UNITED STATES DEPARTMENT OF THE INTERIOR
GEOLOGICAL SURVEY

A program in Hewlett-Packard BASIC for calculation of Mesonormative minerals using HP-Series 80 computers and VISICALC electronic worksheet

by

J. S. Stuckless

Open-File Report 83-923
1983

INTRODUCTION

The calculation of normative minerals for igneous rocks was proposed by Cross and others (1902). Since that time, several schemes have been proposed for the calculation of standard sets of minerals for igneous and metamorphic rocks. Such mineral sets are convenient for comparing chemically similar rocks that have formed in or have been subjected to different sets of physical conditions.

The mesonorm, as proposed by Barth (1955), was intended to calculate minerals typical of the mesozonal metamorphism. This norm allows for hydrous minerals not found in the older CIPW norm (Cross and others, 1902). Furthermore, because the results are expressed in cation percent, they more closely reflect the modal percentages of minerals in a rock. For these reasons, some petrologists prefer to calculate a mesonorm, not only for metamorphic rock, but for certain igneous rocks as well.

The program "MESO" described here uses steps set for by Barth (1955, 1959, 1962a, 1962b), with a few modifications for handling exceptions as suggested for the CIPW norm by Washington (1917), and described by Stuckless and VanTrump (1979). These modifications include calculation of magnesite and siderite before the calculation of sodium carbonate if all CO_2 is not used to calculate calcite. Also, MESO prints any excess amounts of reported elements beyond what is used in computing the norm.

The program MESO makes a few assumptions with regard to ambiguities in the various descriptions of the mesonorm. Barth (1962a) gives the normative minerals as biotite, actinolite, edenite, riebeckite, sphene, and spinel, and states that "except for ilmenite (il) and acmite (ac), all other mesonormative minerals are in common with the catanorm (p. 497). This presumably means that all other minerals of the CIPW norm are to be used because Barth (1959, p. 135) states: "The catanorm here proposed is given in cation percentages; otherwise it corresponds to the CIPW norm". However, silica-deficient potassium minerals (kaliphilite and leucite) are not given as possibilities in the mesonormative steps to balance silica in silica-undersaturated rock. Therefore, these minerals are not calculated by MESO. Minor minerals (such as zircon and perovskite) which may have been omitted from the description of the mesonorm for the sake of brevity, are calculated in the order given for the CIPW norm.

EQUIPMENT, TIMING, AND STORAGE REQUIREMENTS

MESO is written for HP-series 80 computers, and may require modification if it is to be run on other computers that use BASIC as a programming language. Storage of the program requires approximately 32 records of 256-byte length. Results of calculations and original input data are written to a file of 256-byte records. The number of records is 13 plus 5 times the number of samples.

The program, as listed in Appendix I, requires approximately 68 K bytes of memory to run. However, if the matrix is redimensional for 55 instead of 62 samples (line 20, Appendix I), the memory requirement is decreased to approximately 63 K bytes.

Execution time for the program is largely consumed by data storage and retrieval operations. It takes about 2 minutes to load data for 62 samples, and nearly 8 minutes to store the results. Computations for these samples, 22 of which were silica deficient, requires about 3-1/2 minutes.

NORMATIVE COMPUTATIONS

All norms described by Barth (catanorm, mesonorm, and epinorm) are expressed in terms of cation proportions (Barth, 1955). The first step is to convert the chemical analyses from weight percent (in which they are usually reported) to equivalent molecular proportions. This is accomplished by dividing the amount (in weight percent) of each reported oxide by its molecular weight, and adjusting each result for the number of cations in the oxide as reported. For example, alumina is reported as Al_2O_3, and therefore, the equivalent molecular proportion of alumina is twice the amount of reported oxide, divided by the molecular weight of Al_2O_3. The sum of equivalent molecular porportions of all reported cations is then adjusted to 100 percent.

Data for anions are likewise adjusted to a sum of 100 percent, although the exact procedures used by Barth (1955) are somewhat ambiguous. On the basis of data reported by Barth (1955; 1957), it appears that equivalent molecular proportions of anions have been adjusted by the constant determined for the cations, and this method is employed in MESO. These adjustments cause the final data used to calculate a mesonorm to sum to more than 100 percent, if data for anions are reported. Finally, for purposes of normative calculations, water is treated implicitly as the anion $(OH)^-$.

Chemical data used to calculate the mesonorm, resulting minerals, and chemical formulae used for minerals are presented in Table 1. Oxides are listed in the order required by MESO. Water can be H_2O^+, H_2O^-, total H_2O, or LOI (loss on ignition). Water is not actually used as a variable; the calculation of hydrous minerals simply assumes sufficient amounts of OH radicals.

1. The first steps in calculating a mesonorm are:

   a. add MnO and NiO to FeO;

   b. add BaO to CaO;

   c. decrease F by 1/3 the amount of P_2O_5.

2. The amount of apatite is equal to the lesser of:

   a. 8/5 times the amount of CaO or

   b. 8/3 times the amount of P_2O_5.

In the first case, there will be an excess of P_2O_5 beyond that expressed in the norm, and because P is used as a cation, the sum of the normative minerals will be less than 100 percent. CaO is then set equal to 0. In the second case, CaO is decreased by 5/3 times P_2O_5.

3. The amount of halite is equal to the lesser of:

   a. the amount of Na_2O or

   b. the amount of Cl.

In the first case, there will be excess Cl, but because Cl is an anion, the normative total will still be 100 percent. Na_2O is set equal to 0. In the second case, Na_2O is decreased by the amount of Cl.

4. The amount of thenardite is equal to the lesser of:

   a. the amount of Na_2O or

   b. 2 times the amount of SO_3.

In the first case, there will be excess SO_3, and Na_2O is set equal to 0. In the second case, Na_2O is decreased by 2 times the amount of SO_3.

5. The amount of pyrite is equal to the lesser of:

   a. the amount of FeO or

   b. 1/2 times the amount of S.

In the first case, there will be excess S, and FeO is set equal to 0. In the second case, FeO is decreased by 1/2 the amount of S.

6. The amount of chromite is equal to the lesser of:

   a. 3 times the amount of FeO or

   b. 3/2 times the amount of Cr_2O_3.

In the first case, there will be an excess of Cr_2O_3, and FeO is set equal to 0. In the second case, FeO is decreased by 1/2 the amount of Cr_2O_3.

7. The amount of fluorite is equal to the lesser of:

   a. the amount of CaO or

   b. 1/2 times the amount of F (as adjusted above).

In the first case, there will be excess F, and CaO is set equal to 0. In the second case, CaO is decreased by 1/2 the amount of F.

8. Carbonates are calculated in the order calcite, magnesite, siderite, and sodium carbonate until all CO_2 has been used. The amount of each of the first three carbonates is equal to the lesser of:

   a. 2 times the amount of CO_2 (decreased as necessary for previously calculated carbonates) or

   b. 2 times the amount of CaO or MgO or FeO.

After each mineral is calculated, the amounts of CO_2 and CaO, MgO, or FeO are decreased by 1/2 the amount of the mineral calculated. If CO_2 is left after calculation of siderite, sodium carbonate is equal to the lesser of:

c. 3/2 times the amount of Na_2O or

d. 3 times the amount of CO_2.

