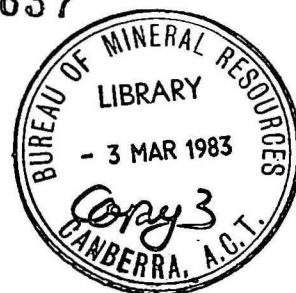


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BUREAU OF MINERAL RESOURCES, GEOLOGY AND GEOPHYSICS

RECORD

HP9825A Software system for electron probe data, major/trace
and RE element geochemistry, magmatic fractionation models,
and Rb-Sr isotopic parameters

Record No.1982/39

A.Y. Glikson & M. Owen
Bureau of Mineral Resources, Geology & Geophysics,
Canberra, A.C.T.

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2	-	"	"	"	"	A10
3	-	"	"	"	"	A11
4	-	"	"	"	"	A12
5	-	"	"	"	"	B2
6	-	"	"	"	"	B10
7	-	"	"	"	"	B15
8	-	"	"	"	"	B18
9	-	"	"	"	"	B19
10	-	"	"	"	"	B20
11	-	"	"	"	"	B21
12	-	"	"	"	"	B23
13	-	"	"	"	"	C2
14	-	"	"	"	"	D1(a)
15	-	"	"	"	"	D1(e)

Table 2 had been omitted from
the hardcopy of record 1982/39.

INTRODUCTION

Four software systems are described for the HP9825A or HP9825B desktop computer and peripheral HP9871A printer and HP9872A plotter, using either HP9885M flexible disc storage or magnetic tape storage. Package (A) allows storage and selective retrieval of electron probe mineral chemistry data (14 major/minor elements), data tabulation, calculations of mineral formulae and of optional ratios, XY and XYZ plotting, calculation of mean, standard deviation and other statistical parameters, and mineral species classifications, calculations and plotting for the pyroxenes and amphiboles. Package (B) allows storage/selective retrieval and tabulation of major and trace element data (34 elements), XY and XYZ plots, normalized plots, stratigraphic columnar plots, frequency distribution plots, calculation of statistical parameters, model computations of partial melting and fractional crystallization, model parental magma/source rock compositions for Mg number and for trace elements, and an alteration screening program. Package (C) allows storage/selective retrieval of rare earth element (REE) data, chondrite-normalized plots, model calculations of element distributions consequent on partial melting and fractional crystallization, tabulation, and statistical and plotting procedures as for package (B). The storage/retrieval, tabulation, XY and XYZ plotting, and statistical procedures are modified after, or include subroutines of programs written by, M. Owen (BMR). The packages each include a selection index, title and analyses listing, selective tabulation, and disc or tape data transfer programs. Package (D) allows storage/retrieval of Rb/Sr isochron ages, initial $\text{Sr}^{87}/\text{Sr}^{86}$ ratios and relevant information, and the computation and plotting of model crustal residence times and mantle derivation ages of precursor source materials. In the following each package and program are outlined separately. For the more composite programs, the first part indicates the principles of the program and the second part lists input, option/selection and output modes, providing a condensed manual. This manual assumes an elementary acquaintance with the HP9825B system on the part of the user. The maximum RWM (Read/Write Memory) capacity required by these programs is 21700 bytes. If ROMs memory (Read Only Memory cards) are loaded onto memory from tape option an HP9825B (61670 Bytes) is required, though the majority of programs can be accommodated by memory option 003 (31420 Bytes). ROMs required are General I/O ROM, String Variables ROM, Advanced Programming ROM, Disk ROM and 9872A Plotter ROM.

Package A - MINERAL CHEMISTRY PROGRAMS

These programs are stored on one HP flexible disc and/or tape. The following programs are included (in the order they appear in the "index" program).

- A1 - Probe system index ("index")
- A2 - Electron probedata storage("storet") (AYG)
- A3 - Continuous data tables printing ("contab") (MO)
- A4 - Table and sample title listing ("list") (AYG)
- A5 - Data transfer programs ("dtrans") (AYG)
- A6 - Selective data retrieval/tabulation ("retprt") (MO)
- A7 - Data retrievalfor plot programs ("xyret") (MO)
- A8 - XY plots and regression ("xyplot") (MO)
- A9 - Triangular plots ("xyzplt") (MO)
- A10 - Statistics program ("stats") (MO)
- A11 - Pyroxene program ("pyrox") (AYG)
- A12 - Amphibole program ("amph")(AYG)

Common features of all programs

- (1) positive response to prompt (yes) - enter 1, press continue key
- (2) negative response to prompt (no) - no entry, press continue key
- (3) for choice of alternative options, enter the desired number indicated in the prompt, then press continue key. For example: Prompt "DISC (1) or TAPE (2) STORAGE"; enter 1 for disc or 2 for tape storage modes.

- A1 - Probe system index ("index")

Program titles are displayed consecutively and can be selected and loaded by entering a positive response. The titles order is as in the preceding programs list. To load "index" execute get "index" (for disc) or trk0;ldf0 (for tape) from keyboard, then press run.

- A2 - Electron probe data storage ("storet"; 10016 Bytes) (AYG, inc, sub-routines by MO)

A single program run enables storage of up to 10 analyses, each including up to 14 oxides on a 1260 Byte long string, and of a table title on an 80 Byte long string (up to 80 alphanumeric characters). Each analysis

includes a 70 Byte long title group (7 lines of 10 characters each) allowing storage of sample number, rock type, mineral codes, geological unit and locality. Any of these codes can be used for samples' retrieval. Oxides (wt%) include SiO_2 , TiO_2 , Al_2O_3 , V_2O_3 , Cr_2O_3 , FeO (total as FeO), MnO, MgO, NiO, CaO, Na_2O , K_2O , P_2O_5 , and Cl, and a calculated total is printed. The number of ideal oxygens and cations per formula is also entered and stored. Data are stored using integer precision storage, allowing values in the range of -32768 to +32767 to be stored on 2 Byte long substrings. Iron is entered as total iron as FeO and is optionally calculated as FeO and Fe_2O_3 , printed below with a new total. The oxide values (total Fe as FeO) are computed to give a mineral formula for the number of oxygens specified in the input. Calculations are according to Hutchison (1974, pp. 401-411), as follows:

- (1) Oxide (wt%) values are divided by their respective molecular weights to obtain molecular proportions.
- (2) Atomic proportions of oxygen are obtained by multiplying each molecular proportion value by the oxygen/cation ratio.
- (3) The number of oxygen atoms is normalized to the ideal formula.
- (4) Cation proportion values are derived by multiplying the normalized oxygen values by the ideal cation/oxygen ratios for respective oxides.

Since this program is intended for a variety of minerals, no recalculation of cations according to specific lattice occupancy sites, cf. $(\text{Ca}+\text{Na})_{\text{B}}$ and $(\text{Na}+\text{K})_{\text{A}}$ in amphibole, is performed. This is achieved in specific mineral groups program, i.e. "pyrox", "amph", which include classifications and calculations specific to these minerals species.

Calculation of Fe_2O_3 and FeO assumes an ideal number of cations, as specified from keyboard, allocating any excess oxygens to Fe_2O_3 ($\text{Fe}^{+3} = 2 \times$ excess oxygen atoms). The ideal formula oxygen and cation numbers are printed below the actual total cation number. The program allows calculation/printing of up to 10 cation ratios selected from keyboard at the outset, i.e. 100 Mg/(Mg+Fe), 100 Fe/(Fe+Mg), 100 Ca/(Ca+Na), 100 K/(K+Na+Ca), 100 Ti/(Ti+Fe+Mg), 100 Cr/(Cr+Al), 100 V/(V+Fe), Ca:Mg:Fe, Ca:Na:K.

Retrieval and correction/addition of data or titles are allowed at the end of the storage routine, or an existing data file can be corrected at the outset of the program. The latter procedure requires a full string, i.e.

that 10 analyses (or 10 analyses and blank entries) are stored in the data file. Tables are printed in 10 column format (Table 1). When new entries are made as oxide wt%, the mineral formula is recalculated automatically.

Input Routine

If disc storage is used, an initialised disc is required. If tape storage, mark 1360 Byte long data files on HP tape (see the HP9825A manual for instructions). The prompts will appear "MODIFY TABLE (1) or NEW DATA (2)" and "CALCULATION/PRINT OF RATIOS". If the latter is positive, prompts of 10 ratios (see above) appear consecutively allowing a choice of ratios from keyboard.

If entry of a new data file is desired, the following prompts will appear successively "SAMPLE NUMBER"; "OXYGEN. IDEAL CATIONS XX.YY" (enter as integer and fraction, respectively); "ROCK TYPE" (2 lines); "MINERAL DATA" (2 lines); "GEOLOGICAL UNIT"; "LOCALITY". Enter up to 10 alphanumeric characters for each prompt (except the 2nd). If no entry for any particular line, press space bar then continue key. Next, entry of 14 elements as oxide (wt%) and of Cl is enabled successively. If no value, enter 0. When Cl is entered (or nil), entry of the next analysis proceeds. If entry of less than 10 analysis, press continue when the prompt "SAMPLE NUMBER" appears. If this is done before 10 analyses are stored, the rest of the string is automatically filled with blanks for the title group and nils for numeric values. Next, entry of a table title of up to 80 characters is invited, following which a printout is made on the 9871A printer (Table 1). Next, if any errors are found on the printout the table can be modified following appearance of the prompt "DOES TABLE NEED MODIFYING", and making appropriate entries on subsequent prompts, "COLUMN NUMBER", "LINE NUMBER" (add 7 to line numbers in Table 1), and "NEW ENTRY", which appear in cycles. Change title and oxides only, cations are recalculated automatically. When the cycle is broken (by responding negatively to "COLUMN NUMBER"), the data can be recorded by entering the appropriate data file code (3 letter code for disc) or track number, and of the file number. To facilitate systematic data retrieval from disc, enter same code word for same data types, followed by consecutive file numbers, cf. PLG2...PLG62, etc.

If modification of an existing data file is desired, the correction subroutine will invite specifications of the data file code (3 letters followed by a 1-3 digit file number, cf. PLG8, CPX24, GNT125, or track and file number, followed by prompts "COLUMN NUMBER", "LINE NUMBER" (see Table 1) and "NEW ENTRY", which appear cyclically as in the new data correction procedure. Next, title modification is invited, then printing proceeds, followed by re-recording of the file as specified from keyboard. If recording overprints an existing data file, a warning message appears "REPRINTING DATA FILE" to avoid possible loss of data; if applicable, re-entry of the correct parameter is then possible.

TABLE 1

ARNS [1/5] MOUNT HAY GRANULITES

SAMPLE NUMBER	74930037	74930037	74930037	74930037	74930037	74930037	74930037	74930037	74930037	74930037
ROCK NAME	BiOpAmPl	BiOpAmPl	BiOpAmPl	BiOpAmPl	BiOpAmPl	BiOpAmPl	BiOpAmPl	BiOpAmPl	BiOpAmPl	BiOpAmPl
MINERAL DATA	GRANULITE	GRANULITE	GRANULITE	GRANULITE	GRANULITE	GRANULITE	GRANULITE	GRANULITE	GRANULITE	GRANULITE
	OPX	OPX	OPX	OPX	AMPH	AMPH	ILMENITE	ILMENITE	PLG	PLG
GEOLOGICAL UNIT	Mt Hay	Mt Hay	Mt Hay	Mt Hay	Mt Hay	Mt Hay	Mt Hay	Mt Hay	Mt Hay	Mt Hay
LOCALITY	ARUNTA	ARUNTA	ARUNTA	ARUNTA	ARUNTA	ARUNTA	ARUNTA	ARUNTA	ARUNTA	ARUNTA
1 SiO ₂	50.32	49.75	49.54	49.28	39.43	39.47	0.18	9.30	54.07	54.55
2 TiO ₂					1.98	1.88	49.79	42.06		
3 Al ₂ O ₃	1.62	1.54	1.51	1.94	12.58	12.34		0.19	28.92	28.86
4 V ₂ O ₃					0.14	0.12	0.48	0.27		
5 Cr ₂ O ₃					0.11			0.98		
6 FeO[t]	29.87	29.17	29.26	29.22	16.99	17.07	48.43	39.68		
7 MnO	0.60	0.54	0.54	0.67			0.68	1.34		
8 MgO	16.96	16.83	17.03	16.67	8.98	9.10		0.33	0.11	
9 NiO										
10 CaO	0.47	0.49	0.40	0.60	11.68	11.74	0.26	0.50	11.12	11.09
11 Na ₂ O	0.16	0.14	0.14		1.30	1.23			5.08	5.03
12 K ₂ O					2.47	2.34	0.10	0.12	0.19	0.29
13 P ₂ O ₅										
14 Cl					0.55	0.54				
TOTAL[wt%]	100.00	98.46	98.42	98.38	96.21	95.83	99.92	94.77	99.49	99.82
15 Si	1.949	1.953	1.948	1.939	6.156	6.182	0.005	0.234	9.808	9.858
16 Ti					0.232	0.221	0.958	0.797		
17 Al	0.074	0.071	0.070	0.090	2.315	2.279		0.006	6.185	6.148
18 V					0.018	0.015	0.010	0.005		
19 Cr					0.014			0.020		
20 Fe	0.967	0.958	0.962	0.962	2.218	2.236	1.036	0.836		
21 Mn	0.020	0.018	0.018	0.022			0.015	0.029		
22 Mg	0.979	0.985	0.998	0.978	2.089	2.124		0.012	0.030	
23 Ni										
24 Ca	0.020	0.021	0.017	0.025	1.954	1.970	0.007	0.013	2.161	2.147
25 Na	0.012	0.011	0.011		0.394	0.374			1.787	1.762
26 K					0.492	0.468	0.003	0.004	0.044	0.067
27 P										
TOTAL[cations]	4.021	4.017	4.024	4.016	15.882	15.869	2.034	1.956	20.015	19.982
OXYGENS.CATIONS	6.04	6.04	6.04	6.04	23.15	23.15	3.02	3.02	32.20	32.20
FeO[%wt]	28.00	27.62	27.17	27.77	15.95	15.66	43.79	39.68	0.00	0.00
Fe2O3[%wt]	2.08	1.72	2.32	1.61	1.16	1.56	5.16	0.00	0.00	0.00
RETOTAL[%wt]	100.21	98.63	98.65	98.54	96.33	95.99	100.44	94.77	99.49	99.82
100Mg/Mg+Fe	50.3	50.7	50.9	50.4	48.5	48.7		1.4	100.0	
100Fe/Fe+Mg	49.7	49.3	49.1	49.6	51.5	51.3	100.0	98.6		
100Ca/Ca+Na	62.5	65.6	60.7	100.0	83.2	84.0	100.0	100.0	54.7	54.9
100K/K+Na+Ca					17.3	16.6	30.0	23.5	1.1	1.7
100Ti/Ti+Fe+Mg					5.1	4.8	48.0	48.4		
100Mn/Mn+Fe+Mg	1.0	0.9	0.9	1.1			1.4	3.3		
100Cr/Cr+Al					0.6			76.9		
100V/V+Fe					0.8	0.7	1.0	0.6		
Ca:Mg:Fe	1:50:49	1:50:49	1:50:49	1:50:49	31:33:35	31:34:35	1: 0:99	2: 1:97	99: 1: 0	55: 0: 0
Ca:Na:K	63:38: 0	66:34: 0	61:39: 0	55: 0: 0	69:14:17	70:13:17	70: 0:30	76: 0:24	54:45: 1	54:44: 2

The storage program provides the basis for all subsequent programs, which utilize selective retrieval of data according to any of the alphanumeric parameters stored in the samples title groups. For example, data for any particular mineral name, rock type or geological unit can be selectively retrieved for various modes of calculation, printing or plotting in subsequent programs.

A3 - Continuous data tables printing ("contab"; 3628 Bytes)(MO)

The program enables continuous printing of 1360 Byte data files as specified from keyboard according to a 3-letter file code and first and last file numbers if stored on disc, or track and file numbers if stored on tape. Printing is executed in horizontal format, allowing better paper alignment control, i.e. a lesser need for readjustment of the printer.

A4 - Tables and sample title listing ("list")(1188 Bytes)(AYG)

An option is allowed at the outset between listing of table titles or individual sample titles, entering the appropriate response to the prompt "TABLE (1) or SAMPLE (2) LISTING". Listing of data file titles is obtained for any specified range of file numbers on disc (entering 3 letter data files code and file number range) or tape (entering track number and file numbers range). Horizontal format listing of individual sample titles is obtained for the file number range specified from keyboard

A5 - Data transfer programs ("dtrans"; 1376 Bytes)(AYG)

Four data transfer modes can be selected from keyboard, namely "DISC TO DISC (1), TAPE TO DISC (2), DISC TO TAPE (3), TAPE TO TAPE (4)". For the sake of consistency and to avoid error, it is necessary that file numbers on disc and tape are identical. For each transfer mode, the appropriate disc data file code (3 letters), or where relevant the track number, and file numbers, are entered. As data transfer proceeds, codes/numbers of recorded files are successively listed on the thermal printer.

A6 - Selective data retrieval/tabulation ("retprt"; 4238 Bytes)(MO,
mod. by AYG)

The program allows tabulation of selected analyses retrieved from 1360 Byte long data files according to two inclusive or exclusive search keywords specified from keyboard. The number of columns per table (up to 10)

can be specified. It is possible to delete unwanted lines from the columnar format by entering when the prompt "LINE NUMBERS TO BE DELETED" appears corresponding line numbers (add 7 to line numbers in Table 1) with leading spaces, for example as follows: " 13 21 25". When a table is printed a title can be inserted from keyboard and printing of the next table commences.

A7 - Data retrieval for plots program ("xyret"; 2746 Bytes)(MO)

This program allows selective retrieval of data from 1360 Byte long data files, storing up to 150 analyses on a 150x70 Byte large string array, which constitutes a master file applied to XY and XYZ plots (programs A8 and A9). Data retrieval proceeds in cycles of 6 keywords, allowing coding of data as 6 single or 3 pairs of keywords, each pair consisting of inclusive or exclusive keywords. Symbol (Fig. 1) and pen type (1-4) are specified in the format XX.Y along with the keywords and are applied in subsequent plot programs. Following each 6 keywords cycle, a search/retrieval is conducted through the data file range specified from keyboard. On completion of the search, the data is recorded on the 15000 master file and selection of a plotting program can be proceeded with.

Input routine

Prompt "1st SEARCH KEYWORD" (up to 10 characters); prompt "1st SYMBOL. PEN CODE XX.Y ". Enter according to symbol chart (Fig. 1) and desired pen colour, cf. 26.1 (gives symbol no. 26 with pen colour no. 1). Prompts: "2nd SEARCH KEYWORD", "2nd SYMBOL. PEN CODE XX.Y ", etc. The search words and codes entered are listed on the thermal printer. prompt "ARE 1st and 2nd SAME SAMPLE". If both 1st and 2nd keywords are inclusively required to define a sample, enter 1; if any one of them suffices, press continue. The same procedure applies to each of the successive pairs of keyword entries. Following the 6th search keyword, prompts ask for the files code (up to 3 letters) or track number, and for file number range for retrieval. The cumulative number of retrieval samples is printed. A new search can now start, if desired. When retrieval (up to 150 samples) is completed, a choice is allowed between XY(1) or XYZ(2) plots.

A8 - XY plots and regression ("xyplot"; 6918 + 2832 Bytes)(MO, mod. by AYG)

The program utilizes the 150x70 Byte "master" data file in which data are stored by program A7. It allows XY plotting of elements A and B individually or as the expression A+B, A-B, AxB, A/B, A/(A+B), 100A(A+B), A

and/or Bxconstant, and log A and/or log B. The program retrieves and prints the maximum and minimum values for the elements (or combinations) entered, which allows determination of the limits of the plot. Diagram dimensions, axes tic frequency, label/tic ratio and pen speed can be selected. Plot symbols and pen colour have been predetermined in program A7. Plotting is followed by an optional linear regression subprogram loaded automatically from a separate file ("xyreg"). Samples with anomalous values can be deleted from the regression analysis. A regression line, confidence interval plot and the regression equation can be plotted. Regression parameters including line slope (+standard error), line intercept (+standard error), and correlation coefficients are printed on the HP9871A printer. Sample statistics including mean $\bar{w} = \frac{\sum w}{n}$, variance $S^2 = \frac{\sum (w - \bar{w})^2}{n-1}$, sum of squares $ss = \sum (w - \bar{w})^2$, degrees freedom (n-1), mean square and F-test results (Hutchison, 1974, pp. 425-437) are also printed (W - sample value, $\bar{w}$ - mean value, n - number of samples). At the end of the program plotting of a title and of a symbol legend located at coordinates specified from keyboard are possible.

Input routine

Display "X-Y PLOTS WITH 9872A PLOTTER"; prompt "ELEMENT CODE PRINT REQUIRED? 1 "; if positive, a printout of oxides and cations coded by numbers (corresponding to line numbers in Table 1) are printed, allowing selection of entries when "X-AXIS REGISTER" and "Y-AXIS REGISTER" appear. If 40 is entered a list of A and B value combinations indicated above is printed with corresponding modify code numbers which are entered on prompt "WHICH TYPE OF RATIO?". Next, entries of log function is possible; following this the maximum and minimum X and Y values retrieved from the "master" data file are printed, which allows design of diagram field limits. The design proceeds in terms of numeric parameters, X and Y axes length in cm, tic intervals, numeric label intervals, axes labels, size factors of axes labels and symbols (default factor = 1.5), optional pen speed (1-36) and repeat line drawing which allows higher drawing quality for final diagrams. The diagram can be offset to allow plotting of more than one diagram on a single sheet. Note that if the X axis is displaced no axis label is plotted and if Y axis is displaced no label plotted on respective axes. Concomitantly with symbol plotting the corresponding X and Y values can be printed on the 9871A printer.

On completion of plotting, prompt "REGRESSION ANALYSES? 1 " appears. If positive, the regression subroutine ("xyreg") is loaded. If desired X and/or Y parameters of anomalous samples can be deleted from regression analysis by entering these parameters (read from the

Fig. 1 - PLOTTING SYMBOL CODES

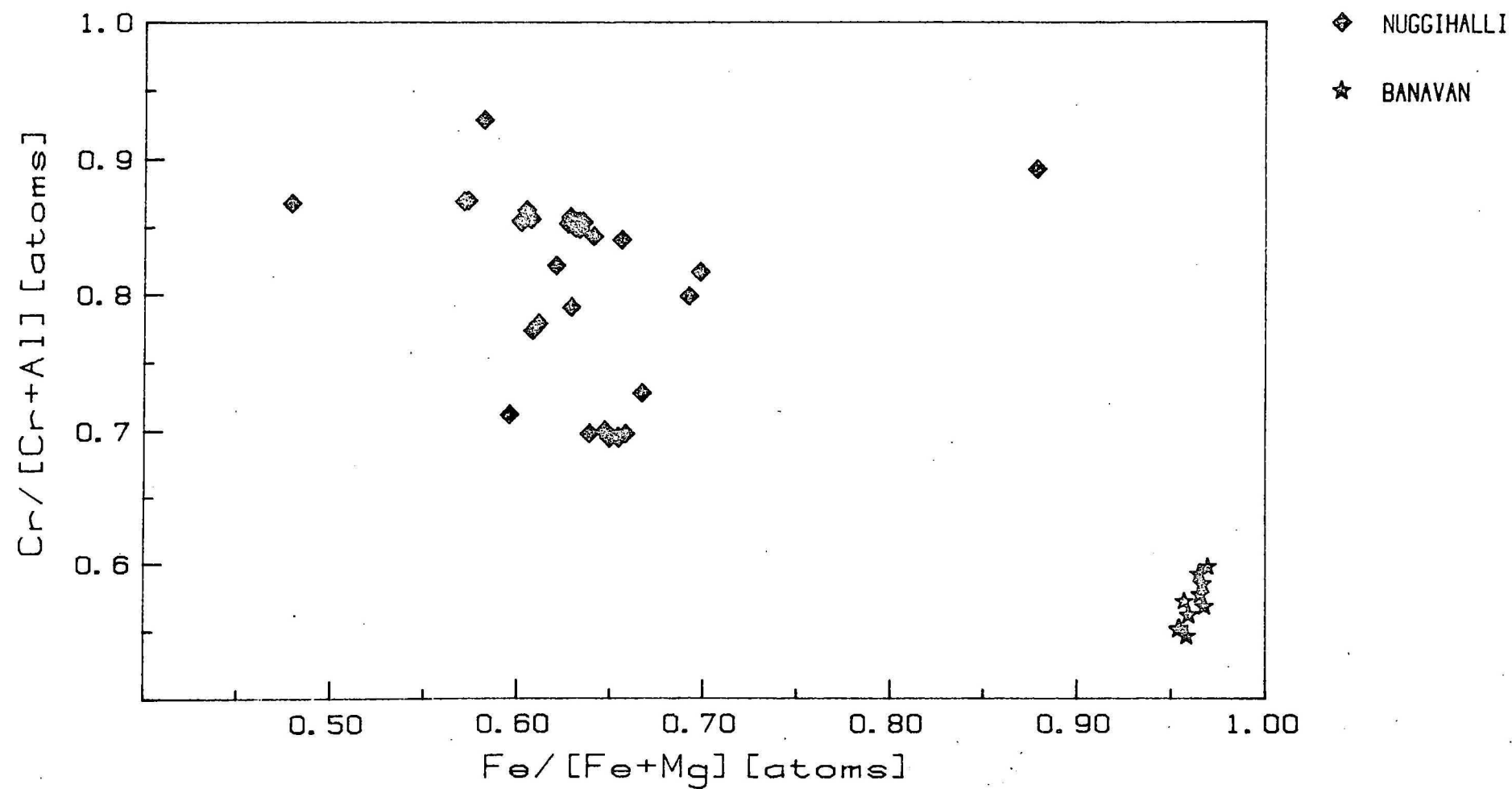
△	◇	◊	◊	○	☆	✱	○	▽	□
1	2	3	4	5	6	7	8	9	10
◊	◊	○	✱	✱	○	☆	⊗	⊗	⊗
11	12	13	14	15	16	17	18	19	20
○	✱	✱	○	▲	◆	◊	⊗	⊗	☆
21	22	23	24	25	26	27	28	29	30
✱	●	▽	■	◊	⊗	⊗	✱	✱	○
31	32	33	34	35	36	37	38	39	40
☆	⊗	⊗	⊗	⊗	✱	✱	●	人	+
41	42	43	44	45	46	47	48	49	50
★	✱	✱	★	✱	●	Y	X	✱	✱
51	52	53	54	55	56	57	58	59	60
✱	✱	✱	●	✱	✱	✱	✱	⊗	✱
61	62	63	64	65	66	67	68	69	70
✱	●	▲	◆	◊	⊗	⊗	☆	✱	●
71	72	73	74	75	76	77	78	79	80
▽	⊗	◊	⊗	⊗	✱	✱	●	☆	⊗
81	82	83	84	85	86	87	88	89	90
⊗	⊗	⊗	✱	✱	●	▲	◆	◊	⊗
91	92	93	94	95	96	97	98	99	100
⊗	☆	✱	●	▽	⊗	◊	⊗	⊗	✱
101	102	103	104	105	106	107	108	109	110
✱	●	▽	■	◊	⊗	⊗	✱	✱	●
111	112	113	114	115	116	117	118	119	120

