program tape in the right-hand drive, and turn the machine back on. All you have lost is time.

Most decay constants, reactor correction factors, mass spectrometer and extraction line parameters, minimum counts for detection limit, and default blank are defined in lines 400 - 740 and may be readily changed. The inverse of the decay constant for ^{40}K (1804, in millions of years) is not defined in one place; to change this decay constant it must be changed in the **Print_final** subroutine and in the **Age** and **Fage** subprograms.

Many questions want a Y/N answer. For all, I have tried to (1) provide a default answer, highlighted on the screen, and (2) send responses to a filtering subprogram which takes **yes**, **NO**, **Y**, etc. and converts this response to **Y** or **N** as appropriate. If you add to the program, you can maintain consistency by coding Y/N inputs as

```
nn10  Z$="Y"                                      ! set up default
nn20  INPUT "Answer this question (Y/N)",Z$       ! highlight default
nn30  CALL Yn(Z$)                                 ! send response
                                                  !  to filter
```

Note that most errors are input as amounts, e.g. blank errors are in counts, while the errors in J and monitor age need to be entered as percent errors.

At several points in ArAr* you are asked to approve a screenful of data. If you answer **N**, you will be asked to enter each value on the screen. You need not retype all values; pressing <CONT> will preserve the present values. You need enter new values only for those variables you wish to change.

Unusual effects, such as negative corrections, may indicate that the estimated blank is too large. For easy visualization of some of the effects of blank uncertainty, plot a ternary correlation diagram (option

2 on the plot menu) with air-error lines.

To interrupt the plotter, press **<PAUSE>** or **<STOP>**. Then type

PEN 0

<EXECUTE>

to return the pen to its holder.

The highly correlated errors in typical argon data lead to slow convergence of the York regression routine. Don't be surprised if you go through 30 or more iterations.

Entry of data from the keyboard is tedious and prone to error. If most of your data is correctly recorded on data tapes but a few values are in error, you may read the data tapes using option 1 and then manually change the few incorrect values. To do this, start by adding two new lines to the program, in the subroutine Rue_des_vaches (line numbers are those of v 2/17/88), so it reads

```
1020  GOSUB Read_data_file
1030  Sample$=Lab1$=Lab2$=Lab3$=""
1031  DISP "FUDGE YOUR DATA HERE"      ( new line )
1032  PAUSE                            ( new line )
1040  GOSUB Calc_n_plot
```

and re-start the program by pressing **<STOP>** then **<RUN>**. When you get the message **FUDGE YOUR DATA HERE**, you can change values by typing

```
Raw40(m) = nnnnn      {m is heating-step number, nnnn is new value}
                      {or Raw38 or Raw37 or...}
<EXECUTE>

Raw40err(m) = nnnn

<EXECUTE>
```

and so on. Then press **<CONT>** to continue the program. Note that HP BASIC is case-sensitive. Typing RAW40 will provoke an error message. Variable names are given in Appendix 2.

The error polygons on ternary correlation diagrams may be misleading. This stems from two factors: the algorithm used to calculate polygon vertices does not cope well with large errors which produce negative total gas volumes; and the polygons do not reflect the strong correlation between ^{36}Ar and ^{40}Ar errors induced by large, poorly known blank corrections. Similarly, errors on the 36/40 - 39/40 correlation plot commonly are strongly correlated, though the error bars on the plot do not indicate this.

Plots should reproduce well for publication if drawn with 0.3 mm pens. Fatter lines for plots that will be photographed for slides can be produced by using 0.7 mm pens or by drawing plots twice, shifting the paper slightly between each pass. The latter produces a nice "chiseled" effect to the lettering.

When starting a program, BASIC initializes all numeric variables to zero and all strings to the null string. When reducing multiple sets of data ArAr* does not re-initialize variables, with the exception of blank corrections and plot labels. All previous values are retained unless they are overwritten. Because of this feature, when you are reducing multiple sets of data you can recover previously entered values for measured atmospheric $^{40}Ar/^{36}Ar$, sample weight, sensitivity, etc. by pressing <CONT>.

ArAr* calculates apparent K/Ca ratios using the factor

$$K/Ca = 0.52 \frac{^{39}Ar_K}{^{37}Ar_{Ca}}$$

(Fleck and others, 1977). Apparent K/Cl ratios are calculated as

$$K/Cl = 2.42 \frac{^{39}Ar_K}{^{38}Ar_{Cl}}$$

The factor of 2.42 was obtained from measurements of argon derived from irradiated samples of MMHb-1, the K concentration in MMHb-1 given by Dalrymple and others (1981) and the Cl concentration reported by Roddick (1983). Using this value, the apparent K/Cl ratio of different aliquots of MMHb-1 varies along the length of the irradiation package. Apparently the production ratio $^{39}Ar_K/^{38}Ar_{Cl}$ varies from point to point in the TRIGA reactor, perhaps because of variations in the fast to thermal neutron flux. Such variation in the production ratio has no effect on calculated ages. It is possible that the ratio $(^{36}Cl_{Cl}/^{38}Cl_{Cl})_{reactor}$ varies with location in the reactor; this could be a source of error in ages for high-Cl samples. Numerical experiments (setting C13638_err on line 59 to 200) suggest that this additional uncertainty would be minimal.

Appendix 3. Partial glossary of variable names

Some variables are defined in program lines 320-74. Definitions of most other variables in ArAr* are given here. Variables with indices in parentheses ( ) are arrays; indices in square brackets [ ] refer to the lengths of strings. Array variables with dimension (50) are variables with values for each heating step; those with dimension (21) are for a single heating step, for input to the age calculation subprogram; those with dimension (20) are for irradiation-history calculations. A couple of array variables have dimension (5); these refer to the five isotopes of argon.

Hewlett-Packard BASIC allows implicit definition of array variables with upper bounds of 10 or less, strings of 18 or fewer characters, and all non-array variables. Many such variables, especially if they only appear within a single subroutine, are not included in this glossary.

A$(50) file name for each heating step, read from input tape

Aa$[80] sample name, printed at top of all tables and at bottom edge of all plots

Ad measured atmospheric $^{40}Ar/^{36}Ar$ ratio, for mass discrimination correction

Ad_err standard deviation in Ad

Age(50) age

Age295(50) age assuming $^{40}Ar/^{36}Ar_{initial} = 295.5$

Age_err1(50) intra-sample standard deviation of Age

Age_err2(50) inter-sample, intra-irradiation package standard deviation of Age

Age_err3(50) inter-irradiation package standard deviation of Age

Age_err295(50) intra-sample standard deviation of Age, assuming $^{40}Ar/^{36}Ar_{initial} = 295.5$

Airblnk(50) ^{40}Ar extraction line blank, in counts; this portion of blank is assumed to be atmospheric

Airblnker(50) standard deviation in **Airblnk**, in counts

Ar36ca(50) ^{36}Ar produced by irradiation of Ca, in counts

Ar36cl(50)	^{36}Ar produced by decay of ^{36}Cl since irradiation, in counts
Ar36in(50)	^{36}Ar in sample prior to irradiation, in counts
Ar37ca(50)	^{37}Ar produced by irradiation of Ca, in sample at end of irradiation, in counts
Ar37k(50)	^{37}Ar produced by irradiation of K, in sample at end of irradiation, in counts
Ar38cl(50)	^{38}Ar produced by decay of ^{38}Cl since irradiation, in counts
Ar38in(50)	^{38}Ar in sample prior to irradiation, in counts
Ar38ca(50)	^{38}Ar produced by irradiation of Ca, in counts
Ar39ca(50)	^{39}Ar produced by irradiation of Ca, in sample at end of irradiation, in counts
Ar39k(50)	^{39}Ar produced by irradiation of K, in sample at end of irradiation, in counts
Ar40(50)	^{40}Ar in sample prior to irradiation, in counts
Ar40k(50)	$^{40}Ar_K$ produced by irradiation of K, in counts
Ar4036in	initial $^{40}Ar/^{36}Ar$ ratio of sample
Ar4036in_err	standard deviation in **Ar4036in**
Blank$	flag for blank correction
Cfactor(50)	factor to convert counts into moles, equal to sensitivity * manifold factor * trap current factor
Cor(14)	corrections, as returned by age calculation
Dec36(50)	ratio of ^{36}Cl at end of irradiation to ^{36}Cl at time of analysis
Dec37(50)	ratio of ^{37}Ar at end of irradiation to ^{37}Ar at time of analysis
Decayed37(50)	amount of ^{37}Ar that has decayed since irradiation, in counts

Dec39(50)	ratio of ^{39}Ar at end of irradiation to ^{39}Ar at time of analysis
Decayed39(50)	amount of ^{39}Ar that has decayed since irradiation, in counts
E	standard deviation, in percent, within a package, in irradiation parameter J (variable Z in ArAr*). (See **J_pkg_er**)
E(21)	array of standard deviations in input variables for age calculation
Err(50)	holding variable, for swapping array values
E1(20)	day of year irradiation increment ended
F(50)	calculated $^{40}Ar_{rad}$ / $^{39}Ar_K$
F_err1(50)	standard deviation in F due to heating-step specific errors
F_err2(50)	similar to F_err1, but also includes effects of uncertainties in mass discrimination correction and initial $^{40}Ar/^{36}Ar$ ratio
G(21)	array of variables for input to age calculation
H(20)	hour of day (Denver time) irradiation increment ended
Irrad_steps	number of steps in incremental irradiation
J	index for heating steps; used as counter variable in loops
J$(21)	string variables for labelling table of relative weights of various sources of error
J_pkg_er	standard deviation, in percent, between packages, in irradiation parameter J. (See **E**)
Kca(50)	approximate molecular K/Ca ratio
Lab1$[50]	string for plot label
Lab2$[50]	string for plot label

Lab3$[50]	string for plot label
Manifold$(50)	description of manifold option
Mar36in(50)	moles of ^{36}Ar in sample prior to irradiation
Mar36in_er(50)	standard deviation in **Mar36in(50)**
Mar37ca(50)	moles of $^{37}Ar_{Ca}$ in sample immediately following irradiation
Mar37ca_er(50)	standard deviation in **Mar37ca(50)**
Mar38cl(50)	moles of $^{38}Ar_{Cl}$ in sample immediately followng irradiation
Mar38cl_er(50)	standard deviation in **Mar38cl(50)**
Mar39k(50)	moles of $^{39}Ar_{K}$ in sample immediately following irradiation
Mar39k_er(50)	standard deviation in **Mar39k(59)**
Mar40(50)	moles of ^{40}Ar in sample prior to irradiation
Mar40_er(50)	standard deviation in **Mar40(50)**
N	number of heating steps
Percent(50)	cumulative percent of ^{39}Ar evolved
R(50)	correlation coefficient for errors in $^{36}Ar/^{40}Ar$ and $^{39}Ar/^{40}Ar$, for York regression routine
Raw36(50)	measured counts of ^{36}Ar
Raw36err(50)	standard deviation in **Raw36(50)**
Raw37(50)	measured counts of ^{37}Ar
Raw37err(50)	standard deviation in **Raw37(50)**
Raw38(50)	measured counts of ^{38}Ar
Raw38err(50)	standard deviation in **Raw38(50)**
Raw39(50)	measured counts of ^{39}Ar

Raw39err(50)	standard deviation in **Raw39(50)**
Raw40(50)	measured counts of ^{40}Ar
Raw40err(50)	standard deviation in **Raw40(50)**
R3640er(50)	calculated standard deviation in $^{36}Ar/^{40}Ar$ ratio
R3940er(50)	calculated standard deviation in $^{39}Ar/^{40}Ar$ ratio
Regress$	flag for regression of analytical data to define age and initial argon ratio
Sample$[50]	sample name, for labelling plots
T(20)	length of irradiation increment, in hours
Tb(5)	non-air contribution to blank, assumed constant from one heating step to another. Array is for 5 isotopes of Ar
Tber(5)	standard deviation in **Tb(5)**
Tc(50)	flag for trap current; read from input tape
Tdays(50)	time, in days, since end of irradiation
Temp(50)	holding variable, for swapping array values
T5(50)	temperature of heating step
U(20)	energy (= power level x time) of irradiation increment
V(50,21)	array (heating steps, variables in age calculation) of relative contribution of various sources to error in calculated ages
Version$[30]	string for labelling output with version of program--usually the date of revision
W(20)	power level during irradiation increment
Wx(50)	relative weight of X ($^{39}Ar/^{40}Ar$); input for York regression routine
Wy(50)	relative weight of Y ($^{36}Ar/^{40}Ar$); input for York regression routine
X(50)	X = $^{39}Ar/^{40}Ar$; input for York regression routine

Y(50)	Y = $^{36}Ar/^{40}Ar$; input for York regression routine
Z	irradiation factor J
Z$	response to yes-no question