In the first case, there will be excess CO_2 and Na_2O is set equal to 0. In the second case, Na_2O is decreased by 3/2 times the amount of CO_2.

9. The amount of zircon is equal to 2 times the amount of ZrO_2, and SiO_2 is decreased by the amount of ZrO_2.

10. The amount of titanite (sphene) is provisionally set equal to the lesser of:

a. 3 times the amount of TiO_2 or

b. 3 times the amount of CaO.

In the first case, CaO is decreased by the amount of TiO_2. In the second case, rutile is set equal to the amount of TiO_2 minus the amount of CaO, and CaO is set equal to 0.

11. The amount of orthoclase is provisionally set equal to the lesser of:

a. 5 times the amount of K_2O or

b. 5 times the amount of Al_2O_3.

In the first case, Al_2O_3 is decreased by the amount of K_2O. In the second case, potassium metasilicate is set equal to 3/2 times (the amount of K_2O minus the amount of Al_2O_3), and Al_2O_3 is set equal to 0.

12. The amount of albite is provisionally set equal to the lesser of:

a. 5 times the amount of Na_2O or

b. 5 times the amount of Al_2O_3.

In the first case, Al_2O_3 is decreased by the amount of Na_2O. In the second case, riebeckite is equal to the lesser of:

i) 15/2 times the amount of Na_2O or

ii) 15/2 times the amount of Fe_2O_3 or

iii) 5 times the amount of FeO.

In the first case, Fe_2O_3 is decreased by the amount of Na_2O, and FeO is decreased by 3/2 times the amount of Na_2O. In the second case, FeO is decreased by 3/2 times the amount of Fe_2O_3; the amount of sodium metasilicate

is equal to 3/2 times (the amount of Na_2O minus the amount of Fe_2O_3), and Fe_2O_3 is set equal to 0. In the third case, Fe_2O_3 is decreased by 2/3 times the amount of FeO; the amount of sodium metasilicate is equal to 3/2 times (the amount of Na_2O minus 2/3 times the amount of FeO), and FeO is set equal to 0.

13. The amount of magnetite is equal to the lesser of:

    a. 3 times the amount of FeO or

    b. 3/2 times the amount of Fe_2O_3.

In the first case, hematite is equal to the amount of Fe_2O_3, minus 2 times the amount of FeO, and FeO is set equal to zero. In the second case, FeO is decreased by 1/2 times the amount of Fe_2O_3.

14. The amount of anorthite is equal to the lesser of:

    a. 5 times the amount of CaO or

    b. 5/2 times the amont of Al_2O_3.

In the first case, corundum is provisionally set equal to the amount of Al_2O_3, minus 2 times the amount of CaO. In the second case, CaO is decreased by 1/2 times the amount of Al_2O_3.

15. Any remaining FeO and MgO are added together to form a single cation (symbolized as Mg') which is used to calculate all of the remaining ferro-magnesian minerals.

16. The amount of biotites is equal to the lesser of:

    a. 8/5 times the amount of orthoclase or

    b. 8/3 times the amount of Mg'.

In the first case, Mg' is decreased by 3/5 times the amount of provisional orthoclase (calculated in step 11), and orthoclase is set equal to 0. In the second case, orthoclase is decreased by 5/3 times Mg', and Mg' is set equal to 0.

17. The amounts of actinolite, diopside, hypersthene, and wollastonite are determined as follows:

    a. If all Mg' has been used, the amount of Wollastonite is equal to 2 times the amount of CaO, and the amounts of the ferro-magnesian minerals are set equal to zero.

    b. If all CaO has been used, the amount of hypersthene is equal to 2 times the amount of Mg', and the amounts of actinolite, diopside, and wollastonite are set equal to zero.

    c. If both Mg' and CaO are available, there are three possible assemblages. If CaO/Mg' $\leq$0.4, actinolite (15/2 times CaO) plus

hypersethene (2 times (Mg' minus 2.5 times CaO)) is calculated. If 0.4> CaO/MgO >1.0, actinolite (5 times (Mg' -CaO)) plus diopside (1/3 times (20 times CaO minus 8 times Mg') is calculated. If CaO/MgO < 1, diopside (4 times Mg') plus wollastonite (2 times (CaO-Mg')) is calculated.

18. If the rock contains muscovite, and both orthoclase and corundum have been calculated, these minerals can be converted to muscovite. The amount of muscovite is equal to the lesser of:

a. 7/2 times the amount of corundum or

b. 7/5 times the amount of orthoclase.

In the first case, the amount of orthoclase is reduced by 5/2 times the amount of corundum, and corundum is set equal to zero. In the second case, the amount of corundum is reduced by 2/7 times the amount of orthoclase, and orthoclase is set equal to zero.

19. The amount of silica available for quartz is then calculated from the sum: 1/3 (sphene + sodium metasilicate + potassium metasilicate) + 6/10 (orthoclase + albite) + 4/10 (anorthite + 8/15 (riebeckite + actinolite) + 1/2 (zircon + diopside + wollastonite + hypersthene) + 3/7 muscovite + 3/8 biotite.

If this sum is less than the cation percentage of silica, the excess silica is expressed as quartz, and the computation is finished

20. If too much silica has been used, desilicification of the mineral assemblage is necessary. Albite and actinolite are converted to edenite according to one of three possibilities:

a. If the silica deficiency is less than or equal to both 4/5 times the amount of albite and 4/15 times the amount of actinolite, the amount of edenite is equal to 4 times the deficiency, albite is decreased by 5/4 times the deficiency, and actinolite is decreased by 15/4 times the deficiency. Silica is now balanced, quartz content is zero, and the computation is finished.

b. If the amount of actinolite is less than or equal to 3 times the amount of albite, edenite is equal to 16/15 times the amount of actinolite, albite is decreased by 1/3 times the amount of actinolite, the silica deficiency is decreased by 4/15 times the amount of actinolite, and actinolite is set equal to zero.

c. If conditions in neither a nor b are met, edenite is equal to 16/5 times the amount of albite, the silica deficiency is decreased by 4/5 times albite, actinolite is set equal to zero.

21. Desilicification is continued, if necessary, by conversion of hypersthene to olivine.

a. If the silica deficiency is less than or equal to 1/4 times the amount of hypersthene, hypersthene is decreased by 4 times the deficiency, the amount of olivine is equal to 3 times the deficiency, quartz content is 0, and the computation is finished.

b. If the deficiency is greater than 1/4 times the amount of hypersthene, the deficiency is decreased by 1/4 times the amount of hypersthene, olivine content is equal to 3/4 times the hypersthene content, and hypersthene is equal to 0.

22. If there is still a silica deficiency, olivine and corundum are converted to spinel.

a. If the deficiency is less than or equal to both 1/4 times the amount of corundum and 1/3 times the amount of olivine, spinel content is equal to 6 times the deficiency, corundum content is decreased by 4 times the deficiency, olivine is decreased by 3 times the deficiency, and the computation is finished.

b. If 1/3 times the amount of olivine is less than or equal to 1/4 times the amount of corundum, spinel is equal to 2 times the amount of olivine, corundum content is decreased by 4/3 times the olivine content, the deficiency is decreased by 1/3 times the olivine content, and olivine is equal to 0.

c. If the conditions in neither a nor b are met, spinel is equal to 3/2 times the amount of corundum, olivine content is decreased by 3/4 times the amount of corundum, the deficiency is decreased by 1/4 times the amount of corundum, and corundum is equal to 0.