DOT [.] - CODE 0

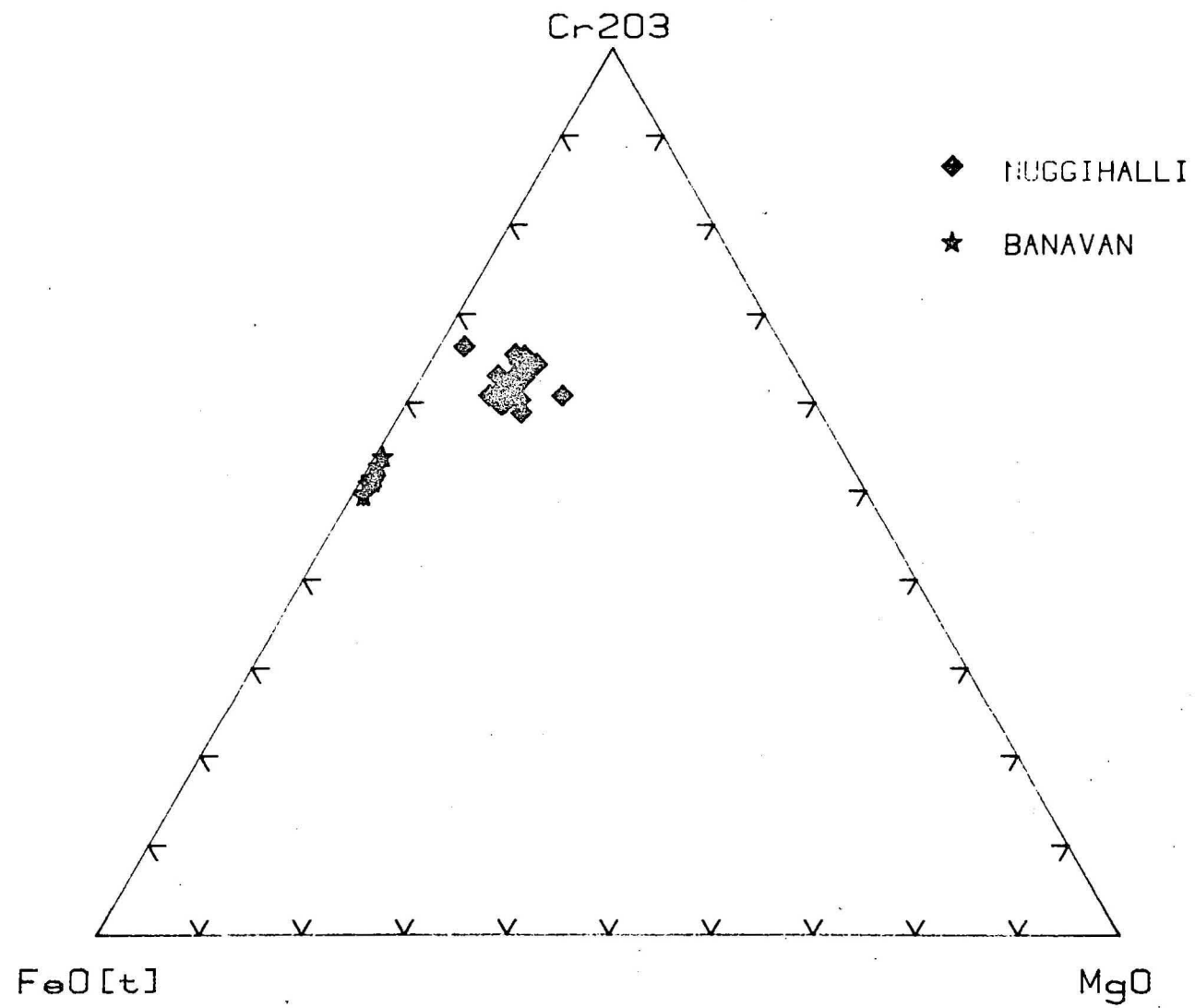
SYMBOL SIZE FACTOR = 2 [DEFAULT VALUE]

Fig. 2

NUGGIHALLI BELT CHROMITES & BANAVAN CHROMITES



NUGGIHALLI BELT CHROMITES AND BANAVAN CHROMITES



printout) upon prompts "X-VALUE TO BE DELETED" and "Y VALUE TO BE DELETED" which can be repeated any number of times. Next, regression results are printed on the 9871A printer. On prompt "REGRESSION LINE PLOT REQUIRED? (1)", if positive the line type (1-6) and pen colour (1-4) can be specified as L.C., cf. 5.3, and the regression equation can be labelled on the diagram at specified XY coordinates. Next, a confidence interval plot with a chosen T-value can be plotted, followed by optional printing of analysis of variance statistics. The number of samples is also printed. The program then returns to the main subroutine, allowing labelling of a title and plotting of legend symbols at specified XY coordinates. An example of a plot is given in Fig. 2.

A9 - Triangular plot ("xyzplt"; 5768 Bytes)(MO)

As in program A8 this program retrieves data from a "master" file, including pre-selected symbol type and pen colour codes for each batch of samples. At the outset prompts invite entry of element line code numbers (Table 1) into X, Y and Z registers, or entry of modified element combination values, i.e. A+B, A-B, AxBy, A/B, or Axconstant, coded as in program A8. Entry of labels for the X, Y and Z apices is followed by selection of pen speed, length of triangle side (in cm) and axes tic interval. Offset of diagrams on the sheet is possible. On choice from keyboard, a concomitant printout of corresponding X, Y and Z values on the 9871A printer is obtained. Size factors for labels and symbols, repeat drawing, plotting and spacing of tics (in percent) on triangle sides can be specified. A legend can be plotted. An example of an XYZ plot is given in Fig. 3.

A10 - Statistics program ("stats"; 3444 Bytes)(MO, mod. by AYG)

The program allows selective retrieval of data from 1260 Byte data files according to up to 4 alphanumeric search keywords, either as 4 independent keywords or a two inclusive pair. This is achieved by responding to prompts "1st SEARCH KEYWORD", "2nd SEARCH KEYWORD", "ARE 1st and 2nd SAME SAMPLE", etc. Up to 50 samples can be retrieved in a single program run; the message "ARRAY FULL" is displayed when that limit is reached. The retrieved analyses are printed in horizontal format, oxides in one block and cations per formula in a second block. Next, the program pauses and samples can be omitted from calculation of a mean by entering the sample numbers to be deleted. The program calculates the mean $\bar{w} = \frac{\sum w}{n}$, minimum (w), maximum (w),

and standard deviation $S = \frac{\sum(w-w)^2}{n-1}$ values for each type of oxide and cation,

printing them at the bottom of the corresponding data blocks (Table 2).

A11 - Pyroxene program ("pyrox"; 14054 Bytes)(AYG)

The program retrieves pyroxene data from 1260 Byte data files according to search words specified from keyboard, and tabulates the data and the mineral formula in either horizontal or columnar formats. If horizontal format is selected, the mean is calculated and printed below. Iron is calculated as FeO and Fe_2O_3 as in program A2, i.e. Fe^{+3} equals twice the excess oxygen atoms per ideal number of cations. Values calculated and printed below the mineral formula include Mg' number for Fe^{+2} , the Mg' number for total Fe as Fe^{+} , Kushiro's norm (Ac:Jd:Tsch:Wo:En:Fes) and Yoder and Tilley's norm (Tsch:Jd+Ac:Hd:Di). Either the Di:Hd:En:Fes tetrahedron or the Jd+Ac:Di:Hd triangle can be plotted. The Di:Hd:En:Fes diagram provides the basis for a pyroxene classification (Poldervaart and Hess, 1951) (Fig. 4). The classified mineral name and the Wo:En:Fes ratio are printed within the title group. An example of a plot and printout is shown in Fig. 4 and Table 3.

Input Routine

Prompts allow a choice of type of diagram and printing format. Data selection is through two inclusive or exclusive search keywords. The table title is entered from keyboard. Next, a design of the diagram is enabled, including length of triangle side, offset of diagram, symbol/pen number (XY.YY), size factor of axes labels and of the symbol, optional repeat drawing and axes tics. Concomitant with plotting of data, a printout is attained on the 9871A printer, including classification of pyroxene type. When 10 pyroxene analyses are retrieved, automatic paper transfer to the next table occurs. When all data are printed, prompts invite "FURTHER DATA ON PLOT" or "ANOTHER PLOT", allowing further runs. If negative for both options, if horizontal format, the calculation and printing of an average can be pursued. When printing is complete, labelling of diagram title can be conducted from keyboard on the printer-type writer mode (ptyp).

A12 - Amphibole program ("amph"; 15776 Bytes)(AYG)

The program plots the Ed:Tr:Tsch:Pg tetrahedral diagram (Leake, 1968) and classifies amphibole species according to Leake's (1978) scheme (Fig. 5). This classification is based on the number of Ca+Na atoms in the

TABLE 3

ARUNTA PYROXENES

sample number	74934028	74934028	74934028	74934028	74934036	74934036	74934036	74934036	74930037	74930037
ROCK NAME	op/hb/plg	op/hb/plg	op/hb/plg	op/hb/plg	BiOpCpPl	BiOpCpPl	BiOpCpPl	BiOpCpPl	BiOpAmPl	BiOpAmPl
MINEPAL/ZONE	ANORTHOSIT	ANORTHOSIT	ANORTHOSIT	ANORTHOSIT	B.GRANULIT	B.GRANULIT	B.GRANULIT	B.GRANULIT	GRANULITE	GRANULITE
CLASSIFICATION	PIGEONITE	PIGEONITE	PIGEONITE	PIGEONITE	PIGEONITE	PIGEONITE	SALITE	SALITE	PIGEONITE	PIGEONITE
Wo:En:Fs	0:61:37	1:60:38	1:59:39	0:60:38	1:53:45	1:52:46	46:35:18	46:36:17	1:49:49	1:49:49
SiO ₂ %wt	52.34	51.59	51.44	52.21	51.12	51.10	51.28	51.75	50.32	49.75
TiO ₂			0.13				0.18	0.11		
Al ₂ O ₃	1.25	1.33	1.34	1.25	1.61	1.56	2.39	2.01	1.62	1.54
V ₂ O ₃							0.14	0.13		
Cr ₂ O ₃										
FeO(tl)	23.10	23.37	23.67	24.02	27.33	28.03	10.83	10.20	29.87	29.17
MnO	0.51	0.63	0.68	0.73	0.58	0.49	0.17	0.21	0.60	0.54
MgO	21.87	21.52	20.79	21.56	18.50	18.23	12.19	12.65	16.96	16.83
NiO										
CaO	0.39	0.51	0.53	0.47	0.56	0.49	22.42	22.52	0.47	0.49
Na ₂ O		0.20	0.35				0.40	0.29	0.16	0.14
K ₂ O										
TOTAL	99.46	99.15	98.93	100.24	99.70	99.90	100.00	99.87	100.00	98.46
FeO	22.59	21.11	21.58	22.68	26.86	27.47	9.00	9.03	28.00	27.62
Fe ₂ O ₃	0.57	2.51	2.33	1.48	0.52	0.62	2.03	1.30	2.08	1.72
TOTAL	99.52	99.40	99.16	100.39	99.75	99.96	100.20	100.00	100.21	98.63
Si cation/6ox	1.967	1.954	1.957	1.958	1.959	1.959	1.935	1.949	1.949	1.953
Ti			0.004				0.005	0.003		
Al	0.055	0.059	0.060	0.055	0.073	0.071	0.106	0.089	0.074	0.071
V							0.004	0.004		
Cr										
Fe ⁺²	0.710	0.668	0.666	0.711	0.861	0.881	0.284	0.284	0.906	0.907
Fe ⁺³	0.016	0.072	0.067	0.042	0.015	0.018	0.058	0.037	0.061	0.051
Mn	0.016	0.020	0.022	0.023	0.019	0.016	0.005	0.007	0.020	0.018
Mg	1.225	1.215	1.179	1.205	1.056	1.042	0.686	0.710	0.979	0.985
Ni										
Ca	0.016	0.021	0.022	0.019	0.023	0.020	0.907	0.909	0.020	0.021
Na		0.015	0.026				0.029	0.021	0.012	0.011
K										
TOTAL	4.005	4.024	4.023	4.013	4.006	4.007	4.019	4.013	4.021	4.017
100Mg/[Mg+Fet]	62.8	62.1	61.0	61.5	54.7	53.7	66.7	68.9	50.3	50.7
100Mg/[Mg+Fe ⁺²]	63.3	64.5	63.2	62.9	55.1	54.2	70.7	71.4	51.9	52.1
KUSHIRO										
Ac:Jd:	0.0: 0.0:	0.8: 0.8:	1.3: 1.3:	0.0: 0.0:	0.0: 0.0:	0.0: 0.0:	1.5: 0.0:	0.8: 0.3:	0.6: 0.6:	0.6: 0.6:
Tsch:Wo:	0.8: 0.0:	1.1: 0.0:	1.1: 0.0:	1.0: 0.0:	1.2: 0.4:	1.0: 0.1:	3.5:43.9:	2.6:44.5:	1.0: 0.0:	1.1: 0.0:
En:Fs	62.3:36.9	62.2:35.2	60.1:36.1	61.5:37.5	53.7:44.7	53.1:45.7	35.9:15.1	36.8:15.1	50.2:47.5	50.4:47.4
YODER&TILLEY										
Tsch:Jd+Ac:	5.4: 0.0:	5.8: 1.5:	5.9: 2.5:	5.4: 0.0:	7.2: 0.0:	7.0: 0.0:	10.5: 2.9:	8.8: 2.1:	7.3: 1.2:	7.0: 1.1:
Hd:Di	71.4:23.2	70.8:22.0	71.4:20.2	73.8:20.8	85.8: 7.0	88.0: 5.0	28.7:57.9	28.1:61.0	93.1:-1.5	92.5:-0.5

Fig. 4 - PYROXENE DIAGRAM
[POLDERVAART & HESS, 1951]

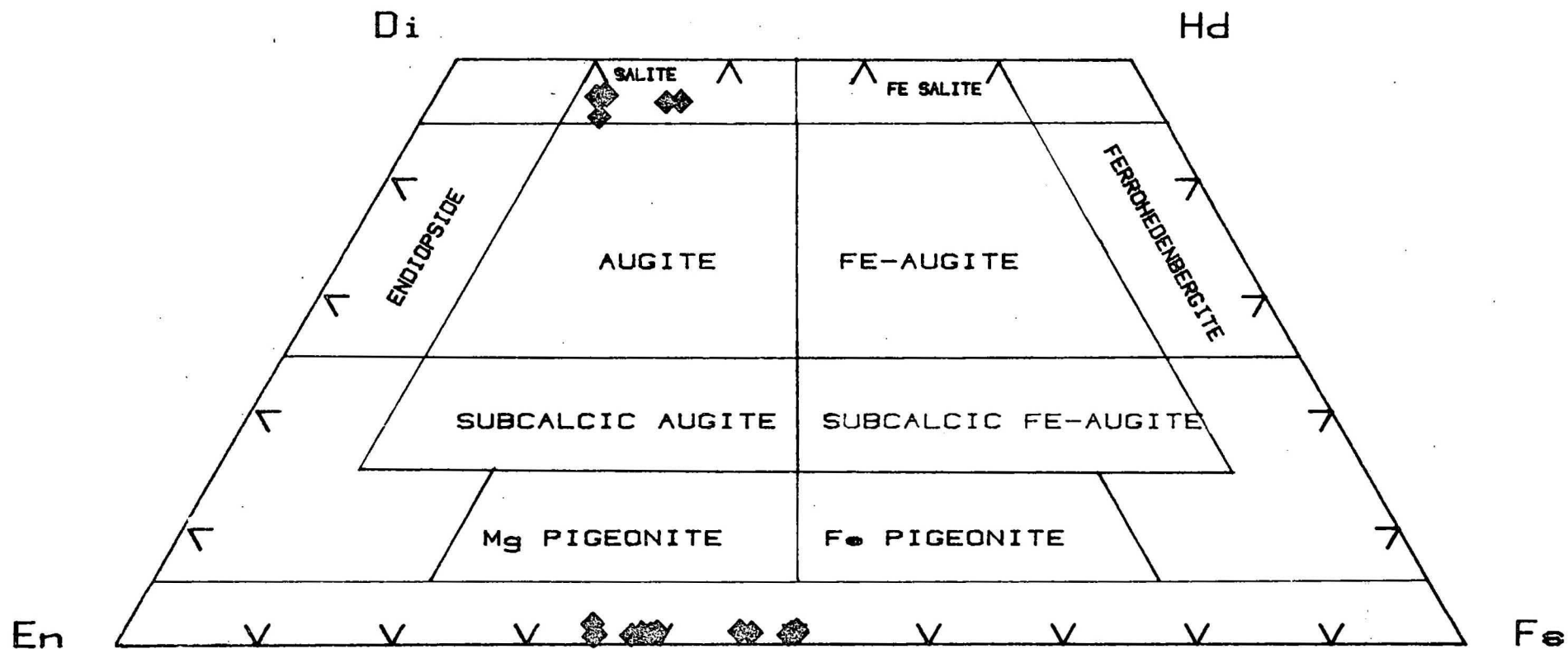


TABLE 4

MOUNT HAY [WEST ARUNTA] AMPHIBOLES

sample number	74934028	74934028	74934028	74930037	74930037
ROCK NAME	op/hb/plg	op/hb/plg	op/hb/plg	BiOpAmPl	BiOpAmPl
MINERAL/ZONE	ANORTHOSIT	ANORTHOSIT	ANORTHOSIT	GRANULITE	GRANULITE
CLASSIFICATION [LEAKE 1978]	EDENITE	EDENITE	EDENITE	potassian KAERSUTITE	potassian KAERSUTITE
SiO ₂ %wt	46.98	47.77	47.55	39.43	39.47
TiO ₂	0.97	0.91	0.99	1.98	1.88
Al ₂ O ₃	9.11	8.72	8.89	12.58	12.34
V ₂ O ₃				0.14	0.12
Cr ₂ O ₃	0.30	0.23	0.25	0.11	
FeO[t]	11.36	11.07	11.01	16.99	17.07
MnO		0.25	0.13		
MgO	14.69	14.93	14.67	8.98	9.10
NiO					
CaO	11.66	11.65	11.95	11.68	11.74
Na ₂ O	1.07	1.05	1.18	1.30	1.23
K ₂ O	0.35	0.40	0.35	2.47	2.34
P ₂ O ₅					
Cl			0.05	0.55	0.54
TOTAL	96.49	96.98	97.02	96.21	95.83
FeO	6.22	6.10	7.64	15.95	15.66
Fe ₂ O ₃	5.71	5.52	3.74	1.16	1.56
TOTAL	97.06	97.53	97.39	96.33	95.99
Si cation/23ox	6.779	6.851	6.857	6.136	6.155
Ti	0.105	0.099	0.107	0.231	0.220
Al	1.550	1.475	1.511	2.308	2.269
V				0.018	0.015
Cr	0.034	0.026	0.029	0.014	
Fe ⁺²	0.751	0.732	0.922	2.076	2.043
Fe ⁺³	0.621	0.596	0.406	0.135	0.183
Mn		0.031	0.016		
Mg	3.160	3.191	3.152	2.082	2.115
Ni					
Ca	1.830	1.816	1.864	1.954	1.970
Na	0.304	0.296	0.333	0.394	0.374
K	0.065	0.074	0.065	0.492	0.468
TOTAL	15.199	15.186	15.262	15.640	15.812
100Mg/[Mg+Fet]	69.7	70.6	70.4	48.5	48.7
100Mg/[Mg+Fe ⁺²]	80.8	81.3	77.4	50.1	50.9
Ca:Mg:Fe	39:30:31	40:29:31	39:29:32	24:45:31	24:45:31
[Ca+Na] _B	2.13	2.11	2.20	2.35	2.34
[Na+K] _A	0.20	0.19	0.26	0.84	0.81

Fig. 5 - AMPHIBOLE CLASSIFICATION
[LEAKE, 1968]

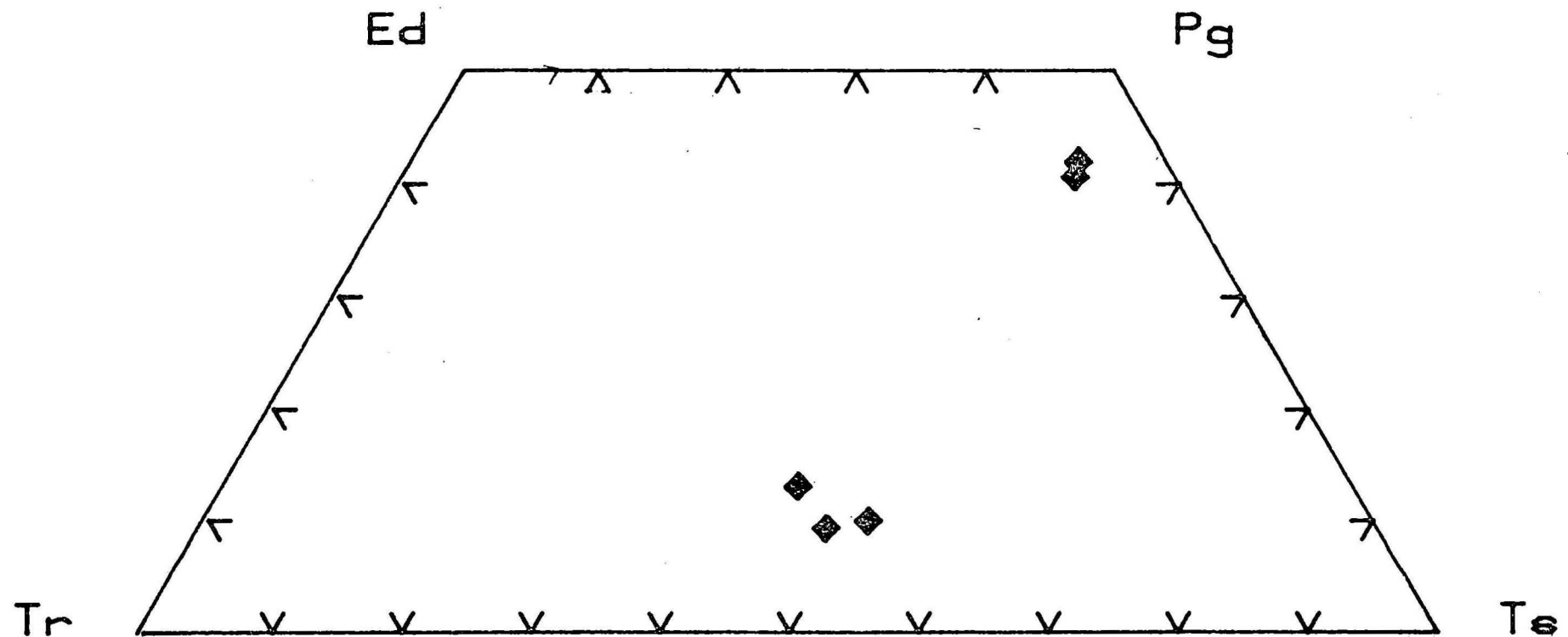
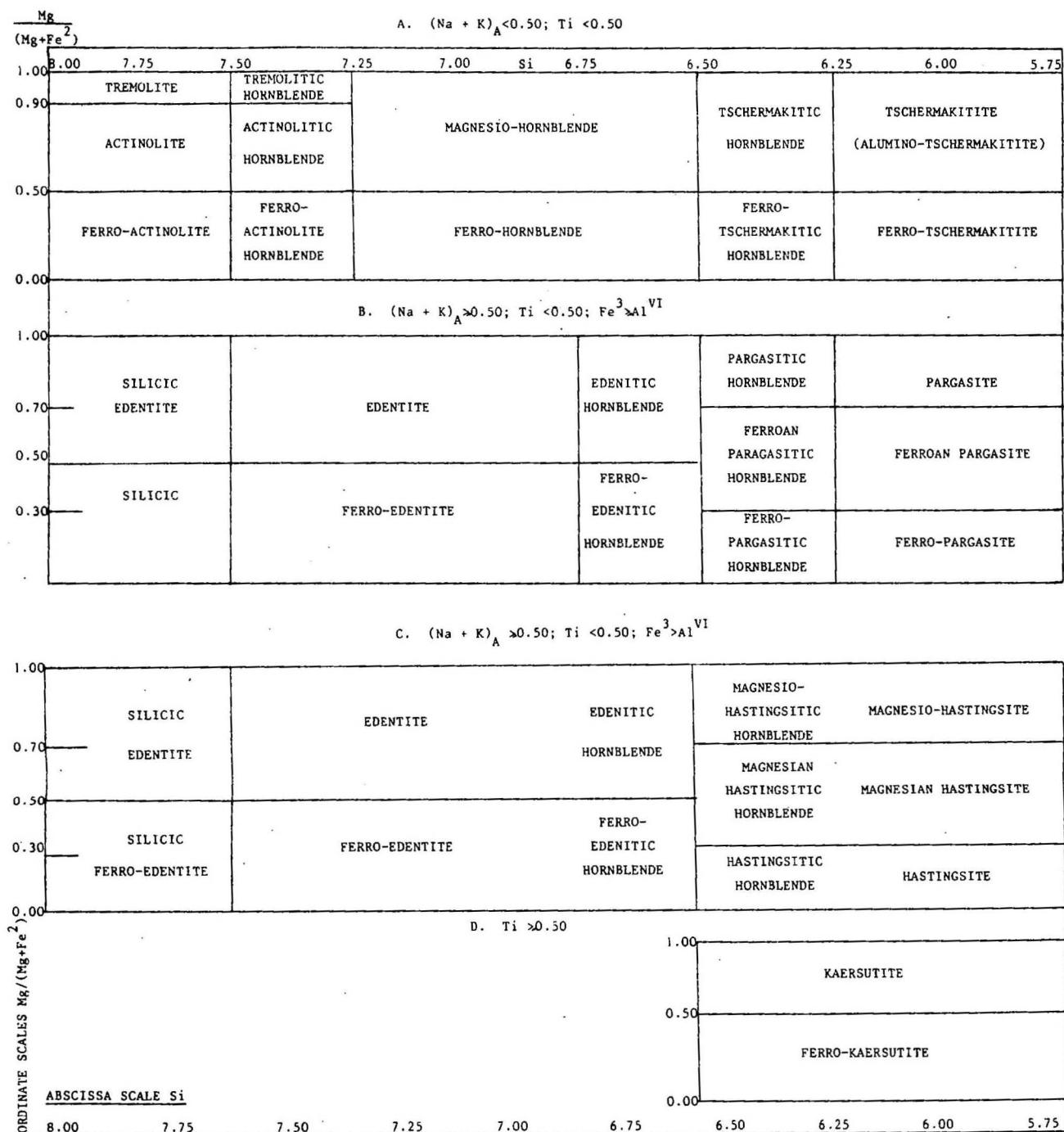


Fig. 5(b)



B site and Na atoms in the A site, distinguishing the main groups:

(1) Fe-Mg-Mn amphiboles - $(Ca+Na)_B < 1.34$; (2) Calcic amphiboles - $(Ca+Na)_B > 1.34$ and $Na_A < 0.67$; (3) Na-Ca amphiboles - $(Ca+Na)_B > 1.34$ and $0.67 < Na_A < 1.34$; (4) alkali amphibole - $Na_A > 1.34$. Subgroups are defined by Si atoms and $Mg/Mg+Fe^{+2}$ ratios. Prefix qualifiers such as "chromium", "ferri", "ferrian", "manganese", "manganoean", "potassium", "potassian", "subsilicic", "titanium", "titanian" (Leake, 1978) are determined by corresponding parameters and are also specified by the program.

Plotting of the amphibole tetrahedron proceeds concomitantly with horizontal or columnar printing of oxide wt% and mineral formula (cations per 23 oxygens). The title group includes the amphibole species name as classified by the program. FeO and Fe_2O_3 are calculated on the basis of the difference between the number of oxygens calculated for the ideal cation number and 21 oxygens. At the bottom of each column the Mg' number for Fe^{+2} and for total Fe as Fe^{+2} , the $Ca:Mg:Fe$, and the $(Ca+Na)_B$ and $(Na+K)_A$ values of the amphibole formula are printed. An example of the printout is given in Table 4.