Appendix 4. Listing of program ArAr*

```
10    ! "ArAr*"  revised version of "ArM*"
20    ! mostly coded by
30    !  Ralph Haugerud
40    !  US Geological Survey
50    !  959 National Center
60    !  Reston, Virginia  22092
70    !  703-648-6304   (FTS 959-6304)
80    ON ERROR GOSUB Error
90    OPTION BASE 1
100   DIM Version$[30]
110   Version$="v 2/17/88 "
120   DIM Aa$[80],Sample$[50],Lab1$[50],Lab2$[50],Lab3$[50]
130   DIM A$(50),Manifold$(50),Tdays(50),Cfactor(50),Tc(50),T5(50)
140   DIM Raw36(50),Raw37(50),Raw38(50),Raw39(50),Raw40(50)
150   DIM Raw36err(50),Raw37err(50),Raw38err(50),Raw39err(50),Raw40err(50)
160   DIM Ar36in(50),Ar36ca(50),Ar36cl(50)
170   DIM Ar37ca(50),Dec37(50),Decayed37(50),Ar37k(50)
180   DIM Ar38cl(50),Ar38k(50),Ar38in(50),Ar38ca(50)
190   DIM Dec39(50),Decayed39(50),Ar39ca(50),Ar39k(50)
200   DIM Ar40(50),Ar40k(50)
210   DIM Mar36in(50),Mar37ca(50),Mar38cl(50),Mar39k(50),Mar40(50)
220   DIM Mar36in_er(50),Mar37ca_er(50),Mar38cl_er(50),Mar39k_er(50),Mar40_er(50
)
230   DIM F(50),F_err1(50),F_err2(50),Age(50),Age_err1(50),Age_err2(50),Age_err3
(50)
240   DIM Age295(50),Age_err295(50)
250   DIM Dec36(50),Percent(50),Kca(50),Airblnk(50),Airblnker(50),Tb(5),Tber(5)
260   DIM R3640er(50),R3940er(50),Temp(50),Err(50)
270   DIM G(21),E(21),J$(21),Cor(14)  ! parameter arrays for age calculation
280   DIM V(50,21)
290   DIM X(50),Y(50),R(50),S(50),Wx(50),Wy(50) ! to pass to York regression
300   !  following are used for irradiation history calculation
310   DIM E1(20),W(20),U(20),T(20),H(20)
320   Message$=CHR$(27)&"&a19y10C"
330   Clreol$=CHR$(27)&"K"
340   Page=63  !  number of lines on page of output
350   Penspeed=4 ! plotter pen speed in cm/sec
360   Lit$="N" ! flag for analyses from literature
370   !
380   Ar4036atm=295.5
390   Ar3836atm=63/337
400   Lambda36=6.122E-9  ! decay constant, IN 1/DAYS, for 36Cl
410   Lambda37=1.975E-2  ! decay constant, IN 1/DAYS, for 37Ar
420   Lambda39=7.327E-6  ! decay constant, IN 1/DAYS, for 39Ar
430   !
440   !      REACTOR CONSTANTS
450   !
460   Ca3637reactor=2.64E-4 ! production ratios for indicated isotopes of Ar
470   Ca3637_err=1.7E-6
480   Ca3837reactor=3.17E-5 ! from specified element
490   Ca3837_err=2.4E-7
500   Ca3937reactor=6.73E-4
510   Ca3937_err=3.7E-6
520   K3739reactor=0   ! Using 2.2E-3 (PP 1176 value), Snee had troubles,
530   K3739_err=2.2E-3 ! calculating negative Ca for high K/Ca phases
540   K3839reactor=1.34E-2
550   K3839_err=2.4E-4
560   K4039reactor=5.68E-3
570   K4039_err=4E-3
```

```
580   Cl3638reactor=316 ! ratio in which 36Cl and 38Cl are produced
590   Cl3638_err=0
600   Kcl_factor=2.42 ! number by which one multiplies Ar39K/Ar38Cl to get K/Cl
610   !
620   !       MASS SPECTROMETER CONSTANTS
630   !
640   Mdc(1)=1      !
650   Mdc(2)=3.6    !  manifold option factors
660   Mdc(3)=3.6^2!
670   Mdc(4)=3.6^3!
680   Tc40=1        !
690   Tc100=1       !  trap current factors
700   Tc200=1       !
710   Sensitivity=1.65E-17 ! moles per count
720   ! NB: Moles = counts * sensitivity * manifold factor * Tc factor
730   Mincnts=40    !  minimum number of counts--detection limit
740   Airblank=1E-12    ! default furnace blank, in moles 40Ar
750   !
760   !
770   PRINTER IS 16
780   PRINT PAGE;"program ArAr*, ";Version$;LIN(2)
790   PRINT TAB(24);'WELCOME TO ARGON-LAND";LIN(1)
800   PRINT TAB(19);' THE NEW REVISED VERSION OF ArM* "
810   PRINT TAB(9);"Data reduction program for the USGS-Reston argon laboratory"
820   PRINT
830   PRINT "YOUR CHOICES:"
840   PRINT
850   PRINT "  1 Read an existing irradiation history and reduce data on tape"
860   PRINT "  2 Read an existing irradiation history and reduce data from keybo
ard"
870   PRINT "  3 Enter a new irradiation history"
880   PRINT "  4 Reduce data from literature and make plots"
890   PRINT "  5 Go home";LIN(2);TAB(21);"(WHEN IN DOUBT, PRESS CONT)"
900   Choice=1
910   INPUT "Enter your choice",Choice
920   IF Choice>5 THEN CALL Conniption
930   IF (Choice>5) OR (Choice<1) THEN GOTO 770
940   ON Choice GOSUB Rue_des_vaches,Pain_n_agony,New_history,Literature,Go_home
950   IF Choice<>5 THEN GOTO 770
960   END
970   !
980 Rue_des_vaches:     ! Usual path through program
990   CALL Read_history(Rd,Dl,Irrad_steps,Total_irrad,Ttt1,T(*),E1(*),H(*),W(*),
U(*))
1000  GOSUB Get_sample
1010  CALL Check_constants(Tc40,Tc100,Tc200,Mdc(*),Sensitivity,Mincnts,Airblank)
1020  GOSUB Read_data_file
1030  Sample$=Lab1$=Lab2$=Lab3$=""
1040  GOSUB Calc_n_plot
1050  Z$="Y"
1060  INPUT "Do you want to reduce data for another sample from the same package
? (Y/N)",Z$
1070  CALL Yn(Z$)
1080  IF Z$="Y" THEN GOTO 1000
1090  RETURN
1100  !
1110 Pain_n_agony: ! Entering data from keyboard!
1120  CALL Read_history(Rd,Dl,Irrad_steps,Total_irrad,Ttt1,T(*),E1(*),H(*),W(*),
U(*))
1130  GOSUB Get_sample
1140  CALL Check_constants(Tc40,Tc100,Tc200,Mdc(*),Sensitivity,Mincnts,Airblank)
1150  GOSUB Enter_counts
1160  Sample$=Lab1$=Lab2$=Lab3$=""
1170  GOSUB Calc_n_plot
1180  Z$="Y"
1190  INPUT "Do you want to reduce another sample from the same irradiation pack
```

```
age? (Y/N)",Z$
1200  CALL Yn(Z$)
1210  IF Z$="Y" THEN GOTO 1130
1220  RETURN
1230  !
1240 New_history: !  To enter a new irradiation history
1250  CALL Enter_history
1260  RETURN
1270  !
1280 Literature:  !  To reduce data from literature and make plots
1290  Label$="N"
1300  Sample$=Lab1$=Lab2$=Lab3$=""
1310  Lit$="Y"
1320  Mincnts=0
1330  GOSUB Get_sample
1340  GOSUB Enter_moles
1350  Ar4036in=Ar4036atm
1360  Ar4036in_err=0
1370  Blank$="N"
1380  Regress$="Y"
1390  INPUT "Do you want to regress data for the initial 40/36 ratio? (Y/N)",R
egress$
1400  CALL Yn(Regress$)
1410  GOSUB Moles_to_ages
1420  IF Regress$="N" THEN GOTO 1470
1430    MAT Age295=Age
1440    MAT Age_err295=Age_err1
1450    GOSUB Regress_initial
1460    GOSUB Moles_to_ages
1470  Z$="Y"
1480  INPUT "Do you want tables printed? (Y/N)",Z$
1490  CALL Yn(Z$)
1500  IF Z$="N" THEN GOTO 1550
1510  PRINTER IS 0
1520  GOSUB Print_more
1530  PRINT LIN(1);Version$;PAGE
1540  GOSUB Print_final
1550  Z$="N"
1560  INPUT "Ya wanna re-reduce this data? (Y/N)",Z$
1570  CALL Yn(Z$)
1580  IF Z$="Y" THEN GOTO 1310
1590  GOSUB Plots
1600  Z$="N"
1610  INPUT "Do you want to re-reduce and replot this data? (Y/N)",Z$
1620  CALL Yn(Z$)
1630  IF Z$="Y" THEN GOTO 1310
1640  Lit$="N"
1650  RETURN
1660  !
1670  !
1680 Go_home:    !
1690  PRINT PAGE;LIN(10);TAB(39);"bye"
1700  RETURN
1710  !
1720  !
1730  !
1740 Get_sample: !
1750  PRINT PAGE;LIN(2);"Some numbers, please";LIN(3)
1760  IF Lit$="Y" THEN GOTO 1800
1770  INPUT "Measured atmospheric 40Ar/36Ar and its uncertainty',Ad,Ad_err
1780  IMAGE "   Measured atmospheric 40Ar/36Ar = ",DDD.DD," ± ",DD.DD
1790  PRINT USING 1780;Ad;Ad_err
1800  INPUT "SAMPLE NUMBER ?",Aa$
1810  PRINT LIN(1);"   sample is"
1820  PRINT "   ";Aa$;LIN(1)
1830  INPUT "SAMPLE WEIGHT (grams) ?",Wt
```

```
1840  IMAGE "   Sample weight = ",Z.5D," g"
1850  PRINT USING 1840;Wt
1860  INPUT "J and its % error  (separated by a comma)",Z,E
1870  PRINT
1880  IMAGE "   J = ',Z.6D," ± ",Z.2D," %"
1890  PRINT USING 1880;Z;E
1900  INPUT "uncertainty in J due to uncertainty in monitor age, in %",J_pkg_er
1910  IMAGE "   uncertainty J due to uncertainty in monitor age = ",DZ.2D," %"
1920  PRINT USING 1910;J_pkg_er
1930  Z$="Y"
1940  INPUT "Are these values OK  (Y/N)?",Z$
1950  CALL Yn(Z$)
1960  IF Z$="N" THEN GOTO 1750
1970  RETURN
1980  !
1990  !
2000  !
2010 Read_data_file:    !
2020  COM SHORT Mmm(12,5),Backpeak(12,2),Time(12,60),Peak(12,60)
2030  DIM C$[50]
2040  PRINTER IS 16
2050  PRINT PAGE;LIN(2);"Data tape should be in T14 (left drive).  Press CONT"
2060  PAUSE
2070  PRINT LIN(1);"FILES AVAILABLE"
2080  PRINT
2090  CALL Catalog(":T14")
2100  Seq$="Y"
2110  INPUT "ARE FILES TO BE READ SEQUENTIAL (Y/N)",Seq$
2120  CALL Yn(Seq$)
2130  IF Seq$="N" THEN INPUT "NUMBER OF FILES TO BE READ___?",N
2140  IF Seq$="N" THEN GOTO 2210
2150  Name$=" "
2160  IF Seq$="Y" THEN INPUT "Numbers of FIRST _____ and LAST ____ files to be r
ead?",Name$,N
2170  IF Name$=" " THEN GOTO 2130
2180  N=N-VAL(Name$)+1
2190  IF (N<1) OR (N>50) THEN CALL Conniption
2200  IF (N<1) OR (N>50) THEN 2110
2210  FOR J=1 TO N
2220    IF Seq$="N" THEN PRINT Message$;Clreol$;"Step ";VAL$(J)
2230    IF Seq$="N" THEN INPUT "Number of file?",Name$
2240    IF (Seq$="Y") AND (J>1) THEN Name$=VAL$(VAL(Name$)+1)
2250    Name$=Name$&':T14"
2260    ASSIGN #2 TO Name$,R
2270    ON R+1 GOTO 2360,2280,2340
2280    IF (Seq$="N") OR (J=1) THEN PRINT CHR$(27)&"&a19Y";"FILE ";Name$;" DOES
NOT EXIST"
2290    DISP "Maybe you change tape and press CONT?"
2300    PAUSE
2310    PRINT PAGE
2320    CALL Catalog(":T14")
2330    GOTO 2260
2340    PRINT "FILE IS PROTECTED"
2350    GOTO 2160
2360    DISP "Reading file ";Name$
2370    BEEP
2380    ON END #2 GOTO 2600
2390    READ #2;Aaaa$,B$,C$,D$,Ee$,H$,Aa,Bb,Cc,Dd,Cycles,Sequence
2400    A$(J)=Aaaa$
2410    File_type=TYP(2)
2420    IF File_type=2 THEN READ #1;Header$,M0(1),Y0(1),M0(2),Y0(2)
2430    FOR A=1 TO 12
2440      READ #2;Mmm(A,1),Backpeak(A,1),Time(A,1)
2450    NEXT A
2460    READ #2;Time
2470    FOR A=1 TO Cycles
```

```
2480        File_type=TYP(2)
2490        IF File_type=2 THEN READ #2;Header$,M0(1),Y0(1),M0(2),Y0(2)
2500        FOR B=1 TO 12
2510          READ #2;Mmm(B,1),Peak(B,1),Time(B,1)
2520        NEXT B
2530      NEXT A
2540      READ #2;H$,Aa,Bb,Cc,Dd
2550      File_type=TYP(2)
2560      IF File_type=2 THEN READ #2;Header$,M0(1),Y0(1),M0(2),Y0(2)
2570      READ #2;Time_max,Tpp,Tc,Man,Ds,Tr,Beam(1),Beam(2),Beam(3),Beam(4),Er(1),
Er(2),Er(3),Er(4)
2580      Beam(5)=0
2590      READ #2;Beam(5),Er(5)
2600      T5(J)=Tpp
2610      Tc(J)=Tc
2620      IF Tc=40 THEN Ff=Tc40
2630      IF Tc=100 THEN Ff=Tc100
2640      IF Tc=200 THEN Ff=Tc200
2650      IF Man=1 THEN Manifold$(J)="ALL"
2660      IF Man=2 THEN Manifold$(J)="SPLIT 1"
2670      IF Man=3 THEN Manifold$(J)="SPLIT 2"
2680      IF Man=4 THEN Manifold$(J)="SPLIT 3"
2690      FOR B=1 TO 5
2700        IF Beam(B)<0 THEN Beam(B)=0
2710      NEXT B
2720      Raw36(J)=Beam(3)
2730      Raw37(J)=Beam(4)
2740      Raw38(J)=Beam(5)
2750      Raw39(J)=Beam(2)
2760      Raw40(J)=Beam(1)
2770      Raw36err(J)=Er(4)