23. If there is still a silica deficiency, albite is converted to nepheline.

a. If the deficiency is less than or equal to 4/10 times the amount of albite, nepheline content is 3/2 times the deficiency, albite content decreased by 5/2 times the deficiency, and the calculations are finished.

b. If the deficiency is greater than 4/10 times the amount of albite, nepheline is 3/5 times the amount of albite, the deficiency is decreased by 2/5 times the amount of albite, and albite is equal to 0.

24. If there is still a silica deficiency, sphene is converted to perovskite.

a. If the deficiency is less than or equal to 1/3 times the amount of sphene; perovskite content is equal to 2 times the deficiency, sphene content is decreased by 3 times the deficiency, and the computation is finished.

b. If the deficiency is greater than 1/3 times the amount of sphene, perovskite content is equal to 2/3 times the amount of sphene, the deficiency is decreased by 1/2 times sphene content, and sphene equals 0.

25. A final attempt to balance silica is made by converting diopside to olivine plus wollastonite.

a. If the deficiency is less than or equal to 1/8 times the amount of diopside, diopside content is decreased by 8 times the deficiency, olivine content is increased to 3 times the deficiency, wollastonite content is increased by 4 times the deficiency, and the computation is finished.

b. If the deficiency is greater than 1/8 times the amount of diopside, it is decreased by 1/8 times the amount of diopside, olivine content is increased by 3/8 times the amount of diopside, wollastonite content is increased by 1/2 times the amount of diopside, diopside is equal to 0, and the computation is ended with an incomplete mesonorm.

PROGRAM OPERATION

Data used by MESO must have been placed in mass storage by VISICALC or other program which creates a "/SS"-type file. The format is fixed such that the first row must contain the sample identification (maximum length of 18 characters); the second row may contain a plotting symbol or other sample information, or a blank. Rows 3 through 23 must contain numeric data or blanks that correspond to oxide or element concentrations in the order SiO_2, Al_2O_3, Fe_2O_3, FeO, MgO, CaO, Na_2O, K_2O, H_2O (which can be total water, - water, + water, or loss on ignition (LOI)), TiO_2, P_2O_5, MnO, ZrO_2, CO_2, SO_3, Cl, F, S, Cr_2O_3, NiO, and BaO. If information other than numeric data or blanks (which are read as zero) is encountered during the reading of rows 3 through 23, an error will be displayed and the program will pause until instructions are received from the user.

MESO runs interactively through a series of queries, which are largely self-explanatory. Many queries are answered by "Y" or "N", followed by pressing "END LINE". The first query asks for the file name for the data and provides an option to display the catalog of the disc in current use by pressing "END LINE" without entering a file name.

After a file name has been entered, the restrictions for the data format (given above) are displayed, and the program asks if the data are ready to load. Any answer other than "Y" will restart the program. An answer of "Y" will lead to a display of "WHAT IS PRINTER ADDRESS FOR ERROR MESSAGES". Addressing a hard-copy printer is desirable because it will provide a permanent record of error messages, such as an excess of an element left after calculation of the mesonorm.

Table 1.--Chemical data used by the program MESO and minerals calculated
[Mineral formulae are given in parentheses after the mineral name]

Oxides and Elements

1.	SiO_2	12.	MnO
2.	Al_2O_3	13.	ZrO_2
3.	Fe_2O_3	14.	CO_2
4.	FeO	15.	SO_3
5.	MgO	16.	Cl
6.	CaO	17.	F
7.	Na_2O	18.	S
8.	K_2O	19.	Cr_2O_3
9.	H_2O	20.	NiO
10.	TiO_2	21.	BaO
11.	P_2O_5		

Minerals

1. Q = quartz (SiO_2)
2. C = corundum (Al_2O_3)
3. Z = zircon ($ZrSiO_4O$)
4. Or = orthoclase ($AlSi_3O_8$)
5. AB = ablite ($NaAlSi_3O_8$)
6. AN = anorthite ($CaAl_2Si_2O_8$)
7. BI = biotite ($KAl(Fe,Mg)_3Si_2O_8$)
8. NE = nepheline ($Na_2Al_2Si_2O_8$)
9. MS = muscovite ($KAl_3Si_3O_8(OH)_2$)
10. HL = halite (NaCl)
11. TH = thenardite (Na_2SO_4)
12. NC = sodium carbonate (Na_2CO_3)
13. HY = hypersthene (Mg,Fe) SiO_3
14. NS = sodium metasilicate (Na_2SiO_3)
15. KS = potassium metasilicate (K_2SiO_3)
16. WO = wollastonite ($CaSiO_3$)
17. DI = diopside ($1/2(Ca(Mg,Fe)Si_2O_6)$)
18. RI = riebeckite ($Na_2(Fe,Mg)_3Fe_2^{+++}Si_8O_{22}(OH)_2$))
19. ACT = actinolite ($Ca_2(Fe,Mg)_5Si_8O_{22}(OH)_2$)
20. ED = edenite ($NaCa(Mg,Fe)_5AlSi_7O_{22}(OH)_2$)
21. OL = olivine ($(Fe,Mg)_2SiO_4$)
22. MT = magnetite (Fe_3O_4)
23. CM = chromite ($FeCr_2O_4$)
24. HM = hematite (Fe_2O_3)
25. SP = spinel ($MgAl_2O_4$)
26. TN = sphene ($CaTiSiO_5$)
27. PF = perovskite ($CaTiO_3$)
28. RU = rutile (TiO_2)
29. AP = apatite ($Ca_5F(PO_4)_3$)
30. FR = fluorite (CaF_2)
31. PR = pyrite (FeS_2)
32. CC = calcite ($CaCO_3$)
33. MG = magnesite ($MgCO_3$)
34. SD = siderite ($FeCO_3$)

Failure to find a requested data file will lead to a display of "FILE DOES NOT EXIST! DO YOU NEED TO CHANGE MASS STORAGE? (YES OR NO). An answer of "Y" will lead to a query for a new mass storage address. An answer of "N" will lead to a query for a new file name. Any other alpha-numeric answer will restart the program.

After the data file has been loaded, the program presents four queries. "DEFAULT EXPRESSES EXCESS Al_2O_3 AS CORUNDUM. DO YOU WANT MUSCOVITE CALCULATED INSTEAD? (YES OR NO)". An answer of "Y" will cause muscovite to be calculated for any sample that generates both orthoclase and corundum. This alternate mineral is suggested by Barth (1959), but is rejected for the case where excess amounts of alumina are small because the excess is probably in hornblende or biotite. However, in the same paper, Barth suggests that muscovite should be calculated if modal muscovite or sericite are present. Muscovite should not be calculated for silica deficient rocks because once calculated, it will interfere with the process of balancing silica.

The next query asks for a file name for the results. This name must be different from other names in the current mass storage, or a new name will be requested when an attempt to store the data is made.