PACKAGE B - PETROCHEMISTRY PROGRAMS

Programs B1-B21 are stored on one HP flexible disc and/or tape. Programs B22-B27 are stored on a separate disc or tape. The following programs are included in this package, in the order in which they appear in the "INDEX" legend:

- B1 - Petrochemistry system index ("INDEX")
- B2 - Petrochemistry data storage ("STORET")(MO)
- B3 - Continuous data tables printing ("CONTAB")(MO)
- B4 - Tables and Samples title listing ("LIST")(AYG)
- B5 - Data transfer programs ("DTRANS")(AYG)
- B6 - Selective data retrieval/tabulation ("RETPRT")(MO)
- B7 - Data retrieval for plot programs ("XYRET")(MO)
- B8 - XY plots and regression ("XYPLOT")(MO)
- B9 - Triangular plots ("XYZPLT")(MO)
- B10 - Statistics program ("STATS")(MO)
- B11 - Geochemical frequency distribution plots ("FRQPLT")(AYG)
- B12 - Normalized plots ("NORMAL")(AYG)
- B13 - Stratigraphic/geochemical columnar plots ("STRAT")(AYG)

- B14 - Log molecular proportion (alteration screening)("LMPR")(AYG)
- B15 - Partial melting programs ("PRTMLT")(AYG)
- B16 - Fractional crystallization programs ("FRCRYS")(AYG)
- B17 - Major Elements fractionation
- B18 - Mantle Fe/Mg distribution ("MANTFM")(AYG)
- B19 - Mantle trace element levels ("MANTRC")(AYG)
- B20 - Primary magma computation ("PRIMAG")(AYG)
- B21 - Siliceous magma by partial melting ("SILMAG")(AYG)
- B22 - Petrochemical classifications ("CLASS")(AYG)
- B23 - CIPW calculations from disc/tape storage ("CIPW")(MO)
- B24 - CIPW calculations from keyboard ("CPWKEY")(MO)
- B25 - CIPW retrieval for plots ("CPWRET")(MO)
- B26 - CIPW XY PLOTS ("CPWXY")(MO)
- B27 - CIPW XYZ plots ("CPWXYZ")(MO)

Common features of all programs

- (1) positive response (yes) - enter 1, press continue key
- (2) negative response (no) - no entry, press continue key
- (3) for choice of option, enter the indicated number, then press continue key. For example: Prompt "DISC (1) or TAPE (2) STORAGE"; enter 1 for disc storage of 2 for tape storage mode, press continue key
- (4) for further explanations of the principles on which these programs are based refer to Glikson (1979) and Glikson and Hickman (1981)

B1 - Petrochemistry system index ("INDEX")

The program titles given above are displayed consecutively and any one program can be selected and loaded into memory, through a positive response (1, continue key) to the desired title.

B2 - Petrochemistry data storage ("STORET"; 5022 Bytes)(MO, modified by AYG)

The program enables storage and modification of up to 10 chemical analyses, each including up to 14 major elements (in wt%) and up to 20 trace elements (in ppm), stored on 1380 Byte strings. Each analysis includes an 80 Byte long alphanumeric title/code group. Major and minor elements include SiO₂, TiO₂, Al₂O₃, Fe₂O₃, FeO, MnO, MgO, CaO, Na₂O, K₂O, P₂O₅, H₂O⁺, H₂O⁻, and CO₂. Trace elements include Ba, Rb, Sr, Pb, Th, U,

TABLE 5

PLB2[0/2] - NORTH STAR BASALT, WARRAWOONA GROUP, PILBARA, W.A.

SAMPLE NUMBER	75040002A	75040002B	75040003C	75040004A	75040004B	75040005A	75040005B	75040007A	75040007B	75040008A
FORMATION	North Star	North Star	North Star	North Star	North Star	North Star	North Star	North Star	North Star	North Star
ROCK TYPE	Basalt	Basalt	Basalt	Basalt	Basalt	Basalt	Basalt	Basalt	Basalt	Basalt
	am.cl.ep.	am.cl.ep.	sp.ep.tr.	am.sa.al.	am.qz.al.	am.al.ep.	am.sa.al.	sp.am.qz.	am.cl.al.	am.cl.al.
	al.TB	al.TB	HMB	dolerite	TB	dolerite	qz.TB	al.TB	qz.TB	qz.TB
GRID/PHOTO POINT	11951:2101	11951:2101	11951:2100	11951:2100	11951:2100	11951:2100	11951:2100	11951:2100	11951:2100	11951:2100
MAP SHEET	MARBLE BAR	MARBLE BAR	MARBLE BAR	MARBLE BAR	MARBLE BAR	MARBLE BAR	MARBLE BAR	MARBLE BAR	MARBLE BAR	MARBLE BAR
1 SiO ₂	49.54	49.22	49.68	51.21	49.72	50.69	51.13	50.49	50.64	52.58
2 TiO ₂	1.59	1.62	0.68	1.08	1.67	0.67	1.33	1.14	1.07	1.23
3 Al ₂ O ₃	13.96	13.55	5.84	15.95	14.46	15.28	13.84	14.42	13.79	14.20
4 Fe ₂ O ₃	16.07	16.30	12.44	11.84	15.14	10.43	14.01	12.96	13.01	11.97
5 FeO										
6 MnO	0.22	0.24	0.24	0.17	0.36	0.18	0.22	0.22	0.20	0.23
7 MgO	5.32	6.07	13.91	6.01	4.76	8.85	6.06	6.91	7.61	6.33
8 CaO	10.77	9.08	14.94	9.10	8.94	9.37	10.46	10.33	10.45	8.49
9 Na ₂ O	1.58	2.42	0.42	3.18	4.02	2.66	2.00	2.45	2.14	3.48
10 K ₂ O	0.37	0.30	0.22	0.49	0.37	0.88	0.32	0.19	0.23	0.32
11 P ₂ O ₅	0.17	0.17	0.40	0.15	0.16	0.05	0.16	0.10	0.09	0.11
12 H ₂ O+	0.80	0.90	0.38	1.16	0.47	1.33	0.78	0.90	0.83	1.15
13 H ₂ O-										
14 CO ₂	0.05	0.05	0.24	0.05	0.04	0.02	0.07	0.08	0.06	0.12
TOTAL	100.44	99.92	99.39	100.39	100.11	100.41	100.38	100.19	100.12	100.21
Mg NUMBER	57.0	52.4	70.4	60.3	53.9	64.0	59.6	61.2	61.4	58.4
15 Ba	81	538	36	216	52	232	106	105	82	67
16 Rb	11	11	2	32	12	57	8	4	8	10
17 Sr	317	258	26	336	115	191	144	119	115	107
18 Pb	2	2								
19 Th										
20 U	1							1	1	
21 Zr	137	145	29	84	147	46	129	96	81	106
22 Nb	5	7		5	8	2	6	5	4	4
23 Y	33	35	14	21	33	16	32	26	24	25
24 La	5	5		12	10	3	5	4	4	2
25 Ce	28	29		23	24		13	3	5	12
26 Li	31	36	13	32	16	39	21	19	17	21
27 V	374	352	324	229	391	248	312	349	332	302
28 Cr	132	116	1400	146	187	865	52	199	194	70
29 Co	49	51	66	40	50	40	42	41	42	49
30 Ni	62	57	399	65	87	109	56	71	71	51
31 Cu	99	99	236	63	8	69	46	64	75	33
32 Zn	106	120	64	86	121	64	103	90	87	88
33 Ga	22	20	9	17	20	13	17	17	18	16
34 S	1040	480	640	160	40	80	80	40	40	

Zr, Nb, Y, La, Ce, Li, V, Cr, Co, Ni, Cu, Zn, Ga, and S. The program can readily be changed to include other elements. Title group entry prompts include "SAMPLE NUMBER", "FORMATION" (2 lines), "ROCK TYPE" (2 lines), "GRID OR PHOTO REFERENCE", and "MAP SHEET". These can also be easily changed within the program. Up to 10 alphanumeric characters can be entered in each line.

For tape storage mark data files 1470 Byte long on HP tape. Data input and modification procedures are the same as for program A2. For disc storage data files coding should consist of 3 alphabetic characters followed by a file number in the 1-999 range, cf. YLG3, PLB64, KAP325. A printout format is shown in Table 5. The Mg' number is calculated and printed at the bottom of each column.

- B3 - Continuous data tables printing ("CONTAB"; 3664 Byte)(MO)
- B4 - Tables and samples title listing ("LIST"; 1172 Bytes)(AYG)
- B5 - Data transfer programs ("DTRANS"; 1376 Bytes)(AYG)
- B6 - Selective data retrieval/tabulation ("RETPRT"; 4272 Bytes)(MO)
- B7 - Data retrieval for plots programs ("XYRET"; 2872 Bytes)(MO)
- B8 - XY plots and regression ("XYPLOT"; 7210 + 2808)(MO)(Fig. 6)
- B9 - Triangular plots ("XYZPLT"; 5846 Bytes)(MO)(Fig. 7)

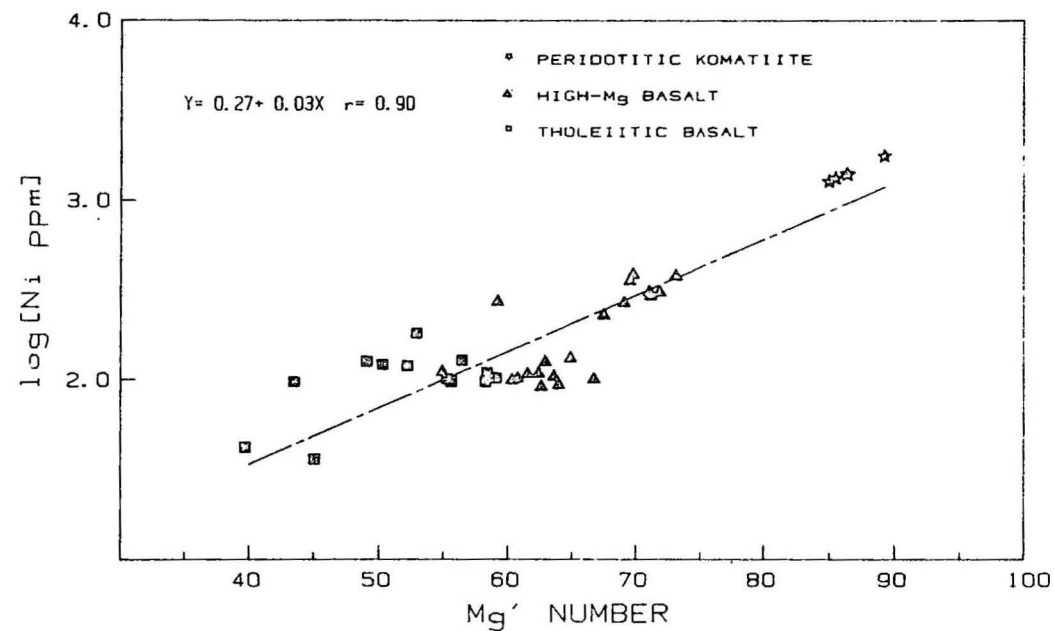
The principles of these programs and the input/output modes are similar to programs A3, A4, A5, A6, A7, A8, and A9 respectively, of the Mineral Chemistry program package described above. The main difference relates to the tabulation, listing, transfer, retrieval and plotting of trace elements rather than of mineral formula cations. For instruction for running these programs refer to corresponding package A programs. For line/element numbers refer to Table 5. For percentage to ppm conversion factors, refer to Appendix I.

- B10 - Statistics program ("STATS"; 5896 Bytes)(MO)

This program yields a list of samples retrieved by a two inclusive or exclusive search keywords specified from keyboard, lists the analyses in horizontal format, allows deletion of individual analyses from the calculation of a mean value, and prints the maximum value, minimum value, mean and standard deviation for the selected sample population. In this regard the program is analogous to program A10. However, the program

Fig. 6

APEX BASALT [PILBARA. W. A.]



SAMPLE STATISTICS

Mg' NUMBER-mean	63.54	Mg' NUMBER-variance	144.75	Mg' NUMBER standard dev.	12.03
log[Ni ppm]-mean	2.27	log[Ni ppm]-variance	0.18	log[Ni ppm] standard dev.	0.42
Number of Samples =	38				

REGRESSION RESULTS

Slope = 0.03 Standard error = 0.00
Intercept = 0.27 Standard error = 0.17
Correlation Coefficient = 0.90

T-Value = 1.00

ANALYSIS OF VARIANCE TABLE

SOURCE	TOTAL	REGRESSION	RESIDUAL
SUM-OF-SQUARES	6.56	5.28	1.28
DEGREES FREEDOM	37.00	1.00	36.00
MEAN SQUARE	0.18	5.28	0.04

F-TEST RESULTS

F-statistic = 148.88 deg. freedom in num. = 1.00 deg. freedom in den. = 36.00

Fig. 7

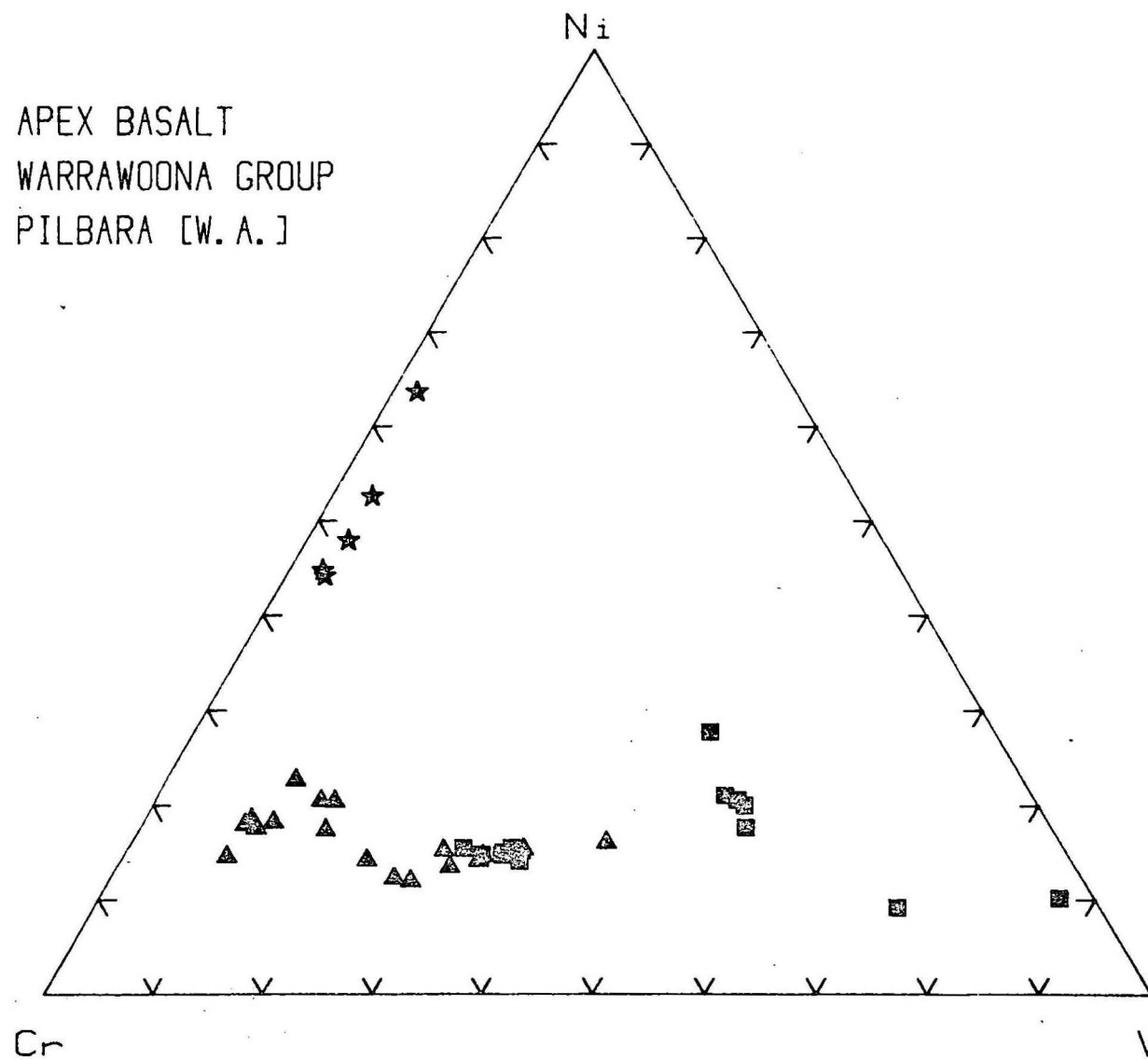


TABLE 6 [A]

Mount Edgar Batholith

Sample no.	SiO ₂	TiO ₂	Al ₂ O ₃	Fe ₂ O ₃	FeO	Tot. Fe	MnO	MgO	CaO	Na ₂ O	K ₂ O	P ₂ O ₅
75040015	74.70	0.05	13.38	1.34	0.00	1.21	0.05	0.81	1.60	4.35	2.96	0.00
75040015	74.39	0.08	13.55	1.68	0.00	1.51	0.04	0.11	0.49	3.00	3.25	0.01
75040016	71.39	0.28	14.60	3.63	0.00	3.27	0.06	0.55	2.45	4.93	1.40	0.07
75040018	72.20	0.20	14.34	2.75	0.00	2.48	0.06	0.42	2.27	4.58	2.33	0.05
75040018	72.55	0.17	14.54	2.45	0.00	2.21	0.05	0.35	2.27	4.83	2.32	0.04
75040040	65.93	0.51	14.95	5.33	0.00	4.80	0.09	2.22	4.33	3.97	1.64	0.13
75040040	66.28	0.52	15.18	5.49	0.00	4.94	0.10	0.48	4.72	3.97	1.46	0.13
75040042	73.16	0.19	13.35	2.26	0.00	2.03	0.02	0.43	1.90	4.81	2.00	0.04
75040049	67.92	0.44	16.05	3.77	0.00	3.39	0.06	1.01	3.27	5.37	1.60	0.12
75040049	68.77	0.35	16.00	3.01	0.00	2.71	0.05	0.73	2.84	5.25	2.30	0.09
75040090	72.98	0.20	14.18	2.96	0.00	2.66	0.05	0.36	2.70	5.32	0.95	0.04
75040090	72.21	0.16	14.16	2.62	0.00	2.36	0.07	0.26	2.35	4.96	1.93	0.05
75040090	70.65	0.00	15.75	0.48	0.00	0.43	1.93	0.00	0.34	7.56	2.75	0.02
75040090	72.47	0.00	16.06	0.49	0.00	0.44	2.01	0.00	0.28	4.80	2.77	0.01
75040091	68.74	0.33	16.11	2.84	0.00	2.56	0.05	0.75	2.61	4.49	3.14	0.08
Mean	70.96	0.27	14.81	2.74	0.00	2.47	0.31	0.65	2.29	4.81	2.19	0.06
Maximum	74.70	0.52	16.11	5.49	0.00	4.94	2.01	2.22	4.72	7.56	3.25	0.13
Minimum	65.93	0.05	13.35	0.48	0.00	0.43	0.02	0.11	0.28	3.00	0.95	0.01
S. Dev.	0.59	0.02	0.35	0.03	0.00	0.02	0.07	0.03	0.08	0.09	0.25	0.00

Sample no.	Ba	Rb	Sr	Pb	Th	U	Zr	Nb	Y	La	Ce	Li	V	Cr	Cc	Ni	Cu	Zn	Ga	S
75040015	413	134	86	17	8	2	60	9	21	22	27	22	4	6	3	5	8	30	15	120
75040015	454	54	166	9	14	2	258	12	15	47	72	39	21	6	3	4	4	32	17	40
75040016	617	150	87	11	8	3	85	9	21	22	32	48	6	11	6	5	8	46	15	
75040018	352	88	164	14	9	3	167	10	21	29	46	55	13	10	7	4	10	44	16	40
75040018	342	84	165	14	9	3	155	9	20	31	40	49	12	9	5	4	8	39	16	
75040040	363	77	284	6	8	1	174	9	24	36	57	42	70	89	17	49	21	59	16	40
75040040	317	69	290	7	8		146	8	23	40	63	36	68	104	16	50	44	59	16	40
75040042	612	52	176	9	16	3	156	8	16	41	54	11	17	16	6	6	64	21	14	200
75040049	385	112	411	12	17	2	194	6	10	55	85	321	41	19	11	11	12	84	21	240
75040049	866	136	426	13	12	1	169	7	15	51	74	301	37	14	10	10	18	63	19	200
75040090	99	70	145	8	9	1	208	16	9	34	50	408	11	8	4	5	6	54	17	200
75040090	293	85	134	13	14	2	146	14	19	45	70	173	9	9	5	3	4	54	18	
75040090	8	799	19	8	3	2	12	34	20			72		5	2	3	3	8	57	
75040090	132	79	146	10	12	1	213	16	10	50	82	415	14	8	5	4	6	61	18	280
75040091	498	114	339	18	8	2	136	6	11	35	48	40	33	12	7	9	12	56	19	
Mean	383	140	203	11	10	2	152	12	17	38	57	135	25	22	7	11	15	47	20	140
Maximum	866	799	426	18	17	3	258	34	24	55	85	415	70	104	17	50	64	84	57	280
Minimum	8	52	19	6	3	1	12	6	9	22	27	11	4	5	2	3	3	8	14	40
S. Dev.	31	7	36	2	1	0	4	1	2	1	3	26	2	3	0	1	1	2	0	47

Number of samples is 15

TABLE 6 [B]

Mount Edgar Batholith (major elements)												
	SiO ₂	TiO ₂	Al ₂ O ₃	Fe ₂ O ₃	FeO	Tot. Fe	MnO	MgO	CaO	Na ₂ O	K ₂ O	P ₂ O ₅
SiO ₂												
TiO ₂	-0.98											
Al ₂ O ₃	-0.67	0.75										
Fe ₂ O ₃	-0.74	0.93										
FeO												
Tot. Fe	-0.74	0.93		1.00								
MnO		0.68		-0.61		-0.61						
MgO	-0.64	0.61		0.56		0.56						
CaO	-0.75	0.91		0.96		0.96	-0.61	0.58				
Na ₂ O							0.55					
K ₂ O				-0.67		-0.67			-0.67			
P ₂ O ₅	-0.91	0.99		0.91		0.91		0.72	0.92			
Ba							-0.59					
Rb							0.64			0.81		
Sr	-0.69	0.73	0.52	0.57		0.57			0.61			0.73
Pb												
Th												
U												
Zr										-0.58		
Nb				-0.56		-0.56	0.77		-0.57	0.69		-0.55
Y												
La												
Ce												
Li												
V	-0.91	0.89		0.78		0.78		0.63	0.75			0.84
Cr	-0.75	0.78		0.79		0.79		0.54	0.76			0.74
Co	-0.88	0.94		0.88		0.88		0.68	0.86			0.92
Ni	-0.78	0.80		0.79		0.79		0.62	0.76			0.77
Cu												
Zn	-0.56	0.74	0.52	0.56		0.56			0.59			0.64
Ga							0.68			0.80		
S							0.50			0.78		

Mount Edgar Batholith (trace elements)

	Ba	Rb	Sr	Pb	Th	U	Zr	Nb	Y	La	Ce	Li	V	Cr	Co	Ni	Cu	Zn	Ga	S
Ba																				
Rb																				
Sr	0.51																			
Pb																				
Th		-0.57																		
U																				
Zr		-0.70			0.65															
Nb	-0.70	0.85	-0.63																	
Y																				
La			0.58		0.76		0.69		-0.53											
Ce			0.53		0.69		0.72			0.98										
Li						-0.65			-0.72	0.55	0.58									
V			0.72																	
Cr				-0.52									0.88							
Co			0.69										0.94	0.89						
Ni													0.91	0.99	0.90					
Cu																				
Zn	-0.53	0.74					0.51	-0.54		0.52	0.59	0.57	0.51		0.60					
Ga	0.98						-0.56	0.87		0.69	0.69									
S					0.53				-0.82			0.79		-0.50		-0.50				

described here also calculated and tabulated correlation coefficients for (1) major elements vs major and trace elements, and (2) trace elements vs trace elements (Table 6). Only correlation coefficients higher than 0.5 or lower than -0.5 are printed. These limits can be altered by simple changes to the program.

B11 - Geochemical frequency distribution plots ("FRQPLT"; 8094 Bytes)(AYG)

The program retrieves data from 1470 Byte data files and enables plotting of frequency distribution curves or of percentage frequency distribution curves of specified compositional intervals for any particular element, or for the element combinations A/B, major element A/trace element B. Frequency distribution of FeO_t (total iron as FeO) and $\text{FeO}_t/\text{element B}$ can also be plotted. Calculation of cumulative frequency distribution can be performed by automatic storage of values in cumulative registers. These registers can be cleared at the outset of each program cycle if desired. Subtitles for each frequency distribution curve and the number of samples N for each plot are printed at the right hand top part of the diagram (Fig. 8).

Input routine

The following input information and diagram design parameters can be entered:

"GRAPH TITLE"; overall title to be labelled above the diagram.

"ABSOLUTE (0) or % FREQUENCY (1)". Where only a small sample population is concerned, or populations of very different numbers of samples (N) are compared, % frequency plots are preferable and can be selected.

"MAJOR ELEMENT SYMBOL" or "MINOR ELEMENT SYMBOL", to be plotted below the X axis.

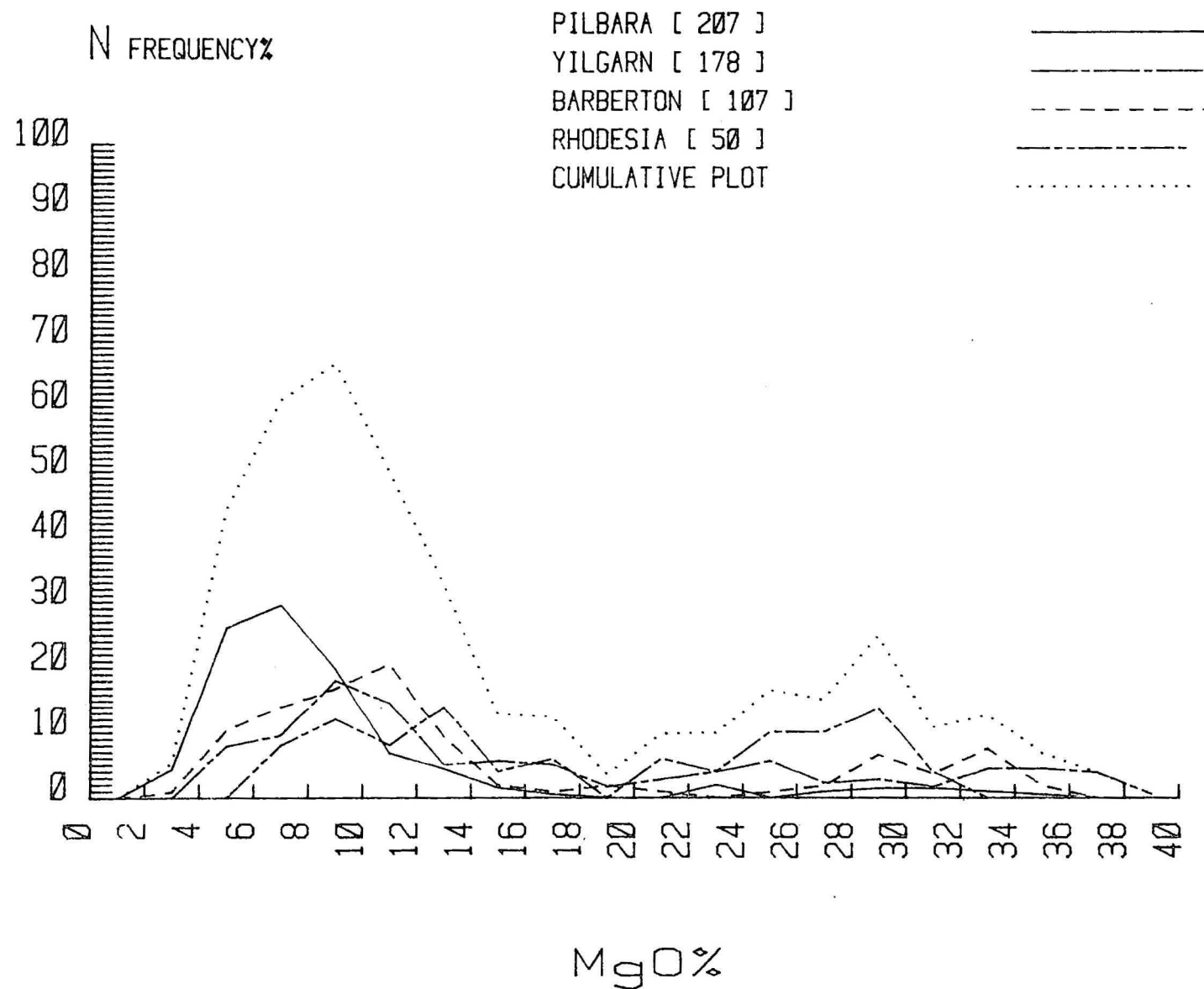
"ELEMENT CODE LINE (Modify = 40)"; see Table 5 for element/line numbers. For element combinations enter 40, followed by optional printing of modify codes printed on the thermal printer, followed by entry of a selected modify code.