2780      Raw37err(J)=Er(3)
2790      Raw38err(J)=FNEr(Raw38(J))/100*Raw38(J)
2800      Raw39err(J)=Er(2)
2810      Raw40err(J)=Er(1)
2820      Cfactor(J)=Sensitivity*Mdc(Man)*Ff
2830      Tdays(J)=Ds+Tr/24
2840    NEXT J
2850    RETURN
2860    !
2870    !
2880  Enter_counts:! FOR HAND ENTRY OF ANALYTICAL DATA
2890    PRINTER IS 16,WIDTH(100)
2900    PRINT PAGE;"TEMP        40Ar        39Ar        38Ar        37Ar        36
Ar  Trap  Manifold"
2910    INPUT "Number of heating steps",N
2920    FOR J=1 TO N
2930      INPUT "Temperature",T5(J)
2940      PRINT Message$,"Heating step ";J;"  ";T5(J);" degrees"
2950      INPUT "Counts 40 and 1 sigma uncertainty",Raw40(J),Raw40err(J)
2960      INPUT "Counts 39 and 1 sigma uncertainty",Raw39(J),Raw39err(J)
2970      INPUT "Counts 38 and 1 sigma uncertainty",Raw38(J),Raw38err(J)
2980      INPUT "Counts 37 and 1 sigma uncertainty",Raw37(J),Raw37err(J)
2990      INPUT "Counts 36 and 1 sigma uncertainty",Raw36(J),Raw36err(J)
3000      Man=0
3010      INPUT "Manifold option?",Man
3020      IF (Man<>1) AND (Man<>2) AND (Man<>3) AND (Man<>4) THEN GOTO 3000
3030      IF Man=1 THEN Manifold$(J)="ALL"
3040      IF Man=2 THEN Manifold$(J)="SPLIT 1"
3050      IF Man=3 THEN Manifold$(J)="SPLIT 2"
3060      IF Man=4 THEN Manifold$(J)="SPLIT 3"
3070      INPUT "Trap current (40, 100, or 200)?",Tc(J)
3080      IF (Tc(J)<>40) AND (Tc(J)<>100) AND (Tc(J)<>200) THEN GOTO 3070
3090      IF Tc(J)=40 THEN Ff=Tc40
3100      IF Tc(J)=100 THEN Ff=Tc100
3110      IF Tc(J)=200 THEN Ff=Tc200
```

```
3120    Cfactor(J)=Sensitivity*Mdc(Man)/Ff
3130    INPUT "Day, hour of analysis?",Tdays(J),Hour
3140    Tdays(J)=Tdays(J)+Hour/24
3150    L1$=CHR$(27)&"&a0c"&VAL$(J)&"Y"
3160    IMAGE #,K,4D,"C ",7D,"±",4D,1X,4(6D,"±",4D,1X),3D3X,7A
3170    PRINT USING 3160;L1$;T5(J),Raw40(J),Raw40err(J),Raw39(J),Raw39err(J),Raw
38(J),Raw38err(J),Raw37(J),Raw37err(J),Raw36(J),Raw36err(J),Tc(J),Manifold$(J)
3180    PRINT USING 'K";"  DAY ANALYSED = ",Tdays(J)
3190  NEXT J
3200  Z$="Y"
3210  INPUT "Are these values OK? (Y/N)",Z$
3220  CALL Yn(Z$)
3230  IF Z$="N" THEN GOTO 2900
3240  RETURN
3250  !
3260  !
3270 Enter_moles: !  For entering literature data
3280  PRINTER IS 16
3290  PRINT PAGE;"TEMP          40Ar          39Ar          38Ar          37Ar
        36Ar"
3300  INPUT "Number of heating steps",N
3310  FOR J=1 TO N
3320    INPUT "Temperature",T5(J)
3330    Cfactor(J)=1
3340    INPUT "Moles 40Ar and 1 sigma uncertainty",Mar40(J),Mar40_er(J)
3350    INPUT "Moles K-derived 39Ar and 1 sigma uncertainty",Mar39k(J),Mar39k_er
(J)
3360    INPUT "Moles Cl-derived 38Ar and 1 sigma uncertainty",Mar38cl(J),Mar38cl
_er(J)
3370    INPUT "Moles Ca-derived 37Ar and 1 sigma uncertainty",Mar37ca(J),Mar37ca
_er(J)
3380    INPUT "Moles initial 36Ar and 1 sigma uncertainty",Mar36in(J),Mar36in_er
(J)
3390    IMAGE 4D,"C ",5(4XMD.3DE)
3400    IMAGE "  ±   ",5(5XMD.2DE)
3410    PRINT USING 3390;T5(J),Mar40(J),Mar39k(J),Mar38cl(J),Mar37ca(J),Mar36in(
J)
3420    PRINT USING 3400;Mar40_er(J),Mar39k_er(J),Mar38cl_er(J),Mar37ca_er(J),Ma
r36in_er(J)
3430  NEXT J
3440  Z$="Y"
3450  INPUT "Are these values OK (Y/N)",Z$
3460  CALL Yn(Z$)
3470  IF Z$="N" THEN GOTO 3290
3480  RETURN
3490  !
3500 Moles_to_ages: !
3510  DISP "Calculating ages and errors"
3520  Sum40=Sum39=Sum38=Sum37=Sum36=0
3530  FOR J=1 TO N
3540    F=F(J)=(Mar40(J)-Mar36in(J)*Ar4036in)/Mar39k(J)
3550    Df40=1/Mar39k(J)
3560    Df39=-(Mar40(J)-Ar4036in*Mar36in(J))/Mar39k(J)^2
3570    Df36=-Ar4036in/Mar39k(J)
3580    Dfin=Mar36in(J)/Mar39k(J)
3590    Fer1=SQR((Df40*Mar40_er(J))^2+(Df39*Mar39k_er(J))^2+(Df36*Mar36in_er(J))
^2)
3600    Fer2=SQR(Fer1^2+(Dfin*Ar4036in_err)^2)
3610    CALL Fage(F,Fer1,Z,0,Age(J),Age_err1(J))
3620    CALL Fage(F,Fer2,Z,E,Dummy,Age_err2(J))
3630    CALL Fage(F,Fer2,Z,E+J_pkg_er,Dummy,Age_err3(J))
3640    Airblnker(J)=0
3650    Raw40(J)=Mar40(J)
3660    Raw40err(J)=Mar40_er(J)
3670    R3940er(J)=SQR((Mar40_er(J)*Mar39k(J)/Mar40(J)^2)^2+(Mar39k_er(J)/Mar40(
J))^2)
```

```
3680     R3640er(J)=SQR((Mar40_er(J)*Mar36k(J)/Mar40(J)^2)^2+(Mar36k_er(J)/Mar40(
J))^2)
3690     IF R3940er(J)=0 THEN R3940er(J)=1E-4 ! to avoid divide-by-zero errors
3700     IF R3640er(J)=0 THEN R3640er(J)=1E-5 ! when calculating the corr. coeff.
3710     Sum40=Sum40+Mar40(J)
3720     Sum39=Sum39+Mar39k(J)
3730     Sum38=Sum38+Mar38cl(J)
3740     Sum37=Sum37+Mar37ca(J)
3750     Sum36=Sum36+Mar36in(J)
3760   NEXT J
3770   RETURN
3780   !
3790   !
3800 Calc_n_plot:  !   core of data reduction routine, calls plot routines
3810   GOSUB Zero_blank
3820   Firsttime$="Y"
3830   Label$="N"
3840   Sample$=Lab1$=Lab2$=Lab3$=""
3850   PRINTER IS 16
3860   PRINT PAGE
3870   DISP "Calculating decay correction factors"
3880   GOSUB Decay_factors
3890   GOSUB Fix_raw_data
3900   Old_blank$="N"
3910   Blank$="Y"
3920   Regress$="Y"
3930   INPUT "Do you want to make blank corrections? (Y/N)",Blank$
3940   CALL Yn(Blank$)
3950   PRINT CHR$(27)%"&a0c19Y";"Do you want to iteratively regress the data for
the initial 40/36"
3960   PRINT "ratio, then recalculate ages and errors? (Y/N)"
3970   INPUT " ",Regress$
3980   CALL Yn(Regress$)
3990   Blankchanged$='N"
4000   GOSUB Blank_correct
4010   Old_blank$=Blank$
4020   IF (Firsttime$="N") AND (Blankchanged$="N") AND (Regress$=Oldregress$) THE
N GOTO 4110
4030     GOSUB How_long
4040     Ar4036in=Ar4036atm
4050     Ar4036in_err=0
4060     GOSUB Ages
4070     GOSUB Moles
4080     GOSUB Errors
4090     MAT Age295=Age
4100     MAT Age_err295=Age_err1
4110   IF Regress$="N' THEN GOTO 4160
4120     GOSUB Regress_initial
4130     GOSUB How_long
4140     GOSUB Ages
4150     GOSUB Errors
4160   Firsttime$="N"
4170   Oldregress$=Regress$
4180   Zz$="Y"
4190   INPUT "Do you want tables printed? (Y/N)",Zz$
4200   CALL Yn(Zz$)
4210   IF Zz$="Y" THEN GOSUB Tables
4220   IF Zz$="Y" THEN GOTO 4300
4230   Z$="N"
4240   INPUT "Do you want final tables printed? (Y/N)",Z$
4250   CALL Yn(Z$)
4260   IF Z$="N" THEN GOTO 4300
4270   Nlines=0
4280   PRINTER IS 0
4290   GOSUB Final_tables
4300   PRINTER IS 16
```

```
4310  PRINT PAGE;"You can, if you wish, re-reduce this data with (or without) a
blank correction";LIN(1);"and regression for initial 40/36 ratio."
4320  Z$="N"
4330  INPUT "Re-reduce this data? (Y/N)",Z$
4340  CALL Yn(Z$)
4350  IF Z$="Y" THEN GOTO 3910
4360  GOSUB Plots
4370  PRINTER IS 16
4380  Z$="N"
4390  INPUT "Re-reduce and re-plot this data? (Y/N)",Z$
4400  CALL Yn(Z$)
4410  IF Z$="Y" THEN GOTO 3910
4420  RETURN
4430  !
4440  !
4450 Decay_factors:  !
4460  FOR J=1 TO N
4470    Dec37(J)=Dec36(J)=Dec39(J)=0
4480    FOR I=1 TO Irrad_steps
4490      Tm=Tdays(J)-E1(I)+(H(I)-2)/24 !  (H(I)-2) corrects for 2 hour time dif
ference, Reston-Denver
4500      Tinc=T(I)/24
4510      P1=Tinc*U(I)/Total_irrad
4520      Dec37(J)=Dec37(J)+P1*Lambda37*EXP(Lambda37*Tm)/(1-EXP(-Lambda37*Tinc))
4530      Dec39(J)=Dec39(J)+P1*Lambda39*EXP(Lambda39*Tm)/(1-EXP(-Lambda39*Tinc))
4540      Dec36(J)=Dec36(J)+P1*Lambda36*EXP(Lambda36*Tm)/(1-EXP(-Lambda36*Tinc))
4550    NEXT I
4560    Dec36(J)=EXP(Lambda36*Tm)
4570    IF Dec39(J)<1.1 THEN Dec39(J)=EXP(Lambda39*Tm)
4580    IF Dec36(J)<1.1 THEN Dec36(J)=EXP(Lambda36*Tm)
4590    ! above 2 lines are because of machine-error effects for small amounts
4600    ! of decay--stepwise decay correction gives unacceptably bad answers
4610    ! such as Dec36<1 !!
4620    Decayed37(J)=(Dec37(J)-1)*Raw37(J)
4630    Decayed39(J)=(Dec39(J)-1)*Raw39(J)
4640  NEXT J
4650  RETURN
4660  !
4670  !
4680 Fix_raw_data:   !  fixes raw data so things don't bonb
4690    FOR J=1 TO N
4700      IF Raw36(J)<.2 THEN Raw36(J)=.2
4710    NEXT J
4720    IF (Dec37(1)<4) OR (Raw37(1)>100) AND (Dec37(1)<10) THEN RETURN
4730    PRINTER IS 16
4740    Z$="N"
4750    PRINT LIN(1);"This data is subject to a severe 37Ar decay correction--";
PROUND((Dec37(1)-1)*100,0);"%"
4760    PRINT "The error on 37 counts will be substantially amplified.  Do you w
ant to set"
4770    INPUT "37 counts and errors in 37 counts to zero for all steps? (Y/N)"
,Z$
4780    CALL Yn(Z$)
4790    IF Z$="N" THEN RETURN
4800    FOR J=1 TO N
4810      Raw37(J)=0
4820      Raw37err(J)=0
4830      Decayed37(J)=0
4840    NEXT J
4850    RETURN
4860    !
4870    !
4880 How_long: !
4890    PRINT PAGE
4900    Nsteps=Nsteps+N
4910    T=INT(N*2/15)
```

```
4920     IF T<=1 THEN DISP "This will take a minute or two"
4930     IF (T>1) AND (Nsteps<35) THEN DISP "This will take ";T;' to ";T+1;" minu
tes.  Better go get a cup of coffee."
4940     IF (T>1) AND (Nsteps>=35) THEN DISP "This will take ";T;" to ";T+1;" min
utes.  Better go pee."
4950     RETURN
4960     !
4970     !
4980 Ages:  !
4990   G(11)=Ad
5000   G(12)=Z
5010   G(13)=K4039reactor
5020   G(14)=K3839reactor
5030   G(15)=K3739reactor
5040   G(16)=Ca3937reactor
5050   G(17)=Ca3837reactor
5060   G(18)=Ca3637reactor
5070   G(19)=Cl3638reactor
5080   G(20)=Ar3836atm
5090   G(21)=1  !  for measure of effects of inter-package error in J
5100   Oldar4036in=Ar4036in
5110   G(10)=Ar4036in
5120   FOR J=1 TO N
5130     PRINT "Calculating corrections and age, heating step #";J
5140     GOSUB Stuff_g
5150     G(7)=Dec39(J)
5160     G(8)=Dec37(J)
5170     G(9)=Dec36(J)
5180         Age(J)=FNAge(G(*),Cor(*))
5190     Ar37ca(J)=Cor(1)
5200     Ar39ca(J)=Cor(2)
5210     Ar39k(J)=Cor(3)
5220     Ar37k(J)=Cor(4)
5230     Ar36ca(J)=Cor(5)
5240     Ar38k(J)=Cor(6)
5250     Ar38ca(J)=Cor(7)
5260     Ar38cl(J)=Cor(8)
5270     Ar36cl(J)=Cor(9)
5280     Ar36in(J)=Cor(10)
5290     Ar38in(J)=Cor(11)
5300     Ar40k(J)=Cor(12)
5310     Ar40(J)=Cor(13)
5320     F(J)=Cor(14)
5330   NEXT J
5340   RETURN
5350   !
5360   !
5370 Moles:  !
5380     Sum40=Sum39=Sum38=Sum37=Sum36=0
5390     ! Cfactor(J) = Sensitivity * manifold correction factor * trap current f
actor
5400     FOR J=1 TO N
5410       Mar40(J)=Ar40(J)*Cfactor(J)
5420       Mar39k(J)=Ar39k(J)*Cfactor(J)
5430       IF Mar39k(J)<0 THEN Mar39k(J)=0
5440       Mar38cl(J)=Ar38cl(J)*Cfactor(J)
5450       IF Mar38cl(J)<0 THEN Mar38cl(J)=0
5460       Mar37ca(J)=Ar37ca(J)*Cfactor(J)
5470       IF Mar37ca(J)<0 THEN Mar37ca(J)=0
5480       Mar36in(J)=Ar36in(J)*Cfactor(J)
5490       IF Mar36in(J)<0 THEN Mar36in(J)=0
