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A Computer Program in Hewlett-Packard BASIC for Plotting and Processing U-Pb Isotope Data on "Concordia" Diagrams

by

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INTRODUCTION

The most common way of graphically presenting U-Pb isotope data is on a "concordia" diagram, wherein the X and Y axes are generally $^{207}Pb/^{235}U$ and $^{206}Pb/^{238}U$[1/], and the concordia curve is the locus of X and Y values which give concordant $^{207}Pb/^{235}U$ and $^{206}Pb/^{238}U$ ages. A highly useful characteristic of the concordia diagram is that systems (minerals, rocks...) which have either undergone varying degrees of no more than one episodic disturbance to their U/Pb ratio (Wetherill, 1956) or have lost varying amounts of Pb by a process of continuous diffusion (Tilton, 1960), will define a straight-line trend whose upper intercept with concordia is the primary age of the system. Thus it is common to calculate a least-squares line for such data to infer the primary age.

The minicomputer program described in this paper was constructed to provide a simple yet very flexible tool for plotting U-Pb isotope data (complete with error-ellipses if desired), determining the best-fit line to any of the data, and solving for the concordia intercepts and intercept uncertainties of the best-fit line. The quality of the resulting plot (figs. 1, 2) can easily satisfy requirements for both publication and color-transparencies. Besides the common $^{206}Pb/^{238}U$-$^{207}Pb/^{235}U$ concordia plot, $^{206}Pb/^{207}Pb$-$^{238}U/^{207}Pb$ and $^{207}Pb/^{206}Pb$-$^{238}U/^{206}Pb$ concordia plots can be constructed with only slight modifications to this program.

1/ All Pb isotopes are assumed to be radiogenic in this paper.

EQUIPMENT REQUIRED

This program was written specifically for use with the Hewlett-Packard model 9831 minicomputer with 12K words of memory, and the Hewlett-Packard model 9872 plotter. With a few modifications, the model 9830 minicomputer and 9862 plotter may also be used. In the standard mode (fig. 1), the plot is drawn on an 8" x 10-1/2" sheet of paper, but dimensions and sizes of the plot may be arbitrarily assigned without distortion of plot-symbols or letters.

CAPABILITIES

The program permits the plot limits to be defined either by maximum and minimum ages on the concordia curve or by any (> 0) minimum or maximum limits on the X and Y axes.

The tick intervals for the X and Y axes and the concordia curve are chosen by the program. Every other tick is labeled, except for concordia ticks which lie so close to the X or Y axes that the tick label would overwrite the axes. Note that if a minimum X- or Y-plot limit is poorly chosen (for instance $X_{min.}$ = .1317, $X_{max.}$ = .4), the ticks will be at odd locations (.1317, .1617, .1917, 2217, .2517, etc.). In most cases, however, this problem will not arise. The X-axis tick labels are automatically centered with the ticks themselves, are lettered with only the significant figures of the tick values, and are right-justified in the case of the concordia and Y-axis tick labels.

Data Input

The data are input as a block of five values: $^{206}Pb/^{238}U$, $^{207}Pb/^{235}U$, Error (%2σ) in $^{206}Pb/^{238}U$, Error (%2σ) in $^{207}Pb/^{235}U$, and the correlation between the $^{206}Pb/^{238}U$ and $^{207}Pb/^{235}U$ errors. The errors and correlations correspond to estimates of analytical uncertainty, and are required for calculation of error-ellipses and for the least-squares line-fitting routine. Equations for

calculation of the errors and error correlations that take into account mass-spectrometric, blank, and initial-Pb uncertainties are given in Ludwig (in press), and are especially suitable for use with this program. Any mistakes in the entering of the data are easily corrected before plotting of the data. The program will accept up to 30 data points as dimensioned.

Data-Point Plotting

The data may be plotted in three different ways; as an error-ellipse, as a polygon, or as a keyboard symbol. The error-ellipse is constructed for the 2σ errors input by the user, and can be plotted as either an open or solid figure. The polygon plotting option provides for a regular polygon of any number of sides (> 10 sides gives a good circle), with size chosen by the user, with arbitrary rotational orientation and with the option of either open or solid (filled in) polygons. In addition, any keyboard symbol besides L, I, E, or P (either upper or lower case) may be used, such as , +, X, or O.

Line-Fitting

The routine for calculating a least-squares best-fit line to the data is taken from York (1969) with slight modifications (table). The first (model-1) calculation of the best-fit line weights the points according to the inverse square of their analytical uncertainties, and includes a calculation of the probability that the assigned errors of the data account for all of the observed scatter from the best-fit line. If this probability is less than 0.30, the best-fit line is recalculated (model-2) with equal weights and zero error-correlation given to the data points. For the model-1 solutions, the 95% confidence limits on the best-fit line slope and intercept are taken to be 1.96 (Student's-t for ∞ degrees of freedom) times the $1\text{-}\sigma$ "A PRIORI" uncertainties,

whereas the model-2 95% confidence-limits are taken to be the Student's-t value for N-2 degrees of freedom (N = # of data points) times the 1-σ "INCLUDING SCATTER" uncertainties. In effect, the "model-2" solution recognizes that most of the scatter cannot be due to analytical error alone, and assumes that nothing is therefore known about the reason for the scatter. For the "Model 2" solution to be meaningful, however, the scatter must have a normal distribution about a meaningful line.

Concordia Intercept Solutions

The solutions for intercepts of the best-fit line with the concordia curve use the rapidly-converging iterative method outlined in Ludwig (in press), such that the uncertainties in the concordia intercepts are calculated at the 95% confidence-limit from the intersections with the concordia curve of the 95% confidence-limit error envelope about the best-fit line. The intercepts and the average of the + and - errors are lettered in the lower right portion of the plot after they are calculated. If solutions to several data-sets are done, the lettering is stepped up each time so no overwriting occurs, and the style of the dashed/dotted line showing the Yorkfit line is changed. To aid in visualization of the intercept-uncertainty calculation, the error-envelope itself may be plotted.

Lettering Capability

As an additional aid to the construction of camera-ready figures, the program includes an option to letter in any characters or phrases, with arbitrary letter size and location on the plot (but always with a horizontal orientation), via a few simple keyboard commands.

Storing and Recovery of Frequently-Used Data

A simple and reasonably convenient method of storing and reusing data for this program is to store up to 24 data-points at a time in the special function keys of the HP-9831 or 9830. For each data point, FETCHKEY (key f0 through f11, shift in or out) is executed, and the data then input exactly as normally requested by the program, except that the input is bracketed by asterisks. Thus a typical data point ready to store in a special-function key would appear as

* .2314, .79, 4.797, .85, 0.96 *

The "store" key then stores the point in that special function key. When the display requesting data input appears, the appropriate special-function key is pressed to enter that data point. The data may be stored on a data cartridge via the "STORE KEY" command, and thus retained for later use.

Plot Size

Two standard plot sizes may be selected, as well as any other special sizes designed by the user. The most useful size nearly fills an 8" x 10.5" area. The other standard size is only 2/3 as large (fig. 2), and is specially designed for reproduction as color transparencies. In this case, the relative size of the symbols and apparent line thicknesses are automatically adjusted to yield suitably legible transparencies. For user-defined plot sizes, any ratio of height to width may be selected without distortion of letters or symbols.

Decay Constants

The uranium decay constants used in the program (lines 100 and 110) are 0.155125×10^{-9}/yr for ^{238}U and 0.98485×10^{-9}/yr for ^{235}U.

PROGRAM INSTRUCTIONS

The instructions to the main program (appendixes I, III) are stored as a separate program, accessed by the main program (appendix II) when desired, (enter 3 in response to the "SIZE: 1=STD, 2=SMALL, 3=INSTR." query). The location of the main and instructions program on the tape cartridge must be specified in line 790 of the main program and lines 40 and 1080 of the instructions program.