The last two queries control the format of output data. The first of these: "DO YOU WANT NO DATA REPRESENTED BY LEADERS (---) (YES OR NO)?" will replace null data by leaders if answered by "Y". Any other input will cause null data to have values of zero. The last query "ROUND TO HOW MANY DECIMAL PLACES?" causes rounding of the data during the data storage operation and, therefore, does not affect accuracy of calculations.

After all queries have been answered, the program proceeds with calculations. The analytical total is found and adjusted for Cl and F (if these are reported). No attempt is made to adjust the total for reported S because such an adjustment requires assumptions about analytical methods, and the correction is generally very small. However, if the amounts of S are large, a correction to the final data table may be desirable.

If excesses of elements beyond what is required to calculate the mesonorm are encountered during the calculations, error messages are sent to the printer along with a statement as to the effect the error will have on the normative total. If no errors are generated, the normative total should be 100 percent. Examples of the printed messages can be found in Appendix II, Fig. 1. After results of the calculations have been stored, the total number of error statements executed is printed.

Data are stored with several instructions for the VISICALC program. Oxide and mineral names (which are stored for column 1 as row identifiers) are left justified by a local format command. All other data (plot symbols, sample names, oxide values, and mineral values) are right justified by a global-format command. Column width is set at 8 spaces, and page length is set at 20 lines. Any recalculations necessitated by modification of the data when VISICALC is running will occur automatically, and by column. An example of the output file from MESO is presented in Appendix II.

REFERENCES CITED

Barth, T. F. W., 1955, Presentation of rock analyses: Journal of Geology, v. 63, p. 348-363.

Barth, T. F. W., 1959, Principles of classification and norm calculations of metamorphic rocks: Journal of Geology, v. 67, p. 135-152.

Barth, T. F. W., 1962a, A final proposal for calculating the mesonorm of metamorphic rocks: Journal of Geology, v. 70, p. 497-498.

Barth, T. F. W., 1962b, Theoretical Petrology, second edition: New York, John Wiley and Sons, A16 p.

Cross, C. W., Iddings, J. P., Pirsson, L. V., and Washington, H. S., 1902, Quantitative chemico-mineralogical classification and nomenclature of igneous rocks: Journal of Geology, v. 10, p. 555-690.

Stuckless, J. S., and VanTrump, George, Jr., 1979, A revised version of graphic normative analysis program (GNAP) with examples of petrologic problem solving: U.S. Geological Survey Open-File Report 79-1237, 112 p.

Washington, H. S., 1917, Chemical analysis of igneous rocks. U.S. Geological Survey Professional Paper 99, 1201 p.

```
THERE IS EXCESS F OF .129  MOLE % IN SAMPLE A2
TOTAL FOR CALCULATED MINERALS SHOULD STILL BE 100%.

THERE IS EXCESS P2O5 OF .076  MOLE % IN SAMPLE B2
THIS WILL LOWER THE TOTAL BY .076  %.

THERE IS EXCESS Cr2O3 OF .047  MOLE % IN SAMPLE C2
THIS WILL LOWER THE TOTAL BY .047  %.

THERE IS EXCESS S OF .164  MOLE % IN SAMPLE D2
TOTAL FOR CALCULATED MINERALS SHOULD STILL BE 100%.

THERE IS EXCESS Cl OF .148  MOLE % IN SAMPLE E3
TOTAL FOR CALCULATED MINERALS SHOULD STILL BE 100%.

THERE IS EXCESS CO2 OF .778  MOLE % IN SAMPLE F5
THIS WILL LOWER THE TOTAL BY .778  %.

THERE IS EXCESS SO3 OF .588  MOLE % IN SAMPLE F6
TOTAL FOR CALCULATED MINERALS SHOULD STILL BE 100%

THERE IS EXCESS P2O5 OF .081  MOLE % IN SAMPLE H3
THIS WILL LOWER THE TOTAL BY .081  %.

THERE IS A DEFICIENCY OF SiO2 OF 1.385 MOLE % IN SAMPLE H3
THIS WILL INCREASE NORM TOTAL BY  1.385 %.

THERE IS A DEFICIENCY OF SiO2 OF 15.84 MOLE % IN SAMPLE H4
THIS WILL INCREASE NORM TOTAL BY  15.84 %.

THIS RUN GENERATED 10 ERRORS OF INCOMPLETE NORMS.
```

Figure 1.--Error messages generated during operation of MESO for the samples listed in Table 2.