5500       Sum36=Sum36+Mar36in(J)
5510       Sum37=Sum37+Mar37ca(J)
5520       Sum38=Sum38+Mar38cl(J)
5530       Sum39=Sum39+Mar39k(J)
5540       Sum40=Sum40+Mar40(J)
```

```
5550      Kca(J)=0
5560      IF Mar37ca(J)>0 THEN Kca(J)=.52*Mar39k(J)/Mar37ca(J)
5570    NEXT J
5580    Percent(1)=100*Mar39k(1)/Sum39
5590    FOR J=2 TO N
5600      Percent(J)=Percent(J-1)+100*Mar39k(J)/Sum39
5610    NEXT J
5620    RETURN
5630    !
5640    !
5650 Errors: ! subroutine to calculate errors on ages by numerically
5660         ! differentiating the age function
5670  E(11)=Ad_err
5680  E(7)=Dec39_err=0
5690  E(8)=Dec37_err=0
5700  E(9)=Dec36_err=0
5710  E(10)=Ar4036in_err
5720  E(12)=Z*E/100   !  error in J
5730  E(13)=K4039_err
5740  E(14)=K3839_err
5750  E(15)=K3739_err
5760  E(16)=Ca3937_err
5770  E(17)=Ca3837_err
5780  E(18)=Ca3637_err
5790  E(19)=C13638_err
5800  E(20)=Ar3836atm_err=0
5810  E(21)=J_pkg_er/100
5820  FOR J=1 TO N
5830    PRINT "Calculating age errors the slow way, heating step #";J
5840    GOSUB Stuff_g
5850    E(1)=Airblnker(J)
5860    E(2)=SQR(Raw40err(J)^2+Tber(1)^2)
5870    E(3)=SQR(Raw39err(J)^2+Tber(2)^2)
5880    E(4)=SQR(Raw38err(J)^2+Tber(3)^2)
5890    E(5)=SQR(Raw37err(J)^2+Tber(4)^2)
5900    E(6)=SQR(Raw36err(J)^2+Tber(5)^2)
5910    Age_r1=Age_r2=Age_r3=F_er1=F_er2=M40=M39=M38=M37=M36=R3640=R3940=0
5920    FOR Jj=1 TO 21
5930      V(J,Jj)=0
5940      IF E(Jj)*1E5=0 THEN GOTO 6310
5950         G(Jj)=G(Jj)+E(Jj)/4
5960         Age1=FNAge(G(*),Cor(*))
5970         F1=Cor(14)
5980         M401=Cor(13)
5990         M391=Cor(3)
6000         M381=Cor(8)
6010         M371=Cor(1)
6020         M361=Cor(10)
6030         R36401=M361/M401
6040         R39401=M391/M401
6050         G(Jj)=G(Jj)-E(Jj)/2
6060         Age2=FNAge(G(*),Cor(*))
6070         F2=Cor(14)
6080         M402=Cor(13)
6090         M392=Cor(3)
6100         M382=Cor(8)
6110         M372=Cor(1)
6120         M362=Cor(10)
6130         R36402=M362/M402
6140         R39402=M392/M402
6150         G(Jj)=G(Jj)+E(Jj)/4
6160      V(J,Jj)=Ersq=4*(Age1-Age2)^2
6170      Age_r3=Age_r3+Ersq
6180      IF Jj>12 THEN GOTO 6310
6190      Age_r2=Age_r2+Ersq
6200      F_er2=F_er2+(F1-F2)^2*4
```

```
6210      IF Jj>9 THEN GOTO 6310
6220      Age_r1=Age_r1+Ersq
6230      F_er1=F_er1+(F1-F2)^2*4
6240      M40=M40+(M401-M402)^2*4
6250      M39=M39+(M391-M392)^2*4
6260      M38=M38+(M381-M382)^2*4
6270      M37=M37+(M371-M372)^2*4
6280      M36=M36+(M361-M362)^2*4
6290      R3640=R3640+(R36401-R36402)^2*4
6300      R3940=R3940+(R39401-R39402)^2*4
6310    NEXT Jj
6320    FOR Jj=1 TO 21
6330      V(J,Jj)=PROUND(1000*V(J,Jj)/Age_r3,0)
6340    NEXT Jj
6350    Age_err1(J)=SQR(Age_r1)          !  intra-sample precision
6360    Age_err2(J)=SQR(Age_r2)          !  intra-package precision
6370    Age_err3(J)=SQR(Age_r3)          !  inter-package precision
6380    F_err1(J)=SQR(F_er1)             !  intra-sample precision of F
6390    F_err2(J)=SQR(F_er2)             !  intra-package precision of F
6400    Mar40_er(J)=Cfactor(J)*SQR(M40)
6410    Mar39k_er(J)=Cfactor(J)*SQR(M39)
6420    Mar38cl_er(J)=Cfactor(J)*SQR(M38)
6430    Mar37ca_er(J)=Cfactor(J)*SQR(M37)
6440    Mar36in_er(J)=Cfactor(J)*SQR(M36)
6450    R3640er(J)=SQR(R3640)
6460    R3940er(J)=SQR(R3940)
6470  NEXT J
6480  RETURN
6490  !
6500  !
6510 Stuff_g:  !
6520   G(1)=Airblnk(J)
6530   G(2)=Raw40(J)-Tb(1)
6540   G(3)=Raw39(J)-Tb(2)
6550   G(4)=Raw38(J)-Tb(3)
6560   G(5)=Raw37(J)-Tb(4)
6570   G(6)=Raw36(J)-Tb(5)
6580   RETURN
6590   !
6600   !
6610 Blank_correct:!
6620   IF Blank$="N" THEN GOSUB Zero_blank
6630   IF Blank$="N" THEN RETURN
6640   IF Old_blank$="N" THEN GOTO 6670
6650   Z$="N"
6660   INPUT "You wanna change the blank (Y/N)",Z$
6670   IF (Z$="Y") OR (Old_blank$="N") THEN GOSUB Get_blank
6680   RETURN
6690   !
6700 Get_blank:!
6710   Blankchanged$="Y"
6720   Repeat=0
6730   PRINTER IS 16
6740   PRINT PAGE;"    Blanks are assumed to have two components: a fixed 'tube
blank', which is"
6750   PRINT "the same for each heating step, the isotopic composition of which
is not con-"
6760   PRINT "strained; and a furnace blank, WHICH IS ASSUMED TO BE AIR.  The am
ount of "
6770   PRINT "furnace blank may change from step to step.  Each of these blanks
has an"
6780   PRINT "associated error.  It is recommended that errors be AT LEAST 50% o
f the amount.";LIN(2)
6790   PRINT "                 Mass 40      Mass 39      Mass 38      Mass 37
  Mass 36"
6800   L1$=CHR$(27)&'&a19y0C"
```

```
6810    IMAGE #,K,K
6820    FOR M=1 TO 5
6830      IF Repeat<>0 THEN GOTO 6860
6840      Tb(M)=Tber(M)=10
6850      GOTO 6880
6860      PRINT USING 6810;L1$;"Tube blank and its error IN COUNTS - mass "&VAL$(
41-M)
6870      INPUT " ",Tb(M),Tber(M)
6880    NEXT M
6890    PRINT CHR$(27)&"&a9y0C";"Tube blank:";
6900    IMAGE #,2X5D,'±",5D
6910    FOR M=1 TO 5
6920      PRINT USING 6900;Tb(M);Tber(M)
6930    NEXT M
6940    PRINT LIN(1);'Furnace blanks:"
6950    PRINT USING 6810;L1$;CHR$(27)&"K"
6960    FOR J=1 TO N
6970      IF Repeat<>0 THEN GOTO 7010
6980      Airblnk(J)=Airblank/Cfactor(J) ! set default blank
6990      Airblnker(J)=Airblnk(J)*2/3
7000      IMAGE #,K,4D," C     "
7010      PRINT USING 7000;CHR$(27)&"&a0c"&VAL$(10+J)&"R",-5(J)
7020      IF Repeat=0 THEN GOTO 7050
7030      INPUT "40Ar furnace blank and its error IN COUNTS",Airblnk(J),Airblnker
(J)
7040      IMAGE #,2X8D,"±",8D,K
7050      PRINT USING 7040;Airblnk(J);Airblnker(J),"    (and corresponding 38Ar a
nd 36Ar)"
7060    NEXT J
7070    PRINT TAB(8);'Use arrow keys (top center of keyboard) to roll screen disp
lay"
7080    Repeat=1
7090    Z$="Y"
7100    BEEP
7110    INPUT "Are these values OK? (Y/N)",Z$
7120    CALL Yn(Z$)
7130    IF Z$="N" THEN GOTO 6730
7140    RETURN
7150    !
7160 Zero_blank: !
7170    FOR M=1 TO 5
7180      Tb(M)=Tber(M)=0
7190    NEXT M
7200    FOR J=1 TO N
7210      Airblnker(J)=0
7220      Airblnk(J)=0
7230    NEXT J
7240    RETURN
7250    !
7260    !
7270 Get_weights:!
7280      FOR J=1 TO N
7290        Wx(J)=1/R3940er(J)^2
7300        Wy(J)=1/R3640er(J)^2
7310      NEXT J
7320      RETURN
7330      !
7340      !
7350 Regress_initial:!
7360      Drop$=""
7370      PRINTER IS 16
7380      FOR J=1 TO N
7390        X(J)=Mar39k(J)/Mar40(J)
7400        Y(J)=Mar36in(J)/Mar40(J)
7410        Xa=1/295.5
7420        Xs=Y(J)
```

```
7430      IF Xs=0 THEN Xs=1E-10
7440      Saa=Airblnker(J)/Raw40(J)
7450      Sx=R3940er(J)/X(J)
7460      Sy=R3640er(J)/Xs
7470      Sa=Raw40err(J)/Raw40(J)
7480      R(J)=((1-Xa/Xs)*Saa^2+Sa^2)/(Sx*Sy)
7490      ! the formula used above for the correlation coefficient is from
7500      ! Roddick, Cliff, and Rex, 1980, Evolution of excess argon in Alpine
7510      !     biotites-a 40Ar-39Ar analysis: EPSL, v. 48, p. 185-208
7520      S(J)=1  ! set flags that all points are used
7530    NEXT J
7540    GOSUB Get_weights
7550    DISP ""
7560    CALL York(X(*),Y(*),R(*),Wx(*),Wy(*),S(*),N,Nn,Meanx,Meany,A,B,C,A_err,B
_err,C_err,Sums)
7570    PLOTTER IS 13,"GRAPHICS"
7580    GRAPHICS
7590    LOCATE 14,115,10,95
7600    Bar$="Y"
7610    Line$="N"
7620    GOSUB Plot_cor
7630    PRINTER IS 0
7640    MOVE 0,A
7650    DRAW C,0
7660    PRINT Version$;", sample ";Aa$
7670    DUMP GRAPHICS
7680    EXIT GRAPHICS
7690    PRINTER IS 16
7700    GOSUB P_regress_param
7710    PRINTER IS 0
7720    PRINT
7730    IMAGE 4(K,M.3DE)
7740    PRINT Nn;" points regressed out of ";N;
7750    IF Nn=N THEN GOTO 7770
7760    PRINT " includes ";PROUND(Sumgas,-1);"% of 39Ar";
7770    PRINT
7780    PRINT USING 7730;"Mean X = ";Meanx;"   Mean Y = ";Meany;"   Slope = ";B;
" +";B_err
7790    PRINT USING 7730;"36/40 = ";A;" +";A_err;"  39/40 = ";C;" +";C_err
7800    IF Nn<3 THEN GOTO 7820
7810    PRINT "Fit parameters:  SUMS =";PROUND(Sums,-3);"  MSWD =";PROUND(Sums/(
Nn-2),-3)
7820    Ar4036in=1/A
7830    Ar4036in_err=A_err/A^2
7840    Regressed_f=Meanf=1/C
7850    Meanf_err=C_err/C^2
7860    CALL Fage(Meanf,Meanf_err,Z,E,Ap,Ep)
7870    PRINT "40Ar/36Ar =";PROUND(Ar4036in,-2);"+";PROUND(Ar4036in_err,-2);
7880    PRINT "   F =";PROUND(Meanf,-3);"+";PROUND(Meanf_err,-3);"  AGE =";PRO
UND(Ap,-2);"+";PROUND(Ep,-2);"Ma"
7890    Z$="N"
7900    IF Nn>2 THEN INPUT "You wanna drop some points and repeat the regression
? (Y/N)",Z$
7910    CALL Yn(Z$)
7920    IF Z$="N" THEN GOTO 8150
7930    Drop$=""
7940    INPUT "Drop which points (ENTER AS MANY AS YOU WANT, NO SPACES OR COMMAS
--e.g. ABM )",Drop$
7950    GOSUB Get_weights
7960    FOR J=1 TO N
7970      S(J)=1
7980    NEXT J
7990    FOR J=1 TO LEN(Drop$)
8000      D$=Drop$[J;1]
8010      S(NUM(D$)-64)=0
8020      !   NB  this won't work for J>26
```

```
8030    NEXT J
8040    Sumgas=0
8050    FOR J=1 TO N
8060      IF S(J)<>0 THEN Sumgas=Sumgas+100*Mar39k(J)/Sum39
8070    NEXT J
8080    PRINTER IS 16
8090    CALL York(X(*),Y(*),R(*),Wx(*),Wy(*),S(*),N,Nn,Meanx,Meany,A,B,C,A_err,B
_err,C_err,Sums)
8100    PRINTER IS 0
8110    PRINT LIN(1);"Point";
8120    IF LEN(Drop$)>1 THEN PRINT "s";
8130    PRINT " ";Drop$;" deleted;  ";
8140    GOTO 7690
8150    GOSUB P_regress_param
8160    PRINT PAGE
8170    PRINTER IS 16
8180    RETURN
8190    !
8200 P_regress_param: !
8210    IMAGE K,K,5D,4(K,M.2DE)
8220    FOR J=1 TO N
8230      PRINT USING 8210;CHR$(J+64);" ";T5(J);"C  WT X = ";Wx(J);"  WT Y = ";W
y(J);"  R = ";R(J);"  Residual = ";S(J)
8240    NEXT J
8250    RETURN
8260    !
8270    !
8280 Tables: ! prints data tables
8290    PRINTER IS 0
8300    GOSUB Print_raw_data
8310    Nlines=10+2*N
8320    IF Blank$="Y" THEN Nlines=Nlines+N+4
8330    IF Page-Nlines<7+N THEN GOSUB New_page
8340    GOSUB Print_correct
8350    Nlines=Nlines+N+7
8360    IF Page-Nlines<N+12 THEN GOSUB New_page
8370 Final_tables:!
8380    GOSUB Print_more
8390    Nlines=Nlines+N+12
8400    Z$="N"
8410    IF N>1 THEN INPUT "Ya wanna printout of the importance of various source
s of error? (Y/N)",Z$
8420    CALL Yn(Z$)
8430    IF (Z$="Y") AND (Page-Nlines<31) THEN GOSUB New_page
8440    IF Z$="Y" THEN GOSUB Print_v
8450    IF Z$="Y" THEN Nlines=Nlines+32
8460    IF N>1 THEN PRINT LIN(Page-Nlines-1);Version$;PAGE
8470    IF N=1 THEN PRINT LIN(2)
8480    GOSUB Print_final
8490    RETURN
8500    !
8510    !