PROGRAM EXPLANATION

LINES	FUNCTION
30-110	Initialize conditions and dimension arrays.
230-270	Functions for calculating isotope ratios from ages and ages from isotope ratios.
280-490	Functions for calculating tick intervals, and number of spaces required to letter numbers.
510-740	Functions for calculating cumulative chi-square distribution.
850-890	Input plot size and limits.
900-1080	Calculate X and Y plot limits and concordia curve age limits.
1090-1320	Calculate proper dimensions of letters and absolute plot limits.
1330-1470	Draw plot box (X-Y axes).
1480-1920	Label ticks and axes.
1930-2190	Draw concordia curve, ticks, and tick labels.
2240-2670	Data input.
2680-2820	Plot data points.

2830-3010	Error-ellipse plot subroutine [1].
3020-3120	Polygon plot subroutine.
3230-4610	Yorkfit routine.
4620-4750	Plot Yorkfit line.
4790-4890	Calculate intercepts of Yorkfit line.
4900-5280	Calculate intercepts of error envelope about Yorkfit line with concordia curve.
5290-5490	Label intercept on plot.
5500-5640	Plot error envelope.
5650-5720	Lettering subroutine.

[1] Modified from algorithm kindly supplied by G. Cumming (written communication, 1978).

AVAILABILITY

This program can be copied onto the appropriate tape cartridge for either the 9831/9872 system or 9830/9862 system, if the appropriate cartridge is sent to me at Mail Stop 963, Denver Federal Center, Denver, CO 80225. Versions are also available for $^{207}Pb/^{206}Pb$-$^{238}U/^{206}Pb$ and $^{206}Pb/^{207}Pb$-$^{238}U/^{207}Pb$ concordia plots.

REFERENCES

Ludwig, K. R., in press, Calculation of uncertainties of U-Pb isotope data: Earth and Planetary Science Letters.

Tilton, G.R., 1960, Volume diffusion as a mechanism for discordant lead ages: Jour. Geophys. Res., v. 65, p. 2933-2945.

Wetherill, G. W., 1956, Discordant uranium-lead ages: Trans. Am. Geophys. Union, v. 37, p. 320-328.

York, Derek, 1969, Least squares fitting of a straight line with correlated erors: Earth and Planetary Science Letters, v. 6, p. 320-324.

FIGURE CAPTIONS

Figure 1. Sample of a "standard" size concordia plot produced by the program. Two data-sets are plotted; the first with open error-ellipses as plotting symbols, the second with solid triangles. Best-fit lines are shown for both data-sets (dashed and dash-dot line patterns), and the 95% confidence error-envelope (dotted curves) shown for the second data-set.

Figure 2. Sample of a "slide"-size plot, photographically reduced from 5"x7" size to fit in a 3-1/2" wide journal format. 15-side, solid polygon as plotting symbol.

TABLE CAPTIONS

Table 1. Printout of Yorkfit and concordia-intercept solutions for the error-ellipse data set used in figure 1.

FIGURE 1

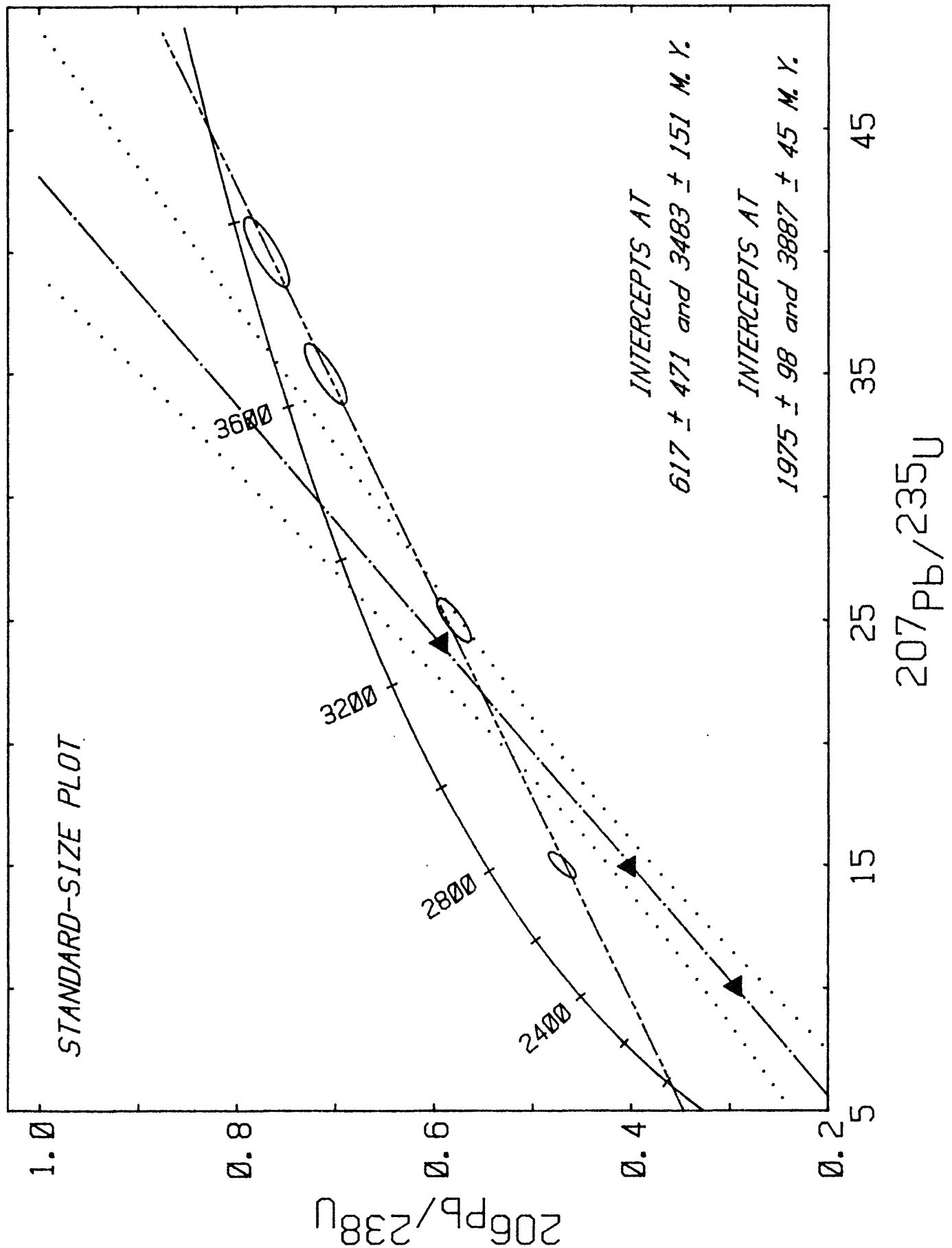
STANDARD-SIZE PLOT
INTERCEPTS AT
617 ± 471 and 3483 ± 151 M.Y.
INTERCEPTS AT
1975 ± 98 and 3887 ± 45 M.Y.
3600
3200
2800
2400
1.0
0.8
0.6
0.4
0.2
5
15
25
35
45
$^{206}Pb/^{238}U$
$^{207}Pb/^{235}U$