Enter "MAXIMUM VALUE" and "MINIMUM VALUE" to specify the compositional range of the frequency plot.

Enter "HISTOGRAM INTERVAL", for the compositional intervals desired. Up to 20 intervals are allowed, i.e. down to 5% of the total range. The number of intervals selected is printed on the thermal printer.

Enter "SUBTITLE OF FREQUENCY PLOT", to be plotted along with the line type and number of samples (N) as a legend located at the upper right hand side of the diagram (Fig. 8).

Fig. 8
MgO FREQUENCY% DISTRIBUTION



Data retrieval uses 4 search keywords, three of them inclusive or exclusive and one exclusive.

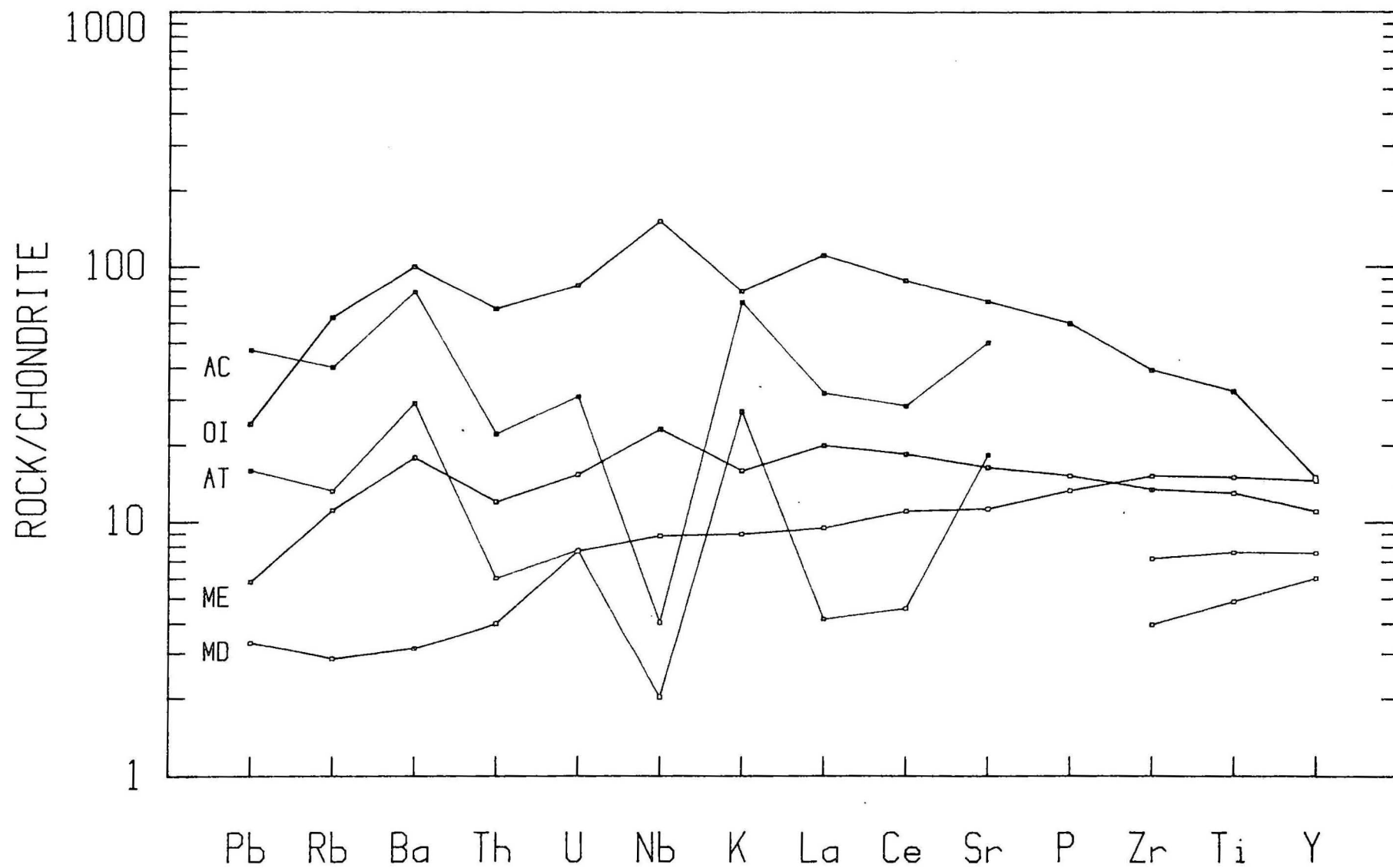
If absolute frequency is plotted, the maximum of Y axis units (the mode) can be specified from keyboard on the basis of the maximum value printed on the thermal printer (when determining Y allow for possible higher modes in subsequent curves and in the cumulative plot). The length of the X and Y axes is specified in cm. The P1 and P2 plotter field parameters are then set according to specified dimensions as desired. Tic/label ratios, decimal points on axes labels, pen type(1-4), line type (1-6), and line segment (scale of line components)(see 9872A plotter manual) are specified from keyboard. Several plots can be made on the same diagram, the legends being labelled consecutively after completion of each graph. A cumulative plot can be activated at the end of each plot cycle.

B12 - Normalised plots ("NORMAL"; 3982 Bytes)(AYG)

The program retrieval data from 1470 Byte data files, divides the values of Y, Ti, Zr, P, Sr, Ce, La, K, Nb, U, Th, Ba, Rb, and Pb by model mantle values of these elements (Sun, 1980) stored in the program, or other data sets entered from keyboard, and plots the normalised values on a linear scale, or a log scale within the range of 0.1-1000. The above elements, listed in increasing ionic radii yield smooth normalised curves for ocean basalts (MORB)(Fig. 9), and departures of plotted data curves from this regularity are geochemical significance. The program can be readily adopted for other elements.

Design of the diagram from keyboard includes entry of a title and its preferred letter size and H/W (height/width) proportions, entry of minimum and maximum normalised values: for log plots select 0.1, 1, 10, or 100 as a minimum value. Tic intervals, tic/label ratio, decimal of numeric label and pen number can be specified from keyboard. The diagram can be offset on the sheet (in cm). Following drawing of the diagram, data retrieval can proceed, selecting samples by one or two search keywords and the file number range through which retrieval is desired. When plotting is complete further data can be retrieved and plotted on the same diagram, or a new diagram of same dimensions can be plotted without having to re-specify its design. The sample number and the Mg' number are printed to the left and the right of the plot, respectively. A normalised log plot is shown in Fig. 9.

Fig. 9 AVERAGE MODERN BASALTS [S. SUN, 1980, PTRSL]



B13 - Stratigraphic/geochemical plots ("STRAT"; 4068 Bytes)(AYG)

This program plots the value of a major or trace element or their combinations retrieved from 1470 byte data files against its stratigraphic level or bore hole depth. For successions of samples it thus constructs a stratigraphic/geochemical variation diagram (Fig. 10). Modified values including element A/element B, major A/trace B, and FeO_t (total iron as FeO) can be also calculated and plotted. Different plot symbols are allotted to different petrochemical rock types identified by the program in the title groups, as follows: P - periodotitic komatiite ("PK"); H - high-Mg basalt ("HMB"); X-pyroxenite ("pyrox"); T - tholeiitic basalt ("TB"), D - dolerite ("doler"), G - gabbro ("gabbro"); A - andesite ("and"); C - dacite ("dac"); and R - rhyolite ("rrhyol"). The code words shown in inverted comas must be stored in the corresponding sample title groups, using program B2 ("STORET"). For any other rock type the symbol (+) is labelled. To enable retrieval of a stratigraphic level value this value must be stored in the 7th line of the sample title group, in place of "MAP SHEET".

Design of diagram

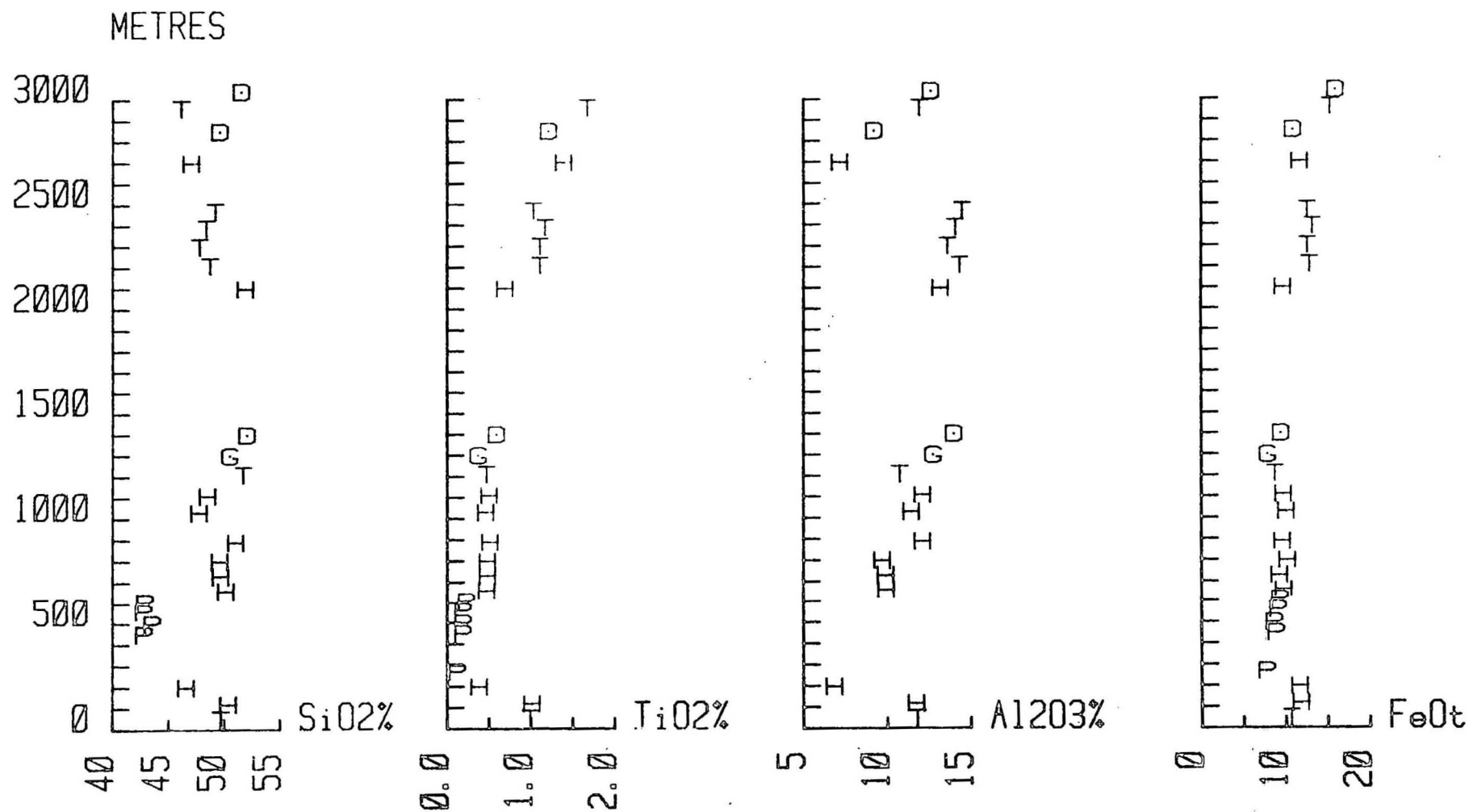
The following parameters are entered from keyboard: "MAJOR ELEMENT SYMBOL" or "MINOR ELEMENT SYMBOL". "ELEMENT CODE LINE (Modify = 40)"; refer to Table 5 for element/line codes. A modify code can be optionally printed on the thermal printer. Next, parameters are allocated for "MINIMUM ELEMENT LEVEL", "MAXIMUM ELEMENT LEVEL" (to define the X axis), "BASE OF SECTION" (in metres), and "TOP OF SECTION" (in metres) to define the Y axis. Diagram dimensions in cm, X and Y axes tic intervals, label/tic ratios, decimal point of numeric labels, diagram offset (in cm) on the sheet, and pen colour for symbols are specified from keyboard. Selective retrieval proceeds by specifying two inclusive or exclusive search keywords and the file number range to be searched. On completion of plotting, labelling of the diagram from keyboard, with specified letter size and H/W proportions, is enabled. Plotting of several diagrams on the same sheet can be achieved by offsetting (Fig. 10).

B14 - Log molecular proportions (alteration screening)("LMPR", 7240 Bytes (AYG)

The program allows plots of $\log (A/\text{Alk})$ vs $\log (B/\text{Alk})$, A or B being SiO_2 , Al_2O_3 , $(\text{FeO}+\text{MgO})$, or CaO , Alk being K_2O or Na_2O . Plots include: $\log (\text{SiO}_2/\text{K}_2\text{O})$ vs $\log (\text{Al}_2\text{O}_3/\text{K}_2\text{O})$; $\log (\text{CaO}/\text{K}_2\text{O})$ vs $\log (\text{SiO}_2/\text{K}_2\text{O})$; $\log$

Fig. 10

SALGASH SUBGROUP - CAMEL CREEK SECTION



($\text{CaO}/\text{K}_2\text{O}$) vs $\log (\text{Al}_2\text{O}_3/\text{K}_2\text{O})$; $\log (\text{SiO}_2/\text{K}_2\text{O})$ vs $\log (\text{FM}/\text{K}_2\text{O})$, and $\log (\text{CaO}/\text{K}_2\text{O})$ vs $\log (\text{FM}/\text{K}_2\text{O})$ (Fig. 11). The plotted sample points are compared by the program to the distribution fields of least-altered modern volcanic suites as outlined by Beswick and Soucie (1978). The measurement of departure of individual samples from the least-altered field provides a possible alteration index. Note that, since variations in the rationing alkali oxides (K_2O or Na_2O) effect the migration of a point mainly within the modern field, departures are caused mainly by variations in Si, Al, Ca, Fe and Mg. The program contains the parameters of the modern fields, measures the relations between each plotted sample and these fields and, where applicable, prints a departure index and the corresponding sample number on the 9871A printer (Fig. 11). Significant departure indices can be subsequently used to screen these analyses out in programs to which the application of only least-altered samples is desired, i.e. the LMPR program can be used as an alteration screening procedure. This can be done by inserting an alteration parameter or code into the sample title group and screening it out accordingly. For example, altered samples can be coded by entering the rock type in U.C. or L.C. letters to distinguish them from less altered samples upon data retrieval.

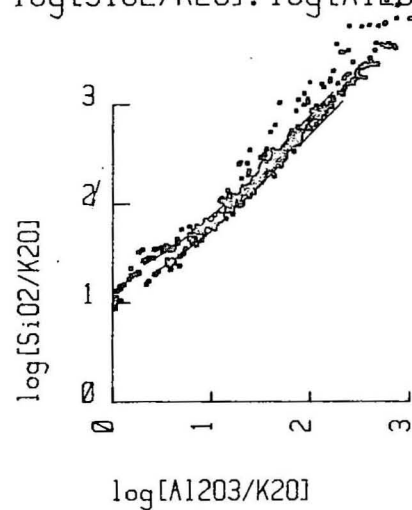
Input routine

A rationing oxide (K_2O or Na_2O) and its line code number (Table 5) are entered; then the major oxides for the X and Y axes (SiO_2 , Al_2O_3 , CaO or FeO+MgO) and their respective line code numbers are entered. If "FM" (FeO+MgO) is entered into the X axis register, the corresponding value will be retrieved automatically without need for entering the line code numbers of FeO and MgO. The LMPR diagram is designed by entering maximum and minimum values for the X and Y axes (normal range 0-3), X and Y axes length (in cm), axes tic/label ratios, decimal points on numeric labels, title of plot, offset parameters and pen type. Data are retrieved using two inclusive or exclusive search keywords. The data can be visually compared to the approximate limits of the modern least-altered field by responding positively to the prompt "MODERN FIELD LIMIT PLOTS?". Concomitant with plotting, departure indices in $\log (\text{C}/\text{K}_2\text{O})$ units perpendicular to field limit (C = function of A and B) are printed on the 9871A printer (Fig. 11), allowing an estimate of the possible degree of alteration of each point.

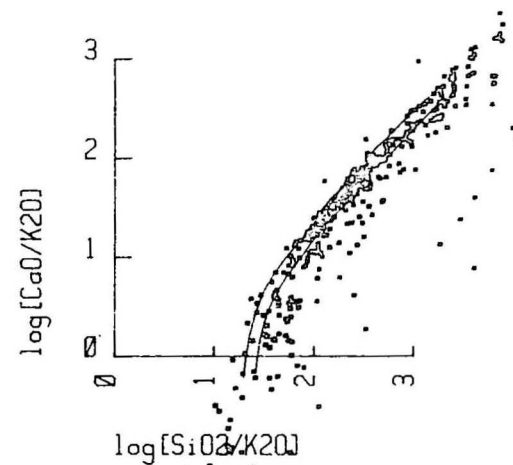
Fig. 11

WARRAWOONA GROUP & GORGE CREEK GROUP

$\log[\text{SiO}_2/\text{K}_2\text{O}] : \log[\text{Al}_2\text{O}_3/\text{K}_2\text{O}]$

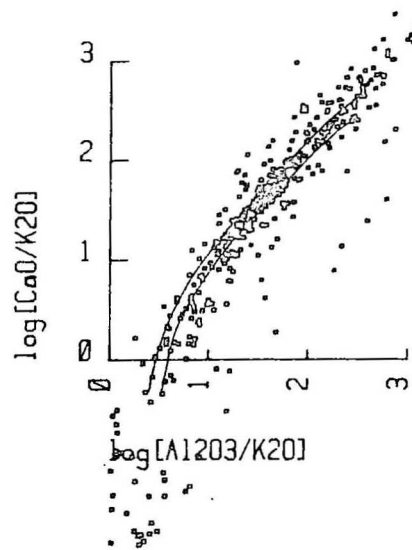


$\log[\text{CaO}/\text{K}_2\text{O}] : \log[\text{SiO}_2/\text{K}_2\text{O}]$

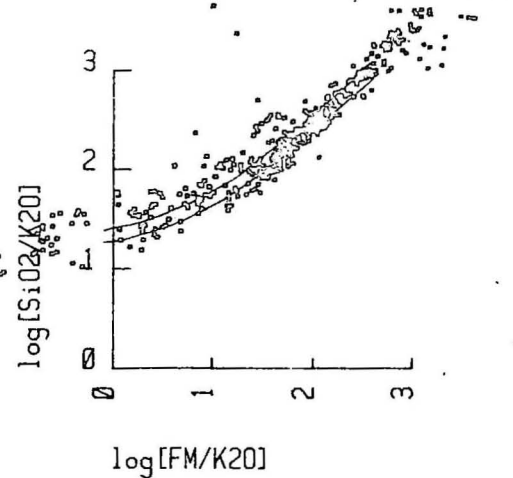


KOMATIITES & PYROXENITES
BASALTS & DOLERITES
DACITES & ANDESITES
RHYOLITES

$\log[\text{CaO}/\text{K}_2\text{O}] : \log[\text{Al}_2\text{O}_3/\text{K}_2\text{O}]$



$\log[\text{SiO}_2/\text{K}_2\text{O}] : \log[\text{FM}/\text{K}_2\text{O}]$



$\log[\text{CaO}/\text{K}_2\text{O}] : \log[\text{FM}/\text{K}_2\text{O}]$

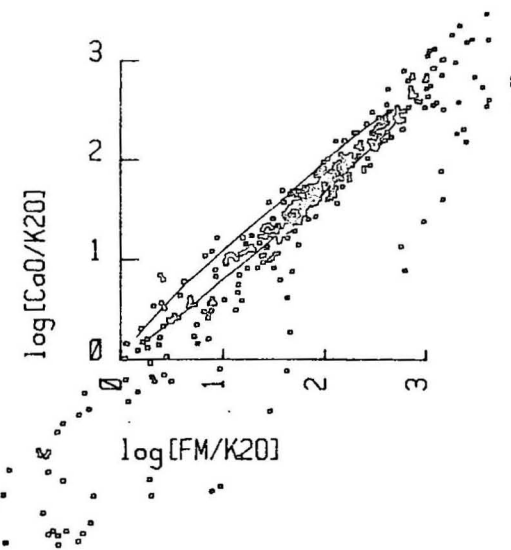


TABLE 7

Zr MANTLE ABUNDANCES

ASSUMED FRACTION MELTING = 0.30

SOURCE MINERALOGY:				Op=0.20 Kd= 0.000:				Plg=0.30 Kd= 0.100:			
				Cp=0.30 Kd= 0.010:				Bi=0.10 Kd= 0.200:			
SAMPLE NO.	ELEMENT SYMBOL	ROCK ppm	SOURCE ppm	SAMPLE NO.	ELEMENT SYMBOL	ROCK ppm	SOURCE ppm	SAMPLE NO.	ELEMENT SYMBOL	ROCK ppm	SOURCE ppm
75040002A	Zr	137	46	75040002B	Zr	145	49	75040004B	Zr	147	50
75040005B	Zr	129	43	75040007A	Zr	96	32	75040007B	Zr	81	27
75040008A	Zr	106	36	75040008b	Zr	104	35	75040009	Zr	98	33
75040012	Zr	86	29	75040016B	Zr	74	25	75040016F	Zr	62	21
75040016H	Zr	77	26	75040016I	Zr	77	26	75040016J	Zr	76	26
75040016O	Zr	62	21	75040016Q	Zr	63	21	75040017A	Zr	94	32
75040017B	Zr	88	30								

FINDING FRACTION MELTING

ASSUMED SOURCE REGION ELEMENT ABUNDANCE = 46 ppm

SOURCE MINERALOGY:				Op=0.20 Kd= 0.000:				Plg=0.30 Kd= 0.100:			
				Cp=0.30 Kd= 0.010:				Bi=0.10 Kd= 0.200:			
SAMPLE NO.	ELEMENT SYMBOL	ROCK ppm	F MELT	SAMPLE NO.	ELEMENT SYMBOL	ROCK ppm	F MELT	SAMPLE NO.	ELEMENT SYMBOL	ROCK ppm	F MELT
75040002A	Zr	137	0.30	75040002B	Zr	145	0.28	75040004B	Zr	147	0.27
75040005B	Zr	129	0.32	75040007A	Zr	96	0.45	75040007B	Zr	81	0.54
75040008A	Zr	106	0.40	75040008b	Zr	104	0.41	75040009	Zr	98	0.44
75040012	Zr	86	0.51	75040016B	Zr	74	0.60	75040016F	Zr	62	0.73
75040016H	Zr	77	0.57	75040016I	Zr	77	0.57	75040016J	Zr	76	0.58
75040016O	Zr	62	0.73	75040016Q	Zr	63	0.72	75040017A	Zr	94	0.46
75040017B	Zr	88	0.50								

B15 - Partial melting programs ("PRTMLT", 7138 Bytes)(AYG)

The program applies Henry's equilibrium batch melting law (Shaw, 1968) to three different problems: (1) finding the initial level of a trace element (C_o^e) in the source rocks of an analysed igneous rock representing liquid composition (C_L^e); (2) finding the fraction of partial melting (F) of a given source composition required to yield a given trace element concentration of an analysed rock, given the residue mineralogy and D^e mineral/melt partition coefficients; and (3) finding the concentration of a trace element in a melt (C_L^e) formed from a given (C_o^e), a given (F), the residue mineral composition, and D^e mineral/melt partition coefficients. Subprograms (1) and (2) retrieve data from disc or tape, while in subprogram (3) all parameters are entered from keyboard.

in Henry's law
$$\frac{C_L^e}{C_o^e} = \frac{1}{K_d^e + F(1-K_d^e)} \quad \dots (1)$$

e - trace element symbol

C_L^e - element (e) level in the liquid (partial melt)

C_o^e - initial level of element (e) in the source rocks

F - fraction of partial melting

K_d^e - bulk crystals/melt partition coefficient

$$K_d^e = D_a^e A + D_b^e B + D_c^e C \text{ etc} \quad \dots (2)$$

D_a^e - crystal/melt partitioning coefficient for mineral (a)

A - fraction of mineral A in the total residue

Any one of the three subprograms can be selected at the outset of the program by responding positively to consecutive prompts.

Subprogram B15 (A): Finding (C_o^e), as derived from equation (1):

$C_o^e = C_L^e (K_d^e + F(1-K_d^e))$. Input information includes title of table, trace element symbol, and element code line (see Table 5). The F values can either be retrieved from the data files, where they can be stored in the

title groups (in the 6th line of the title group, cf. "LPx27xHP34x" (LP stands for low pressure and HP for high pressure, read from program B18), or (F) can be entered from keyboard. Up to 5 residual minerals can be specified; for each mineral a name (up to 10 characters), a percentage and a D^e value are entered. For D^e mineral/melt values refer to Arth (1976), Irvine (1978), Allegre et al. (1977), and others. The printout format is shown in Table 7. It includes a print of the (D^e) values entered for the various minerals. For each sample, the sample number, element (e) symbol, observed concentration of element (e) in the rock (C_L^e) in ppm, and calculated source rock level (C_o^e), are printed.

Subprogram B15 (B): As a derivation from equation 1:

$$F = \frac{C_o^e - C_L^e K_d^e}{C_L^e - C_L^e K_d^e} \quad \dots (3)$$

Keyboard input specified (C_o^e) and residue mineralogy composition. (C_L^e) is retrieved from data files. The printout gives the sample number, element (e) symbol, (C_L^e), and the calculated F value.

Subprogram B15 (C): This subprogram allows keyboard entry of (C_L^e) (which is retrieved in Subprograms (A) and (B) from disc or tape storage), applied to the same type of calculations as in Subprograms (A) and (B). A third option is the calculation of the trace element (e) level of a partial melt (C_L^e) from a given source composition (C_o^e) and a given (F) value entered from keyboard. The element concentration in the melt (C_L^e) is given by:

$$C_L^e = \frac{C_o^e}{(K_d^e + F(1 - K_d^e))} \quad \dots (4)$$

Any one of the three options is selected at the outset of the subprogram by responding positively to consecutive prompts. In all options entry of up to 10 residual minerals is allowed and for each mineral its percentage in the residue and (D^e) mineral/melt value are entered. The bulk partition coefficient K_d^e calculated by equation 2 is printed on the thermal printer.