8520 New_page:   !
8530   PRINT LIN(Page-Nlines-1);Version$;
8540   PRINT PAGE
8550   PRINT Aa$
8560   Nlines=1
8570   RETURN
8580   !
8590   !
8600 Print_raw_data:    ! SUBROUTINE TO PRINT RAW DATA
8610    PRINT Aa$
8620    PRINT TAB(33);"R A W   D A T A"
8630    PRINT
8640    PRINT "FILE     TEMP     40Ar     39Ar     38Ar     37Ar     36Ar      T
RAP   MANIFOLD"
```

```
8650    PRINT RPT$("_",63);"CURRENT   OPTION"
8660    PRINT
8670    IMAGE 6A3X,4D,5(2X7D),7X3D,4X7A
8680    IMAGE 9X, "  ± ",5(2X7D)
8690    IMAGE "  furnace blank 40Ar ",8D,"±",8DX
8700    FOR J=1 TO N
8710      PRINT USING 8670;A$(J);T5(J);Raw40(J);Raw39(J);Raw38(J);Raw37(J);Raw36
(J);Tc(J);Manifold$(J)
8720      PRINT USING 8680;Raw40err(J);Raw39err(J);Raw38err(J);Raw37err(J);Raw36
err(J)
8730      IF Blank$='Y" THEN PRINT USING 8690;Airblnk(J),Airblnker(J)
8740    NEXT J
8750    PRINT RPT$("_",80)
8760    PRINT "38Ar errors assigned from experience, rest calculated from regres
sion statistics";
8770    IF Blank$="N' THEN GOTO 8840
8780    PRINT LIN(1);"Raw counts and errors do not include blank corrections.  B
lanks include indi-"
8790    PRINT "cated amount of air 40Ar, with corresponding 38Ar and 36Ar, as we
ll as the";LIN(1);"following tube blank:"
8800    IMAGE #,K,K,'±",K,"  "
8810    FOR M=1 TO 5
8820      PRINT USING 8800;"mass "&VAL$(41-M)&":",Tb(M),Tber(M)
8830    NEXT M
8840    PRINT LIN(0);RPT$("_",80);LIN(1)
8850    RETURN
8860    !
8870    !
8880 Print_correct:    !  SUBROUTINE TO PRINT CORRECTIONS
8890    PRINT TAB(29);"C O R R E C T I O N S"
8900    PRINT
8910    PRINT "TEMP     39Ar    37Ar    -----K-derived----    ----Ca-derived----  C
l-der Initial"
8920    PRINT " ";CHR$(179);"C      Decay  Decay   40Ar    38Ar    37Ar    39Ar    38
Ar   36Ar    36Ar    38Ar";
8930    PRINT LIN(0);RPT$("_",80)
8940    PRINT
8950    IMAGE 4D2X,6DX,9(7D)
8960    FOR J=1 TO N
8970       PRINT USING 8950;T5(J);Decayed39(J);Decayed37(J);Ar40k(J);Ar38k(J);Ar
37k(J);Ar39ca(J);Ar38ca(J);Ar36ca(J);Ar36cl(J);Ar38in(J)
8980    NEXT J
8990    PRINT RPT$("_",80)
9000    PRINT TAB(12);" All values in counts, corrected for mass discrimination"
;LIN(0);RPT$("_",80)
9010    PRINT
9020    RETURN
9030    !
9040    !
9050 Print_more:    !
9060    PRINT SPA(61);"precision"
9070    PRINT "  TEMP  % TOT   RAD     APP     APP       F          AGE      intra-
intra-  inter-"
9080    PRINT "     C   39Ar   YIELD    K/Ca    K/Cl                (Ma)     sample
package package";LIN(0);RPT$("_",80)
9090    IMAGE AX,4D2X, 3D.D2X,3D.D2X, 3D.2D1X, 5DX, 4D.3D,1X6D.2D," ±",3(4D.D
D1X)
9100    PRINT
9110    FOR J=1 TO N
9120      Radyield=100*(Mar40(J)-Ar4036in*Mar36in(J))/Mar40(J)
9130      Percentyield=100*Mar39k(J)/Sum39
9140      Kcl=0
9150      IF Mar38cl(J)>0 THEN Kcl=Kcl_factor*Mar39k(J)/Mar38cl(J)
9160      PRINT USING 9090;CHR$(J+64);T5(J);Percentyield;Radyield;Kca(J);Kcl;F(J
);Age(J),Age_err1(J);Age_err2(J);Age_err3(J)
9170    NEXT J
```

```
9180    PRINT RPT$("_",80)
9190    IMAGE "Precisions are 1 sigma, measured in Ma.   Measured 40/36 atm = ",
K," ±",K
9200    PRINT USING 9190;Ad;Ad_err
9210    IMAGE "J = ",Z.6D," ± ",Z.DD,"% (intra-package)  ± ",Z.DD,"% (inter-
package)"
9220    PRINT USING 9210;Z;E;J_pkg_er
9230    IMAGE "Trap current factors-  40: ",K,"   100: ",K,"   200: ",K
9240    PRINT USING 9230;Tc40;Tc100;Tc200
9250    IMAGE "Manifold factors-  ALL: ",K,"  SPLIT 1: ",K,"  SPLIT 2: ",K,"  SP
LIT 3: ",K
9260    PRINT USING 9250;Mdc(1);Mdc(2);Mdc(3);Mdc(4)
9270    IMAGE "Sensitivity = ",D.DDDE,"   Detection limit = ",K," counts"
9280    PRINT USING 9270;Sensitivity;Mincnts
9290    IMAGE "Data reduced assuming initial 40/36 = ",8D.2D," ±",8D.2D
9300    PRINT USING 9290;Ar4036in;Ar4036in_err
9310    PRINT LIN(0);RPT$("_",80)
9320    RETURN
9330    !
9340    !
9350 Print_v:  ! PRINTS MATRIX V
9360  PRINT
9370  PRINT "Relative importance of various sources of error in age, normalized
to inter-"
9380  PRINT "package error = 1000"
9390  PRINT
9400  J$(11)="Mass discrim"
9410  J$(1)="Furnace blnk"
9420  J$(2)="Raw 40      "
9430  J$(3)="Raw 39      "
9440  J$(4)="Raw 38      "
9450  J$(5)="Raw 37      "
9460  J$(6)="Raw 36      "
9470  J$(7)="39 Decay cor"
9480  J$(8)="37 decay cor"
9490  J$(9)="36Cl decay  "
9500  J$(10)="40/36 in    "
9510  J$(12)="intra-pkg J "
9520  J$(13)="K4039 reac  "
9530  J$(14)="K3839 reac  "
9540  J$(15)="K3739 reac  "
9550  J$(16)="Ca3937 reac "
9560  J$(17)="Ca3837 reac "
9570  J$(18)="Ca3637 reac "
9580  J$(19)="Cl3638 reac "
9590  J$(20)="init Ar3836 "
9600  J$(21)="monitor age "
9610  Nm=1
9620  Nn=N
9630  IF Nn>Nm+16 THEN Nn=Nm+16
9640  FOR Jj=1 TO 21
9650    PRINT J$(Jj);
9660    FOR J=Nm TO Nn
9670      Var$=RPT$(" ",4-LEN(VAL$(V(J,Jj))))&VAL$(V(J,Jj))
9680      PRINT Var$;
9690    NEXT J
9700    PRINT
9710  NEXT Jj
9720  IF Nn=N THEN GOTO 9750
9730  Nm=Nm+17
9740  GOTO 9620
9750  PRINT LIN(1);"Intra-sample error includes effects of Furnace blnk to 36
Cl Decay errors"
9760  PRINT "(first 9) inclusive; intra-package error also includes effects of e
rror in"
9770  PRINT "initial 40/36 ratio and mass discrimination and intra-package uncer
```

```
tainty in J;"
9780  PRINT "interpackage error includes effects of all sources of uncertainty."
9790  PRINT "Uncertainties in decay corrections and initial 38/36 ratio are assu
med to be 0."
9800  PRINT "Uncertainties in tube blank are included in uncertainties in raw co
unts."
9810  RETURN
9820  !
9830  !
9840 Print_final:    !  SUBROUTINE TO PRINT FINAL DATA TABLE
9850   PRINT TAB(40-LEN(Ra$)/2);Ra$
9860   PRINT RPT$("=",80)
9870   IMAGE "    J = ",Z.6D," ± ",Z.DD,"%",28X,"SAMPLE W" = ",Z.4D," g"
9880   PRINT USING 9870;Z;E;Wt
9890   PRINT RPT$("-",80)
9900   PRINT "       Initial &  Potassium   Chlorine    Calcium'
9910   PRINT "TEMP   radiogenic  derived     derived     derived     Initial
 AGE*     **"
9920   PRINT "  C       40Ar        39Ar        38Ar        37Ar        36Ar
in Ma";
9930   PRINT LIN(0);RPT$("_",80)
9940   PRINT
9950   IMAGE #, 4DX !, 5(XMD.3DE)
9960   IMAGE 1X7D.2D, " ±", 4D.2D
9970   FOR J=1 TO N
9980     PRINT USING 9950;T5(J)
9990     CALL Pnum(Mar40(J),Cfactor(J),Mincnts)
10000    CALL Pnum(Mar39k(J),Cfactor(J),Mincnts)
10010    CALL Pnum(Mar38cl(J),Cfactor(J),Mincnts)
10020    CALL Pnum(Mar37ca(J),Cfactor(J),Mincnts)
10030    CALL Pnum(Mar36in(J),Cfactor(J),Mincnts)
10040    PRINT USING 9960;Age(J);Age_err2(J)
10050  NEXT J
10060  IF N=1 THEN GOTO 10270
10070  PRINT LIN(1);'TOTAL"
10080  PRINT " GAS ";
10090  Cfactor=Cfactor(INT(1+N)/2)
10100  CALL Pnum(Sum40,Cfactor,Mincnts)
10110  CALL Pnum(Sum39,Cfactor,Mincnts)
10120  CALL Pnum(Sum38,Cfactor,Mincnts)
10130  CALL Pnum(Sum37,Cfactor,Mincnts)
10140  CALL Pnum(Sum36,Cfactor,Mincnts)
10150  Ff=(Sum40-Ar4036in*Sum36)/Sum39
10160  CALL Fage(Ff,0,Z,E,Ap,Dummy)
10170  IMAGE 1X7D.2D
10180  PRINT USING 10170;Ap
10190  IF Ar4036in<>295.5 THEN PRINT USING "23X,K,7D.2D";"assuming 40Ar/36Ar ini
tial = 295.5    ";1804*LOG(Z*(Sum40-295.5*Sum36)/Sum39+1)
10200  PRINT
10210  IF N>1 THEN GOSUB Plateau_test
10220  Z$="N"
10230  IF N>1 THEN INPUT "Ya wanna calculate an average age for some steps? (Y/
N)",Z$
10240  CALL Yn(Z$)
10250  IF Z$="Y" THEN GOSUB Plateau_calc
10260  IF Z$="Y" THEN GOTO 10220
10270  PRINT RPT$("_",80)
10280  PRINT
10290  PRINT " Note: all gas quantities are in moles.  ";
10300  IF Blank$="Y" THEN PRINT "Corrected for analytical blank."
10310  IF Blank$="N" THEN PRINT "No blank correction."
10320  PRINT USING "K,K,K,K";" *   Ages calculated assuming initial 40Ar/36Ar =
",PROUND(Ar4036in,-1)," ± ",PROUND(Ar4036in_err,-1)
10330  PRINT " **  1-sigma precision estimates are for intra-irradiation package
 reproduci-";LIN(1);'     bility."
10340  PRINT " *** below detection limit"
```

```
10350  PRINT RPT$("_',80);LIN(2);Version$;PAGE
10360  RETURN
10370  !
10380  !
10390 Plateau_test:  !  ROUTINE TO TEST FOR AGE PLATEAUX
10400  !  called by subroutine Print_final
10410  Auto_plateau=1
10420  Noplat=0
10430  Last_pst=0
10440  FOR J1=1 TO N-1
10450    DISP "Please wait while we think about plateaux"
10460    Sumgas=Mar39k(J1)
10470    Plat=0
10480    FOR Pst=J1+1 TO N
10490      Dif=ABS(Age(J1)-Age(Pst))
10500      Dif2=ABS(F(J1)-F(Pst))
10510      Aerr=1.96*SQR(Age_err1(J1)^2+Age_err1(Pst)^2)
10520      Berr=.00693*(F(J1)+F(Pst))/2
10530      IF ((Dif<Aerr) OR (Dif2<Berr)) AND (Plat=0) THEN GOSUB Plateau2
10540      IF (Dif>=Aerr) AND (Dif2>=Berr) THEN Plat=1
10550      IF (Dif>=Aerr) AND (Dif2>=Berr) THEN GOTO 10570
10560    NEXT Pst
10570    IF (Sumgas/Sum39>.5) AND (Pst<>Last_pst) THEN GOSUB Plateau3
10580  NEXT J1
10590  IF Noplat=0 THEN PRINT ,"NO PLATEAU"
10600  Auto_plateau=0
10610  RETURN
10620  !
10630 Plateau2: !
10640  FOR J3=J1+1 TO Pst
10650    Dif=ABS(Age(J3)-Age(Pst))
10660    Dif2=ABS(F(J3)-F(Pst))
10670    Aerr=1.96*SQR(Age_err1(J3)^2+Age_err1(Pst)^2)
10680    Berr=.00693*(F(J3)+F(Pst))/2
10690    IF (Dif>=Aerr) AND (Dif2>=Berr) THEN Plat=1
10700    IF (Dif>=Aerr) AND (Dif2>=Berr) THEN RETURN
10710  NEXT J3
10720  Sumgas=Sumgas+Mar39k(Pst)
10730  J2=Pst
10740  RETURN
10750  !
10760 Plateau3:!
10770   IF J2=J1 THEN RETURN
10780  Last_pst=Pst
10790  Noplat=1
10800  GOSUB Plateau_calc
10810  RETURN
10820  !
10830 Plateau_calc:! CALCULATES AVERAGE AGE AND ERROR FOR PLATEAU, STEPS
10840               ! J1 TO J2
10850  IF Auto_plateau=0 THEN INPUT "CALCULATE PLATEAU AGE FOR INCREMENT# ____ ,
TO INCREMENT# ___   ?',J1,J2
10860  IF J2<=J1 THEN GOTO 10850
10870  Fsws=Ws=Rp=0
10880  Agesum=Weightsum=0
10890  FOR J=J1 TO J2
10900    Weight=1/Age_err3(J)^2
10910    Weightsum=Weightsum+Weight
10920    Agesum=Agesum+Age(J)*Weight
10930    Rp=Rp+Mar39k(J)
10940    W=1/F_err2(J)^2
10950    Fsws=Fsws+F(J)*W
10960    Ws=Ws+W
10970  NEXT J
10980  Ap=Agesum/Weightsum
10990  Rp=100*Rp/Sum39
```

```
11000  Best_f=Fsws/Ws
11010  Best_f_err=1/SQR(Ws)
11020  IF Best_f_err<.0025*Best_f THEN GOSUB Sutter_err
11030  Dage_f=1804*Z^2/(Z*Best_f+1)      ! partial derivative of age wrt F
11040  Dage_j=1804*Best_f^2/(Z*Best_f+1) ! partial derivative of age wrt J (=Z)
11050  CALL Fage(Best_f,Best_f_err,Z,E,Ap,Ep)
11060  IMAGE 3D.D"% of gas on plateau, steps ",4D" through ",4D,2X,"PLATEAU AGE