APPENDIX I

```
10 REM MESONORMATIVE PROGRAM BY J. S. STUCKLESS SEPT 5,1983
20 DIM C$[511],S(62,55),N$(55),T(22,55),M$(55),RR(21)
30 I$=" ("&CHR$ (217)&"ES OR "&CHR$ (240)&"O)" @ CLEAR @ JMAX,L=0
40 GOSUB 220 @ INPUT A$
50 IF NOT LEN (A$) THEN GOSUB 240 @ C1=1 @ GOTO 40
60 CLEAR ! DISPLAY PROGRAM RESTRICTIONS FOR DATA INPUT **********************
70 DISP "PROGRAM ASSUMES THAT SAMPLE NAME IS IN ROW 1, SYMBOL IS IN ROW 2, "
80 DISP "OXIDE NAMES ARE IN COLUMN 1 IN THE ORDER : SiO2, Al2O3, Fe2O3, FeO,"
90 DISP "MgO, CaO, Na2O, K2O, TiO2, TiO2, P2O5, MnO, ZrO2, CO2, SO3, Cl, F, "
100 DISP "S, Cr2O3, BaO, and BaO." @ DISP @ DISP
110 DISP "BLANKS WILL BE READ AS ZEROS" @ DISP
120 DISP "DATA MUST HAVE BEEN STORED FROM 'VZCALC' OR OTHER /SS TYPE FILE."
130 DISP @ DISP "IS "&A$&" DATA FILE OK TO LOAD ? "&I$ @ INPUT B$@ IF B$#"Y" THE
N 40
140 DISP "WHAT IS PRINTER ADDRESS FOR ERROR MESSAGES"
150 INPUT A@ PRINTER IS A @ CLEAR @ GOTO 270
160 OFF ERROR @ IF ERRN =89 THEN DISP "INVALID DATA ENCOUNTERED IN ROW";I;@ GOTO
 2160
170 GOTO 2150
180 OFF ERROR @ BEEP @ DISP A$;" FILE DOES NOT EXIST! DO YOU NEED TO CHANGE MASS
 STORAGE?:"&I$ @ INPUT A$
190 IF NOT LEN (A$) THEN CLEAR @ GOTO 20
200 IF UPC$ (A$[1,1])#"Y" THEN CLEAR @ GOTO 40
210 DISP "MASS STORAGE IS '        '" @ INPUT S$@ MASS STORAGE IS S$ @ GOTO 40
220 CLEAR @ DISP @ DISP "ENSURE THAT FILE IS ON THE CURRENT STORAGE MEDIUM BEFOR
E ENTERING FILE NAME" @ DISP
230 DISP "ENTER FILE NAME, OR PRESS [END LINE] FOR CATALOG" @ RETURN
240 CRT IS 2 @ DISP @ CAT @ DISP USING "3/" @ CRT IS 1
250 DISP @ DISP "PRESS [CONT] KEY WHEN READY " @ PAUSE
260 RETURN
270 ON ERROR GOTO 180 @ ASSIGN# 1 TO  A$ ! SUBROUTINE TO LOAD 'VISICALC' FILE *
280 CLEAR @ DISP "FILE NAME: "&A$&" IS BEING LOADED" @ ON ERROR GOTO 160
290 READ# 1 ; C$
300 IF POS (C$,">") THEN 310 ELSE ASSIGN# 1 TO  * @ CLEAR @ GOTO 420
310 IF C$[2,2]="A" AND NUM (C$[3])<55 THEN 290
320 C$=C$[2] @ J=NUM (C$)-65 @ GOSUB 400 @ C$=C$[2]
330 IF NUM (C$)<58 THEN 360 ELSE X=NUM (C$)-64
340 IF J=0 THEN J=25+X ELSE J=51+X
350 GOSUB 400 @ C$=C$[2]
360 I=VAL (C$) @ Z=POS (C$,":")+1 @ C$=C$[Z] @ IF I<3 THEN 380 ELSE I=I-2
370 S(I,J)=VAL (C$) @ GOTO 290
380 IF I=1 THEN N$(J)=C$ ELSE N$(J)=C$
390 GOTO 290
400 IF J>JMAX THEN JMAX=J
410 RETURN
420 CLEAR @ DISP "DATA FILE "&A$&" IS LOADED" @ DISP @ DISP
430 DISP " DO YOU EXPECT EXPRESSED EXCESS Al2O3 AS CORUNDUM"
440 DISP " OR YOU WISH TO USE MOLECULAR CALCULATED INSTEAD "&I$ @ INPUT I$
450 DISP "FILE NAME FOR QUANTITATIVE DATA" @ INPUT A$
460 DISP "DO YOU WISH NO DATA BE ENTERED BY LEADERS (----) "&I$ @ INPUT J$
470 DISP "RECALC IN MOLE PROPORTION" @ INPUT Y1
480 CLEAR @ DISP "ADJUSTING OXIDES TO 100%"
```

```
490 FOR J=1 TO JMAX @ S=0 ! FIND THE SUM OF EACH COLUMN **************************
500 FOR I=1 TO 22 @ ON ERROR GOTO 520
510 S=S+S(I,J) @ NEXT I @ GOTO 530
520 OFF ERROR @ IF ERRN=7 THEN S(I,J)=0 @ GOTO 510 ELSE GOTO 160
530 S=S-.42*S(17,J)-.23*S(16,J) @ S(22,J)=S @ NEXT J ! ADJUST SUM FOR F & CI **
540 FOR I=1 TO 21 @ READ RM(I)@ NEXT I ! MOLECULAR CONVERSIONS FACTORS ********
550 DATA .01664314,.015615304,.012524094,.01391858,.02480688,.01703186,.032269,.
02123066,.1110165,.01251583,.014096e04,.01402694,.008115645,.02272213
560 DATA .01249029,.02820636,.05263601,.03118762,.013158744,.0133852,.006521481
570 CLEAR @ DISP "CONVERTING OXIDES TO MOLAR VALUES" ! CONVERT OXIDE TO CATION
580 FOR J=1 TO JMAX @ S=0 @ FOR I=1 TO 21 @ T(I,J)=S(I,J)*RM(I)
590 IF I=2 OR I=15 OR I=16 OR I=17 OR I=18 THEN 600 ELSE S=S+T(I,J)
600 NEXT I @ T(22,J)=S
610 FOR Z=1 TO 21 @ T(Z,J)=100*T(Z,J)/T(22,J) @ NEXT Z ! NORMALIZE MOLAR DATA
620 T(4,J)=T(4,J)+T(12,J)+T(20,J) ! ADD MnO AND N2O TO FeO ********************
630 T(6,J)=T(6,J)+T(21,J) ! ADD BaO TO CaO. THEN ADJUST F FOR P2O5 ************
640 IF T(17,J)<1/3*T(11,J) THEN T(17,J)=0 ELSE T(17,J)=T(17,J)-1/3*T(11,J)
650 NEXT J
660 DISP "CALCULATING NORM"
670 FOR J=1 TO JMAX
680 IF T(11,J)=0 THEN S(54,J)=0 @ GOTO 750 ! CALCULATE APATITE ****************
690 IF 5/3*T(11,J)<= T(6,J) THEN 740 ELSE S(54,J)=T(6,J)*8/5
700 T(11,J)=T(11,J)-.6*T(6,J) @ T(6,J)=0 @ X=T(11,J)
710 IF X>.004 THEN GOSUB 2110 ELSE GOTO 750
720 PRINT "THERE IS EXCESS P2O5 OF";X;" CATION % IN SAMPLE "&N$(J)[2]
730 PRINT "THIS WILL LOWER THE TOTAL BY";X;" %." @ PRINT @ E=E+1 @ GOTO 750
740 S(54,J)=8/3*T(11,J) @ T(6,J)=T(6,J)-5/3*T(11,J)
750 IF T(16,J)=0 THEN S(35,J)=0 @ GOTO 830 ! CALCULATE HALITE ******************
760 IF T(16,J)<= T(7,J) THEN 820 ELSE S(35,J)=T(7,J)
770 T(16,J)=T(16,J)-T(7,J) @ T(7,J)=0 @ X=T(16,J)
780 IF X>.004 THEN GOSUB 2110 ELSE GOTO 830
790 PRINT "THERE IS EXCESS CL EQUIVALENT TO";X;"CATION % IN SAMPLE "&N$(J)[2]
800 PRINT "TOTAL FOR CALCULATED MINERALS SHOULD STILL BE 100%." @ PRINT
810 E=E+1 @ GOTO 830
820 S(35,J)=T(16,J) @ T(7,J)=T(7,J)-T(16,J)
830 IF T(15,J)=0 THEN S(36,J)=0 @ GOTO 900 ! CALCULATE THENARDITE *************
840 IF T(7,J)>= 2*T(15,J) THEN S(36,J)=2*T(15,J) ELSE S(36,J)=T(7,J)
850 T(7,J)=T(7,J)-2*T(15,J) @ IF T(7,J)<0 THEN T(7,J)=0 ELSE 900
860 T(15,J)=T(15,J)-.5*S(36,J) @ X=T(15,J)
870 IF X>.004 THEN GOSUB 2110 ELSE GOTO 900
880 PRINT "THERE IS EXCESS SO3 EQUIVALENT TO";X;"CATION % IN SAMPLE "&N$(J)[2]