B16 - Fractional crystallization programs ("FRCRYS"; 7152 Bytes)(AYG)

The program allows similar calculations as program B15, except that the Rayleigh non-equilibrium fractional crystallization equation is applied:

$$\frac{C_L^e}{C_O^e} = F(K_d^e - 1) \quad \dots (5)$$

(symbols as for equation 1).

The first subprogram B16(a) calculates the trace element abundance of a parent magma (C_O^e), given the residual liquid composition (C_L^e) and the degree of fractional crystallization (F). The second subprogram B16(b) calculates (F) from given parental magma (C_O^e) and residual liquid compositions (C_L^e). Both subprograms retrieve (C_L^e) data from disc/tape. In the third subprogram B16(c) data are entered from keyboard, with three optional calculations: (1) finding C_O^e from given C_L^e and F; (2) finding F from given C_O^e and C_L^e , and (3) finding C_L^e given C_O^e and F.

B17 - Major elements fractionation ("MAJFRC"; 3026 Bytes)(AYG)

In this program the major element composition of a partial melt or residual liquid is calculated for a given major elements source rock of magma composition, and given mineral residue composition specified from keyboard. Up to 5 minerals can be entered; the percentage and major element composition of each mineral are entered from keyboard and are stored on a 5x13 Bytes array. The major element data for an assumed source can also be retrieved from 1470 Byte data files using two inclusive search keywords. The residual melt composition is calculated according to mass balance, as follows:

$$C_O^E = PT + C_L^E (1-P) \quad \dots (6)$$

$$\text{or } C_L^E = \frac{C_O^E - PT}{1-P} \quad \dots (7)$$

E - major element

C_L^E - fraction element (E) in residual liquid

C_O^E - fraction element (E) in parent rock or magma

P - fraction of mineral in the solid+melt system

T - fraction of element (E) in mineral

For a number of minerals $PT = P_1T_1 + P_2T_2 + P_3T_3 \dots$ etc. and F (fraction of liquid) = $1 - (P_1 + P_2 + P_3)$.

If data are retrieved from file, the 9871A printer lists the sample number and the calculated major element composition of the residual liquid. If all data are entered from keyboard, the results are printed on the thermal printer.

B18 - Mantle Fe-Mg distribution ("MANTFM"; 4502 Bytes)(AYG)

The calculations performed by this program follow Hanson and Langmuir (1978), computing the Mg' number ($100\text{MgO}/(\text{MgO}+\text{FeO})$ (in mol. %) of mantle source peridotite on the basis of (1) the MgO and FeO_t of an observed ultramafic liquid composition (analysed rock); (2) partition coefficient for olivine D_{O1}^{Mg} and D_{O1}^{Fe} deduced from Roeder and Emslie's (1970) formulas:

$$\log D_{O1}^{\text{Fe}} = \frac{3911}{T} - 2.50 \quad \log D_{O1}^{\text{Mg}} = \frac{3440}{T} - 1.87 \quad \dots (8)$$

assuming that for highly magnesian magmas olivine is the only liquidus phase, the liquidus temperature T is read from the MgO-FeO (Mol %) pyrolite melting diagram of Hanson and Langmuir (1978) (Fig.12), from which the fraction of partial melting (F) is also read. Both T and F can be read from grids for low-P (Okb) or high-P (30kb) melting conditions. However, since the mantle Mg-Fe distribution is the unknown in question in this program, to avoid a circular argument a different method of estimating (F) has been devised (Glikson, 1979; Glikson and Hickman, 1981). Since for high degrees of melting:

$$C_{\text{mantle}}^{\text{MgO}+\text{FeO}} = F C_{\text{melt}}^{\text{MgO}+\text{FeO}} + (1-F) C_{O1}^{\text{MgO}+\text{FeO}} \quad \dots (9)$$

For an ultramafic liquid composition with a known $C_L^{MgO+FeO}$, assuming MgO + FeO of 53.15% (mol. %) for the mantle as in pyrolite, since MgO+FeO in O1 is 66.6% (mol. %), F is obtained by

$$F = \frac{(53.15 - 66.6)}{C_L^{Mg+Fe} - 66.6} \quad \dots (10)$$

The mantle Mg' number = $\frac{100 C_O^{MgO}}{(C_O^{MgO} + C_O^{FeO})}$ can be derived from:

$$Mg' = \frac{100 C_L^{Mg} (D_{O1}^{Mg} (1-F) + F)}{C_L^{Mg} (D_{O1}^{Mg} (1-F) + F) + C_L^{Fe} (D_{O1}^{Fe} (1-F) + F)} \quad \dots (11)$$

Since the liquidus temperature T can be read from the diagram from both low and high P grids, two sets of D_{O1}^{Mg} and D_{O1}^{Fe} are calculated and two different mantle Mg' values are obtained.

The analytical data are retrieved from disc or tape storage, while keyboard input specifies the following: (1) An incompatible (hygromagmato- phile) element (i) symbol and line number (Zr is commonly used). If calculation of (F) is derived from equation 5, where $K_d^i = 0$ (Allegre et al., 1977):

$$F = C_O^i / C_L^i \quad \dots (12)$$

C_L^i is retrieved from data file storage. However, since the level of C_O^i can only be assumed, the method is of questionable value.

Analyses are retrieved using two inclusive or exclusive search keywords. The design of the MgO-FeO plot proceeds by entering pen type, pen velocity, X and Y axes length (in cm), tic intervals and tic/label ratios, decimal points for axes numbers, axes labels and diagram offset parameters. The plotter P_1 and P_2 parameters are set at 38/25. Following the plotting of each point, the program stops, calling for entry of T and F parameters read by superposing a transparent overlay on Fig. 12 on the plot. To facilitate this procedure, draw a transparent copy of Fig. 12 and match the dimensions of the plot precisely to those of the overlay.

The program will send the prompts: "READ FRACTIONMELTING"; "READ TEMPERATURE (Okb)"; "LOW-P PYROLITE COMPUTATION?"; "HIGH-P READING REQUIRED?"; "READ FRACTION MELTING (30kb)"; "READ TEMPERATURE (30kb)"; "HIGH-P PYROLITE

TABLE 8

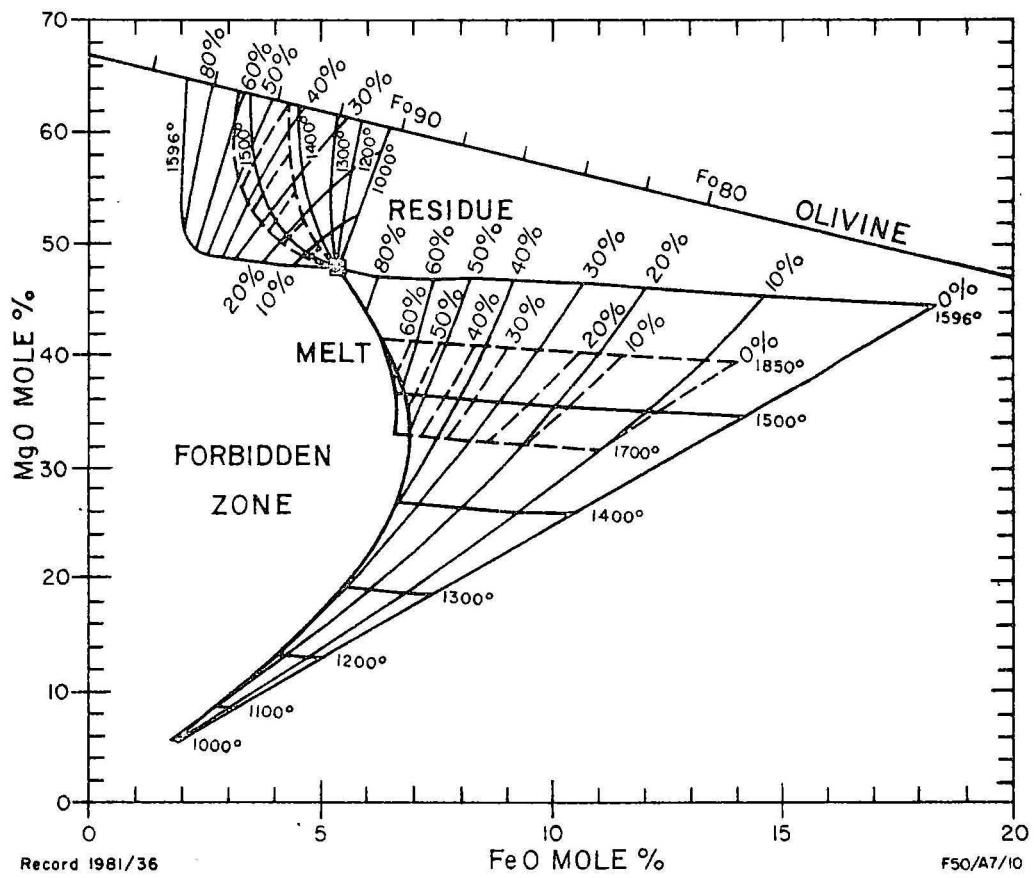
LOWER BASIC UNIT - PK

SAMPLE NO.	MgO mol%	FeO mol%	Mg'	%MELT 0kb	%MELT 30kb	Temp (C) 0kb	Temp (C) 30kb 0kb	MANTLE MgO mol% 0kb	MANTLE FeO mol% 0kb	MANTLE Mg' 0kb	MANTLE Mg' 30kb	%MELT BY MASS BALANCE	%MELT FROM Zr
1688	31.60	8.35	79	26	20	1460	1680	47.94	5.21	90	89	47	29
1042	31.28	8.49	79	26	20	1460	1680	47.83	5.32	90	88	46	45
1070	31.92	8.98	78	22	12	1460	1700	47.56	5.59	89	87	48	20
1509	33.67	10.77	76	14	5	1490	1750	46.26	6.89	87	84	57	32
1072	44.28	8.78	83	40	35	1570	1900	45.07	8.08	85	84	95	42
1585	48.13	7.19	87	60	55	1600	2000	43.72	9.43	82	86	\$\$	143

LOWER BASIC UNIT - STKP

SAMPLE NO.	MgO mol%	FeO mol%	Mg'	%MELT 0kb	%MELT 30kb	Temp (C) 0kb	Temp (C) 30kb 0kb	MANTLE MgO mol% 0kb	MANTLE FeO mol% 0kb	MANTLE Mg' 0kb	MANTLE Mg' 30kb	%MELT BY MASS BALANCE	%MELT FROM Zr
1513	31.73	9.18	78	20	10	1460	1700	47.41	5.74	89	87	48	31
1877	32.44	8.76	79	25	18	1460	1700	47.73	5.42	90	88	49	26
1150	34.58	8.21	81	35	28	1480	1740	48.10	5.05	91	88	53	32
1696	39.31	8.98	81	34	28	1540	1830	47.01	6.14	88	86	70	40
1105	38.71	8.65	82	36	29	1530	1810	47.42	5.73	89	87	66	31
1107	39.71	9.98	80	27	22	1540	1850	45.94	7.21	86	84	76	31
1106	40.53	7.66	84	48	45	1540	1850	47.99	5.16	90	88	69	67

Fig. 12



COMPUTATION?". Positive or negative responses and T and F values read from low-P and high-P grids are entered. Following this, the next point is plotted and its parameters can be read and entered, and so on. Following each entry printing of these values and of calculated mantle Mg' numbers is performed on the 9871A printer. If the point plots outside of the primary melt field (Fig. 12), make no entry and press continue; the printout will state "OUT OF PRIMARY MELT FIELD". The printout includes the MgO (mol. %) and FeO (mol. %) of the sample, Mg' number of the sample, F at 0kb and 30kb (read from the diagram), liquidus temperature (T) at 0kb and 30kb (read from the diagram), the calculated MgO (mol. %) and FeO (mol. %) of the source mantle for 0kb, the mantle Mg numbers for 0kb and 30kb, F calculated by mass balance (equation 10) and F calculated from equation 12. The calculation of the mantle Mg' number uses the F value deduced from equation 10.

B19 - Mantle trace elements levels ("MANTRC"; 5122 Bytes)(AYG)

The program retrieves the minor/trace element (e) values of ultramafic rocks from disc or tape storage and calculates the source mantle composition (C_O^E) as a derivation from equation (1). F is derived by MgO+FeO mass balance (equation 10). The residue composition is calculated from the major element melt composition assuming a pyrolite source, as a derivation from:

$$C_R^E = C_O^E(1-F) - FC_L^E \quad \dots (13)$$

R = residue composition; O = initial composition;

L = liquid composition

The bulk residue composition is then calculated in terms of normative Ol, Opx, and Cpx, allocating all CaO to Cpx, the MgO, FeO and SiO₂ first to Ol, and excess SiO₂ for converting Ol to Opx (Hutchison, 1974). Combining the normative mineralogy of the residue with appropriate D^E mineral/melt partition coefficients cited from the literature, the bulk K_d^E value is obtained from equation 2. For further explanation refer to Glikson and Hickman (1981, p. 51).

Input information includes: title of table; trace element (e) symbol and code line; % to PPM conversion factor (i.e. if elements such as TiO₂, MnO or P₂O₅ are entered); the degree of partial melting (F) can be retrieved from data files if it has been previously stored within the title group of the respective analysis. Storage of percentage partial melting is

V - ONVEFWACHT GROUP [high-Mg basalts]

TABLE 9

* MELTING BY Fe+Mg MASS BALANCE
Kd Ol = 0.02 Kd Cpx = 0.30 Kd Cp = 1.50

SAMPLE NO	ELEMENT SYMBOL	ROCK ppm	SOURCE PYROLITE	% PARTIAL MELTING	NORMATIVE RESIDUE			RESIDUE BULK Kd
					Ol	Cpx	Cpx	
5042	V	213	81	30	89	11	0	0.113
5046	V	273	106	31	87	13	0	0.117
5050	V	278	117	34	86	14	0	0.118
5052	V	266	105	31	84	16	0	0.123
5041	V	239	94	32	88	12	0	0.116
5045	V	333	126	30	86	14	0	0.118
5049	V	330	132	31	84	16	0	0.124
5053	V	292	103	27	87	13	0	0.117
5001	V	221	77	27	92	8	0	0.112
5003	V	224	84	29	95	4	2	0.120
5012	V	237	82	27	92	8	0	0.107
5026	V	116	44	28	92	6	3	0.138
5067	V	110	43	26	94	0	6	0.180
5077	V	179	66	30	92	8	0	0.106
5080	V	188	70	26	93	3	3	0.143
5084	V	182	70	31	94	6	0	0.104
5085	V	212	86	31	97	0	3	0.133
5092	V	130	51	28	91	5	4	0.155
5082	V	237	86	26	93	4	3	0.140
5086	V	261	100	27	96	0	4	0.152
5051	V	292	124	35	87	13	0	0.117
AVG. OF 21		229	88	29	90	8	1	0.126

made in line No. 6, for example "LP38XHP45" (38-low P; 45-high P).

Alternatively, (F) can be entered from keyboard.

Subsequently, selective data retrieval (major elements and element (e) takes place according to two inclusive or exclusive search keywords. The printout includes the sample number, element (e) symbol, element (e) level in the retrieved analysis, element (e) level in the source mantle, partial melting (F), normative residue (Ol, Opx, Cpx), and the bulk K_d^e of the residue (Table 9). D^e values for residual minerals are printed at the top of the table.

B20 - Primary magma computation ("PRIMAG"; 5032 Bytes)(AYG)

Allegre et al. (1977) modelled the derivation of bulk partitioning coefficient D^e for any element (e) from log (e) vs log (i) plots, (i) being an incompatible hygromagmatophile element whose K_d^i relative to residual mantle minerals is practically nil. As a derivation from Rayleigh's disequilibrium fractionation law (equation 5), where $K_d^i = 0$, $F = C_o^i / C_L^i$ as in equation 12. Substituting for (F) in Rayleigh's equation:

$$C_L^e = C_o^e \left(\frac{C_o^i}{C_L^i} \right)^{(K_d^e - 1)} \quad \dots (14)$$

thereby:

$$C_o^e = \frac{C_L^e}{\left(\frac{C_o^i}{C_L^i} \right)^{(K_d^e - 1)}} \quad \dots (15)$$

To derive C_o^e , the partition coefficient K_d^e and the initial level of the incompatible element C_o^i must be known or assumed. As a derivation from equation 14:

$$\log (C_L^e) = \log (C_o^e) + (K_d^e - 1) \log (C_o^i) - (K_d^e - 1) \log (C_L^i) \quad \dots (16)$$

since:

$$\frac{\log (C_L^e)}{\log (C_L^i)} = 1 - K_d^e \quad \dots (17)$$

the slope of a straight line on the $\log (C_L^e)$ vs $\log (C_L^i)$ plot can be used to derive the K_d^e value.

If the slope is positive it equals $1-K_d^e$ where K_d^e is less than unity. To derive (C_O^i) the assumption is made that Ni level in the parental high magnesian magma is 450 ppm (Allegre et al., 1977; Jaques et al., 1978) and the level of element (i) is read from a $\log (i)$ vs $\log (Ni)$ plot. Primary magma trace element abundances can then be computed from equation 15 or read directly from the plot. The liquid fraction (F) can be calculated from:

$$F = \frac{(K_d^e - 1)}{\sqrt{(C_L^e / C_O^e)}} \quad \dots (18)$$

For the calculation of the normative residual mineralogy in this program, an assumed parent magma composition is: $SiO_2=51\%$; $TiO_2=0.6\%$; $Al_2O_3=11\%$; $FeO_t=12\%$; $MnO=.25\%$; $MgO=13\%$; $CaO=11\%$; $Na_2O=1.0\%$; $K_2O=0.2\%$. The assumption can be varied as required. The bulk residue composition is deduced by mass balance (equation 13).

Prior to running this program, $\log (e)$ vs $\log (i)$ plots are prepared and linear regressions made for selected elements using program B8 ("XYPLOT"). The K_d^e values can then be read from the slope of the regression line and applied to equation 17.

Input data include the following: table title; assumed Ni (ppm) level in the primary magma; incompatible element (i) symbol and abundance in primary magma; the reference element (e) sign, line (Table 5), and K_d^e value deduced from the $\log (i)$ $\log (e)$ plots; enter D^e values for Ol, Op, Cp, Il and Plg, to allow computation of bulk K_d^e of the normative residue. The major element composition of the bulk residue and their normative mineralogy are calculated by mass balance (equation 13) followed by a CIPW norm procedure (Hutchison, 1974); A retrieval subroutine using two inclusive or exclusive search keywords follows.

The output printed on the 9871A printer includes the sample number, level of trace element (e) in the rock (ppm), calculated trace element (e) level in the primary magma (from equation 15), fraction of residual liquid (F), the norm of the residual minerals including Cpx, Opx, Ol, Il, Plg, and the calculated bulk Kd coefficient (Table 10). The averages of

TABLE 10

V LEVEL PRIMARY MAGMA

ASSUMED PRIMARY MAGMA: SiO₂=51%; TiO₂=.6%; Al₂O₃=11%; FeO_t=12%; MnO=.2%; MgO=13%; CaO=11%; Na₂O=1%; K₂O=.2%
 ASSUMED PRIMARY Ni=400ppm; PRIMARY Zr=50ppm; BULK Kd V = 1.04

SAMPLE NO.	ROCK ppm	PRIMARY MAGMA ppm	RESIDUAL LIQUID Wt FRACTION	NORM OF CUMULATES			Il%	Plg	Qz	CALCULATED BULK Kd
				Cpx%	Opx%	Ol%				
75040002A	374	389	0.36	23	44	9	0	24	0	0.69
75040002B	352	367	0.34	24	48	5	0	23	0	0.73
75040004B	391	408	0.34	24	51	5	0	21	0	0.75
75040005B	312	324	0.39	23	44	10	0	23	0	0.70
75040007A	349	358	0.52	26	44	13	0	17	0	0.73
75040007B	332	338	0.62	28	38	18	0	15	0	0.70
75040008A	302	311	0.47	31	28	21	0	20	0	0.64
75040008b	345	355	0.48	33	33	16	0	19	0	0.69
75040009	321	330	0.51	34	17	29	0	20	0	0.57
75040012	323	330	0.58	44	0	36	0	20	0	0.51
75040016B	385	391	0.68	29	46	14	0	11	0	0.78
75040016F	288	290	0.81	41	0	59	0	0	0	0.54
75040016H	250	254	0.65	42	12	35	1	10	0	0.66
75040016I	244	248	0.65	42	10	36	1	11	0	0.65
75040016J	246	250	0.66	39	16	34	1	10	0	0.67
75040016O	354	357	0.81	36	28	36	0	0	0	0.72
75040016Q	272	275	0.79	23	0	77	0	0	0	0.39
75040017A	364	373	0.53	33	24	24	0	20	0	0.61
75040017B	324	331	0.57	20	30	31	0	19	0	0.56
AV. OF 19	323	331	0.57	31	27	27	0	15	0	0.65

TABLE 11

DACITES - DUFFER FORMATION

ASSUMED SOURCE COMPOSITION: SiO₂=52.0%; TiO₂= 1.2%; Al₂O₃=14.0%; FeO_t=12.0%; MnO= 0.2%; MgO= 7.0%; CaO=10.5%; Na₂O= 2.6%; K₂O= 0.4

ASSUMED KdZr/residue = 0

ASSUMED Zr SOURCE LEVEL: 40

SAMPLE No.	F	RESIDUE[%wt]							EXCESS IN ANALYSIS		
		SiO ₂	TiO ₂	Al ₂ O ₃	FeO _t	MnO	MgO	CaO	SiO ₂	Na ₂ O	K ₂ O
49280	0.25	46.99	1.29	12.92	15.09	0.24	8.79	12.60	0.00	0.00	0.82
49282	0.24	47.91	1.40	13.80	14.39	0.20	8.50	11.23	0.00	0.00	0.56
49287	0.22	47.53	1.35	13.32	13.83	0.23	8.25	12.61	0.00	0.00	1.14
49288	0.25	46.73	1.39	13.24	14.45	0.23	8.25	12.98	0.00	0.00	1.17
49289	0.21	48.01	1.36	13.45	13.81	0.24	7.91	12.67	0.00	0.00	0.49
49290	0.25	47.72	1.38	13.44	13.92	0.24	8.07	12.58	0.00	0.00	0.97
49291	0.26	47.36	1.35	13.31	14.02	0.22	8.21	12.51	0.00	0.00	1.57
49292	0.21	48.59	1.35	12.89	13.88	0.23	8.14	12.67	0.00	0.00	0.51
49293	0.24	47.73	1.36	13.36	14.00	0.23	8.33	12.90	0.00	0.00	0.16
49294	0.21	49.16	1.27	13.44	13.43	0.21	8.08	11.49	0.00	0.00	0.37
49295	0.31	46.94	1.47	14.05	13.87	0.18	8.42	12.85	0.00	0.00	0.00
49296	0.26	46.79	1.39	13.86	14.30	0.22	8.42	12.83	0.00	0.00	0.07
49297	0.34	44.55	1.48	14.56	15.28	0.22	8.95	13.24	0.00	0.00	0.00
49298	0.33	47.71	1.42	14.08	13.81	0.19	8.66	11.95	0.00	0.00	0.00
49299	0.30	46.82	1.40	12.76	14.76	0.25	8.29	13.73	0.00	0.00	0.42
49300	0.24	48.97	1.39	12.46	14.19	0.24	8.06	13.42	0.00	0.00	0.00
49302	0.31	45.37	1.49	13.75	15.28	0.25	8.65	13.71	0.00	0.00	0.08
49303	0.32	45.55	1.49	14.11	15.28	0.24	8.83	12.82	0.00	0.00	0.00
49306	0.41	40.96	1.65	13.49	17.33	0.27	10.13	14.68	0.00	0.00	0.59
49307	0.32	45.61	1.52	13.03	15.79	0.26	9.65	13.11	0.00	0.00	0.00
49308	0.34	43.68	1.57	13.19	16.29	0.26	9.71	13.27	0.00	0.00	0.59
49309	0.44	43.20	1.72	11.87	17.08	0.28	10.24	14.28	0.00	0.00	0.00
49310	0.35	46.70	1.52	12.88	15.27	0.23	9.53	11.71	0.00	0.00	0.00
49311	0.38	45.94	1.52	12.21	15.74	0.25	9.76	13.25	0.00	0.00	0.00
49312	0.31	43.59	1.57	13.06	16.42	0.28	9.94	13.80	0.00	0.00	0.00
49313	0.33	45.68	1.49	12.54	15.65	0.25	9.76	12.85	0.00	0.00	0.47
49317	0.34	45.79	1.51	13.35	15.39	0.25	8.67	13.11	0.00	0.00	0.00
AV. OF 27	0.30	46.36	1.45	13.27	14.91	0.24	8.82	12.92			

these values is printed below.

B21 - Siliceous magma by partial melting ("SILMAG", 3148 Bytes)(AYG)

The program tests the compatibility of the batch partial melting model according to Henry's Law (equation 1) for any given source composition with an observed analysis representing a siliceous or intermediate liquid composition. The bulk major element composition of the residue is calculated by mass balance from the analysed rock and an assumed source composition (equation 13), and is printed in the output (Table 11). F is derived from equation 12. For many such model calculations it is found that mafic sources may not have sufficient K_2O , Na_2O or SiO_2 to account for the observed rock composition for any reasonable value of F. Either more silicic source rocks are required or, alternatively, addition of K-rich siliceous fluid phases can be invoked. The excess Na_2O , K_2O or SiO_2 are calculated and printed. The printout included the sample number, F, residue composition (SiO_2 , TiO_2 , Al_2O_3 , FeO_t , MnO , MgO and CaO , and excess Na_2O , K_2O or SiO_2 if these components yield a minus sign in the residual norm. The assumed parent rock composition is printed above the table, as are the assumed (K_d^i) and (C_o^i). Normally Zr is used as the incompatible element (i). An example of a printout is given in Table 11.