FIGURE 2

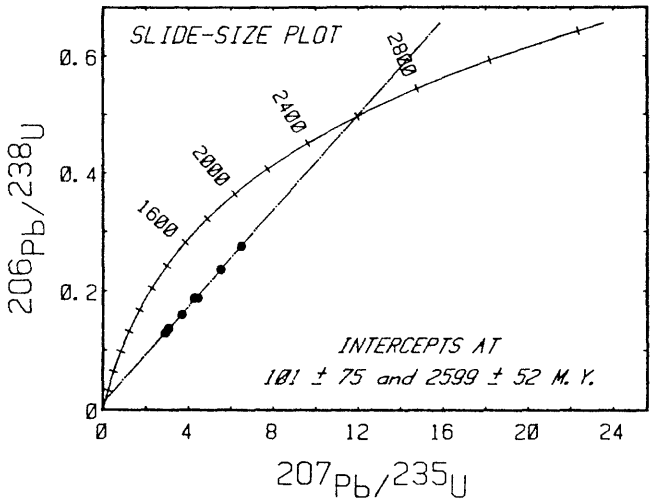
SLIDE-SIZE PLOT
2800
2400
2000
1600
INTERCEPTS AT
101 ± 75 and 2599 ± 52 M. Y.
0.6
0.4
0.2
0
0
4
8
12
16
20
24
206Pb/238U
207Pb/235U

TABLE 1

********** YORKFIT **********

SAMPLE DATA: DATA WITH ERROR-ELLIPSE SYMBOLS - PLOT CODE

(ERRORS ARE % 2-SIGMA)

SET#	206/238	-- %ERR	207/235	-- %ERR	%ERR-7/6	CORREL.
1	0.47000	3.00	15.0000	3.60	2.01	0.83
2	0.58000	3.00	25.0000	3.60	2.01	0.83
3	0.71000	3.00	35.0000	3.60	2.01	0.83
4	0.77000	3.00	40.0000	3.60	2.01	0.83

MODEL 1 SOLUTION -- ASSUMES ALL SCATTER DUE TO ANALYTICAL ERROR

	SLOPE	INTERCEPT
BEST-FIT:	0.012033739	0.286307528
ERROR (1-SIGMA, A PRIORI)	2.84592E-04	7.98410E-03
ERROR (1-SIGMA, INCL. SCATTER)	3.28498E-04	9.21588E-03
ERROR (95% CONFIDENCE LIMITS)	5.57800E-04	0.015648826

COORDINATES OF CENTROID: X= 26.32065623 Y= 0.603043442

SUMS = 2.7 -- FOLLOWS CHI-SQUARE DISTRIBUTION ABOUT 2

THE OBSERVED SCATTER WILL BE CAUSED BY THE ASSIGNED ANALYTICAL ERRORS ALONE 26.39% OF THE TIME

**********MODEL 2 SOLUTION -- EQUALLY WEIGHTED POINTS, ASSUMES
**********NORMAL DISTRIBUTION OF RESIDUALS*****

	SLOPE	INTERCEPT
BEST-FIT:	0.012109677	0.284346782
ERROR (1-SIGMA, INCL. SCATTER)	3.10937E-04	9.42414E-03
ERROR (95% CONFIDENCE LIMITS)	1.33703E-03	0.040523795

COORDINATES OF CENTROID: X= 28.75000000 Y= 0.632500000

<<<<<<<<< MODEL 1 CONCORDIA-INTERCEPT SOLUTION >>>>>>>>>

LOWER INTERCEPT: 1974.6 +/- 95.4 (> 1879.8 ,< 2070.5) M.Y.

UPPER INTERCEPT: 3887.0 +/- 32.0 (> 3856.6 ,< 3920.6) M.Y.

(UNCERTAINTIES ARE 95% CONFIDENCE LIMITS)

APPENDIX I -- PRINTOUT OF INSTRUCTIONS PROGRAM

INSTRUCTIONS FOR HP-9831/9872 CONCORDIA PLOTTING PROGRAM
U.S. Geological Survey Open-File Report #79-1692, K.R. Ludwig

DISPLAY	RESPONSE
SIZE: 1=STD, (2)=SMALL, 3=INSTR.?	If 1 is entered, the plot will be scaled to fill an 8x10.5 inch sheet of paper. If 2 is entered, the plot will be only 2/3 as large, and the numerals larger so that an acceptable 35mm transparency can be made from the plot. If 0 or -2 is entered, the plot may be user-scaled using the P1-P2 keys on the plotter. 0 will give relative label and symbol sizes similar to an input of 1, whereas -2 will give relative sizes similar to 2. To obtain a printout of these instructions, enter 3.
AGE LIMITS, M.Y. (MAX., MIN.)?	Enter the maximum and minimum ages which are to be included in the plot. If you wish a specific area to be shown, however, answer with any two equal numbers (such as 0,0).
7/5 AND 6/8 LIMITS?	This display appears if you answered the above display with a equal numbers. Enter 4 values- 7/5 min., 7/5 max., 6/8 min. and 6/8 max. to define the plot area.
TITLE?	Type in a title (no more than 38 letters) to be lettered in the upper-left corner of the plot.

P=POLYGON,E=ERROR/ELL,I=INTERCEPTS?

An input of 'p' or 'P' will permit any regular polygon of any orientation to be used as a plotting-symbol. 'P' will result in a solid (filled in) polygon, whilst 'p' gives an open (unfilled) figure. The subsequent 'ROTATION?' request asks for the angle in degrees (3 o'clock=0 degrees, 12 o'clock=90 degrees, etcetera) of a vertex

of the polygon, and the 'SIZE?' request asks for relative size of the polygon. Values of 2 to 3 are most useful. Size is proportional to the number entered.

An input of 'e'or'E' will give open or solid error-ellipses, respectively, as plotting-symbols.

Any other upper-case keyboard character may also be used as a plotting symbol (such as *,+,X,O), provided that it does not plot asymmetrically such as a '.' or ','.

An input of 'I' or 'i' will result in calculation of the concordia intercepts of a just-calculated Yorkfit chord.

An input of 'L' or 'l' will permit you to letter any statement anywhere on the plot. The subsequent 'LETTER SIZE?' request asks for a number defining size of the letters, relative to the size used for the plot title. A '?' will then appear in the display, at which point you may position the pen by using the four 'arrow' keys at the top of the keyboard. DO NOT PRESS A CHARACTER KEY, or the character will be immediately printed on the plot. Press the STOP key when the pen is positioned correctly. Then type in the statement to be lettered, and press the 'EXECUTE' key. You can repeat the sequence to obtain several lines.

NUMBER OF POINTS?	Enter the number of data-points (must be <=30) that you wish plotted with a given plotting symbol or color.
6/8, ERR, 7/5, ERR, CORREL.?	Enter 5 values- the 206/238 and 207/235 values and errors, and the error-correlations. The errors must be entered in percent and at the 2-sigma (or 95%-conf. level), and the error-correlation must be between -1 and 1. The errors and correlations must agree with the form Rxy=(Ex^2+Ey^2-Ez^2)/2ExEy, where Rxy is the error-correlation, Ex, Ey, and Ez are the percent errors in 207/235, 206/238 and 207/206, respectively.
SET# TO BE EDITED (0=OK)?	If all of the numbers in the above 'scratchpad' printout are correct, enter 0. Otherwise, enter the number of the data-set that you wish to edit.

YORKFIT? 1=YES?	If you wish a York regression line calculated for the plotted data, enter 1. If not, enter any other number.
DATA TO BE RETAINED?- 1=YES?	If you wish the just-plotted data to be added to later data-points with differ--ent plotting-symbols or colors, for a later Yorkfit, enter 1. If not, enter any other number.
NAME FOR THIS DATA SET?	Enter a name for the Yorkfit printout

REMARKS:

The Yorkfit routines are done on the basis of one of two sets of assumptions. The initial Yorkfit weights the points according to analytical error, and calculates the 95% confidence-limit uncertainties considering only the assigned analytical errors, without regard to the actual scatter of the points (MODEL 1). This is equivalent to York's original method and to a McIntyre Model 1 fit. If the chi-square probability calculation indicates that the assigned errors should result in the observed scatter more than 30% of the time, this MODEL 1 result is accepted without further calculation. If, however the calculated probability is less than 30%, the Yorkfit is repeated, using equally-weighted points with zero correlation, and with 95% confidence-limit uncertainties calculated on the basis of the observed scatter and N-2 degrees of freedom (MODEL 2). If the Chi-square probability was less than 1%, the program will consider only the MODEL 2 result for any subsequent calculations. If the probability is between 1% and 30%, the choice of models is left to the user.