890 PRINT "TOTAL FOR CALCULATED MINERALS SHOULD STILL BE 100%" @ PRINT @ E=E+1
900 IF T(18,J)=0 THEN S(55,J)=0 @ GOTO 980 ! CALCULATE PYRITE ***************
910 IF T(18,J)=.5<= T(4,J) THEN 970 ELSE S(55,J)=T(4,J)
920 T(18,J)=T(18,J)-2*T(4,J) @ T(4,J)=0 @ X=T(18,J)
930 IF X>.004 THEN GOSUB 2110 ELSE GOTO 980
940 PRINT "THERE IS EXCESS S EQUIVALENT TO";X;"CATION % IN SAMPLE "&N$(J)[2]
950 PRINT "TOTAL FOR CALCULATED MINERALS SHOULD STILL BE 100%." @ PRINT
960 E=E+1 @ GOTO 980
970 S(55,J)=.5*T(18,J) @ T(4,J)=T(4,J)-.5*T(18,J)
980 IF T(19,J)=0 THEN S(48,J)=0 @ GOTO 1050 ! CALCULATE CHROMITE *************
990 IF 1/2*T(19,J)<= T(4,J) THEN 1040 ELSE S(48,J)=T(4,J)*3
1000 T(19,J)=T(19,J)-T(4,J)*2 @ T(4,J)=0 @ X=T(19,J)
```

```
1010 IF X>.004 THEN GOSUB 2110 ELSE GOTO 1050
1020 PRINT "THERE IS EXCESS Cr2O3 OF";X;"CATION % IN SAMPLE "&N$(J)[2]
1030 PRINT "THIS WILL LOWER THE TOTAL BY";X;" %." @ PRINT @ E=E+1 @ GOTO 1050
1040 S(48,J)=3/2*T(19,J) @ T(4,J)=T(4,J)-1/2*T(19,J)
1050 IF T(17,J)<.0 THEN S(55,J)=0 @ GOTO 1130 ! CALCULATE FLUORITE **************
1060 IF T(17,J)*.5<= T(6,J) THEN GOTO 1120 ELSE S(55,J)=T(6,J)
1070 T(17,J)=T(17,J)-2*T(6,J) @ T(6,J)=0 @ X=T(17,J)
1080 IF X>.004 THEN GOSUB 2110 ELSE GOTO 1130
1090 PRINT "THERE IS EXCESS F EQUIVALENT TO";X;" CATION % IN SAMPLE "&N$(J)[2]
1100 PRINT "TOTAL FOR CALCULATED MINERALS SHOULD STILL BE 100%." @ PRINT
1110 E=E+1 @ GOTO 1130
1120 S(55,J)=.5*T(17,J) @ T(6,J)=T(6,J)-.5*T(17,J)
1130 S(37,J),S(57,J),S(58,J),S(59,J)=0 ! CALCULATE CARBONATES ******************
1140 IF T(14,J)=0 THEN 1300
1150 IF T(14,J)<= T(6,J) THEN 1170 ELSE S(57,J)=T(6,J)*2 ! CALCITE LOOP
1160 T(14,J)=T(14,J)-T(6,J) @ T(6,J)=0 @ GOTO 1180
1170 S(57,J)=T(14,J)*2 @ T(6,J)=T(6,J)-T(14,J) @ GOTO 1300
1180 IF T(14,J)<= T(5,J) THEN 1200 ELSE S(58,J)=T(5,J)*2 ! MAGNESITE LOOP
1190 T(14,J)=T(14,J)-T(5,J) @ T(5,J)=0 @ GOTO 1210
1200 S(58,J)=T(14,J)*2 @ T(5,J)=T(5,J)-T(14,J) @ GOTO 1300
1210 IF T(14,J)<= T(4,J) THEN 1230 ELSE S(59,J)=T(4,J)*2 ! SIDERITE LOOP
1220 T(14,J)=T(14,J)-T(4,J) @ T(4,J)=0 @ GOTO 1240
1230 S(59,J)=T(14,J)*2 @ T(4,J)=T(4,J)-T(14,J) @ GOTO 1300
1240 IF 2*T(14,J)<= T(7,J) THEN 1260 ELSE S(37,J)=T(7,J)*3/2 ! Na2CO3 LOOP
1250 T(14,J)=T(14,J)-.5*T(7,J) @ T(7,J)=0 @ X=T(14,J) @ GOTO 1270
1260 S(37,J)=T(14,J)*3 @ T(7,J)=T(7,J)-2*T(14,J) @ GOTO 1300
1270 IF X>.004 THEN GOSUB 2110 ELSE GOTO 1300
1280 PRINT "THERE IS EXCESS CO2 EQUIVALENT TO";X;"CATION % IN SAMPLE "&N$(J)[2]
1290 PRINT "THIS WILL LOWER THE TOTAL BY";X;" %." @ PRINT @ E=E+1
1300 IF T(13,J)=0 THEN S(28,J)=0 @ GOTO 1370 ! CALCULATE ZIRCON ****************
1310 IF T(13,J)<= T(1,J) THEN 1330 ELSE S(28,J)=T(1,J)*2
1320 T(13,J)=T(13,J)-T(1,J) @ T(1,J)=0 @ X=T(13,J)
1330 IF X>.004 THEN GOSUB 2110 ELSE GOTO 1370
1340 PRINT "THERE IS EXCESS ZrO OF";X;"CATION % IN SAMPLE "&N$(J)[2] @ PRINT
1350 E=E+1 @ GOTO 1370
1360 S(28,J)=T(13,J)*2
1370 IF T(6,J)>= T(10,J) THEN 1390 ELSE S(51,J)=3*T(6,J) ! CALCULATE SPHENE ***
1380 S(53,J)=T(10,J)-T(6,J) @ T(6,J)=0 @ GOTO 1400
1390 S(51,J)=3*T(10,J) @ T(6,J)=T(6,J)-T(10,J) @ S(53,J)=0
1400 IF T(8,J)>T(2,J) THEN 1420 ELSE S(29,J)=T(8,J)*5 ! CALCULATE OR & KS *****
1410 T(2,J)=T(2,J)-T(8,J) @ S(40,J)=0 @ GOTO 1430
1420 S(29,J)=T(2,J)*5 @ T(8,J)=T(8,J)-T(2,J) @ T(2,J)=0 @ S(40,J)=T(8,J)*3/2
1430 IF T(7,J)>T(2,J) THEN 1450 ELSE S(39,J)=T(7,J)*5 ! CALCULATE ALBITE ******
1440 T(2,J)=T(2,J)-T(7,J) @ T(7,J)=0 @ GOTO 1460
1450 S(39,J)=T(2,J)*5 @ T(7,J)=T(7,J)-T(2,J) @ T(2,J)=0
1460 IF T(7,J)=0 THEN S(43,J),S(39,J)=0 @ GOTO 1520 ! CALCULATE RI & NS *******
1470 IF T(7,J)<= T(3,J) AND T(7,J)<= 2/3*T(4,J) THEN S(43,J)=7.5*T(7,J) ELSE 149
0
1480 T(3,J)=T(3,J)-T(7,J) @ T(4,J)=T(4,J)-3/2*T(7,J) @ S(39,J)=0 @ GOTO 1520
1490 IF T(3,J)<= 2/3*T(4,J) THEN S(43,J)=15/2*T(3,J) ELSE 1510
1500 T(4,J)=T(4,J)-3/2*T(3,J) @ S(39,J)=3/2*(T(7,J)-T(3,J)) @ T(3,J)=0 @ GOTO 15
20
1510 S(43,J)=5*T(4,J) @ S(39,J)=3/2*(T(7,J)-2/3*T(4,J)) @ T(3,J)=T(3,J)-2/3*T(4,
J) @ T(4,J)=0
1520 S(50,J),S(52,J)=0 ! CALCULATE MAGNETITE AND HEMATITE **********************
```

```
1530 IF T(4,J)<= .5*T(3,J) THEN S(47,J)=3*T(4,J) @ S(49,J)=T(3,J)-2*T(4,J) @ GOT
O 1560
1550 S(47,J)=3/2*T(3,J) @ T(4,J)=T(4,J)-.5*T(3,J) @ T(3,J),S(49,J)=0
1560 T(21,J) T(4,J)+T(5,J) ! Mg' AND CALCULATE AN AND C **********************
1570 IF T(2,J)=0 THEN S(31,J),S(27,J)=0 @ GOTO 1610
1580 IF T(2,J)<= 2*T(6,J) THEN 1600 ELSE S(31,J)=5*T(6,J)
1590 S(27,J)=T(2,J)-2*T(6,J) @ T(6,J)=0 @ GOTO 1610
1600 S(31,J)=5/2*T(2,J) @ T(6,J)=T(6,J)-.5*T(2,J) @ S(27,J)=0
1610 IF T(21,J)=0 THEN S(32,J)=0 @ GOTO 1660 ! CALCULATE BI **********************
1620 IF T(21,J)>= 3/5*S(29,J) THEN S(32,J)=8/5*S(29,J) ELSE 1640
1630 T(21,J)=T(21,J)-3/5*S(29,J) @ S(29,J)=0 @ GOTO 1660
1640 S(32,J) 8/3*T(21,J) @ S(29,J)=S(29,J)-5/3*T(21,J) @ T(21,J)=0
1650 REM CALCULATE ACT, DI, HY, AND MU ***************************************
1660 IF T(21,J)=0 THEN S(38,J),S(42,J),S(44,J)=0 @ S(41,J)=2*T(6,J) @ GOTO 1720
1670 IF T(6,J)=0 THEN S(44,J),S(42,J),S(41,J)=0 @ S(38,J)=2*T(21,J) @ GOTO 1720
1680 IF T(6,J)<= .4*T(21,J) THEN S(44,J)=15/2*T(6,J) ELSE 1700
1690 S(38,J)=2*(T(21,J)-2.5*T(6,J)) @ S(42,J),S(41,J)=0 @ GOTO 1720