=",X4D.2D," ±",3D.2D
11070  IF Auto_plateau=1 THEN PRINT USING 11060;Rp,T5(J1),T5(J2),Ap,Ep
11080  IMAGE 3D.D,"% of gas released in steps ",4D" through ",4D,2X,"average age
 =",5D.2D," ±",3D.2D
11090  IF Auto_plateau=0 THEN PRINT USING 11080;Rp,T5(J1),T5(J2),Ap,Ep
11100  RETURN
11110  !
11120 Sutter_err:!
11130  PRINTER IS 16
11140  PRINT LIN(2);'Calculated error in the weighted average of F for this set
of steps is"
11150  PRINT PROUND(Best_f_err,-3);"; this is less than 0.25% of the average F.
 You may, if"
11160  PRINT "you wish, reset the error in average F to 0.25% of F (=";PROUND(.0
025*Best_f,-3);")"
11170  Sutter$="Y"
11180  INPUT "Do you want to reset the calculated error in F? (Y/N)",Sutter$
11190  CALL Yn(Sutter$)
11200  IF Sutter$="Y' THEN Best_f_err=.0025*Best_f
11210  PRINT PAGE
11220  PRINTER IS 0
11230  RETURN
11240  !
11250  !
11260 Plots:!
11270  PRINTER IS 16
11280  Z$="Y"
11290  INPUT "Do you want to make plots? (Y/N)",Z$
11300  CALL Yn(Z$)
11310  IF Z$="N" THEN RETURN
11320  PRINT PAGE,"Now we make plots";LIN(2)
11330  PRINT "It is assumed that you want to make plots of a standard size that
fit"
11340  PRINT "conveniently on a piece of 8 1/2 x 11 typing paper.  You need do n
o more than"
11350  PRINT "put the paper on the plotter with the long edge against the LEFT S
IDE of the"
11360  PRINT "plotter platen and the short edge against the BOTTOM of the platen
."
11370  PRINT
11380  PRINT "IF YOU WANT TO RE-SIZE THE PLOTS:  When changing the paper move
the plotter"
11390  PRINT "pen, using the arrow buttons, to the upper right corner of the are
a the re-"
11400  PRINT "sized plots will fit into and press first the orange ENTER button
and then the"
11410  PRINT "button labelled P2."
11420  PRINT
11430  PRINT "The lower left corner (P1) of the plotting area is assumed to be t
he lower left"
11440  PRINT "corner of the plotter platen."
11450  PRINT
11460  PRINT "This program is set up to make plots with colors.  If you don't wa
nt colors, "
11470  PRINT "put all black pens in the plotter."
11480  DISP "Make sure the plotter is connected and turned on, then press CONT
"
11490  PAUSE
11500  Digitize$="N"
```

```
11510  PRINTER IS 16
11520  PRINT PAGE;LIN(2);"Your choices:";LIN(1)
11530  PRINT "    1    all plots"
11540  PRINT "    2    ternary  40Ar / air Ar / K-derived Ar  plot"
11550  PRINT "    3    39/40 - 36/40 correlation plot"
11560  PRINT "    4    age spectrum (± K/Ca plot)"
11570  PRINT "    5    change plotter pen speed (currently";Penspeed;")"
11580  PRINT "    6    quit making plots"
11590  IF Label$="N" THEN GOTO 11620
11600  PRINT LIN(1);'    7  change plot label.  Current label is';LIN(1)
11610  PRINT TAB(24);Sample$;LIN(1);TAB(24);Lab1$;LIN(1);TAB(24);Lab2$;LIN(1);TA
B(24);Lab3$
11620  Plot_choice=1
11630  INPUT "Enter your choice",Plot_choice
11640  IF Plot_choice=7 THEN Label$="N"
11650  IF (Plot_choice<1) OR (Plot_choice>7) THEN CALL Conniption
11660  IF (Plot_choice>=1) AND (Plot_choice<=7) THEN ON Plot_choice GOSUB Allplo
ts,Ternary,Correlation,Plot_spectrum,Changeps,Quitplots,Get_labels
11670  IF Plot_choice<>6 THEN GOTO 11510
11680  RETURN
11690  !
11700  !
11710 Allplots:!
11720  GOSUB Ternary
11730  GOSUB Correlation
11740  GOSUB Plot_spectrum
11750  RETURN
11760  !
11770  !
11780 Changeps:!
11790  INPUT "Enter new pen speed (integer between 1 and 25)",Penspeed
11800  IF (Penspeed<1) OR (Penspeed>25) OR (INT(Penspeed)<>Penspeed) THEN GOTO 1
1790
11810  RETURN
11820  !
11830  !
11840 Quitplots:!
11850  RETURN
11860  !
11870  !
11880 Change_paper:!
11890  DISP "Please change paper on plotter and press CONT"
11900  PAUSE
11910  RETURN
11920  !
11930  !
11940 Init_plotter:!
11950  PLOTTER IS 7,5,"9872A"
11960  PRINTER IS 7,5
11970  LIMIT 10,210,5,274  ! slightly inside upright 8.5 x 11 sheet
11980  PEN 1
11990  MOVE 0,1
12000  LORG 1
12010  CSIZE 2
12020  PRINT "VS"&VAL$(Penspeed)
12030  LABEL USING "#,K,K";Version$,Aa$
12040  RETURN
12050  !
12060 Label_dropstr:!
12070  IF (Regress$='N") OR (Drop$="") THEN RETURN
12080  LABEL USING "#,K";"   W/O POINTS "
12090  PEN 2
12100  LABEL Drop$
12110  PEN 1
12120  RETURN
12130  !
```

```
12140 Plot_spectrum:!
12150  Repeat=0
12160  GOSUB Change_paper
12170  GOSUB Plot_questions
12180  GOSUB Init_plotter
12190  IMAGE #,K
12200  LABEL USING 12190;"   (40/36in = "
12210  IF Ar4036in=295.5 THEN GOTO 12260
12220  IF Spectrum1$="N" THEN GOTO 12250
12230  PEN 2
12240  LABEL USING 12190;VAL$(PROUND(Ar4036in,-1))
12250  IF Spectrum295$="N" THEN GOTO 12280
12260  PEN 3
12270  LABEL USING 12190;"  295.5"
12280  PEN 1
12290  LABEL ")"
12300  LOCATE 14,90,15,85
12310  CSIZE 3.2
12320  FRAME
12330  SCALE 0,100,Ymin,Ymax
12340  AXES 10,Yincr,0,Ymin
12350  PEN 1
12360  LORG 5
12370  LDIR 1,0
12380  SETUU
12390  Bra=(Ymax-Ymin)/20
12400  Brb=Ymin-Bra
12410  MOVE 0,Brb
12420  LABEL "0"
12430  MOVE 30,Brb
12440  LABEL "39"
12450  Brc=Ymin-1.5*Bra
12460  MOVE 53,Brc
12470  LABEL "Ar  Released (%)"
12480  Brd=Ymin-2*Bra
12490  MOVE 39,Brd
12500  LABEL "K"
12510  MOVE 100,Brb
12520  LABEL "100"
12530  LORG 8
12540  FOR Y=Ymin TO Ymax STEP Yincr
12550    IF Y>=Ymax THEN GOTO 12590
12560    MOVE -.3,Y
12570    LABEL Y
12580  NEXT Y
12590  MOVE -15,(Ymax+Ymin)/2
12600  LORG 5
12610  LDIR 0,1
12620  LABEL "Apparent Age (Ma)"
12630  IF Repeat=1 THEN GOTO 12660
12640  Repeat=1
12650  GOTO 12300
12660  IF (Ar4036in<>295.5) AND (Spectrum1$<>"Y") THEN GOTO 12690
12670  GOSUB Draw_spectrum
12680  GOSUB Draw_spectrum
12690  IF (Ar4036in=295.5) OR (Spectrum295$<>"Y") THEN GOTO 12810
12700    Hold=Ar4036in
12710    Ar4036in=295.5
12720    MAT Temp=Age
12730    MAT Err=Age_err1
12740    MAT Age=Age295
12750    MAT Age_err1=Age_err295
12760    GOSUB Draw_spectrum
12770    GOSUB Draw_spectrum
12780    MAT Age=Temp
12790    MAT Age_err1=Err
```

```
12800     Ar4036in=Hold
12810   PEN 1
12820   IF Kca$="N" THEN GOTO 12850
12830   GOSUB Plot_kca
12840   GOSUB Plot_kca
12850   GOSUB Plot_label
12860   PEN 0
12870   RETURN
12880   !
12890 Plot_questions: !
12900   GOSUB Get_labels
12910   INPUT "Enter minimum, maximum, and tick increment for age axis of spectru
m",Ymin,Ymax,Yincr
12920   IF Ymin>=Ymax THEN GOTO 12910
12930   Box$="Y"
12940   INPUT "Do you want 2-sigma error boxes on spectrum? (Y/N)",Box$
12950   CALL Yn(Box$)
12960   Spectrum295$=Spectrum1$="Y"
12970   IF Regress$="Y" THEN INPUT "Do you want the age spectrum for 40/36 initia
l = 295.5 plotted (Y/N)",Spectrum295$
12980   CALL Yn(Spectrum295$)
12990   IF (Regress$='Y") AND (Spectrum295$="N") OR (Regress$="N') THEN GOTO 1305
0
13000   PRINTER IS 16
13010   PRINT Message$;"regressed initial ratio is ";PROUND(Ar4036in,-1)
13020   IF (Spectrum295$="Y") AND (Regress$="Y") THEN INPUT "Do you want the spec
trum for regressed 40/36 initial plotted? (Y/N)",Spectrum1$
13030   CALL Yn(Spectrum1$)
13040   PRINT Message$;Clreol$
13050   Kca$="Y"
13060   INPUT "Do you want the K/Ca ratio plotted? (Y/N)",Kca$
13070   CALL Yn(Kca$)
13080   IF Kca$="N" THEN RETURN
13090   L_min=1E10
13100   L_max=-1
13110   FOR J=1 TO N
13120     IF (Kca(J)<L_min) AND (Kca(J)<>0) THEN L_min=Kca(J)
13130     IF (Kca(J)>L_max) AND (Kca(J)<>0) THEN L_max=Kca(J)
13140   NEXT J
13150   Log_min=INT(LGT(L_min))
13160   Log_max=INT(LGT(L_max))
13170   PRINTER IS 16
13180   Kca(J+1)=Kca(J)
13190   PRINT Message$;"Default Min and Max values for log axis on K/Ca plot are
";Log_min;", ";Log_max
13200   Lm=-100
13210   Ln=-100
13220   INPUT "Press CONT to accept these values or enter new ones",Lm,Ln
13230   IF Lm>-99 THEN Log_min=Lm
13240   IF Ln>-99 THEN Log_max=Ln
13250   IF Log_max<Log_min THEN GOTO 13190
13260   PRINT Message$;Clreol$
13270   Log_max=Log_max+1
13280   RETURN
13290   !
13300 Draw_spectrum:!
13310   IF Ar4036in=295.5 THEN PEN 3
13320   IF Ar4036in<>295.5 THEN PEN 2
13330   IF Box$<>"Y" THEN GOTO 13470
13340     MOVE 0,Age(1)-2*Age_err1(1)
13350     DRAW Percent(1),Age(1)-2*Age_err1(1)
13360     DRAW Percent(1),Age(1)+2*Age_err1(1)
13370     DRAW 0,Age(1)+2*Age_err1(1)
13380     DRAW 0,Age(1)-2*Age_err1(1)
13390     FOR J=2 TO N
13400       MOVE Percent(J-1),Age(J)-2*Age_err1(J)
```

```
13410       DRAW Percent(J),Age(J)-2*Age_err1(J)
13420       DRAW Percent(J),Age(J)+2*Age_err1(J)
13430       DRAW Percent(J-1),Age(J)+2*Age_err1(J)
13440       DRAW Percent(J-1),Age(J)-2*Age_err1(J)
13450     NEXT J
13460   IF Box$="Y" THEN GOTO 13520
13470     MOVE 0,Age(1) ! begin Box$="N"
13480     FOR J=1 TO N
13490       DRAW Percent(J),Age(J)
13500       IF J<N THEN DRAW Percent(J),Age(J+1)
13510     NEXT J
13520   RETURN
13530   !
13540 Get_labels:!
13550   IF Label$="Y" THEN RETURN
13560   INPUT "Sample name (for labelling plots)",Sample$
13570   INPUT "Additional label #1 (on all plots)",Lab1$
13580   INPUT "Additional label #2 (age spectrum only)",Lab2$
13590   INPUT "Additional label #3 (age spectrum only)",Lab3$
13600   Label$="Y"
13610   RETURN
13620   !
13630 Plot_label: !
13640   Z$="N"
13650   IF Digitize$='Y" THEN INPUT "You want to move the label? (Y/N)",Z$
13660   CALL Yn(Z$)
13670   IF Z$="Y" THEN Digitize$="N"
13680   IF Digitize$='Y" THEN GOTO 13730
13690   POINTER 20,Ymin+(Ymax-Ymin)/.8,2
13700   DISP "POSITION PEN FOR LABEL ON GRAPH ,THEN PRESS ORANGE ENTER BUTTON"
13710   DIGITIZE X1,Y1
13720   Digitize$="Y"
13730   Repeat=0
13740   LDIR 1,0
13750   LORG 1
13760   MOVE X1,Y1
13770   LABEL Sample$
13780   LABEL Lab1$
13790   LABEL Lab2$
13800   LABEL Lab3$
13810   IF Repeat=1 THEN GOTO 13840
13820   Repeat=1
13830   GOTO 13740
13840   RETURN
13850   !
13860 Plot_kca:!
13870   PRINTER IS 7,5
13880   LOCATE 14,90,85,112
13890   FRAME
13900   SCALE 0,100,Log_min,Log_max
13910   AXES 0,0,0,Log_min,1,1,170
13920   FOR Decade=Log_min TO Log_max
13930   FOR Interval=1 TO 9
13940   MOVE 0,Decade+LGT(Interval)
13950   DRAW 1,Decade+LGT(Interval)
13960   NEXT Interval
13970   MOVE 0,Decade
13980   DRAW 2,Decade
13990   NEXT Decade
14000   LORG 8
14010   Log_=Log_min
14020   LDIR 1,0
14030   FOR Decade=Log_min TO Log_max
14040   Logs_=10^Log_
14050   MOVE -1.5,Decade
14060   LABEL Logs_
```

```
14070  Log_=Log_+1
14080  NEXT Decade
14090  LDIR 0,1
14100  MOVE -15,(Log_max+Log_min)/2
14110  LABEL "K/Ca"