APPENDIX II -- LIST OF MAIN PROGRAM

```
10 REM K.R. LUDWIG CONCORDIA PLOTTER FOR HP 9831/9872  9/27/79
20 REM U.S.G.S. OPEN-FILE REPT. 79-1692
30 DIM A[30],B[30],C[30],G[30],Q[30],RS[30],US[30],VS[30],XS[30],YS[30],Z[30]
40 DIM A$[38]
42 G=2
44 STDPR G
50 DEG
60 Q1=P1=D=0
70 SLANT 0
80 LINE
90 K0=6
100 L5=9.8485E-04
110 L8=1.55125E-04
120 GOTO 760
130 FIXED 0
140 RETURN
150 FIXED 1
160 RETURN
170 FIXED 2
180 RETURN
190 FIXED 3
200 RETURN
210 FIXED 4
220 RETURN
230 DEF FNA(T)=EXP(L5*T)-1
240 DEF FNB(T)=EXP(L8*T)-1
250 DEF FNC(T)=(L8/L5)*EXP((L8-L5)*T)
260 DEF FND(X)=LOG(1+X)/L5
270 DEF FNE(Y)=LOG(1+Y)/L8
280 DEF FNF(X)
290 STANDARD
300 I1=S=0
310 N=X
320 N=10*(N-INTN)
330 IF N=0 THEN 370
340 S=S+1
350 I1=1
360 GOTO 320
370 RETURN S
380 DEF FNK(X)=1+(X#INTX)+(X >= 1)*FNG(X+ NOT X)+FNFX
390 DEF FNG(X)=INTLGTX
400 DEF FNH(X)
410 Q=10^FNGX/8
420 IF X/Q <= 12 THEN 450
430 Q=2*Q
440 GOTO 420
450 Z2=Q/10^FNGQ
460 IF Z2=INTZ2 THEN 480
470 Q=INTZ2*10^FNGQ
480 RETURN Q
```

```
490 DEF FNI(X)=FNKABSINTG[X]
500 DEF FNJ(X)=-( NOT X)-(X#0)*(FNKX+J-FNFX+(X=INTX)*(J#0))
510 DEF FNT(N)
520 C=I=1
530 A=(N/2=INT(N/2))
540 IF (N-2)/2-I-A<1/2 THEN 580
550 C=C*((N-2)/2-I)
560 I=I+1
570 GOTO 540
580 RETURN C*(1+ NOT A*(SQRPI-1))
590 DEF FNS(K)
600 D=1
610 FOR I=1 TO K
620 D=D*(N-2+2*I)
630 NEXT I
640 RETURN D
650 DEF FNR(S)
660 T1=E=0
670 FOR K=1 TO 100
680 IF K*LGTS<100 THEN 700
690 RETURN -1
700 T1=T1+(S^K)/FNSK
710 IF (T1-E)<1E-05*T1 THEN 740
720 E=T1
730 NEXT K
740 RETURN T1
750 DEF FNO(F)=Y[I]+(-B3*X+F*SQRF1)/(2*S3)
760 DISP "SIZE: 1=STD, (2)=SMALL, 3=INSTF";
770 INPUT F
780 IF F#3 THEN 800
790 LINK # 0,2
800 B=(ABSF=2)
810 IF F#1 AND F#2 THEN 830
820 MAP B*1500',1E+04-B*1500,B*1125,7500-1125*B
830 DISP "TITLE";
840 INPUT A$
850 DISP "AGE LIMITS, M.Y. (MIN., MAX.)";
860 INPUT H1,B3
870 IF B3>H1 THEN 950
880 DISP "7/5 AND 6/8 LIMITS";
890 INPUT A1,B1,A2,B2
900 B3=FND(B1-(B1-A1)/100)
910 IF FNBB3<B2 THEN 930
920 B3=FNEB2
930 H1=FNDA1
940 GOTO 1060
950 B1=FNAB3
960 B2=FNBB3
970 A8=FNH(B1-FNAH1)
980 A5=FNH(B2-FNBH1)
990 FOR A1=0 TO B1 STEP A8
1000 IF FND(A1+A8)>H1 THEN 1020
1010 NEXT A1
1020 B1=B1+A8
```

```
1030 FOR A2=0 TO B2 STEP A5
1040 IF FNE(A2+2*A5)>H1 THEN 1080
1050 NEXT A2
1060 A8=FNH(B1-A1)
1070 A5=FNH(B2-A2)
1080 A9=FNH((B3-H1)/(1+((B3-H1)>3000)))
1090 FOR Y=A2 TO B2 STEP 2*A5
1100 IF FNKY<P1 THEN 1120
1110 P1=FNKY
1120 NEXT Y
1130 WRITE (705,*)"OP"
1140 ENTER (705,*)X1,Y1,S2,H2
1150 S2=S2-X1
1160 H2=H2-Y1
1170 P=H2/S2
1180 P9=P*(P <= 1)*(0.85*(H2<7500)+0.65*(H2 >= 7500)*S2/7500)
1190 P9=P9+(P>1)*(0.85*(S2<7500)+0.65*(S2 >= 7500)*H2/7500)
1200 F=(SQR(S2^2+H2^2)<6000)
1210 F3=1.9/P9+1.3*(B+F)
1220 F4=1.5/P9+(B+F)/2
1230 F=P*(1.8*F3/50+P1*F4/114)
1240 Z1=B1-A1
1250 S1=B2-A2
1260 L=B1+Z1/25
1270 P2=(A1-F*L)/(1-F)
1280 S4=B2+S1/25
1290 P5=L-P2
1300 F=2.3*F3/50
1310 P7=(A2-S4*F)/(1-F)
1320 P6=B2+S1/13-P7
1330 SCALE P2,L,P7,B2+S1/13
1340 WRITE (705,*)"TL.5"
1350 XAXIS A2,A8,A1,B1
1360 WRITE (705,*)"TL0,.5"
1370 YAXIS B1,A5,A2,S4
1380 WRITE (705,*)"TL.5"
1390 YAXIS A1,A5,A2,S4
1400 WRITE (705,*)"TL0,.5"
1410 XAXIS S4,A8,A1,B1
1420 IF B=0 THEN 1480
1430 PLOT B1+Z1/400,S4+(S4-A2)/300
1440 IPLOT -1.005*Z1,0
1450 IPLOT 0,-(1+2/300)*(S4-A2)
1460 IPLOT 1.005*Z1,0
1470 IPLOT 0,(1+2/300)*(S4-A2),-1
1480 J=0
1490 FOR X=A1 TO B1 STEP 2*A8
1500 IF FNFX<J THEN 1520
1510 J=FNFX
1520 NEXT X
1530 FOR X=A1 TO B1 STEP 2*A8
1540 LABEL (*,F4,1.7,0,P)
1550 PLOT X,A2,1
1560 CPLOT FNJX/2-1,-1
```

```
1570 GOSUB 1+J*(1- NOT X) OF 130,150,170,190,210
1580 LABEL (*)X;
1590 NEXT X
1600 J=0
1610 FOR Y=A2 TO S4 STEP 2*A5
1620 IF FNFY<J THEN 1640
1630 J=FNFY
1640 NEXT Y
1650 FOR Y=A2 TO S4 STEP 2*A5
1660 PLOT A1,Y,1
1670 CPLOT FNJY-1.3,-0.3
1680 GOSUB 1+J*(1- NOT Y) OF 130,150,170,190,210
1690 LABEL (*)Y;
1700 NEXT Y
1710 PLOT A1+Z1/2,A2,1
1720 LABEL (*,F3,1.7,0,P)