1700 IF T(6,J)<= T(21,J) THEN S(44,J)=5*(T(21,J)-T(6,J)) @ S(42,J)=1/3*(20*T(6,J
)-8*T(21,J)) @ S(41,J),S(38,J)=0 @ GOTO 1720
1710 S(42,J)=4*T(21,J) @ S(41,J)=2*(T(6,J)-T(21,J)) @ S(44,J),S(38,J)=0
1720 S(34,J)=0 @ IF I$#"Y" THEN 1770 ! CALCULATE MUSCOVITE ********************
1730 IF S(29,J)=0 THEN 1770
1740 IF S(29,J)>= 5/2*S(27,J) THEN S(34,J)=7/2*S(27,J) ELSE 1760
1750 S(29,J)=S(29,J)-5/2*S(27,J) @ S(27,J),S(45,J)=0 @ GOTO 1770
1760 S(34,J)=7/5*S(29,J) @ S(27,J)=S(27,J)-2/7*S(34,J) @ S(29,J)=0
1770 S(25,J),S(33,J),S(60,J),S(46,J),S(52,J),S(45,J)=0 ! BALANCE SiO2 *********
1780 T(9,J)=1/3*(S(51,J)+S(39,J)+S(40,J))+.6*(S(29,J)+S(30,J))+.4*S(31,J)+8/15*(
S(43,J)+S(44,J))
1790 T(9,J)=T(9,J)+.5*(S(28,J)+S(42,J)+S(41,J)+S(38,J))+3/7*S(34,J)+3/8*S(32,J)
1800 IF T(9,J)>T(1,J) THEN 1840 ELSE S(26,J)=T(1,J)-T(9,J)
1810 FOR I=26 TO 59 @ S(60,J)=S(60,J)+S(I,J) @ IF I<38 THEN S(61,J)=S(60,J)
1820 NEXT I
1830 S(61,J)=S(61,J)-S(32,J) @ S(62,J)=S(60,J)-S(61,J) @ GOTO 1850
1840 S(26,J)=0 @ X=T(9,J)-T(1,J) @ GOSUB 1860 @ GOTO 1810
1850 NEXT J @ GOTO 2190
1860 IF S(30,J)=0 OR S(44,J)=0 THEN 1910 ! CONVERT AB AND ACT TO ED **********
1870 IF X<= 4/5*S(30,J) AND X<= 4/15*S(44,J) THEN S(45,J)=4*X @ S(30,J)=S(30,J)-
5/4*X @ S(44,J)=S(44,J)-15/4*X @ RETURN
1880 IF S(44,J)<= 3*S(30,J) THEN S(45,J)=16/15*S(44,J) ELSE 1900
1890 S(30,J)=S(30,J)-1/3*S(44,J) @ X=X-4/15*S(44,J) @ S(44,J)=0 @ GOTO 1910
1900 S(45,J)=16/5*S(30,J) @ X=X-4/5*S(30,J) @ S(44,J)=S(44,J)-3*S(30,J) @ S(30,J
)=0
1910 IF S(38,J)=0 THEN 1940 ! CONVERT HYPERSTHENE TO OLIVINE AND SiO2 *********
1920 IF X<= .25*S(38,J) THEN S(38,J)=S(38,J)-4*X @ S(46,J)=3*X @ RETURN
1930 S(46,J)=.75*S(38,J) @ X=X-.25*S(38,J) @ S(38,J)=0
1940 IF S(46,J)=0 OR S(27,J)=0 THEN 1990 ! CONVERT C AND DI TO SP AND SiO2 ****
1950 IF X<= .25*S(27,J) AND X<= 1/3*S(46,J) THEN S(60,J)=6*X ELSE 1970
1960 S(27,J)=S(27,J)-4*X @ S(46,J)=S(46,J)-3*X @ RETURN
1970 IF 1/3*S(46,J)<= .25*S(27,J) THEN S(60,J)=2*S(46,J) @ S(27,J)=S(27,J)-4/3*S
(46,J) @ X=X-1/3*S(46,J) @ S(46,J)=0 @ GOTO 1990
1980 S(60,J)=1.5*S(27,J) @ X=X-.25*S(27,J) @ S(46,J)=S(46,J)-.75*S(27,J) @ S(27,
J)=0
1990 IF S(30,J)=0 THEN 2020 ! CONVERT ALBITE TO NEPHELINE AND SiO2 ************
2000 IF X<= .4*S(30,J) THEN S(33,J)=2/5*X @ S(30,J)=S(30,J)-5/2*X @ RETURN
2010 S(33,J)=3/5*S(30,J) @ X=X-2/5*S(30,J) @ S(30,J)=0
```

```
2020 IF S(51,J)=0 THEN 2050 ! CONVERT TITANITE TO PEROVSKITE AND SiO2 *********
2030 IF X<= 1/3*S(51,J) THEN S(52,J)=2*X @ S(51,J)=S(51,J)-3*X @ RETURN
2040 S(52,J)=2/3*S(51,J) @ S(51,J)=0 @ X=X-.5*S(52,J)
2050 IF S(42,J)=0 THEN 2080 ! CONVERT DI TO OL + WO + SiO2 **********************
2060 IF X<= 1/8*S(42,J) THEN S(42,J)=S(42,J)-8*X @ S(46,J)=S(46,J)+3*X @ S(41,J)
=S(41,J)+4*X @ RETURN
2070 S(46,J)=S(46,J)+3/8*S(42,J) @ X=X-1/8*S(42,J) @ S(41,J)=S(41,J)+.5*S(42,J)
@ S(42,J)=0
2080 IF X>.004 THEN GOSUB 2120
2090 PRINT "THERE IS A DEFICIENCY OF SiO2 OF";X;"CATION % IN SAMPLE "&N$(J)[21
2100 PRINT "THIS WILL INCREASE NORM TOTAL BY ";X;"%." @ PRINT @ E=E+1 @ RETURN
2110 REM ROUND TO Y DECIMAL PLACES ***************************************
2120 X=X*10^Y1 @ IF CEIL (X)=CEIL (X+.5) THEN X=INT (X) ELSE X=CEIL (X)
2130 X=X/10^Y1 @ RETURN
2140 OFF ERROR @ IF ERRN =63 THEN 2170
2150 DISP "ERROR ENCOUNTERED; NUMBER ";ERRN ;" ON LINE NUMBER ";ERRL
2160 DISP "PROGRAM IS PAUSED." @ PAUSE
2170 DISP "DUPLICATE FILE NAME ENCOUNTERED. CHOOSE A NEW FILE NAME OR DIFFERENT
DISC." @ INPUT A$
2180 GOTO 2220
2190 FOR J=1 TO JMAX ! SUBROUTINE TO STORE DATA ********************************
2200 FOR I=24 TO 3 STEP -1 @ S(I,J)=S(I-2,J) @ NEXT I @ NEXT J
2210 CLEAR @ DISP "FILE "&A$&" IS BEING STORED." @ ON ERROR GOTO 2140
2220 CREATE A$,5*JMAX+13 @ ASSIGN# 1 TO  A$
2230 FOR J=1 TO JMAX @ READ C$@ C$=">"&C$ @ D$=C$
2240 FOR I=3 TO 62 @ IF S(I,J)=0 AND J$="Y" THEN 2270
2250 X=S(I,J) @ GOSUB 2120 @ S(I,J)=X
2260 C$=D$&VAL$ (I)&":"&VAL$ (S(I,J)) @ GOTO 2280
2270 C$=D$&VAL$ (I)&":  ---- "
2280 GOSUB 2350 @ NEXT I
2290 C$=D$&"1:"&N$(J) @ GOSUB 2350 @ C$=D$&"2:"&M$(J) @ GOSUB 2350
2300 NEXT J @ GOSUB 2350
2310 C$="/W1"&CHR$ (13)&"/GOC"&CHR$ (13)&"/CRO"&CHR$ (13) @ GOSUB 2360
2320 C$="/CC8" @ GOSUB 2350 @ C$="/CLR" @ GOSUB 2350 @ C$="/GP" @ GOSUB 2350
2330 C$="/X"&CHR$ (42+128)&"/X>A1:>A1:" @ GOSUB 2360
2340 ASSIGN# 1 TO  * @ GOTO 2450
2350 C$=C$&CHR$ (13)
2360 PRINT# 1 ; C$ @ RETURN
2370 DATA B,C,D,E,F,G,H,I,J,K,L,M,N,O,P,Q,R,S,T,U,V,W,X,Y,Z,AA,AB,AC,AD,AE,AF,AG
,AH,AI,AJ,AK,AL,AM,AN,AO,AP,AQ,AR,AS,AT,AU,AV,AW,AX,AY,AZ
2380 DATA BA,BB,BC,BD,BE,BF,BG,BH,BI,BJ,BK
2390 B$=":/FL" @ RESTORE 2410
2400 FOR I=1 TO 62 @ READ D$@ C$=">A"&VAL$ (I)&B$&D$ @ GOSUB 2350 @ NEXT I
2410 DATA 'SAMPLE','SYMBOL','SiO2','TiO2','Fe2O3','FeO','MgO','CaO','Na2O','K2O','LOI','P
2O2','P2O5','MnO','ZrO2','CO2','SO3','Cl','F','S','Cr2O3','NiO','BaO','TOTAL',' NORM','Q','C','Z
2420 DATA 'OR','OB','AN','DI','HY','NS','HL','FH','PC','MY','NS','KS','WO','DI','RT','ACI','ED','
OL','MT','CM','HM','SP','TN','PF','RU','AP','FR','PR','CC','MG','SD','TOTAL',' SALIC,' FEMIC
2430 DATA 'TOTAL','','','Mg','AI','Ca','NY',' NPLR,' NYES,'OL
2440 RETURN
2450 DISP "END PROGRAM; RESULTS ARE STORED IN "&A$
2460 PRINT "THIS RUN GENERATED";E ;"ERRORS OF INCOMPLETE NORMS." @ PRINT
2470 END
```