14120  LDIR 1,0
14130  MOVE 0,LGT(Kca(1))
14140  FOR J=1 TO N
14150    IF Kca(J)>0 THEN DRAW Percent(J),LGT(Kca(J))
14160    IF Kca(J)=0 THEN DRAW Percent(J),Log_max
14170    IF Kca(J+1)>0 THEN DRAW Percent(J),LGT(Kca(J+1))
14180    IF Kca(J+1)=0 THEN DRAW Percent(J),Log_max
14190  NEXT J
14200  IF Repeat=1 THEN 14230
14210  Repeat=1
14220  GOTO 13890
14230  RETURN
14240  !
14250  !
14260  !
14270 Correlation:  !
14280  GOSUB Change_paper
14290  Repeat=0
14300  Bar$="Y"
14310  INPUT "Do you want 1 sigma error bars drawn on the 39/40 - 36/40 plot? (
Y/N) ",Bar$
14320  CALL Yn(Bar$)
14330  Line$="N"
14340  IF Regress$="Y" THEN INPUT "You want the regression line drawn on the 39/
40 - 36/40 plot? (Y/N)",Line$
14350  CALL Yn(Line$)
14360  GOSUB Get_labels
14370  GOSUB Init_plotter
14380  GOSUB Label_dropstr
14390  CSIZE 3.2
14400  LOCATE 14,90,20,85
14410  GOSUB Plot_cor
14420  GOSUB Plot_cor
14430  PEN 0
14440  RETURN
14450  !
14460 Plot_cor:! plots correlation diagram on unspecified plotter
14470  DEG
14480  PEN 1
14490  FRAME
14500  Xmax=Ymax=0
14510  FOR J=1 TO N
14520    IF 1.1*Mar36in(J)/Mar40(J)>Ymax THEN Ymax=1.1*Mar36in(J)/Mar40(J)
14530    IF 1.1*Mar39k(J)/Mar40(J)>Xmax THEN Xmax=1.1*Mar39k(J)/Mar40(J)
14540  NEXT J
14550  IF (Ymax<3.5E-3) AND (Ymax>.001) THEN Ymax=3.5E-3
14560  SCALE 0,Xmax,0,Ymax
14570  Xtick=DROUND(Xmax/6,1)
14580  Ytick=DROUND(Ymax/7,1)
14590  AXES Xtick,Ytick,0,0
14600  CSIZE 3.3,9/15
14610  LORG 6
14620  FOR J=0 TO Xmax STEP Xtick
14630    MOVE J,-(.03*Ymax)
14640    LABEL VAL$(J)
14650  NEXT J
14660  MOVE Xmax/2,-(.08*Ymax)
14670  LABEL "39Ar/40Ar"
14680  LDIR 90
14690  LORG 4
14700  FOR J=0 TO Ymax STEP 2*Ytick
```

```
14710     MOVE -(.03*Xmax),J
14720     LABEL VAL$(J)
14730   NEXT J
14740   MOVE -(.09*Xmax),Ymax/2
14750   LABEL "36Ar/40Ar"
14760   LDIR 0
14770   MOVE Xmax/2,1.1*Ymax
14780   LABEL Sample$
14790   MOVE Xmax/2,1.05*Ymax
14800   IF Lab1$<>" " THEN LABEL Lab1$
14810   LORG 5
14820   MOVE 0,1/295.5
14830   LABEL "*"
14840   PEN 2
14850   FOR J=1 TO N
14860     MOVE Mar39k(J)/Mar40(J),Mar36in(J)/Mar40(J)
14870     IF J<=26 THEN Fred$=CHR$(J+64)
14880     IF J>26 THEN Fred$=CHR$(J+70)
14890     LABEL Fred$
14900   NEXT J
14910   IF Bar$="N" THEN GOTO 15080
14920   PEN 4
14930   ! GOSUB Get_weights
14940   FOR J=1 TO N
14950     X=Mar39k(J)/Mar40(J)
14960     Y=Mar36in(J)/Mar40(J)
14970     Xer=R3940er(J)
14980     Yer=R3640er(J)
14990     MOVE X+Xer,Y
15000     DRAW X-Xer,Y
15010     MOVE X,Y+Yer
15020     DRAW X,Y-Yer
15030   NEXT J
15040   IF Line$="N" THEN GOTO 15080
15050     PEN 3
15060     MOVE 0,1/Ar4036in
15070     DRAW 1/Regressed_f,0
15080   PEN 1
15090   RETURN
15100   !
15110   !
15120   !
15130 Ternary:!
15140   Ternaryblank$="N"
15150   IF Blank$="Y" THEN INPUT "You want to show error polygons on the ternary?
 (Y/N)",Ternaryblank$
15160   CALL Yn(Ternaryblank$)
15170   Airerror$="N"
15180   IF Blank$="Y" THEN INPUT "You want to show air-error lines on the ternary
? (Y/N)",Airerror$
15190   CALL Yn(Airerror$)
15200   Line$="N"
15210   IF Regress$="Y" THEN INPUT "You want the regression line drawn on the ter
nary? (Y/N)",Line$
15220   CALL Yn(Line$)
15230   Min_f=ABS(F(1))
15240   FOR J=1 TO N
15250     IF F(J)<0 THEN GOTO 15270
15260     IF F(J)*.9<Min_f THEN Min_f=F(J)*.9
15270   NEXT J
15280   PRINTER IS 16
15290   PRINT Message$;"Minimum F (lower right vertex) is ";PROUND(Min_f,-2)
15300   Z$="N"
15310   INPUT "Do you want to change this value? (Y/N)",Z$
15320   CALL Yn(Z$)
15330   IF Z$="N" THEN GOTO 15350
```

```
15340  INPUT "Enter new minimum F",Min_f
15350  PRINT Message$;Clreol$
15360  GOSUB Change_paper
15370  GOSUB Get_labels
15380  GOSUB Init_plotter
15390  GOSUB Label_dropstr
15400  LOCATE 10,86,25,103
15410  SHOW 0,120,-15,100
15420  GOSUB Plot_ternary
15430  GOSUB Plot_ternary
15440  RETURN
15450  !
15460 Plot_ternary:!  plots ternary on unspecified plotter
15470  PEN 1
15480  LDIR 1,0
15490  CSIZE 3.5
15500  MOVE 0,0
15510  DRAW 120,0
15520  DRAW 60,SQR(3)*60
15530  DRAW 0,0
15540  MOVE 0,-2
15550  LORG 6
15560  LABEL "40Ar/36Ar"
15570  LABEL "= 295.5"
15580  MOVE 120,-2
15590  LABEL "40Ar/39Ar"
15600  LABEL "= "&VAL$(PROUND(Min_f,-1))
15610  MOVE 60,SQR(3)*60+2
15620  LORG 4
15630  LABEL "40Ar"
15640  MOVE 60,-15
15650  LORG 6
15660  CSIZE 3.2
15670  LABEL Sample$
15680  LABEL Lab1$
15690  LABEL Lab2$
15700  LABEL Lab3$
15710  MOVE 60,-10
15720  LORG 6
15730  PEN 2
15740  CSIZE 3
15750  FOR J=1 TO N
15760    A=Mar36in(J)
15770    B=Mar39k(J)
15780    C=Mar40(J)
15790    Sum=A+B+C
15800    GOSUB Getxyt
15810    MOVE Xt,Yt
15820    LORG 5
15830    IF J<=26 THEN Fred$=CHR$(J+64)
15840    IF J>26 THEN Fred$=CHR$(J+70)
15850    LABEL Fred$
15860  NEXT J
15870  IF Ternaryblank$="Y" THEN GOSUB Ternary_error
15880  IF Airerror$="Y" THEN GOSUB Air_error
15890  IF Line$="Y" THEN GOSUB T_regress_line
15900  PEN 0
15910  RETURN
15920  !
15930 Getxyt:!
15940  At=A*296.5
15950  Bt=B*(Min_f+1)
15960  Ct=Sum-At-Bt
15970 Getxxyytt:!
15980  Yt=Ct*60*SQR(3)/Sum
15990  Xt=(Bt+Ct/2)*120/Sum
```

```
16000  RETURN
16010  !
16020 Ternary_error:!
16030  PEN 3
16040  FOR J=1 TO N
16050    Am=Mar36in(J)
16060    Bm=Mar39k(J)
16070    Cm=Mar40(J)
16080    Aer=Mar36in_er(J)
16090    Ber=Mar39k_er(J)
16100    Cer=Mar40_er(J)
16110    Summ=Am+Bm+Cm
16120    Sum=Summ+Aer-Cer
16130    A=Am+Aer
16140    B=Bm
16150    C=Cm-Cer
16160    GOSUB Getxy%
16170    MOVE Xt,Yt
16180    Sum=Summ+Ber-Cer
16190    A=Am
16200    B=Bm+Ber
16210    C=Cm-Cer
16220    GOSUB Getxy%
16230    DRAW Xt,Yt
16240    Sum=Summ+Ber-Aer
16250    A=Am-Aer
16260    B=Bm+Ber
16270    C=Cm
16280    GOSUB Getxy%
16290    DRAW Xt,Yt
16300    Sum=Summ+Cer-Aer
16310    A=Am-Aer
16320    B=Bm
16330    C=Cm+Cer
16340    GOSUB Getxy%
16350    DRAW Xt,Yt
16360    Sum=Summ+Cer-Ber
16370    A=Am
16380    B=Bm-Ber
16390    C=Cm+Cer
16400    GOSUB Getxy%
16410    DRAW Xt,Yt
16420    Sum=Summ+Aer-Ber
16430    A=Am+Aer
16440    B=Bm-Ber
16450    C=Cm
16460    GOSUB Getxy%
16470    DRAW Xt,Yt
16480    Sum=Summ+Aer-Cer
16490    A=Am+Aer
16500    B=Bm
16510    C=Cm-Cer
16520    GOSUB Getxy%
16530    DRAW Xt,Yt
16540    PENUP
16550  NEXT J
16560  RETURN
16570  !
16580 Air_error:!
16590  PEN 4
16600  FOR J=1 TO N
16610   Air=296.5*Cfactor(J)*Airblnker(J)/295.5
16620   A=Mar36in(J)
16630   B=Mar39k(J)
16640   C=Mar40(J)
16650   Sum=A+B+C+Air
```

```
16660   At=A*296.5+Air
16670   Bt=(Min_f+1)*B
16680   Ct=Sum-At-Bt
16690   GOSUB Getxxyytt
16700   MOVE Xt,Yt
16710   IF Air>A+B+C THEN Air=(A+B+C)*.98
16720   Sum=A+B+C-Air
16730   At=296.5*A-Air
16740   Ct=Sum-At-Bt
16750   GOSUB Getxxyytt
16760   DRAW Xt,Yt
16770  NEXT J
16780  RETURN
16790  !
16800 T_regress_line:! draws regression line on ternary
16810  PEN 3
16820  A=1
16830  B=0
16840  C=Ar4036in
16850  Sum=A+B+C
16860  GOSUB Getxyt
16870  MOVE Xt,Yt
16880  A=0
16890  B=1
16900  C=Regressed_f
16910  Sum=A+B+C
16920  GOSUB Getxyt
16930  DRAW Xt,Yt
16940  RETURN
16950  !
16960  !
16970 Error:   !
16980  IF ERRN=31 THEN DISP "DIVIDING BY ZERO IN LINE ";ERRL;" AGAIN!  SHAME ON
WHOEVER CODED THIS"
16990  WAIT 300
17000  IF ERRN<>31 THEN DISP "Error number ";ERRN;" in line ";ERRL;", press CON
T to continue"
17010  IF ERRN<>31 THEN PAUSE
17020  RETURN
17030  !
17040  !
17050  !
17060 DEF FNEr(X)  !  NOTE- THESE ARE EXPERIMENTALLY-DERIVED ERRORS
17070  IF X>10000 THEN RETURN .3
17080  IF X>6000 THEN RETURN .5
17090  IF X>3000 THEN RETURN 1
17100  IF X>1000 THEN RETURN 3
17110  IF X>500 THEN RETURN 5
17120  IF X>200 THEN RETURN 10
17130  IF X>70 THEN RETURN 20
17140  IF X>40 THEN RETURN 50
17150  IF X>20 THEN RETURN 50
17160  IF X>20 THEN RETURN 75
17170  IF X<20 THEN RETURN 150
17180  FNEND
17190  !
17200  !
17210 SUB Catalog(X$)   !  writes a directory to screen
17220  OPTION BASE 1
17230  DIM Cat$(50)[41]
17240  Row=4
17250  Col=5
17260  CAT TO Cat$(*),0,R;X$,1
17270  FOR E=1 TO 50
17280    Row=Row+1
17290    IF Row<18 THEN GOTO 17320
```

```
17300       Row=5
17310       Col=Col+12
17320     PRINT USING "#,K";CHR$(27)&"&a"&VAL$(Row)&"y"&VAL$(Col)&"C";Cat$(E)[1,6
]
17330   NEXT E
17340   PRINT
17350   SUBEND
17360   !
17370   !
17380 DEF FNAge(G(*),Cor(*))
17390    Ad=G(11)
17400    Air40=G(1)
17410    Raw40=G(2)
17420    Raw39=G(3)
17430    Raw38=G(4)
17440    Raw37=G(5)
17450    Raw36=G(6)
17460    Dec39=G(7)
17470    Dec37=G(8)
17480    Dec36=G(9)
17490    Ar4036in=G(10)
17500    Z=G(12)
17510    K4039=G(13)
17520    K3839=G(14)
17530    K3739=G(15)
17540    Ca3937=G(16)
17550    Ca3837=G(17)
17560    Ca3637=G(18)
17570    C13638=G(19)
17580    Ar3836atm=G(20)
17590    J_pkg=G(21)
17600    Ad36=Ad/295.5
17610    Ad37=1+3*(Ad36-1)/4
17620    Ad38=1+2*(Ad36-1)/4
17630    Ad39=1+(Ad36-1)/4
17640    Raw36=(Raw36-Air40/295.5)*Ad36
17650    Raw37=Raw37*Ad37*Dec37
17660    Raw38=(Raw38-Air40/1581)*Ad38
17670    Raw39=Raw39*Ad39*Dec39
17680    Raw40=Raw40-Air40
17690 ! simultaneous solution of the equation
17700 !   Ar37ca = Raw37 - Ar37k
17710 ! and the 2nd, 3rd, and 4th lines following yields the relation:
17720    Cor(1)=Ar37ca=(Raw37-K3739*Raw39)/(1-Ca3937*K3739)
17730    Cor(2)=Ar39ca=Ar37ca*Ca3937
17740    Cor(3)=Ar39k=Raw39-Ar39ca
17750    Cor(4)=Ar37k=Ar39k*K3739
17760    Cor(5)=Ar36ca=Ar37ca*Ca3637
17770    Cor(6)=Ar38k=Ar39k*K3839
17780    Cor(7)=Ar38ca=Ar37ca*Ca3837
17790 ! simultaneous solution of the equation
17800 !   Ar38cl=Raw38-Ar38in-Ar38k-Ar38ca
17810 ! and the 2nd, 3rd, and 4th lines following yields the relation:
17820    Cor(8)=Ar38cl=(Raw38-Ar38ca-Ar38k+Ar3836atm*(Raw36-Ar36ca))/(1-Ar3836atm
*C13638*(Dec36-1))
17830    Cor(9)=Ar36cl=C13638*Ar38cl*(Dec36-1)
17840    Cor(10)=Ar36in=Raw36-Ar36cl-Ar36ca
17850    Cor(11)=Ar38in=Ar36in*Ar3836atm
17860    Cor(12)=Ar40k=Ar39k*K4039
17870    Cor(13)=Ar40=Raw40-Ar40k
17880    Cor(14)=F=(Ar40-Ar4036in*Ar36in)/Ar39k
17890    IF Z*J_pkg*F>-1 THEN PRINT "AGE= ";1804*LOG(Z*J_pkg*F+1)
17900    IF Z*J_pkg*F>-1 THEN RETURN 1804*LOG(Z*J_pkg*F+1)
17910    IF Z*J_pkg*F<=-1 THEN RETURN 0
17920    FNEND
17930    !
```

```
17940   !
17950 SUB Pnum(A,B,C)
17960   IMAGE #,XMD.3DE
17970   IF A/B>C THEN PRINT USING 17960;A
17980   IF A/B<=C THEN PRINT "     ***   ";
17990   SUBEND
18000   !
18010   !