1730 CPLOT -5,-1.7
1740 LABEL (*)"207";
1750 CPLOT 0,-0.3
1760 LABEL (*)"Pb/";
1770 CPLOT 0,0.3
1780 LABEL (*)"235";
1790 CPLOT 0,-0.3
1800 LABEL (*)"U";
1810 PLOT A1,A2+S1/2,1
1820 LABEL (*,F4,1.7,0,P)
1830 CPLOT -P1,0
1840 LABEL (*,F3,1.7,90,P)
1850 CPLOT -5,0.8
1860 LABEL (*)"206";
1870 CPLOT 0,-0.3
1880 LABEL (*)"Pb/";
1890 CPLOT 0,0.3
1900 LABEL (*)"238";
1910 CPLOT 0,-0.3
1920 LABEL (*)"U";
1930 FIXED 0
1940 FOR H1=0 TO B3 STEP A9
1950 IF FNAH1>A1 AND FNBH1>A2 THEN 1970
1960 NEXT H1
1970 FOR T=H1-2*A9 TO B3 STEP A9/8
1980 X=FNAT
1990 Y=FNBT
2000 IF X<A1 OR Y<A2 THEN 2190
2010 PLOT X,Y
2020 IF T/A9#INT(T/A9) THEN 2190
2030 IF T=0 THEN 2180
2040 Q=ATN(FNCT*P*P*P5/P6)-90
2050 PLOT X,Y,1
2060 LABEL (*,1.15/P9+0.8*B,1.7,Q,P)
2070 CPLOT -1/3,-1/4
2080 LABEL (*)"-";
2090 IF D/2#INT(D/2) THEN 2170
2100 PLOT X,Y,1
```

```
2110 X1=3+FNGT
2120 E=1.28/P9+0.8*B
2130 IF A1>X+E*P5*P*(SINQ/200-(X1+0.5)*COSQ/(67*1.7)) THEN 2170
2140 IF S4<Y+P6*E*(COSQ/200-X1*SINQ/(67*1.7)) THEN 2170
2150 CPLOT -X1,-1/4
2160 LABEL (*)T;
2170 PLOT X,Y
2180 D=D+1
2190 NEXT T
2200 PLOT A1+Z1/20,B2-S1/20,1
2210 SLANT 20
2220 LABEL (*,1.35/P9+B,1.7,0,P)A$;
2230 PRINT "INPUT L TO LETTER ON PLOT"TAB38"CONT 2240 TO RESTART DATA-PLOT"LIN2
2240 K=1
2250 N=0
2260 SLANT 0
2270 LINE
2280 WINDOW A1,B1,A2,S4
2290 A$="IiLlPpEe+*"
2300 DISP "DATA SYMBOL OR CODE"
2310 WAIT 1500
2320 DISP "P=POLYGON,E=ERR/ELL,I=INTERCEPTS";
2330 INPUT B$[1,1]
2340 A=POS(A$,B$)
2350 GOTO A OF 4790,4790,5650,5650,3020,3020
2360 DISP "NUMBER OF POINTS";
2370 STANDARD
2380 INPUT I1
2390 N=N+I1
2400 IF N <= 20 THEN 2440
2410 PRINT "***NO MORE THAN 20 POINTS ALLOWED***"LIN3
2420 N=N-I1
2430 GOTO 2360
2440 PRINT TAB20"INPUT ERRORS IN PERCENT, 2-SIGMA"LIN2
2450 PRINT "SET#      206/238 --- %ERR"TAB35"207/235 --- %ERR"TAB60"CORRELATION"
2460 PRINT
2470 FOR I=K TO N
2480 GOSUB 2510
2490 NEXT I
2500 GOTO 2620
2510 DISP "6/8, ERR, 7/5, ERR, CORREL.";
2520 INPUT Y[I],G[I],X[I],A[I],R[I]
2530 IF  NOT (X[I]*Y[I]*G[I]*A[I]) THEN 5810
2540 Q[I]=A[I]^2+G[I]^2-2*R[I]*A[I]*G[I]
2550 IF Q[I] >= 0 THEN 2580
2560 PRINT LIN2"ERROR-CORREL. OF"R[I]"IS TOO HIGh FOR ERRORS OF"G[I]"&"A[I],LIN3
2570 GOTO 2510
2580 PRINT I;TAB8;Y[I];TAB20;G[I];TAB33;X[I];TAB46;A[I];TAB61;R[I]
2590 B[I]=X[I]*A[I]/100
2600 C[I]=Y[I]*G[I]/100
2610 RETURN
2620 PRINT LIN2
2630 DISP "SET# TO BE EDITED? (0=OK)";
2640 INPUT I
```

```
2650 IF I=0 THEN 2680
2660 GOSUB 2510
2670 GOTO 2620
2680 FOR I=K TO N
2690 IF (X[I] >= A1)*(Y[I] >= A2)*(X[I] <= B1)*(Y[I]<S4) THEN 2720
2700 PRINT "DATA POINT"I"("Y[I];X[I]") FALLS OUTSIDE PLOT LIMITS"LIN1
2710 GOTO 2810
2720 PLOT X[I],Y[I],1
2730 GOTO A-4 OF 3050,3050,2830,2830,2770,277)
2740 LABEL (*,0.83/P9+B/2,1,0,P)
2750 CPLOT -1/3,-1/4
2760 GOTO 2790
2770 LABEL (*,1.13*(1+B)/P9,1.7,0,P)
2780 GOTO 2750
2790 LABEL (*)B$;
2800 PEN
2810 NEXT I
2820 GOTO 3130
2830 S=1-R[I]^2
2840 B3=-2*R[I]/(B[I]*C[I]*S)
2850 S3=1/(S*C[I]^2)
2860 FOR J=1 TO 1+(A=7)
2870 FOR F=-1 TO 1 STEP 2
2880 F3=-F*B[I]/(1+INT(800*B[I]/P5))
2890 FOR X=F*B[I] TO -F*B[I]+F3/2 STEP F3
2900 F1=(B3*X)^2-4*S3*(X*X/(S*B[I]^2)-1)
2910 F1=F1*(F1>0)
2920 PLOT X[I]+X,FNOF
2930 IF J=1 THEN 2960
2940 F=-F
2950 PLOT X[I]+X,FNOF
2960 NEXT X
2970 IF J=2 THEN 3000
2980 NEXT F
2990 NEXT J
3000 PEN
3010 GOTO 2800
3020 DISP "# SIDES, ROTATION, SIZE (1-10)";
3030 INPUT B3,A9,S3
3040 GOTO 2360
3050 FOR D=0 TO (S3>2.5)+50*(A=5)
3060 B5=P5*(S3/340-D/900)
3070 IF B5<0 THEN 2800
3080 FOR J=A9 TO A9+360 STEP 360/B3
3090 PLOT X[I]+B5*COSJ,Y[I]+B5*SINJ*P6/(P*P5)
3100 NEXT J
3110 NEXT D
3120 GOTO 2800
3130 PLOT B1,S4,1
3140 IF N<2 THEN 3180
3150 DISP "YORKFIT?  1=YES";
3160 INPUT F
3170 IF F=1 THEN 3230
3180 DISP "DATA TO BE RETAINED? 1=YES";
```

```
3190 INPUT F
3200 IF F#1 THEN 2240
3210 K=N+1
3220 GOTO 2300
3230 DISP "NAME FOR YORKFIT DATA";