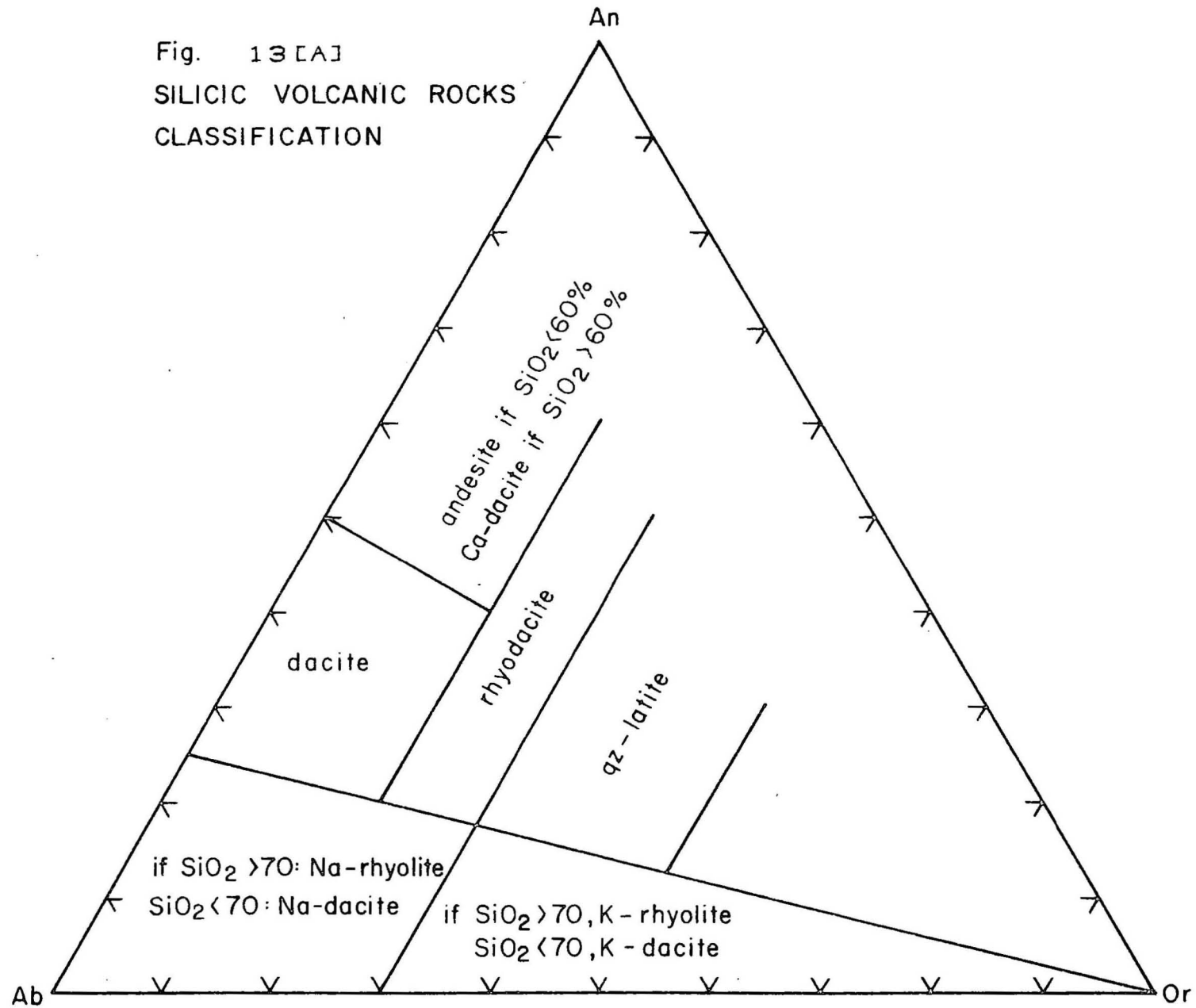
CIPW Subpackage

Programs B22, B23, B24, B25, and B26 are stored along with relevant data files on a separate disc and/or tape, for space reasons, constituting a "CIPW Subpackage".

B22 - Petrochemical classifications ("CLASS"; 1300 Bytes)(AYG)

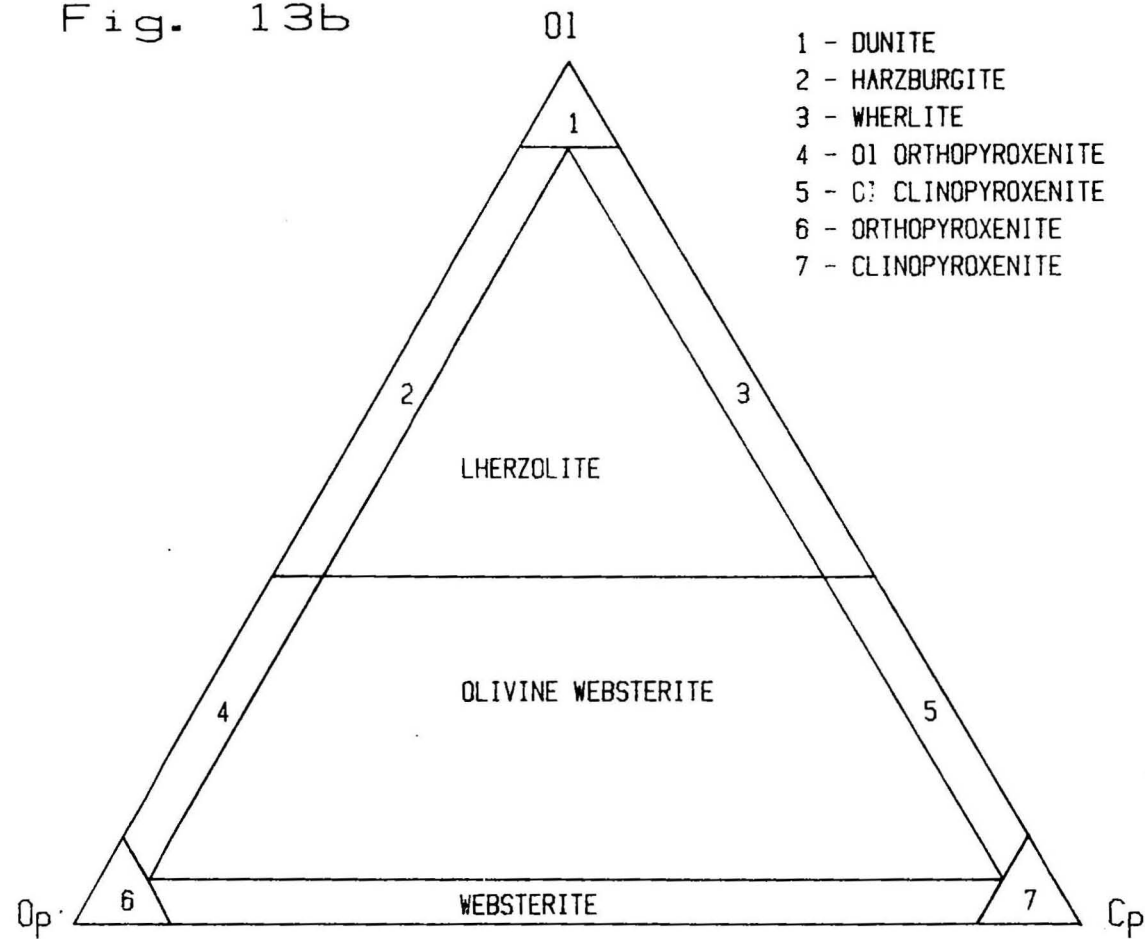
The program allows petrochemical classifications of silicic volcanic or plutonic rocks according to O'Connor's (1965) An-Ab-Or ternary (Fig. 13a) and of ultramafic rocks according to the Ol-Opx-Cpx ternary (Fig. 13b). Normative values read from the CIPW program (B23 or B24) are entered from keyboard on appropriate prompts. The program compares the normative indices with the compositional fields on the ternary diagrams and prints the classified petrochemical name on the thermal printer. Entry of normative parameters of the next sample is then allowed, etc.

Fig. 13 [A]
SILICIC VOLCANIC ROCKS
CLASSIFICATION



16/F50-8/22

Fig. 13b



B23 - CIPW calculations from disc or tape ("CIPW"; 4026 + 3294 Bytes)(MO)

The program retrieves analyses from disc or tape 1470 Byte data storage files according to one search keyword and a file range specified from keyboard, and calculates the CIPW norm following the procedure described in Hutchison (1974). The output (Table 12) lists the sample title group, major element (Wt%) composition and cation %, and prints femic normative minerals, salic normative minerals and petrochemical indices listed in Appendix II.

Other petrochemical indices calculated and printed by the CIPW program include:

Plg (An) - $100 \text{ An}/(\text{An}+\text{Ab})$
S-I index - $\text{Al}/(\text{Na}+\text{K}+2\text{Ca})(\text{cation } \%)$
Differentiation index - $(\text{Qz}+\text{Or}+\text{Ab}+\text{Ne}+\text{Lc}+\text{Kp})$
Solidification index - $100 \text{ MgO}/(\text{MgO}+\text{FeO}+\text{Fe}_2\text{O}_3+\text{Na}_2\text{O}+\text{K}_2\text{O})$
Crystallization index - $\text{An}+\text{Di}+\text{Fo}+\text{Sp}$ (Sp-spinel)
Total iron as FeO - $\text{FeO}+0.8995 \text{ Fe}_2\text{O}_3$
 $\text{K}_2\text{O}/\text{Na}_2\text{O}$

Mg' Number - $100 \text{ MgO}/(\text{MgO}+\text{FeO})$ in mol. %

B24 - CIPW calculations from keyboard ("CPWKEY"; 5882 Bytes)(MO)

The program performs the same calculations as program B23, except that major element data are entered from keyboard in the order: SiO_2 , TiO_2 , Al_2O_3 , Fe_2O_3 , FeO, MnO, MgO, CaO, Na_2O , K_2O , P_2O_5 , H_2O^+ , H_2O^- , CO_2 , SO_3 , S. The printout format is the same as for program B23 (Table 12).

B25 - CIPW data retrieval for plots ("CPWRET"; 6266 Bytes)(MO)

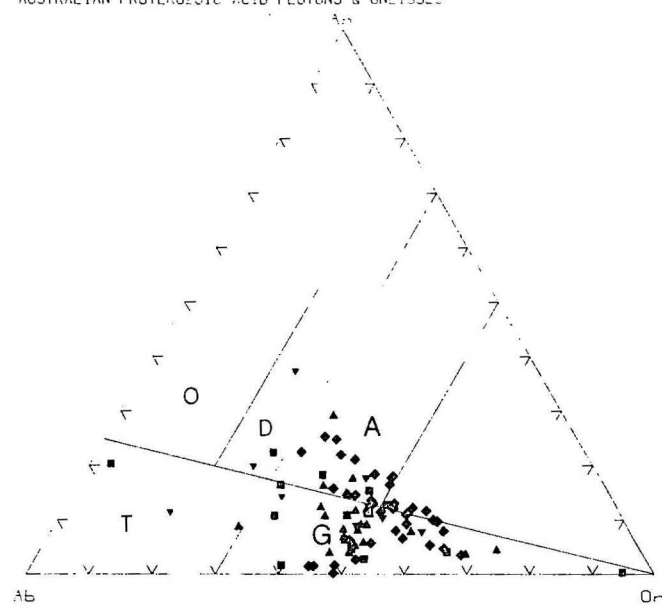
The program retrieves data selected in cycles of 3 pairs of search keywords each from 1470 Byte files ("MSFILE") as for programs A7 and B7. However in this program a CIPW norm is calculated from the chemical analyses using constants retrieved from a data file ("MS"), and the norms stored on 140x78 Byte string array ("MSFILE"). For guidelines for running the programs refer to program A7.

- 24 -

	weight %	cation %	1527 PEMIC MINERALS	U.Basic	ac.pl.	HMB	Mt	Singleton	RATIOS
SiO ₂	51.00	47.96	Acmite	0.00	Larnite	0.00	Quartz	0.00	Plag. An 53.79
TiO ₂	0.59	0.42	Sod. metasilic.	0.00	Magnetite	3.39	Corundum	0.00	S-I Index 0.63
Al ₂ O ₃	14.10	15.63	Pot. metasilic.	0.00	Ilmenite	1.14	Orthoclase	3.30	Diff. Index 25.41
Fe ₂ O ₃	2.30	1.63	Diopside	16.69	Haematite	0.00	Albite	22.11	Solid. Index 39.03
FeO	8.40	6.61	Wollastonite	8.57	Sphene	0.00	Anorthite	25.73	Cryst. Index 48.66
MnO	0.23	0.18	Enstatite	5.14	Perovskite	0.00	Nepheline	0.00	Total Fe (FeO) 10.64
MgO	8.70	12.20	Ferrosilite	2.98	Rutile	0.00	Leucite	0.00	K ₂ O/Na ₂ O 0.21
CaO	9.60	9.67	Wollastonite	0.00	Apatite	0.31	Kaliophilite	0.00	K ₂ O+Na ₂ O 3.17
Na ₂ O	2.57	4.69	Hypersthene	26.56	Calcite	0.46			Mg' number 44.7
K ₂ O	0.55	0.66	Enstatite	16.82	Pyrite	0.00	TOTAL	99.77	
P ₂ O ₅	0.13	0.10	Ferrosilite	9.74					
H ₂ O+	2.00		Olivine	0.08					
H ₂ O-	0.00		Forsterite	0.05					
CO ₂	0.20	0.26	Fayalite	0.03					
S	0.00	0.00							
TOTAL	100.37								

[illegible]

Fig. 14
AUSTRALIAN PROTEROZOIC ACID PLUTONS & GNEISSES



B26 - CIPW XY plots ("CPWXY"; 6492 Bytes)(MO)

The program is similar to programs A8 and B8, except that normative minerals rather than oxides or elements are plotted. The line code numbers for the minerals entered into the axis registers are given in the list of CIPW normative minerals in Appendix II. If 40 is entered into an X or Y axis register, a modify code print can be obtained, allowing plotting of the mineral combinations A+B (code-1), A-B (code-2), AxB (Code-3), A/B (Code-4), A+B+C (Code-5), and Axconstant (Code-6). No regression can be performed on the data. An example of a normative plot is given in Fig. 14. Symbol legend and title can be labelled at end of program.

B27 - CIPW ternary plots ("CPWXYZ"; 5882 Bytes)(MO)

The program is similar to programs A9 and B9, except that normative minerals rather than oxides or elements are plotted. Line code numbers are listed above. If 40 is entered into any one of the 3 axes registers, a print of mineral combination codes as for program B26 is made on the thermal printer, and code entry can proceed. Symbol legend and title can be labelled at end of program.

Package C - RARE EARTH ELEMENTS (REE) PROGRAMS

This package is stored on a separate disc/tape. It consists of the following programs, as listed in the "Index" legend:

- C1 - REE system index ("Index")
- C2 - REE data storage ("REstor")(MO, mod, by AYG)
- C3 - REE continuous table printing ("Contab")(MO)
- C4 - REE tables and samples title listing ("List")(AYG)
- C5 - REE data transfer programs ("Dtrans")(AYG)
- C6 - REE selective data retrieval/tabulation ("Retprt")(MO)
- C7 - REE data retrieval for plot programs ("XYret")(MO)
- C8 - REE XY plots and regression ("XYplot")(MO, mod. by AYG)
- C9 - REE triangular plots ("XYZplt")(MO)
- C10 - REE statistics program ("Stats")(MO)
- C11 - REE geochemical frequency distribution plots ("Frqplt")(AYG)
- C12 - REE normalized plots ("REnorm")(AYG)
- C13 - REE petrogenetic models ("Model")(AYG)

- C14 - REE partial melting models ("Prtmlt")(AYG)
- C15 - REE fractional crystallization models ("Frcrys")(AYG)
- C16 - REE mantle abundances ("REmant")(AYG)

Common features of all program

- (1) positive response (yes) - enter 1, press continue key
- (2) negative response (no) - no entry, press continue key
- (3) for choice of option, enter the indicated number, then press continue key. For example, Prompt "DISC [1] or TAPE [2] STORAGE"; enter 1 for disc or 2 for tape storage modes.

C1 - Rare earth elements system index ("Index")

The preceding program titles are displayed consecutively and the individual programs can be loaded onto memory by positive response from keyboard.

C2 - Rare earth elements data storage ("REstore"; 4864 Bytes)(MO, mod. by AYG)

The program is analogous to program B2 ("STORET") except that trace elements comprise Cs, Rb, Ba, Nb, La, Ce, Pr, Nd, Sm, Eu, Gd, Tb, Dy, Ho, Er, Tm, Yb, Lu, Y and Sr. Element values in PPM are printed to three decimal places (Table 13). The Mg' number is printed below each analysis column.

Programs C3, C4, C5, C6, C7 are analogous to programs B3, B4, B5, B6, and B7, respectively except for the change in type of trace elements and the decimal format for the trace elements.

C8 - REE XY plots and regression ("Xyplot"; 8902 +2808 Bytes)(MO, mod, by AYG)

The program is analogous to program B8, except for additional data modification procedures, as follows:

- (1) An option exist of normalizing all trace element data by dividing them by model mantle values (Sun, 1980) stored in the program.
- (2) A list of modify codes and chondrite values can be obtained on the thermal printer, including the following information:

TABLE 13

EEL[0/1] - ONVERWACHT GROUP, BARBERTON MOUNTAINLAND, TRANSVAAL

Sample number	5038	5046	5049	5052	5053	5019	5031	5067	SA39	5077
ROCK TYPE	TE	HME	HME	HMP	TF	PK	PK	HMR	PK	HMP
GEOLOGICAL UNIT	Sandspruit Formation	Sandspruit Formation	Sandspruit Formation	Sandspruit Formation	Sandspruit Formation	Theespruit Formation	Theespruit Formation	Theespruit Formation	Theespruit Formation	Krati Formation
REFERENCE	Jahn et al 1982	Jahn et al 1982	Jahn et al 1982	Jahn et al 1982	Jahn et al 1982	Jahn et al 1982	Jahn et al 1982	Jahn et al 1982	Jahn et al 1982	Jahn et al 1982
1 SiO ₂	51.08	48.48	47.20	46.32	50.63	42.60	44.29	55.57	38.26	52.72
2 TiO ₂	1.66	1.30	1.19	1.43	1.19	0.27	0.31	0.32	0.24	0.64
3 Al ₂ O ₃	12.96	10.03	9.72	10.94	11.62	2.87	3.31	12.15	2.72	7.37
4 Fe ₂ O ₃										
5 FeO	13.50	13.07	13.75	13.16	12.00	13.61	13.52	7.15	11.16	10.93
6 MnO	0.26	0.23	0.29	0.34	0.26	0.36	0.18	0.13	0.21	0.17
7 MgO	4.22	10.79	11.70	10.94	7.52	34.18	31.34	9.79	32.86	11.34
8 CaO	9.36	12.08	12.59	12.96	12.38	2.29	3.30	7.27	1.74	10.56
9 Na ₂ O	4.21	1.54	1.07	0.97	2.20	0.02	0.09	1.97		2.97
10 K ₂ O	0.15	0.22	0.24	0.32	0.10	0.02	0.05	1.62		0.05
11 P ₂ O ₅	0.20	0.14	0.13	0.13	0.15	0.05	0.07	0.08	0.05	0.08
12 H ₂ O ⁺	0.29	0.59	0.54	0.82	0.47	1.78	2.38	2.16	10.26	1.21
13 H ₂ O ⁻										
14 CO ₂										
TOTAL	97.89	98.47	98.42	98.33	98.52	98.05	98.83	98.21	97.50	98.04
15 Cs										
16 Rb	3.00		3.00	3.00	3.00			50.07	0.26	
17 Ba										
18 Nb	19.00	4.00	5.00	4.00	6.00			6.00	0.10	5.00
19 La	18.25	6.74	4.64	3.54	9.32	1.94	3.38	16.06	0.73	3.78
20 Ce	43.41	16.90	12.63	11.07	20.38			31.18		10.47
21 Pr										
22 Nd	24.75	11.31	9.42	8.97	12.52	2.50	3.57	12.33	1.73	7.47
23 Sm	5.65	3.98	2.99	2.98	3.44	0.66	0.95	2.32	0.50	2.12
24 Eu	1.53	1.19	1.25	1.02	1.12	0.25	0.36	0.57	0.16	0.71
25 Gd	5.66	4.17	3.81	3.90	3.89	0.83	1.21	2.18	0.63	2.73
26 Tb										
27 Dy	5.79	4.49	4.16	5.22	4.02	0.89	1.08	2.49	0.70	2.84
28 Ho										
29 Er	3.32	2.50	2.11	2.40	2.28	0.55	0.60	1.68	0.41	1.71
30 Tm										
31 Yb	3.29	2.23	2.07	2.11	2.07	0.47	0.57	1.74	0.37	1.65
32 Lu	0.51	0.34		0.33	0.31	0.08	0.08	0.29		0.26
33 Y	29.00	19.00	25.00	17.00	20.00		4.00	12.00	3.30	12.00
34 Sr	254.00	158.00	78.00	164.00	138.00		9.00	122.50	1.17	26.00

1 - Elements A+B

2 - Elements A-B

3 - Elements AxB

4 - Elements A/B

5 - Major A/trace B

6 - Constant x Element A

7 - Constant x traces A/B

Model mantle (ppm) Cs - 0.012; Rb - 0.35; Ba - 3.8; Nb - 0.35;

La - 0.315; Ce - 0.813; Pr - 0.115; Nd - 0.597; Sm - 0.192;

Eu - 0.722; Gd - 0.259; Tb - 0.047; Dy - 0.325; Ho - 0.07;

Er - 0.213; Tm - 0.03; Yb - 0.208; Lu - 0.0323; y - 2.0; Sr - 11.0

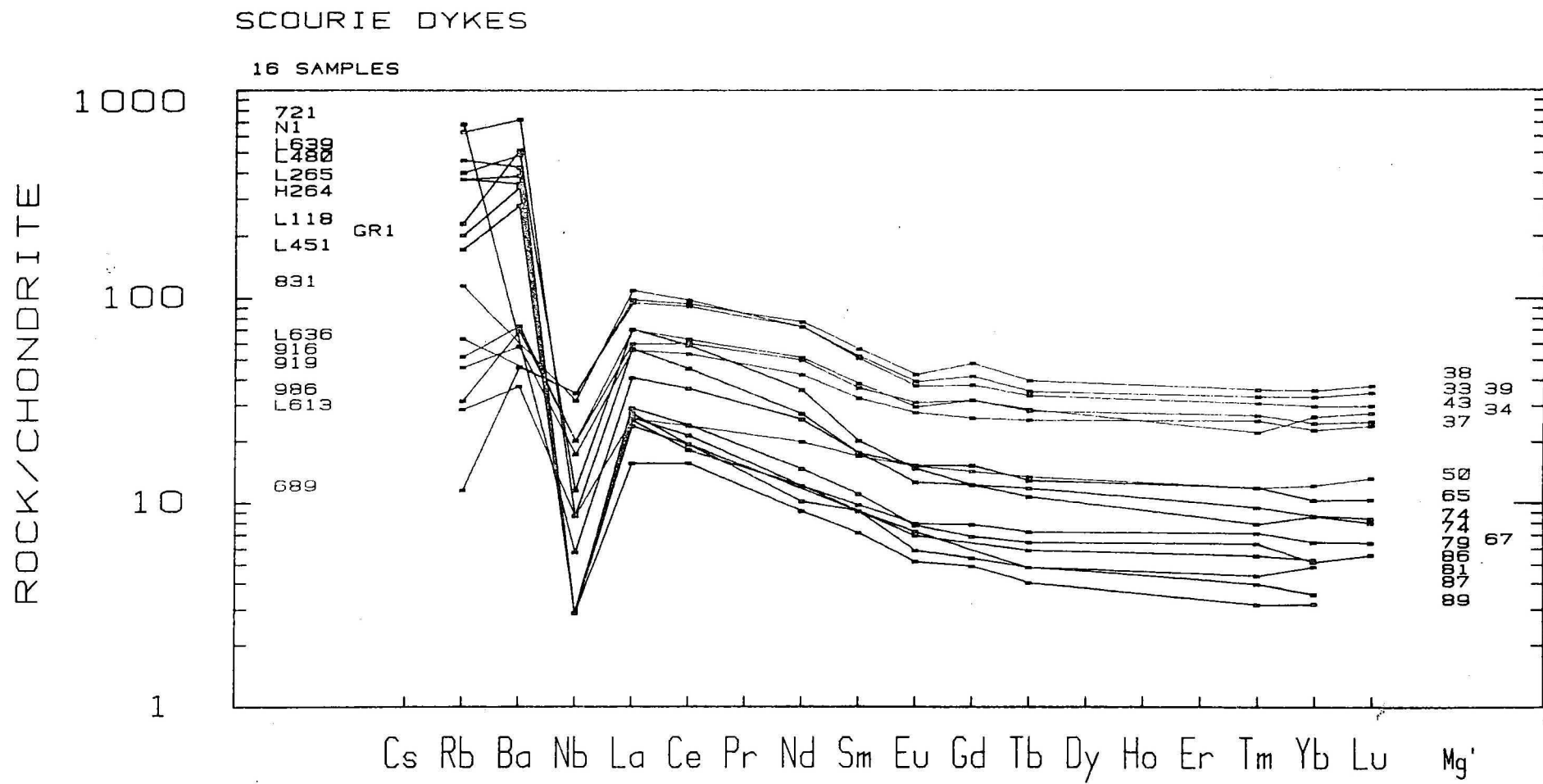
These values or any other sets of values can be used to normalize the analyzed trace element values by using either modification procedure No. 6 (multiplying the trace element A by $1/a$, (a) being the normalizing value of element A, or by modification procedure No.7 (by multiplying A/B by b/a (a - normalizing value of element A; b - normalizing value of element B). This way plots such as of Ce_N/Sm_N vs Sm_N/Yb_N can be obtained. Line numbers of oxides and trace elements used in this program are listed in Table 13. The type of normalizing values used can be changed readily within the program.

Programs C9, C10, and C11 are analogous to programs B9, B10, and B11, respectively, except for processing different trace elements. Element/Line numbers are listed in Table 13.

C12 - REE normalized plots ("REnorm"; 5480 Bytes)(AYG)

Rare earth and other trace elements are normalized through their division by values entered from keyboard or stored in the program, and are plotted on linear or log scale axis in the range of 0.1-1000. Normalizing values stored include chondrite values (Evans et al., 1978), model mantle values (Sun, 1980) and MORB values (Sun et al., 1979). For minimum Y-axis value enter 0.1, 1, 10 or 100; for maximum Y-axis value enter 1, 10, 100 or 1000. The element sequence is plotted in order of decreasing ionic radius: Cs, Rb, Ba, Nb, La, Ce, Pr, Nd, Sm, Eu, Gd, Tb, Dy, Ho, Er, Tm, Yb, Lu. The sample number is labelled to the left and Mg' number or K/Na to the right of the plot. In plotting several REE curves on one diagram, superposition of labels may occur and pen adjustment is therefore allowed during program pauses. The input/output modes are otherwise

Fig. 15



similar to those in program B12. An example of the diagram is in Fig. 15.

C13 - REE petrogenetic models ("Model"; 7130 Bytes)(AYG)

This program allows calculation and plotting of the REE composition of partial melts or of liquids residual after crystal fractionation, given the REE source composition (C_o^e), and assumed (F) values. Bulk partition coefficient (K_d^e) values are computed by entering the residual mineralogy composition (up to 10 minerals) and combining them with appropriate $D_{\text{mineral/melt}}^e$ partition coefficients cited from the literature (Appendix III) and stored on a 10 x 18 Bytes array. The calculated values can be normalized according to chosen values as in program C12.

Input routine

Enter "PARTIAL MELT (1) or FRACTIONAL CRYSTALLIZATION (2)"; if 1, equation 1 is applied to compute the liquid level of the elements (C_l^e), whereas if 2, equation 5 is applied. Next, a prompt will invite "FRACTION OF MELT/LIQUID F", to be assumed for the model. F is printed on the thermal printer. Then, keyboard entry of the source rock or magma composition (C_o^e) is invited by consecutive prompts: "Cs", "Rb", "Ba", "Nb", "La", "Ce", "Pr", "Nd", "Sm", "Eu", "Gd", "Tb", "Dy", "Ho", "Er", "Tm", "Yb", "Lu", or source values stored in the program can be retrieved; including chondrite (Evensen et al., 1978), model mantle (Sun, 1980) and NORB (Sun et al., 1979) values. Normalizing values can be either entered from keyboard or retrieved as for the source rock/magma values. Next, entry of residual mineralogy data is invited, including mineral codes (up to 3 letters per code) and the fraction (P) of each mineral within the solid system. This input is printed on the thermal printer. Next, a prompt "Kd KEYBOARD (1) or RETRIEVAL (2)" appears, and keyboard entry of $D_{\text{mineral melt}}^e$ coefficients is invited or, alternatively, these data can be retrieved from data file if stored previously. D^e data entry proceeds in 18 cycles, i.e. one cycle per element (e), whose symbol is entered at the outset of each cycle. Thus, "D element/mineral 1", "D element/mineral 2", etc. are entered for up to 18 elements for up to 10 minerals, and is printed on the thermal printer. At the end of each cycle an option exists for either entering D^e data for another element or proceeding to storage. When 18 elements are entered, the program proceeds to storage automatically. Before running the program, if tape storage, mark 1500 Bytes data files on tape cartridge. An option of two types of storage files is offered by the program: a prompt appears "BASIC [1] or FELSIC [2] MAGMA D VALUES". If the D^e data is for mineral/basic magma, enter 1, if for silicic magma, enter 2. When data are stored, the thermal printer prints: "D^e data recorded". D^e data after Arth (1976) are listed in Appendix III.