18020 SUB Conniption
18030   PRINTER IS 16,WIDTH(80)
18040   PRINT PAGE
18050   PRINT CHR$(131)
18060   FOR Nn=1 TO 1
18070   FOR N=1 TO 9
18080     PRINT "           Y O U   P I E C E   O F   C A M E L   D U N G !
          "
18090     PRINT "ILLEGAL OR INAPPROPRIATE RESPONSE  -  ARE YOU SURE YOU HAVEN'T
BROKEN SOMETHING?"
18100   NEXT N
18110   FOR N=1 TO 40
18120     BEEP
18130     WAIT 200
18140   NEXT N
18150   NEXT Nn
18160   PRINT CHR$(128);PAGE
18170   SUBEND
18180   !
18190   !
18200 SUB York(X(*),Y(*),R(*),Wx(*),Wy(*),S(*),N,Nn,Meanx,Meany,A,B,C,A_err,B_er
r,C_err,Sums)
18210   ! York (1969, CJES) regression routine
18220   !  X(*), Y(*) are X and Y observations
18230   !  Wx(*) and Wy(*) are relative weights of X and Y observations
18240   !  R(*) are correlations between and X and Y
18250   !  S(*) are flags for dropped analyses
18260   !       and, on return, contain calculated residuals
18270   !  N is number of observations
18280   !  Nn is number of observations actually regressed
18290   !  Meanx and Meany are weighted average of X(*) and Y(*)
18300   !  A, B, and C are Y-intercept, slope, and X-intercept,
18310   !  A_err, B_err, and C_err are the respective errors
18320   !  Sums is a goodness-of-fit parameter
18330   ! Tests for Wx=0, Wy=0 are to allow for possibility of dropping
18340   !   points from regression by setting weights=0
18350   DIM U(50),V(50),Z(50),Alpha(50),Wwx(50),Wwy(50)
18360 ! first estimate slope with ordinary least-squares
18370   Sumxz=Sumy=Sumxx=Sumxy=Nn=0
18380   FOR I=1 TO N
18390     IF S(I)=0 THEN GOTO 18450
18400     Nn=Nn+1
18410     Sumx=Sumx+X(I)
18420     Sumy=Sumy+Y(I)
18430     Sumxx=Sumxx+X(I)^2
18440     Sumxy=Sumxy+X(I)*Y(I)
18450   NEXT I
18460   B=(Nn*Sumxy-Sumx*Sumy)/(Nn*Sumxx-Sumx^2)
18470 ! scale weights to limit numerical problems (this may not be necessary)
18480   K=0
18490   FOR I=1 TO N
18500     IF S(I)=0 THEN GOTO 18530
18510     IF ABS(Wx(I))>K THEN K=Wx(I)
18520     IF ABS(Wy(I))>K THEN K=Wy(I)
18530   NEXT I
18540   FOR I=1 TO N
18550     Wwx(I)=Wx(I)/K
18560     Wwy(I)=Wy(I)/K
```

```
18570   NEXT I
18580 ! iterate to find slope
18590   Iterations=0
18600   Iterations=Iterations+1
18610   PRINT "York regression, iteration ";Iterations;",  slope = ";PROUND(B,-7
)
18620   Old_b=B
18630   Sumz=Sumzx=Sumzy=0
18640   FOR I=1 TO N
18650     Z(I)=Wwx(I)*Wwy(I)/(B^2*Wwy(I)+Wwx(I)-2*B*R(I)*SQR(Wwx(I)*Wwy(I)))
18660     IF S(I)=0 THEN GOTO 18710
18670     Sumz=Sumz+Z(I)
18680     Sumzx=Sumzx+Z(I)*X(I)
18690     Sumzy=Sumzy+Z(I)*Y(I)
18700     Alpha(I)=SQR(ABS(Wwx(I)*Wwy(I)))
18710   NEXT I
18720   Meanx=Sumzx/Sumz
18730   Meany=Sumzy/Sumz
18740   FOR I=1 TO N
18750     U(I)=X(I)-Meanx
18760     V(I)=Y(I)-Meany
18770   NEXT I
18780   Num=Den=0
18790   FOR I=1 TO N
18800     IF S(I)=0 THEN GOTO 18830
18810     Num=Num+Z(I)^2*V(I)*(U(I)/Wwy(I)+B*V(I)/Wwx(I)-R(I)*V(I)/Alpha(I))
18820     Den=Den+Z(I)^2*U(I)*(U(I)/Wwy(I)+B*V(I)/Wwx(I)-B*R(I)*U(I)/Alpha(I))
18830   NEXT I
18840   B=Num/Den
18850   IF ABS((B-Old_b)/B)>1E-6 THEN GOTO 18600  ! test for convergence
18860 ! calculate fit parameters and errors
18870   Sumzuu=Sums=Sumzxx=Sumzyy=0
18880   FOR I=1 TO N
18890     IF S(I)=0 THEN GOTO 18940
18900     Sums=Sums+K*Z(I)*(V(I)-B*U(I))^2
18910     Sumzuu=Sumzuu+Z(I)*U(I)^2
18920     Sumzxx=Sumzxx+Z(I)*X(I)^2
18930     Sumzyy=Sumzyy+Z(I)*Y(I)^2
18940     S(I)=K*Z(I)*(V(I)-B*U(I))^2
18950   NEXT I
18960   A=Meany-B*Meanx
18970   C=-A/B
18980   Var_b=1/(K*Sumzuu)
18990   B_err=SQR(Var_b)
19000   A_err=SQR(Var_b*Sumzxx/Sumz)
19010   C_err=B_err/B^2*SQR(Sumzyy/Sumz)
19020   SUBEND
19030   !
19040   !
19050   SUB Yn(Z$)
19060     Z$=TRIM$(Z$)
19070     Z$=Z$[1,1]
19080     IF Z$="n" THEN Z$="N"
19090     IF Z$="y" THEN Z$="Y"
19100     IF (Z$="Y") OR (Z$="N") THEN GOTO 19140
19110       BEEP
19120       INPUT "HEY DUMMY!    ANSWER  Y  OR  N",Z$
19130       GOTO 19060
19140     SUBEND
19150     !
19160     !
19170   SUB Fage(F,Fer,J,Jer,Age,Ager)
19180     ! NB: Jer is % error in J
19190     Age=1804*LOG(J*F+1)
19200     Dage_f=1804*J/(J*F+1) ! partial derivative of age wrt F
19210     Dage_j=1804*F/(J*F+1) ! partial derivative of age wrt J
```

```
19220     Ager=SQR((Dage_f*Fer)^2+(Dage_j*Jer*J/100)^2)
19230     SUBEND
19240     !
19250     !
19260   SUB Print_history(Rd,D1,Irrad_steps,Total_irrad,Tttt,T(*),E1(*),H(*),W(*)
,U(*))
19270     IMAGE "IRRADIATION HISTORY FOR R-D#",XDD
19280     IMAGE "LAST INCREMENT ENDED ON DAY",XDDD
19290     IMAGE DDX," INCREMENTS IN IRRADIATION"
19300     PRINT USING 19270;Rd
19310     PRINT USING 19280;D1
19320     PRINT USING 19290;Irrad_steps
19330     PRINT LIN(1)
19340     PRINT "INCREMENT   LENGTH OF     ON     AT     POWER"
19350     PRINT "     #      IRRADIATION   DAY  HOUR   LEVEL"
19360     Total_irrad=Tttt=0
19370     FOR I=1 TO Irrad_steps
19380       IMAGE 3XDD8X,DD.DD7X,DDD2X,DD.DD4X,DD
19390       PRINT USING 19380;I,T(I),E1(I),H(I),W(I)
19400       U(I)=W(I)+T(I)
19410       Total_irrad=Total_irrad+U(I)
19420       Tttt=Tttt+T(I)
19430     NEXT I
19440     PRINT "TOTAL IRRADIATION = ";Total_irrad;" MWH"
19450   SUBEND
19460   !
19470   !
19480 SUB Enter_history
19490   DIM U(20),T(20),E1(20),H(20),W(20)
19500   PRINTER IS 16
19510   PRINT PAGE;LIN(2);"Irradiation history tape should be in T15 (right driv
e).  Press CONT"
19520   PAUSE
19530   PRINT LIN(1);"Existing files:"
19540   CALL Catalog(":T15")
19550   INPUT "Enter file name for new history:",R$
19560   PRINT Message$;Clreol$
19570   R$=R$[1,6]
19580   R$=R$&":T15" !
19590   ASSIGN R$ TO #4,R
19600   ON R+1 GOTO 19610,19710,19670
19610   U$=" "
19620   DISP " FILE ';R$;" ALREADY EXISTS, PRESS 'CONT' TO OVERWRITE OR ENTER NE
W IDENTIFIER"
19630   INPUT U$
19640   IF U$=" " THEN 19730
19650   R$=U$
19660   GOTO 19570
19670   PRINT Message$;"YOU CAN'T USE IDENTIFIER";R$;"IDIOT. PLEASE REDEFINE."
19680   BEEP
19690   GOTO 19550
19700   PRINT Message$;"New file is ",R$
19710   CREATE R$,4
19720   ASSIGN R$ TO #4
19730   BUFFER #4
19740   INPUT "IRRADIATION HISTORY FOR R-D#  ?",Rd
19750   INPUT "DAY LAST INCREMENT ENDED ?",D1
19760   INPUT "# OF INCREMENTS IN IRRADIATION ?",Irrad_steps
19770   FOR I=1 TO Irrad_steps
19780     IMAGE #,K,K
19790     PRINT USING 19780;"# ",I
19800     INPUT "LENGTH OF INCREMENT (IN HOURS) ?",T(I)
19810     PRINT USING 19780;"    ",T(I)
19820     INPUT "DAY INCREMENT ENDED ?",E1(I)
19830     PRINT USING 19780;"    ",E1(I)
19840     INPUT "HOUR INCREMENT ENDED (24 HR TIME) ?",H(I)
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19850     PRINT USING 19780;"    ",H(I)
19860     INPUT "POWER LEVEL OF INCREMENT (IN MEGAWATTS) ?",W(I)
19870     PRINT USING 19780;"    ",W(I)
19880     PRINT
19890   NEXT I
19900   PRINT PAGE
19910   CALL Print_history(Rd,Dl,Irrad_steps,Total_irrad,Tttt,T(*),E1(*),H(*),W(
*),U(*))
19920   Z$="Y"
19930   INPUT "Is this OK (Y/N) ?",Z$
19940   CALL Yn(Z$)
19950   IF Z$="N" THEN GOTO 19740
19960   PRINT #4;Rd,Dl,Irrad_steps
19970   FOR I=1 TO Irrad_steps
19980     PRINT #4;T(I),E1(I),H(I),W(I)
19990   NEXT I
20000   ASSIGN * TO #4
20010   SUBEND
20020   !
20030   !
20040 SUB Read_history(Rd,Dl,Irrad_steps,Total_irrad,Tttt,T(*),E1(*),H(*),W(*),U
(*))
20050   PRINTER IS 16
20060   PRINT PAGE;LIN(2);"Irradiation history tape should be in T15 (right driv
e).  Press CONT"
20070   PAUSE
20080   PRINT LIN(1);"FILES AVAILABLE"
20090   CALL Catalog(":T15")
20100   R$="::"
20110   INPUT "Name of irradiation history file to be read:",R$
20120   IF R$="::" THEN GOTO 20110
20130   R$=R$&":T15" !
20140   ASSIGN #1 TO R$,R
20150   PRINT Message$;CHR$(27)&"K"
20160   ON R+1 GOTO 20220,20170,20200
20170   CALL Conniption
20180   PRINT Message$;" THAT HISTORY FILE DOES NOT EXIST DUNDERHEAD"
20190   GOTO 20110
20200   PRINT Message$;" HISTORY FILE IS PROTECTED"
20210   GOTO 20110
20220   PRINT Message$;" FILE ";R$;" TO BE READ"
20230   READ #1;Rd,Dl,Irrad_steps
20240   FOR I=1 TO Irrad_steps
20250     READ #1;T(I),E1(I),H(I),W(I)
20260   NEXT I
20270   PRINTER IS 16,WIDTH(100)
20280   CALL Print_history(Rd,Dl,Irrad_steps,Total_irrad,Tttt,T(*),E1(*),H(*),W(
*),U(*))
20290   DISP "PRESS CONT"
20300   PAUSE
20310   SUBEND
20320   !
20330   !
20340 SUB Check_constants(Tc40,Tc100,Tc200,Mdc(*),Sensitivity,Mincnts,Airblank)
20350   DIM M1$[40],M2$[40],M3$[40],M4$[40],B1$[40],L1$[10],D1$[40]
20360   L1$=CHR$(27)&"&a0c19R"&CHR$(27)&"K"
20370   PRINTER IS 16,WIDTH(80)
20380   PRINT PAGE;LIN(2);TAB(25);" MASS SPECTROMETER CONSTANTS ";LIN(2)
20390   T1$="Tc40 = "
20400   T2$="Tc100 = "
20410   T3$="Tc200 = "
20420   M1$="Manifold factor 1 (option ALL)     = "
20430   M2$="Manifold factor 2 (option SPLIT 1) = "
20440   M3$="Manifold factor 3 (option SPLIT 2) = "
20450   M4$="Manifold factor 4 (option SPLIT 3) = "
20460   Sen$="Sensitivity = "
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```
20470   D1$="Detection limit (counts) = "
20480   B1$="Default 40Ar furnace blank (moles) = "
20490   PRINT T1$;Tc40;LIN(1);T2$;Tc100;LIN(1);T3$;Tc200;LIN(1)
20500   PRINT M1$;Mdc(1);LIN(1);M2$;Mdc(2);LIN(1);M3$;Mdc(3);LIN(1);M4$;Mdc(4);L
IN(1)
20510   PRINT USING 'K,D.2DE";Sen$;Sensitivity
20520   PRINT USING 'K,K";D1$;Mincnts
20530   PRINT USING 'K,D.2DE";B1$;Airblank
20540   PRINT LIN(2);" Moles = counts * sensitivity * manifold factor * Tc facto
r"
20550   FOR J=1 TO 10
20560     WAIT 100
20570     BEEP
20580   NEXT J
20590   Z$="Y"
20600   INPUT "ARE THESE VALUES APPROPRIATE? (Y/N)  CHANGE THEM WITH CAUTION
",Z$
20610   CALL Yn(Z$)
20620   IF Z$="Y" THEN SUBEXIT
20630   IMAGE #,K,K
20640   PRINT USING 20630;L1$,T1$
20650   INPUT " ",Tc40
20660   PRINT USING 20630;L1$,T2$
20670   INPUT " ",Tc100
20680   PRINT USING 20630;L1$,T3$
20690   INPUT " ",Tc200
20700   PRINT USING 20630;L1$,M1$
20710   INPUT " ",Mdc(1)
20720   PRINT USING 20630;L1$,M2$
20730   INPUT " ",Mdc(2)
20740   PRINT USING 20630;L1$,M3$
20750   INPUT " ",Mdc(3)
20760   PRINT USING 20630;L1$,M4$
20770   INPUT " ",Mdc(4)
20780   PRINT USING 20630;L1$,Sen$
20790   INPUT " ",Sensitivity
20800   PRINT USING 20630;L1$,D1$
20810   INPUT " ",Mincnts
20820   PRINT USING 20630;L1$,B1$
20830   INPUT " ",Airblank
20840   GOTO 20340
20850   SUBEND
```