3240 INPUT A$[1,38]
3250 PRINT SPA11"****************** YORKFIT ******************"LIN2
3260 PRINT "SAMPLE DATA: "A$"  - PLOT CODE "B$,LIN2"(ERRORS ARE % 2-SIGMA)"LIN2
3270 PRINT "SET#    206/238 -- %ERR"TAB28"207/235 -- %ERR"TAB51"%ERR-7/6";
3280 PRINT TAB63"CORREL."LIN2
3290 FORMAT F3.0,F12.5,F8.2,F11.4,F8.2,6X,F8.2,5X,F6.2
3300 I3=0
3310 Q=0.1
3320 S3=Q
3330 I1=0
3340 Q=S3
3350 I1=1+I1
3360 DISP "ITERATION"I1
3370 GOTO (I1>1 AND I3=0)+2*(I1>10) OF 3480,5790,5790
3380 FOR I=1 TO N
3390 IF  NOT I3 THEN 3440
3400 G[I]=1
3410 Q[I]=1/Q^2
3420 R[I]=0
3430 GOTO 3470
3440 WRITE (G,3290)I,Y[I],G[I],X[I],A[I],SQRC[I],R[I]
3450 Q[I]=(2/C[I])^2
3460 G[I]=(2/B[I])^2
3470 NEXT I
3480 S1=B5=D=S2=E=Z1=X1=Y1=0
3490 FOR I=1 TO N
3500 A[I]=SQR(G[I]*Q[I])
3510 Z[I]=C[I]*Q[I]/(Q*Q*Q[I]+G[I]-2*Q*R[I]*A[I])
3520 S1=S1+Z[I]
3530 NEXT I
3540 FOR I=1 TO N
3550 X1=X1+Z[I]*X[I]/S1
3560 Y1=Y1+Z[I]*Y[I]/S1
3570 NEXT I
3580 FOR I=1 TO N
3590 U[I]=X[I]-X1
3600 V[I]=Y[I]-Y1
3610 B5=B5+(Z[I]^2)*((U[I]^2)/Q[I]-(V[I]^2)/G[I])
3620 D=D+(Z[I]^2)*(U[I]*V[I]/G[I]-R[I]*(U[I]^2)/A[I])
3630 Z1=Z1+Z[I]*U[I]^2
3640 S2=S2+Z[I]*X[I]^2
3650 E=E+(Z[I]^2)*(U[I]*V[I]/Q[I]-R[I]*(V[I]^2)/A[I])
3660 NEXT I
3670 S3=B5^2+4*D*E
3680 IF S3<0 THEN 5790
3690 S3=(-B5+SQRS3)/(2*D)
3700 IF (ABS(S3-Q)>ABS(S3/1E+04)) THEN 3340
3710 DISP "CALCULATING ERRORS"
3720 Q=S3
```

```
3730 B5=A8=A9=Z1=H1=H2=S2=A=C=F=F1=Z2=Z3=A5=D=E=S=F3=0
3740 FOR I=1 TO N
3750 S=S+(N>2)*Z[I]*((V[I]-Q*U[I])^2)
3760 NEXT I
3770 A7=Y1-Q*X1
3780 FOR I=1 TO N
3790 B[I]=Z[I]^2*(Q^2*V[I]/G[I]-2*Q^2*R[I]*U[I]/A[I]+2*Q*U[I]/Q[I]-V[I]/Q[I])
3800 C[I]=Z[I]^2*(Q^2*U[I]/G[I]-2*Q*V[I]/G[I]-U[I]/Q[I]+2*R[I]*V[I]/A[I])
3810 Z2=Z2+B[I]
3820 Z3=Z3+C[I]
3830 A=Z[I]^3*(R[I]*A[I]-Q*Q[I])*(Q*U[I]-V[I])
3840 C=U[I]/Q[I]+Q*V[I]/G[I]-R[I]*(Q*U[I]+V[I])/A[I]
3850 A5=A5+4*(A*C)/A[I]^2
3860 D4=2*Z[I]^2*(Q*Q[I]-R[I]*A[I])/(S1*A[I]^2)
3870 D=D+D4*U[I]
3880 E=E+D4*V[I]
3890 B5=B5+Z[I]^2*(U[I]^2*(1/Q[I]-2*Q*R[I]/A[I])+V[I]*(2*Q*U[I]-V[I])/G[I])
3900 NEXT I
3910 FOR I=1 TO N
3920 B[I]=B[I]-Z[I]*Z2/S1
3930 A8=A8+B[I]^2/G[I]
3940 C[I]=C[I]-Z[I]*Z3/S1
3950 A=D*(Q*Q*V[I]/G[I]+2*Q*U[I]/Q[I]-V[I]/Q[I])
3960 C=E*(Q*Q*U[I]/G[I]-2*Q*V[I]/G[I]-U[I]/Q[I])
3970 F=-2*R[I]*(Q*Q*U[I]*D-V[I]*E)/A[I]
3980 F1=F1+Z[I]^2*(A+C+F)
3990 A9=A9+C[I]^2/Q[I]
4000 NEXT I
4010 D9=B5+A5+F1
4020 FOR I=1 TO N
4030 F3=F3+Z[I]^2*(R[I]*A[I]-Q*Q[I])*(V[I]-Q*U[I])/(A[I])^2
4040 NEXT I
4050 FOR I=1 TO N
4060 F4=-Q*Z[I]/S1+(2*F3/S1-X1)*(-B[I]/D9)
4070 F7=Z[I]/S1+(2*F3/S1-X1)*(-C[I]/D9)
4080 Z1=Z1+F4^2/G[I]
4090 H1=H1+B[I]*C[I]*R[I]/A[I]
4100 H2=H2+F4*F7*R[I]/A[I]
4110 S2=S2+F7^2/Q[I]
4120 NEXT I
4130 F1=SQR(Z1+S2+2*H2)
4140 B3=(SQR(A8+A9+2*H1))/D9
4150 S1=(N>2)*F1*SQR(S/(N-2+(N=2)))
4160 B5=(N>2)*B3*SQR(S/(N-2+(N=2)))
4170 IF I3 THEN 4320
4180 DISP "CALCULATING CHI-SQUARE SOLUTION"
4190 IF S#0 AND S <= 454 THEN 4220
4200 A= NOT S
4210 GOTO 4240
4220 A=((S/2)^((N-2)/2))*((EXP(-S/2))/FNT(N+2))*(1+FNRS)
4230 A=(1-A)*(A#0)
4240 I0=1+(A<0.01)+(A<0.3)
4250 WRITE (G,4430)
4260 PRINT "**MODEL 1 SOLUTION -- ASSUMES ALL SCATTER DUE TO ANALYTICAL ERROR**"
```

```
4270 I5=P2=1.96*B3
4280 I4=P1=1.96*F1
4290 Q2=Q
4300 A6=A7
4310 GOTO 4400
4320 PRINT LIN1"**********MODEL 2 SOLUTION -- EQUALLY WEIGHTED POINTS, ASSUMES"
4330 PRINT "*******************************NORMAL DISTRIBUTION OF RESIDUALS*****"
4340 RESTORE 4770
4350 FOR I=1 TO N-2
4360 READ C
4370 NEXT I
4380 P2=C*B5
4390 P1=C*S1
4400 PRINT LIN2,SPA33"SLOPE"SPA19"INTERCEPT"
4410 PRINT SPA33"-----"SPA19"---------"LIN2
4420 PRINT "BEST-FIT:"TAB31,Q;TAB56;A7
4430 FORMAT 72"-"
4440 WRITE (G,4430)
4450 IF I3 THEN 4470
4460 PRINT "ERROR (1-SIGMA, A PRIORI) "TAB31,B3;TAB56;F1,LIN1
4470 PRINT "ERROR (1-SIGMA, INCL. SCATTER) "TAB31,B5;TAB56;S1
4480 PRINT LIN1,"ERROR (95% CONFIDENCE LIMITS)"TAB31,P2;TAB56;P1,LIN1
4490 PRINT LIN1"COORDINATES OF CENTROID: X="X1;"Y="Y1,LIN1