Fig. 16

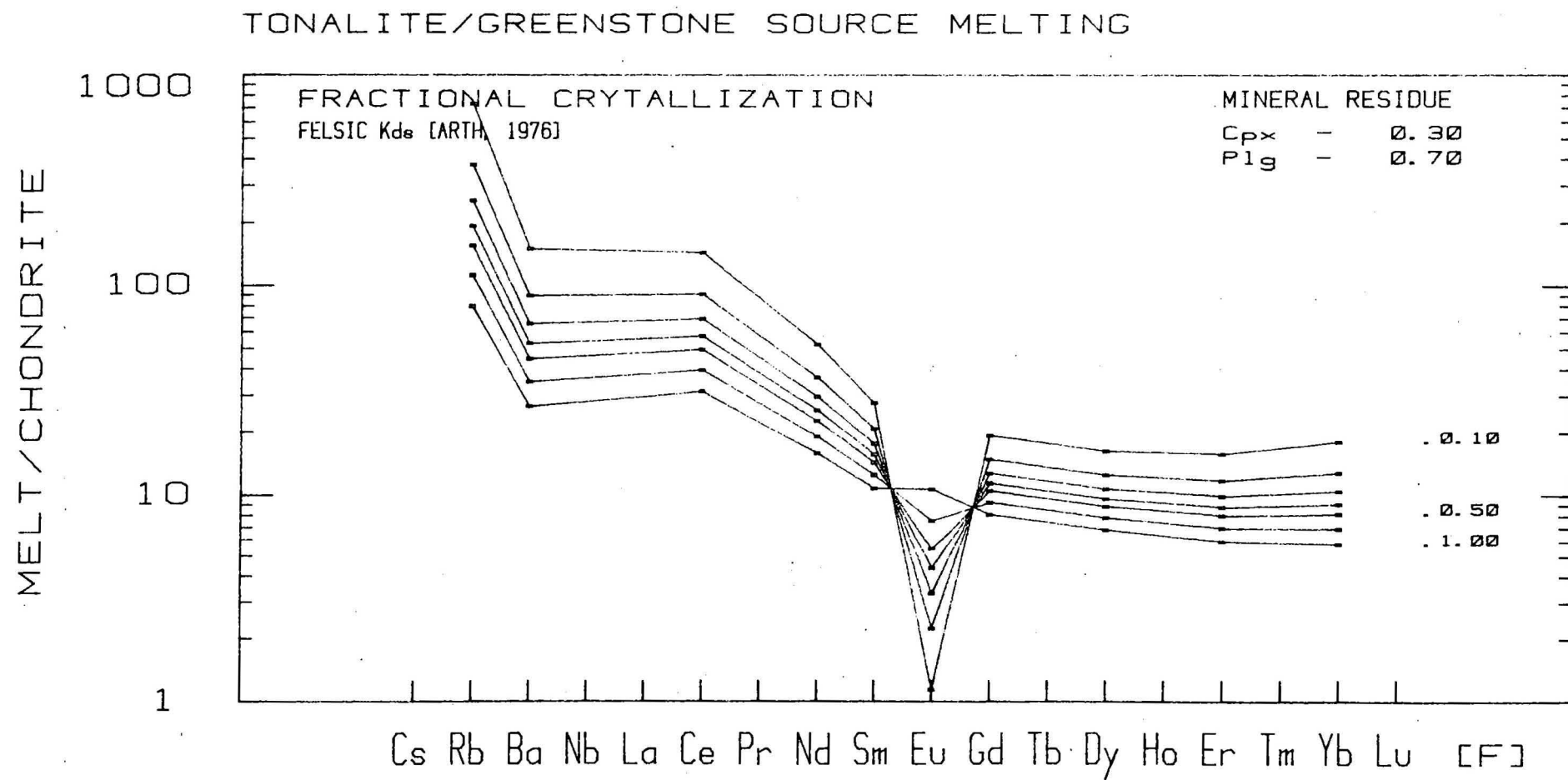


Diagram design includes entry of a title, including specification of letter size and letter height/width proportions, specification of log or normal scale, minimum (0.1, 1, 10 or 100) and maximum (1, 10, 100 or 1000) Y-axis parameters, pen number, length of X and Y axes in cm, Y-axis tic intervals, label/tic ratios, decimal point of numeric labels and diagram offset parameters. The calculated values are normalized according to chosen values as in program C12. The diagram includes information on the type of petrogenetic process specified i.e. partial melting or fractional crystallization. Residual mineral code names and their fraction are printed at top and the fraction of melting (F) is printed to the right of each curve (Fig. 16).

Programs C14, C15, and C16 are analogous to programs B15, B16, and B19 respectively, except that calculations of partial melting and fractional crystallization can be performed for the REE. Refer to these programs for description of principles and running instructions.

Package D - Rb-Sr ISOTOPIC PARAMETERS

This package includes one program comprising 9 subprograms and a frequency plot program, stored on a separate flexible HP disc or tape.

D1 - Rb-Sr isotopic parameters ("RbSrT"; 8896 Bytes)(AYG)

Subprograms:

- D1(a) New data storage
- D1(b) Retrieval/modify
- D1(c) Selective retrieval/tabulation
- D1(d) Initial Sr87/86 vs Time plots
- D1(e) Crustal residence time models
- D1(f) Crustal residence vs age plots
- D1(g) Mantle derivation vs crustal residence plots
- D1(h) Data files titles listing
- D1(i) Data transfer

D2 - Rb-Sr data frequency plots ("RSFRQ"; 6220 Bytes)(AYG)

Common features

- (1) positive response to prompt (yes) - enter 1, press continue key
- (2) negative response to prompt (no) - press continue key
- (3) for choice of alternative options, enter the desired number indicated in the prompt, then press continue key

D1 - Rb-Sr isotopic parameters

The program allows storage of Rb-Sr isochron ages + error limits, initial $\text{Sr}^{87}/\text{Sr}^{86}$ ratios (Ri) + error limits, and coded relevant information including rock type, locality/unit, shield/province, and reference. Data for up to 20 isochrons can be stored on 2200 Byte string arrays, each isochron occupying 110 Bytes and including the above listed data/information. To store the data on tape cartridges, mark files 2200 Byte long. The program comprises nine subprograms, listed above, and also allows for loading of program D2 (Rb-Sr Data frequency plots, "RSFRQ") into memory as a 10th option. Subprograms are selected by responding to titles displayed consecutively at the outset of the program. In the following, each subroutine is separately described.

D1(a) - New data storage

New data input includes a file title of up to 80 alphanumeric characters. Next the entry line number (1-20) is displayed. Press continue key and enter data consecutively in response to prompts:

"LITHOLOGY CODE" (up to 3 characters)

"LOCALITY/UNIT" (up to 3 characters)

"SHIELD/PROVINCE" (up to 3 characters)

"ISOCHRON AGE IN MYR"

"AGE ERROR IN MYR"

"INITIAL $\text{Sr}^{87}/\text{Sr}^{86}$ "

" $\text{Sr}^{87}/\text{Sr}^{86}$ [1] ERROR"

"REFERENCE" (up to 30 characters)

At the end of each data entry cycle a prompt appears "IS PRINTING REQUIRED"; if positive, the data entered so far are printed in horizontal format (Table 14) and can be recorded on disc or tape. If negative, the data entry cycle can be repeated up to 20 times. When 20 isochrons are entered the

title flashes "ARRAY FULL", and printing and recording proceed. For disc storage specify a 3-character code and a file number, and for tape storage track and file numbers. Following recording, data can be modified by responding to a "MODIFICATION REQUIRED" prompt. If positive, the file desired is specified from keyboard, and "LINE NUMBER (1-20)", indicating which isochron data line is desired. The input procedure described above ("LITHOLOGY CODE", "LOCALITY/UNIT", etc.) repeats itself, allowing modifications in appropriate places. If the response to "LINE NUMBER" is negative, a new table title can be inserted and printing and recording proceeds.

D1(b) - Retrieval/modify

If modification (addition/deletion/change) to an existing data file is desired, the procedure following the onset of the program is identical to that at the end of subroutine D1(a) described above.

D1(c) - Selective retrieval/tabulation

Selective retrieval of data is made by specifying two inclusive or exclusive search keywords and the file number range to be searched. Data are printed in horizontal format consecutively. When printing is complete further search and retrieval can be instructed from keyboard according to new search keywords and a file number range.

D1(d) - Initial $\text{Sr}^{87}/\text{Sr}^{86}$ vs Time plots

Keyboard entries include "TITLE OF PLOT", and diagram parameters including "OLDEST TIME (MYR)", "YOUNGEST TIME (MYR)", "LOWEST INITIAL $\text{Sr}^{87}/\text{Sr}^{86}$ ", "HIGHEST INITIAL $\text{Sr}^{87}/\text{Sr}^{86}$ ", length of the X axis and Y axis (in cm), tic intervals, tic/label ratio, and diagram offset in cm. Selective data retrieval is by two search keywords and a specified file number range. The resulting plot is shown in Fig. 17.

D1(e) - Crustal residence time models

Limits on a single stage crustal residence time (R) are derived from the Rb-Sr isochron age (T), the initial $\text{Sr}^{87}/\text{Sr}^{86}$ ratio (R_i), an assumed Rb/Sr ratio of parental materials (P), and a model mantle Rb/Sr ratio (M) applied to equation 19. The relationships between these indices

for a decay constant of $^{87}\text{Rb} = 1.42 \times 10^{-11} \text{yr}^{-1}$, are given by:

$$R = \frac{R_i - 0.699 - 1.42 \times 10^{-11} T_P}{1.42 \times 10^{-11} (M - P)} \quad \dots (19)$$

Data retrieved using two search keywords and a file number range, and are calculated and printed on the 9871A printer, listing the following values: Age (T), initial $\text{Sr}^{87}/\text{Sr}^{86}$, assumed Rb/Sr of parental materials (P), Maximum Crustal residence time (MYR) (R), Mantle derivation age (T + R), and shield reference. On completion of printing, further data can be retrieved and processed if desired. An example of a printout is given in Table 15.

D1(f) - Crustal residence time vs age plots

In this subroutine the crustal residence time (R) calculated in subroutine D1(e) is plotted against the measured isochron age (T) of the rocks. Data are retrieved using two search keywords and a specified data files number range. Diagram design is as for subprogram D1(d). The assumed Rb/Sr ratio of the precursor materials is labelled at the top right hand of the diagram (Fig. 18).

D1(g) - Mantle derivation age vs crustal residence time plots

In this subroutine the crustal residence time (R) calculated in subroutine D1(e) is plotted against the mantle derivation age (T + R) of the source materials for data retrieved by two search keywords and a data files number range. Diagram design is as for subprogram D1(d). The assumed Rb/Sr ratio of the precursor crustal materials is labelled at the top right hand of the diagram (Fig. 19).

D1(h) - Data files titles listing

Titles of the 2200 Byte data files are listed consecutively, each accompanied by the number (N) of isochrons stored in that file. Keyboard listing specifications include disc code or track number, and the data files number range.

TABLE 14

T1/F0 - Yilgarn Shield, W.A.

SYMBOL/CODE	LOCALITY/UNIT	SHIELD/PROVINCE	AGE [MY]	+/-	Pi	+/-	REFERENCE
GN/AUS/ARC	Northam	Yilgarn, W.A.	2981	207	.704	.003	Arriens, 1970
GN/AUS/ARC	Armidale	Yilgarn, W.A.	3161	792	.702	.021	Arriens, 1970
GN/AUS/ARC	Bowgada	Yilgarn, W.A.	2931	127	.707	.006	Arriens, 1970
GN/AUS/ARC	Koolanooka	Yilgarn, W.A.	2574	632	.717	.016	Arriens, 1970
GN/AUS/ARC	Morawa	Yilgarn, W.A.	2828	71	.704	.002	Arriens, 1970
GN/AUS/ARC	Pinjarra	Yilgarn, W.A.	2608	106	.704	.001	Arriens, 1970
GN/AUS/ARC	Dumbleyung	Yilgarn, W.A.	2611	162	.704	.003	Arriens, 1970
GN/AUS/ARC	Corrigin	Yilgarn, W.A.	2639	2061	.708	.055	Arriens, 1970
GN/AUS/ARC	Dangin	Yilgarn, W.A.	2679	297	.714	.002	Arriens, 1970
GN/AUS/ARC	Dangin	Yilgarn, W.A.	3306	373	.706	.004	Arriens, 1970
GN/AUS/ARC	Bruce Rock	Yilgarn, W.A.	2695	366	.703	.004	Arriens, 1970
GN/AUS/ARC	York	Yilgarn, W.A.	2688	211	.712	.009	Arriens, 1970
GR/AUS/ARC	Doodlakine	Yilgarn, W.A.	2732	115	.704	.005	Arriens, 1970
GR/AUS/ARC	Doodlakine	Yilgarn, W.A.	2734	269	.699	.022	Arriens, 1970
GR/AUS/ARC	Doodlakine	Yilgarn, W.A.	2765	92	.7	.006	Arriens, 1970
GR/AUS/ARC	Dale Bridge	Yilgarn, W.A.	2698	232	.704	.006	Arriens, 1970
GR/AUS/ARC	Bencubbin	Yilgarn, W.A.	2696	187	.699	.012	Arriens, 1970
GR/AUS/ARC	Cadoux	Yilgarn, W.A.	2629	553	.704	.073	Arriens, 1970
GR/AUS/ARC	Williams River	Yilgarn, W.A.	2972	768	.699	.026	Arriens, 1970
GR/AUS/ARC	Kondinin	Yilgarn, W.A.	2872	1560	.701	.022	Arriens, 1970

T1/F1 - Yilgarn Shield, W.A.

SYMBOL/CODE	LOCALITY/UNIT	SHIELD/PROVINCE	AGE [MY]	+/-	Ri	+/-	REFERENCE
GR/AUS/ARC	Wongan Hills	Yilgarn, W.A.	2804	565	.686	.062	Arriens, 1970
GR/AUS/ARC	Wiluna	Yilgarn, W.A.	2698	41	.703	.001	Arriens, 1970
GR/AUS/ARC	Cue-Mt Magnet	Yilgarn, W.A.	2664	68	.702	.006	Arriens, 1970
GR/AUS/ARC	Perenjori	Yilgarn, W.A.	2764	264	.704	.01	Arriens, 1970
GR/AUS/ARC	Koolanooka	Yilgarn, W.A.	2604	117	.704	.005	Arriens, 1970
GR/AUS/ARC	Kalg.-Norseman	Yilgarn, W.A.	2617	20	.703	.0007	Arriens, 1970
GR/AUS/ARC/peb	Kurrawang	Yilgarn, W.A.	2670	255	.7025		Compston & Turek, 1973
GR/AUS/ARC	Lawlers	Yilgarn, W.A.	2652	20	.7015		Cooper et al., 1978
GR/AUS/ARC	Mt Keith	Yilgarn, W.A.	2632	17	.7015		Cooper et al., 1978
GR/AUS/ARC	Mt Keith	Yilgarn, W.A.	2689	17	.7015	.0001	Roddick&Compston,1976 [PR3: 55]
GR/AUS/ARC	Lawlers	Yilgarn, W.A.	2576	14	.7022		Cooper et al., 1978
VOL/AUS/ARC	Kolanoola	Yilgarn, W.A.	2555	12	.707		Bennett et al., 1975
GN/AUS/ARC	Cockat./Diemals	Yilgarn, W.A.	2665	100	.7015	.0011	Chapman et al., 1980
GN/AUS/ARC	SE Yilgarn	Yilgarn, W.A.	2690	60	.702	.001	Chapman et al., 1980
GR/AUS/ARC	Pigeon/Diemals	Yilgarn, W.A.	2540	130	.716	.016	Chapman et al., 1980
GR/AUS/ARC	Cue	Yilgarn, W.A.	2590	23	.7028	.001	Muhling & DeLaeter, 1970
GR/AUS/ARC	Cue	Yilgarn, W.A.	2605	51	.7031	.0008	Muhling & DeLaeter, 1970
PEG/AUS/ARC	Mt Keith	Yilgarn, W.A.	2564	50	.7008	.0015	Roddick&Compston,1976 [PR3: 55]

TABLE 15

AGE[MYR]	Sr87/86[i]	Rb/Sr	MAX. CRUSTAL RESIDENCE	MANTLE DERIVATION [MYR]	SHIELD	REFERENCE
2981	.704	0.10	990	3971	Yilgarn, W.A.	Arriens, 1970
3161	.702	0.10	385	3546	Yilgarn, W.A.	Arriens, 1970
2931	.707	0.10	1992	4923	Yilgarn, W.A.	Arriens, 1970
2574	.717	0.10	5249	7823	Yilgarn, W.A.	Arriens, 1970
2828	.704	0.10	924	3752	Yilgarn, W.A.	Arriens, 1970
2608	.704	0.10	830	3438	Yilgarn, W.A.	Arriens, 1970
2611	.704	0.10	831	3442	Yilgarn, W.A.	Arriens, 1970
2639	.708	0.10	2207	4846	Yilgarn, W.A.	Arriens, 1970
2679	.714	0.10	4271	6950	Yilgarn, W.A.	Arriens, 1970
3306	.706	0.10	1811	5117	Yilgarn, W.A.	Arriens, 1970
2695	.703	0.10	526	3221	Yilgarn, W.A.	Arriens, 1970
2688	.712	0.10	3593	6291	Yilgarn, W.A.	Arriens, 1970
2732	.704	0.10	883	3615	Yilgarn, W.A.	Arriens, 1970
2734	.699	0.10	-821	1913	Yilgarn, W.A.	Arriens, 1970
2765	.7	0.10	-467	2298	Yilgarn, W.A.	Arriens, 1970
2698	.704	0.10	869	3567	Yilgarn, W.A.	Arriens, 1970
2696	.699	0.10	-837	1859	Yilgarn, W.A.	Arriens, 1970
2629	.704	0.10	839	3468	Yilgarn, W.A.	Arriens, 1970
2972	.699	0.10	-719	2253	Yilgarn, W.A.	Arriens, 1970
2872	.701	0.10	-80	2792	Yilgarn, W.A.	Arriens, 1970
2804	.686	0.10	SSSS	SSSS	Yilgarn, W.A.	Arriens, 1970
2698	.703	0.10	528	3226	Yilgarn, W.A.	Arriens, 1970
2664	.702	0.10	172	2836	Yilgarn, W.A.	Arriens, 1970
2764	.704	0.10	897	3661	Yilgarn, W.A.	Arriens, 1970
2604	.704	0.10	828	3432	Yilgarn, W.A.	Arriens, 1970
2617	.703	0.10	493	3110	Yilgarn, W.A.	Arriens, 1970
2670	.7025	0.10	345	3015	Yilgarn, W.A.	Compston & Turek, 1973
2652	.7015	0.10	-4	2648	Yilgarn, W.A.	Cooper et al., 1978
2632	.7015	0.10	-12	2620	Yilgarn, W.A.	Cooper et al., 1978
2689	.7015	0.10	12	2701	Yilgarn, W.A.	Roddick & Compston, 1976 [PF3:55]
2576	.7022	0.10	202	2778	Yilgarn, W.A.	Cooper et al., 1978
2555	.707	0.10	1830	4385	Yilgarn, W.A.	Benhett et al., 1975
2665	.7015	0.10	2	2667	Yilgarn, W.A.	Chapman et al., 1980
2690	.702	0.10	183	2873	Yilgarn, W.A.	Chapman et al., 1980
2540	.716	0.10	4893	7433	Yilgarn, W.A.	Chapman et al., 1980
2590	.7028	0.10	413	3003	Yilgarn, W.A.	Muhling & DeLaeter, 1970
2605	.7031	0.10	522	3127	Yilgarn, W.A.	Muhling & DeLaeter, 1970
2564	.7008	0.10	-280	2284	Yilgarn, W.A.	Roddick & Compston, 1976 [PF3:55]
3125	.7016	0.10	233	3358	Pilbara	DeLaeter & Blockley, 1972
2951	.702	0.10	295	3246	Pilbara	DeLaeter et al., 1975
2670	.7397	0.10	SSSS	SSSS	Pilbara	DeLaeter & Blockley, 1972
2602	.7310	0.10	SSSS	SSSS	Pilbara	DeLaeter et al., 1975
2290	.706	0.10	1376	3666	Pilbara	Pidgeon, 1978
2568	.7307	0.10	9918	SSSS	Pilbara	DeLaeter et al., 1977
2651	.7086	0.10	2417	5068	Pilbara	DeLaeter et al., 1977
2765	.6949	0.10	SSSS	559	Pilbara	Hickman & DeLaeter, 1977
2880	.7303	0.10	9916	SSSS	Pilbara	DeLaeter & Trendall, 1970
3280	.7014	0.10	231	3511	Pilbara	Cooper et al., 1980
3227	.7009	0.10	38	3265	Pilbara	Cooper et al., 1980
3087	.7103	0.10	3184	6271	Pilbara	Cocper et al., 1980
2798	.7289	0.10	9403	SSSS	Pilbara	Cooper et al., 1980

Fig. 17

All Data [612 isochrons]

Sr87/86[i]

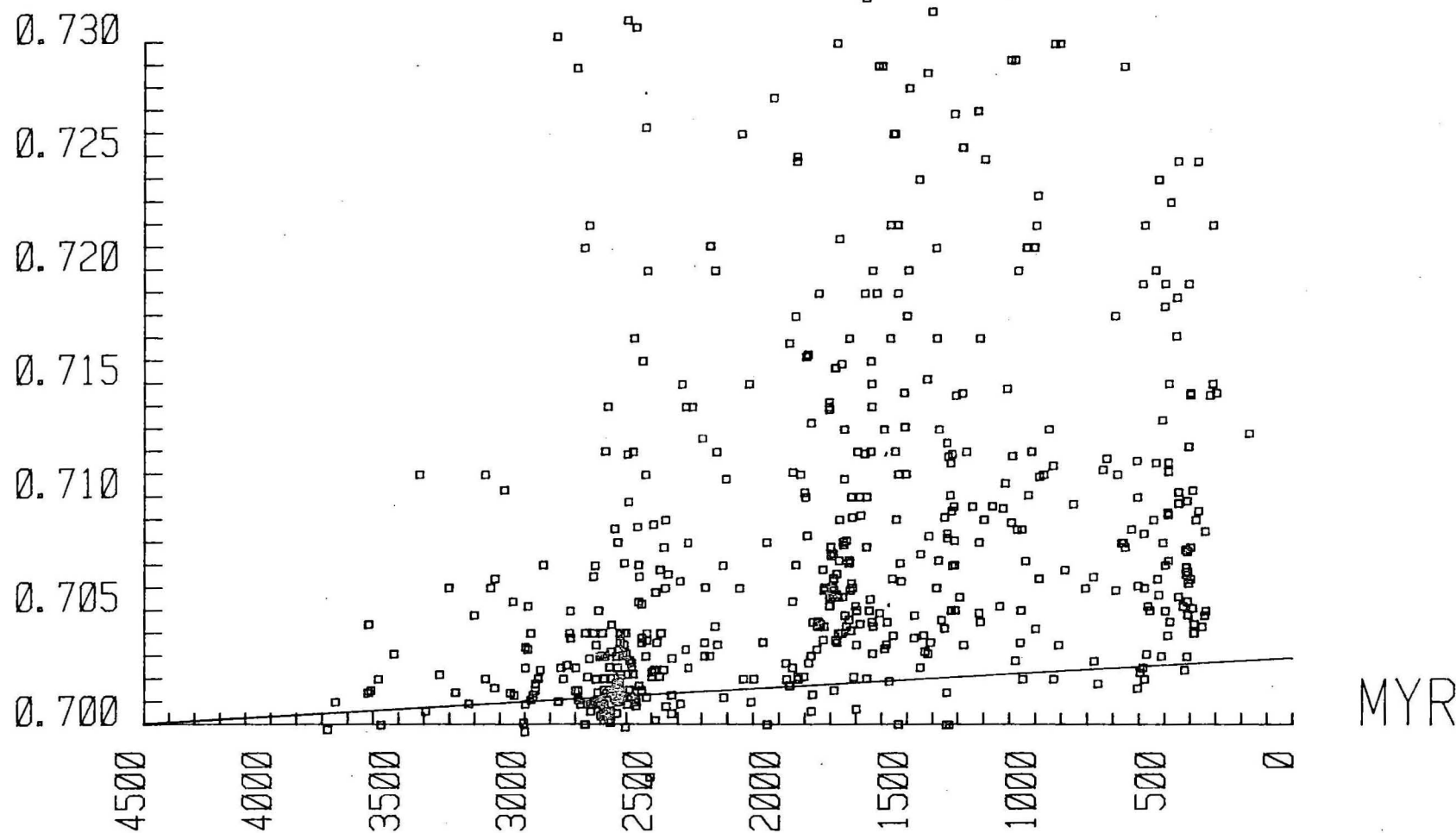


Fig. 18

All Data [612 isochrons]

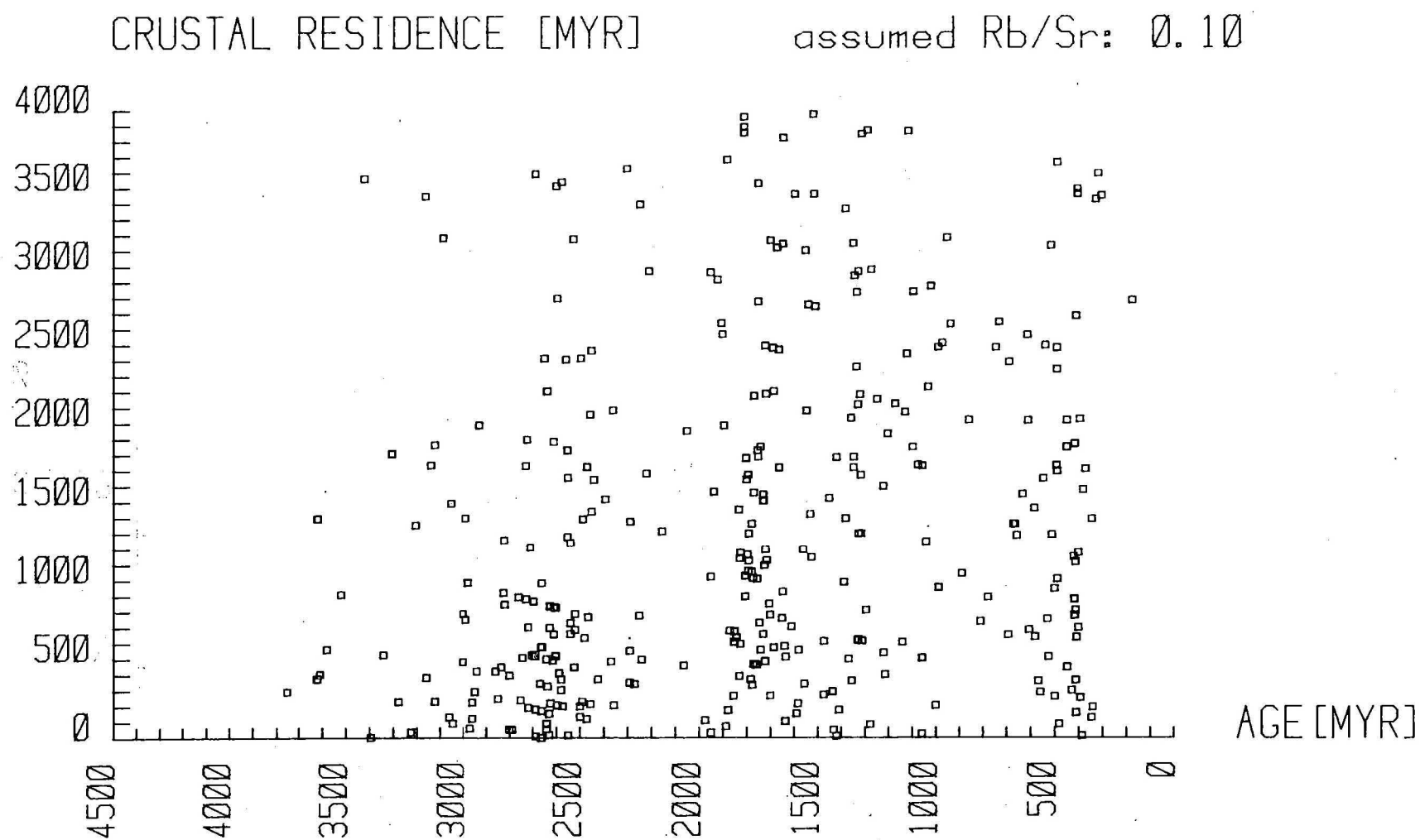


Fig. 19

All Data [612 isochrons]