4500 IF I3 THEN 4560
4510 FORMAT "SUMS =",F7.1," -- FOLLOWS CHI-SQUARE DISTRIBUTION ABOUT",F3.0,/
4520 WRITE (G,4510)S,N-2
4530 PRINT "THE OBSERVED SCATTER WILL BE CAUSED BY THE ASSIGNED ANALYTICAL"
4540 FORMAT 15X,"ERRORS ALONE",F7.2,"% OF THE TIME"
4550 WRITE (G,4540)100*A
4560 WRITE (G,4430)
4570 I3=1+I3
4580 IF I3#2 AND I0>1 THEN 3330
4590 IF I0=2 THEN 4620
4600 I0=(I0=1)+2*(I0=3)
4610 GOTO 4650
4620 DISP "MODEL 1 OR MODEL 2 SOLUTION";
4630 INPUT I0
4640 IF I0#1 AND I0#2 THEN 4620
4650 Q=Q2*(I0=1)+Q*(I0=2)
4660 A7=A6*(I0=1)+A7*(I0=2)
4670 P2=P2*(I0=2)+I5*(I0=1)
4680 P1=P1*(I0=2)+I4*(I0=1)
4690 LINE K0
4700 WINDOW A1,B1-P5/50,A2,B2
4710 F=((A1*Q+A7)<A2)+((B2-A7)/Q>B1)/2
4720 PLOT ((A2-A7)/Q)*INTF+A1* NOT INTF,A2*INTF+(A1*Q+A7)* NOT INTF
4730 PLOT B1*(INTF<F)+((B2-A7)/Q)*(INTF=F),(Q*B1+A7)*(INTF<F)+B2*(INTF=F),2
4740 K0=K0-2+5*(K0<4)
4750 GOTO 2240
4760 REM STUDENTS-T TABLE
4770 DATA 12.71,4.3,3.18,2.78,2.57,2.45,2.36,2.31,2.26,2.23,2.2,2.18,2.16,2.14
4780 DATA 2.13,2.12,2.11,2.1
4790 DISP "CALCULATING INTERCEPTS"
4800 FOR J=1 TO 2
```

```
4810 T1=-500+5500*(J-1)
4820 X=(A7+FNCT1*FNAT1-FNBT1)/(FNCT1-Q)
4830 IF X<-1 THEN 5730
4840 T=FNDX
4850 IF ABS(T-T1)<0.01 THEN 4880
4860 T1=T
4870 GOTO 4820
4880 G[J]=T
4890 NEXT J
4900 DISP "CALCULATING UNCERTAINTIES"
4910 RAD
4920 D=P2*(COS(ATNQ))^2
4930 Q=(TAN(ATN(Q+D))+TAN(ATN(Q-D)))/2
4940 H2=(TAN(ATN(Q+D))-TAN(ATN(Q-D)))/2
4950 A7=Y1-Q*X1
4960 P1=P1+(H2-P2)*X1
4970 FOR J=3 TO 6
4980 T1=-1000+7000*(J>4)
4990 F3=1-2*(J/2#INT(J/2))
5000 I3=1E+99
5010 GOSUB 5050
5020 G[J]=T
5030 NEXT J
5040 GOTO 5190
5050 S1=FNCT1
5060 B5=FNBT1-S1*FNAT1
5070 D=2*((B5-A7)*(S1-Q)+X1*H2^2)
5080 E=(S1-Q)^2-H2^2
5090 S2=D^2-4*E*((B5-A7)^2-P1^2)
5100 IF S2<0 THEN 5750
5110 X=(-D+F3*(SQRS2))/(2*E)
5120 IF X<-1 THEN 5750
5130 T=FNDX
5140 GOTO (ABS(T-T1)>I3)+2*(ABS(T-T1)<0.1) OF 5750,5180,5750
5150 I3=ABS(T-T1)
5160 T1=T
5170 GOTO 5050
5180 RETURN
5190 G[8]=ABS((G[4]-G[3])/2)*(G[3]#0)*(G[4]#0)
5200 G[9]=ABS((G[6]-G[5])/2)*(G[6]#0)*(G[5]#0)
5210 PRINT "<<<<<<<<< MODEL"I0"CONCORDIA-INTERCEPT SOLUTION >>>>>>>>>"LIN2
5220 FIXED 1
5230 PRINT LIN1"LOWER INTERCEPT:  "G[1]"+/-"G[8]"(>"G[3]",<"G[4]") M.Y."
5240 PRINT LIN2"UPPER INTERCEPT:  "G[2]"+/-"G[9]"(>"G[5]",<"G[6]") M.Y."
5250 PRINT LIN2"(UNCERTAINTIES ARE 95% CONFIDENCE LIMITS)"
5260 WRITE (G,4430)
5270 PRINT LIN2
5280 DEG
5290 SLANT 30
5300 PLOT B1,A2,1
5310 FORMAT "UC-99,0,0,99,4,0,-99,-2,9,99,0,-5,-99,-2,3,99,4,0,-99"
5320 LABEL (*,1.2/P9+0.9*B,1.7,0,P)
5330 CPLOT -25,2+Q1*3
5340 Q1=Q1+1
```

```
5350 LABEL (*)"INTERCEPTS AT";
5360 CPLOT -20+3*((G[8]=0)+(G[9]=0)),-1.1
5370 FOR I=1 TO 2
5380 FIXED 0
5390 LABEL (*)C[I];
5400 IF  NOT G[I+7] THEN 5450
5410 CPLOT FNII-3*(FNII>3)-4,0
5420 WRITE (705,5310)
5430 FIXED 0
5440 LABEL (*)G[I+7];
5450 CPLOT FNI(I+7)-3*(FNI(I+7)>3)-3.8+1.5*(G[I+3]=0),0
5460 IF I=2 THEN 5490
5470 LABEL (*)"and";
5480 NEXT I
5490 LABEL (*)"M.Y.";
5500 DISP "ENTER 1 FOR ERROR-ENVELOPE PLOT";
5510 INPUT F3
5520 IF F3#1 THEN 2230
5530 LINE 0
5540 FOR I=1 TO 2
5550 FOR X=A1 TO B1 STEP P5/100
5560 F=(P1^2+H2^2*X*(X-2*X1))
5570 IF F<0 THEN 5610
5580 F=A7+X*Q+(3-2*I)*SQRF
5590 GOTO (F<A2)+2*(F>B2) OF 5600,5610
5600 PLOT X,F
5610 NEXT X
5620 PEN
5630 NEXT I
5640 GOTO 2230
5650 DISP "LETTER SIZE (TITLE WAS 1)";
5660 INPUT F
5670 LABEL (*,F*1.35/P9+B,1.7,0,P)
5680 LETTER
5690 DISP "INPUT STATEMENT FOR LETTERING";
5700 INPUT A$
5710 LABEL (*)A$
5720 GOTO 2240
5730 PRINT "****** CHORD DOES NOT HAVE TWO CONCORDIA INTERCEPTS ********"LIN3
5740 GOTO 2240
5750 T=0
5760 A$="LOWERUPPER"
5770 PRINT A$[1+5*(J>4),5+5*(J>4)]" ERROR-ENVELOPE HAS NO INTERCEPT"LIN2
5780 GOTO 5180
5790 PRINT LIN2"DATA CANNOT BE FIT TO A STRAIGHT LINE"LIN3
5800 GOTO 2240
5810 PRINT LIN2"*** VALUES MUST BE NONZERO ***"LIN2
5820 GOTO 2510
5830 END
```

APPENDIX III -- LIST OF INSTRUCTIONS PROGRAM

```
10 REM INSTRUCTIONS PROGRAM FOR K.R. LUDWIG CONCORDIA PLOTTER
20 SERROR F,40
30 IF F#3 THEN 50
40 FIND #0,1
50 PRINT TAB9"INSTRUCTIONS FOR HP-9831/9872 CONCORDIA PLOTTING PROGRAM"
60 PRINT TAB7"U.S. Geological Survey Open-File Report #79-1692, K.R. Ludwig"LIN3
70 PRINT "  DISPLAY"TAB40,"RESPONSE"
80 PRINT "  -------"TAB40,"--------"LIN2
90 PRINT "SIZE: 1=STD, (2)=SMALL, 3=INSTR.?    If 1 is entered, the plot will"
100 PRINT TAB30,"be scaled to fill an 8x10.5 inch sheet of"
110 PRINT TAB30"paper.  If 2 is entered, the plot will be"
120 PRINT TAB30"only 2/3 as large, and the numerals larger"
130 PRINT TAB30"so that an acceptable 35mm transparency"
140 PRINT TAB30"can be made from the plot.  If 0 or -2"
150 PRINT TAB30"is entered, the plot may be user-scaled"
160 PRINT TAB30"using the P1-P2 keys on the plotter.  0"
170 PRINT TAB30"will give relative label and symbol sizes"
180 PRINT TAB30"similar to an input of 1, whereas -2 will"
190 PRINT TAB30"give relative sizes similar to 2.  To"
200 PRINT TAB30"obtain a printout of these instructions,"
210 PRINT TAB30"enter 3."LIN2
220 PRINT "AGE LIMITS, M.Y. (MAX., MIN.)?    Enter the maximum and minimum ages"
230 PRINT TAB30"which are to be included in the plot."
240 PRINT TAB30"If you wish a specific area to be shown,"
250 PRINT TAB30"however, answer with any two equal numbers"
260 PRINT TAB30"(such as 0,0)."LIN2
270 PRINT "7/5 AND 6/8 LIMITS?"TAB30"This display appears if you answered"
280 PRINT TAB30"the above display with a equal numbers."
290 PRINT TAB30"Enter 4 values- 7/5 min., 7/5 max.,"
300 PRINT TAB30"6/8 min. and 6/8 max. to define the plot"
310 PRINT TAB30"area."LIN2
320 PRINT "TITLE?"TAB30"Type in a title (no more than 38 letters)"
330 PRINT TAB30"to be lettered in the upper-left corner of"
340 PRINT TAB30"the plot."LIN2
350 PRINT "P=POLYGON,E=ERROR/ELL,I=INTERCEPTS?"LIN2
360 PRINT "An input of 'p' or 'P' will permit any regular polygon of any orien-"
370 PRINT "tation to be used as a plotting-symbol. 'P' will result in a solid"
380 PRINT "(filled in) polygon, whilst 'p' gives an open (unfilled) figure."
390 PRINT "The subsequent 'ROTATION?' request asks for the angle in degrees"
400 PRINT "(3 o'clock=0 degrees, 12 o'clock=90 degrees, etcetera) of a vertex"
410 PRINT "of the polygon, and the 'SIZE?' request asks for relative size of"
420 PRINT "the polygon. Values of 2 to 3 are most useful. Size is proportional"
430 PRINT "to the number entered."LIN2
440 PRINT "An input of 'e'or'E' will give open or solid error-ellipses, "
450 PRINT "respectively, as plotting-symbols."LIN2
460 PRINT "Any other upper-case keyboard character may also be used as a plot-"
470 PRINT "ting symbol (such as *,+,X,O), provided that it does not plot asym-"
480 PRINT "metrically such as a '.' or ','."LIN2
490 PRINT "An input of 'I' or 'i' will result in calculation of the concordia"
500 PRINT "intercepts of a just-calculated Yorkfit chord."LIN2
```

```
510 PRINT "An input of 'L' or '1' will permit you to letter any statement"
520 PRINT "anywhere on the plot.  The subsequent 'LETTER SIZE?' request asks for
530 PRINT "a number defining size of the letters, relative to the size used for"
540 PRINT "the plot title. A '?' will then appear in the display, at which"
550 PRINT "point you may position the pen by using the four 'arrow' keys at the"
560 PRINT "top of the keyboard.  DO NOT PRESS A CHARACTER KEY, or the character"
570 PRINT "will be immediately printed on the plot. Press the STOP key when the"
580 PRINT "pen is positioned correctly.  Then type in the statement to be"
590 PRINT "lettered, and press the 'EXECUTE' key.  You can repeat the sequence"
600 PRINT "to obtain several lines."LIN2
610 PRINT "NUMBER OF POINTS?"TAB30"Enter the number of data-points (must"
620 PRINT TAB30"be <=30) that you wish plotted with a"
630 PRINT TAB30"given plotting symbol or color."LIN2
640 PRINT "6/8, ERR, 7/5, ERR, CORREL.?  Enter 5 values- the 206/238 and 207/235
650 PRINT TAB30"values and errors, and the error-correl-"
660 PRINT TAB30"ations.  The errors must be entered in"
670 PRINT TAB30"percent and at the 2-sigma (or 95%-conf."
680 PRINT TAB30"level), and the error-correlation must be"
690 PRINT TAB30"between -1 and 1.  The errors and cor-"
700 PRINT TAB30"relations must agree with the form"
710 PRINT TAB30"Rxy=(Ex^2+Ey^2-Ez^2)/2ExEv, where Rxy"
720 PRINT TAB30"is the error-correlation, Ex, Ey, and Ez"
730 PRINT TAB30"are the percent errors in 207/235, 206/238"
740 PRINT TAB30"and 207/206, respectively."LIN2
750 PRINT "SET# TO BE EDITED (0=OK)?"TAB30"If all of the numbers in the above"
760 PRINT TAB30"'scratchpad' printout are correct, enter"
770 PRINT TAB30"0.  Otherwise, enter the number of the"
780 PRINT TAB30"data-set that you wish to edit."LIN2
790 PRINT "YORKFIT?  1=YES?"TAB30"If you wish a York regression line"
800 PRINT TAB30"calculated for the plotted data, enter"
810 PRINT TAB30"1.  If not, enter any other number."LIN2
820 PRINT "DATA TO BE RETAINED?- 1=YES?  If you wish the just-plotted data to be
830 PRINT TAB30"added to later data-points with differ-"
840 PRINT TAB30"-ent plotting-symbols or colors, for"
850 PRINT TAB30"a later Yorkfit, enter 1. If not, enter"
860 PRINT TAB30"any other number."LIN2
870 PRINT "NAME FOR THIS DATA SET?"TAB30"Enter a name for the Yorkfit printout"
880 PRINT LIN3,TAB35"REMARKS:"LIN2
890 PRINT "     The Yorkfit routines are done on the basis of one of two sets"
900 PRINT "of assumptions.  The initial Yorkfit weights the points according to"
910 PRINT "analytical error, and calculates the 95% confidence-limit uncertain-"
920 PRINT "ties considering only the assigned analytical errors, without regard"
930 PRINT "to the actual scatter of the points (MODEL 1).  This is equivalent to
940 PRINT "York's original method and to a McIntyre Model 1 fit.  If the chi-"
950 PRINT "square probability calculation indicates that the assigned errors"
960 PRINT "should result in the observed scatter more than 30% of the time, this
970 PRINT "MODEL 1 result is accepted without further calculation.  If, however"
980 PRINT "the calculated probability is less than 30%, the Yorkfit is repeated,
990 PRINT "using equally-weighted points with zero correlation, and with 95%"
1000 PRINT "confidence-limit uncertainties calculated on the basis of the ob-"
1010 PRINT "served scatter and N-2 degrees of freedom (MODEL 2).  If the Chi-"
1020 PRINT "square probability was less than 1%, the program will consider only"
1030 PRINT "the MODEL 2 result for any subsequent calculations.  If the proba-"
1040 PRINT "bility is between 1% and 30%, the choice of models is left to the"
```

```
1050 PRINT "user."LIN4
1060 SERROR F,1090
1070 IF F#-1 THEN 1090
1080 LOAD #0,1
1090 END
```