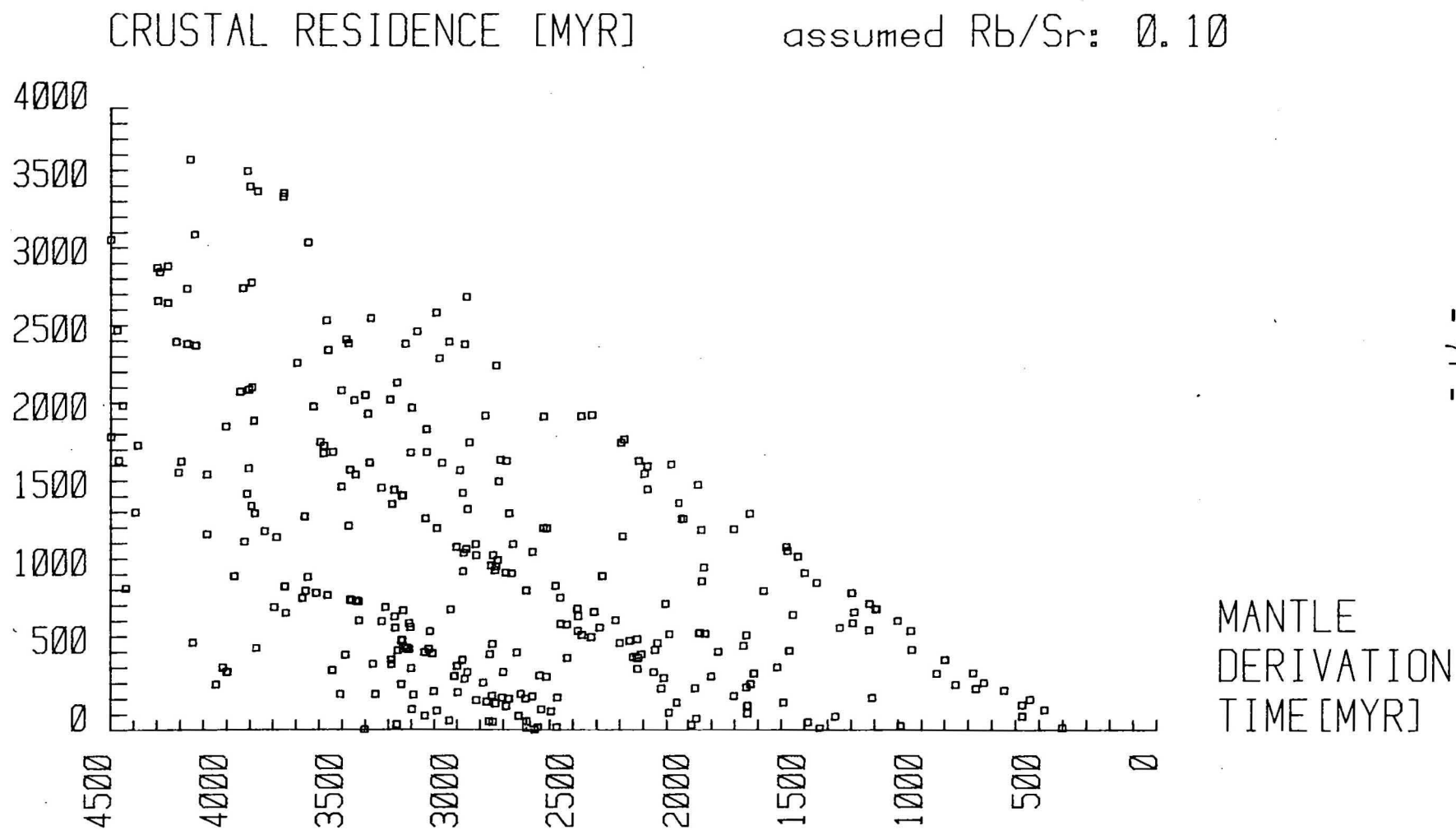


Fig. 20

Rb/Sr AGE FREQUENCY [612 isochrons]

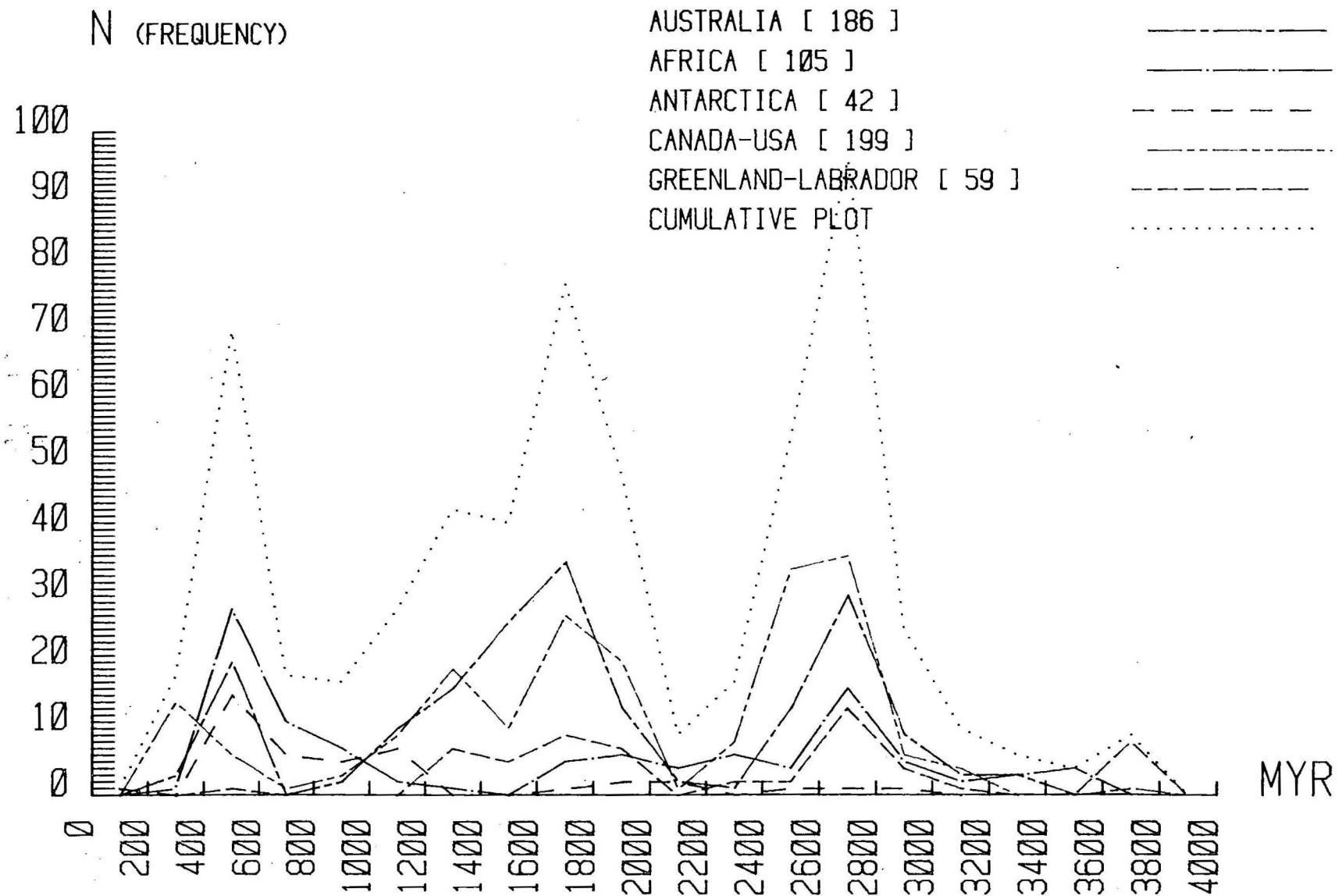
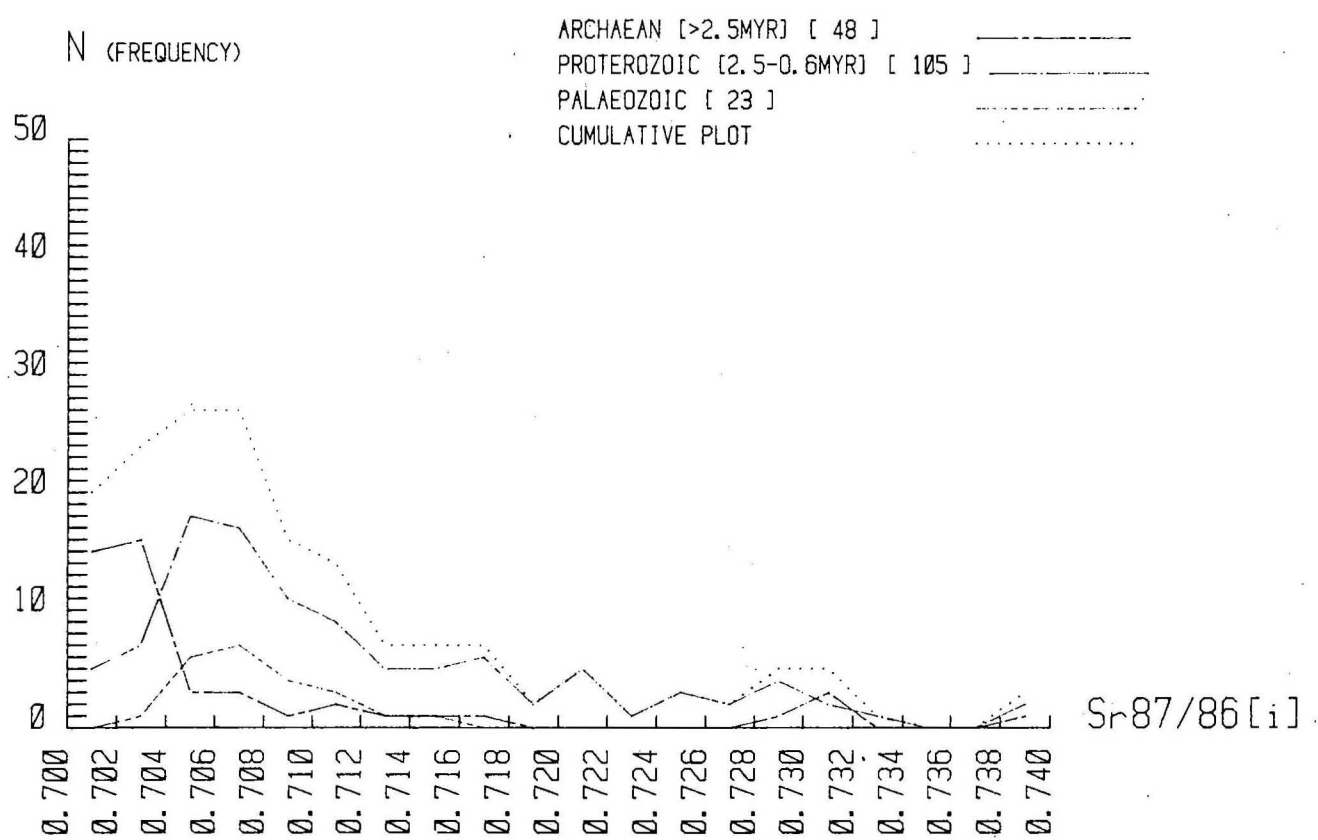


Fig. 21

Sr87/Sr86[i] FREQUENCY: AUSTRALIA



D1(i) - Data transfer

Data can be transferred from Disc to Disc, Disc to tape, tape to disc or tape to tape, as instructed by keyboard specification of desired disc code (up to 3 letters) or track numbers, and of the desired file numbers range, as in program A5.

D2 - Rb-Sr frequency plots ("RSFRQ"; 6220 Bytes)(AYG)

This program can be either loaded at the outset of program D1, where it constitutes the 10th title in the initial selection sequence, or can be loaded independently. At the outset of the program plotting of Rb-Sr isochron ages or of initial $\text{Sr}^{87}/\text{Sr}^{86}$ ratios can be selected by responding to "AGE [1] OR INITIAL $\text{Sr}^{87}/\text{Sr}^{86}$ [2] PLOT". Choice of absolute frequency or % frequency, design of the diagram dimensions and parameters; data retrieval and cumulative frequency are specified as in program B11. Examples of Age frequency plots and Ri frequency plots are given in Fig. 20 and 21 respectively.

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APPENDIX I

CONVERSION FACTORS

Al	→	Al ₂ O ₃	1.88988	Al ₂ O ₃	→	Al	0.52913
Ba	→	BaO	1.11648	BaO	→	Ba	0.89567
Ca	→	CaO	1.39920	CaO	→	Ca	0.71469
Ca	→	CaCO ₃	2.49726	CaCO ₃	→	Ca	0.40044
Co	→	CoO	1.27146	CoO	→	Co	0.78650
Cs	→	Cs ₂ O	1.06020	Cs ₂ O	→	Cs	0.94323
Fe ²⁺	→	FeO	1.28648	FeO	→	Fe ²⁺	0.77731
Fe ³⁺	→	Fe ₂ O ₃	1.42972	Fe ₂ O ₃	→	Fe ³⁺	0.69944
FeO	→	Fe ₂ O ₃	1.11134	Fe ₂ O ₃	→	FeO	0.89981
Fe	→	FeS	1.5791	FeS	→	Fe	0.63327
K	→	K ₂ O	1.20462	K ₂ O	→	K	0.83013
Mn	→	MnO	1.29128	MnO	→	Mn	0.77443
Mg	→	MgO	1.65789	MgO	→	Mg	0.60317
Na	→	Na ₂ O	1.34787	Na ₂ O	→	Na	0.74191
Ni	→	NiO	1.27262	NiO	→	Ni	0.78578
Li	→	Li ₂ O	2.15274	Li ₂ O	→	Li	0.46452
P	→	P ₂ O ₅	2.29116	P ₂ O ₅	→	P	0.43646
Rb	→	Rb ₂ O	1.09359	Rb ₂ O	→	Rb	0.91442
Si	→	SiO ₂	2.14041	SiO ₂	→	Si	0.46720
Sr	→	SrO	1.18259	SrO	→	Sr	0.84560
Ti	→	TiO ₂	1.66806	TiO ₂	→	Ti	0.59950
Zr	→	ZrO ₂	1.35080	ZrO ₂	→	Zr	0.74030
Cr	→	Cr ₂ O ₃	1.46145	Cr ₂ O ₃	→	Cr	0.68425
S	→	SO ₃		SO ₃	→	S	0.40049

Appendix II

CIPW Norm and Molecular Weights

Plotting Code	Mineral	Abbreviation	Formula	Molecular Weight
Salic Group				
1	Quartz	(Q)	SiO_2	60.08
2	Corundum	(C)	Al_2O_3	101.96
	Zircon	(Z)	$\text{ZrO}_2 \cdot \text{SiO}_2$	183.30
3	Orthoclase	(Or)	$\text{K}_2\text{O} \cdot \text{Al}_2\text{O}_3 \cdot 6\text{SiO}_2$	556.64
4	Albite	(Ab)	$\text{Na}_2\text{O} \cdot \text{Al}_2\text{O}_3 \cdot 6\text{SiO}_2$	524.42
5	Anorthite	(An)	$\text{CaO} \cdot \text{Al}_2\text{O}_3 \cdot 2\text{SiO}_2$	278.20
6	Nepheline	(Ne)	$\text{Na}_2\text{O} \cdot \text{Al}_2\text{O}_3 \cdot 2\text{SiO}_2$	283.10
7	Leucite	(Lc)	$\text{K}_2\text{O} \cdot \text{Al}_2\text{O}_3 \cdot 4\text{SiO}_2$	436.48
8	Kaliophilite	(Kp)	$\text{K}_2\text{O} \cdot \text{Al}_2\text{O}_3 \cdot 2\text{SiO}_2$	316.32
	Halite	(Hl)	NaCl	58.44
	Thernardite	(Th)	$\text{Na}_2\text{O} \cdot \text{SO}_3$	142.04
	Sodium carbonate	(Nc)	$\text{Na}_2\text{O} \cdot \text{CO}_2$	105.99
Femic Group				
9	Acmite	(Ac)	$\text{Na}_2\text{O} \cdot \text{Fe}_2\text{O}_3 \cdot 4\text{SiO}_2$	461.99
10	Sodium metasilicate	(Ns)	$\text{Na}_2\text{O} \cdot \text{SiO}_2$	122.06
11	Potassium metasilicate	(Ks)	$\text{K}_2\text{O} \cdot \text{SiO}_2$	154.28
12	Diopside	(Di)	$\text{CaO} \cdot \text{MgO} \cdot 2\text{SiO}_2$	216.55
			$\text{CaO} \cdot \text{FeO} \cdot 2\text{SiO}_2$	248.09
13	Wollastonite	(Wo)	$\text{CaO} \cdot \text{SiO}_2$	116.16
14	Hypersthene	(Hy)	$\text{MgO} \cdot \text{SiO}_2$	100.39
			$\text{FeO} \cdot \text{SiO}_2$	131.93
15	Olivine	(Ol)	$2\text{MgO} \cdot \text{SiO}_2$	140.70
			$2\text{FeO} \cdot \text{SiO}_2$	203.78
16	Dicalcium silicate	(Cs)	$2\text{CaO} \cdot \text{SiO}_2$	172.24
17	Magnetite	(Mt)	$\text{FeO} \cdot \text{Fe}_2\text{O}_3$	231.54
	Chromite	(Cm)	$\text{FeO} \cdot \text{Cr}_2\text{O}_3$	223.84
18	Ilmenite	(Il)	$\text{FeO} \cdot \text{TiO}_2$	151.75
19	Hematite	(Hm)	Fe_2O_3	159.69
20	Sphene	(Tn)	$\text{CaO} \cdot \text{TiO}_2$	196.06
21	Perovskite	(Pf)	$\text{CaO} \cdot \text{TiO}_2$	135.98
22	Rutile	(Ru)	TiO_2	79.90

Plotting Code	Mineral	Abbreviation	Formula	Molecular Weight
23	Apatite	(Ap)	$3\text{CaO} \cdot \text{P}_2\text{O}_5 \cdot 1/3\text{CaF}_2$	336.21
	Fluorite	(Fr)	CaF_2	78.08
24	Calcite	(Cc)	$\text{CaO} \cdot \text{CO}_2$	100.09
25	Pyrite	(Pr)	FeS_2	119.98
33	differentiation index		$\text{Qz} + \text{Or} + \text{Ab} + \text{Ne} + \text{Lc} + \text{Kp}$	
34	crystallization index		$\text{An} + \text{Di} + \text{Fo} + \text{Sp}$	

MOLECULAR-WEIGHTS

SiO ₂	60.08	TiO ₂	79.90
Al ₂ O ₃	101.96	ZrO ₂	123.22
Fe ₂ O ₃	159.69	MnO	70.94
FeO	71.85	NiO	74.71
MgO	40.31	BaO	153.34
CaO	56.08	SrO	103.62
Na ₂ O	61.98	Cr ₂ O ₃	151.98
K ₂ O	94.20	Cl	35.45
SO ₃	80.06	P ₂ O ₅	141.94
F	19.00	CO ₂	44.01
S	32.06		

APPENDIX III (1)

TABLE 1 -Partition coefficients for basaltic and andesitic rocks

	Olivine			Orthopyroxene			Diopside			Augite			Pigeon- ite	Hornblende			Phlogo- pite	Plagioclase			Gar- net*
	Avg	Low	High	Avg	Low	High	Avg	Low	High	Avg	Low	High		Avg	Low	High		Avg	Low	High	
	2 determinations			3 determinations			2 determinations			5 determinations			1 deter- mi- nation	4 determinations			1 deter- mi- nation	8 determinations			5 deter- mi- nations
Ce	0.0069	0.0026	0.0090	0.024	0.0026	0.038	0.070	0.043	0.096	0.15	0.077	0.21	0.02	0.20	0.094	0.34	0.034	0.12	0.023	0.28	0.028
Nd	.0066	.003	.010	.033	.006	.058	.12	.065	.18	.31	.17	.43	.05	.33	.16	.53	.032	.081	.023	.20	.068
Sm	.0066	.003	.011	.054	.014	.100	.18	.090	.26	.50	.26	.74	.10	.52	.24	.93	.031	.067	.024	.17	.29
Eu	.0068	.005	.010	.054	.023	.079	.18	.091	.26	.51	.27	.75	.068	.59	.26	1.1	.030	.34	.055	.73	.49
Gd	.0077	.004	.012	.091	.032	.171	.19	.095	.27	.61	.32	.87	.16	.63	.28	1.1	.030	.063	.017	.21	.97
Dy	.0096	.006	.014	.15	.054	.293	.21	.105	.31	.68	.50	1.0	.23	.64	.31	1.0	.030	.055	.010	.19	3.17
Er	.011	.008	.017	.23	.076	.46	.17	.107	.23	.65	.46	1.0	.32	.55	.24	1.0	.034	.063	.010	.24	6.56
Yb	.014	.009	.023	.34	.11	.67	.16	.092	.23	.62	.43	1.0	.40	.49	.23	.98	.042	.067	.006	.30	11.5
Lu	.016	.009	.026	.42	.11	.84	.13	.071	.19	.56	.27	.95	.45	.43	.22	.82	.046	.060	.0045	.24	11.9
	2 determinations			3 determinations			2 determinations			5 determinations				3 determinations				9 determinations			
K	.0068	.0056	.0081	.014	.009	.019	.011	.0084	.014	.038	.004	.078	.0034	.96	.33	1.40		.17	.019	.36	.015
Rb	.0098	.0084	.011	.022	.015	.029	.015	.014	.015	.031	.015	.039	.0003	.29	.045	.43	3.06	0.71	.016	.14	.042
Sr	.014	.0094	.019	.017	.010	.024	.12	.078	.15	.12	.093	.15	.0019	.46	.19	.64	.081	1.83	1.29	2.87	.012
Ba	.009	.0086	.011	.013	.012	.014	.013	.013	.013	.026	.004	.046	.0004	.42	.10	.73	1.09	.23	.05	.59	.023
Refer- ences#	1, 3, 4, 5.....			2, 3, 5.....			3, 5.....			2, 3, 4, 5.....			3, 5.	1, 3, 4, 5.....			3, 5.	1, 3, 5.....			

* Garnet values obtained by multiplying average garnet/clinopyroxene of reference 6 by average augite/liquid of this table.

References are as follows:

1. Higuchi and Nagasawa (1969).
2. Onuma and others (1968).
3. Philpotts and Schnetzler (1970).
4. Schnetzler and Philpotts (1968).
5. Schnetzler and Philpotts (1970).
6. Philpotts and other (1972).

APPENDIX III (2)

TABLE 2. Partition coefficients for dacitic rocks

(Data represent one determination per mineral)

	Garnet	Biotite	Plagioclase	Hornblende
Ce	0.35	0.037	0.24	0.899
Nd	.53	.044	.17	2.80
Sm	2.66	.058	.13	3.99
Eu	1.50	.145	2.11	3.44
Gd	10.5	.082	.090	5.48
Dy	28.6	.097	.086	6.20
Er	42.8	.162	.084	5.94
Yb	39.9	.179	.077	4.89
Lu	29.6	.185	.062	4.53
K	.020		.263	
Rb	.0085	3.26	.048	
Sr	.015	.12	2.48	
Ba	.017	6.36	.36	
References*	1,2	1,2	1,2	3

* References are as follows:

1. Philpotts and Schetzler (1970).
2. Schnetzler and Philpotts (1970).
3. Arth, unpub. data, 1975.

APPENDIX III (3)

TABLE 3 - Partition coefficients for rhyolitic rocks
(Figures in parentheses indicate number of determinations)

	Hypersthene (4)			Clinopyroxene (2)			Hornblende (3)			K-feld- spar (1)	Bio- tite (1)	Phlog- opite (1)	Apatite (4)			Zircon (2)			Plagioclase (4)					
	Avg	Low	High	Avg	Low	High	Avg	Low	High				Avg	Low	High	Avg	Low	High	Avg	Low	High			
Ce	0.15	1.082	0.26	0.50	0.36	0.65	1.52	1.38	1.77	0.044	0.32	0.23	34.7	18.0	52.5	2.64	2.29	3.00	0.27	0.17	0.35			
Nd	.22	.12	.35	1.11	.94	1.28	4.26	4.03	4.49	.025	.29	.34	57.1	27.4	81.1	2.20	1.97	2.43	.21	.12	.29			
Sm	.27	.16	.38	1.67	1.52	1.18	7.77	7.1	8.1	.018	.26	.39	62.8	29.3	89.8	3.14	2.58	3.70	.13	.084	.15			
Eu	.17	.093	.27	1.56	1.11	2.01	5.14	4.5	5.9	1.13	.24	.50	30.4	20.5	50.2	3.14	1.07	5.22	2.15	.96	2.81			
Gd	.34	.23	.46	1.85	1.5	2.2	10.0	9.3	10.5	.011	.28	.35	56.3	27.2	78.0	12.0	10.0	14.0	.097	.06	.13			
Dy	.46	.33	.55	1.93	1.22	2.63	13.0	12.5	13.5	.006	.29	.20	50.7	25.6	69.2	45.7	37.8	53.5	.064	.04	.08			
Er	.65	.53	.73	1.80	1.07	2.25	12.0	10.8	14.0	.006	.35	.17	37.2	20.0	51.2	135	119	152	.055	.038	.072			
Yb	.86	.73	.99	1.58	1.14	2.01	8.38	7.45	9.0	.012	.44	.17	23.9	13.1	37.0	270	242	299	.049	.03	.07			
Lu	.90	.76	1.14	1.54	1.28	1.81	5.5	4.4	6.3	.006	.33	.21	20.2	11.2	30.2	323	281	366	.046	.03	.06			
	Hypersthene(1)			Clinopy- roxene(1)			Horn- blende(1)												Plagioclase(1)					
K	.0023			.037			.081												.10					
Rb	.0027			.032			.014			0.34(12)			2.24 .94						.041					
Sr	.0085			.516			.022			3.87			.672						4.4					
Ba	.0029			.131			.044			6.12			9.7 15.3						.308					
References*	1.....			1, 4, 5..			1....			4, 5, 6..			2.. 4, 5			3....			3.....			1....		

* References are as follows:

1. Nagasawa and Schnetzler (1971).
2. Higuchi and Nagasawa (1969).

3. Nagasawa (1970).
4. Philpotts and Schnetzler (1970).

5. Schnetzler and Philpotts (1970).
6. Noble and Hedge (1970).