APPENDIX II
Examples of calculations

The following pages of output provide an example of the results obtainable from MESO. The first page of output (fig. 1) presents a series of error statements generated during the computations; the next 3 pages (Table 2), provides hypothetical chemical compositions and normative mineralogy; (the horizontal lines were added with VISICALC and are not part of the usual output from MESO); the last 2 pages (Table 3) present CIPW normative data (expressed in weight percent and calculated water-free) for comparison. The compositions listed in Table 2 provide a good test for the program in that they use nearly all possible branches and loops within the program; however, the calculation of muscovite was not requested.

The first two samples (A1 and A2, Table 2) are identical except that the second sample contains fluorine, which is abundant enough to cause an error statement. The samples pairs B1-B2, C1-C2, D1-D2, and E2-E3, are likewise similar in that the second samples of the pair contains enough of a minor element (P_2)$_5$, Cr_2O_3, S, and Cl, respectively) to cause an error statement to be printed. Samples F5 and F6 generate error statements for excess CO_2 and SO_3, respectively. Samples H3 and H4 are too deficient in silica to yield a complete mesonorm, and therefore generate error statements.

The sequence of samples E1, E2, E4 through E6 shows the effect of increasing Ca/(Fe + Mg) values on the mesonormative mineralogy. The sample with the lowest ratio has hypersthene only in the norm. Increasing the Ca/(Fe + Mg) ratio leads progressively to hypersthene plus actinolite, actinolite plus diopside, diopside plus wollastonite, and wollastonite only.

The sequence of samples F1 through F4 shows the effects of increasing CO_2 content with otherwise constant chemistry. The calculated assemblage changes from calcite, to calcite plus magnesite, to calcite plus magnesite plus siderite, to calcite plus magnesite plus siderite plus sodium carbonate. Note that as iron and magnesium are used to form carbonates, the assemblage of ferro-magnesian silicates is changed.

The sequence of samples G1 through G3 provides three examples of mesonorms for peralkaline rocks. Samples G1 and G2 differ only in the relative proportions of ferrous and ferric iron. Sodium metasilicate is calculated for the less oxidized sample, whereas the more oxidized sample contains magnetite, hematite, and less biotite. Sample G3 is also oxidized and contains enough potassium to generate potassium metasilicate as a calculated mineral.

All of the samples in the sequence H1, H3 through H11, are silica deficient. This group of samples provides a test for all of the possible adjustments used to balance silica.

The total running time, including data retrieval and storage for the 35 samples listed in Table 2, was 6 minutes.

Results from the program MESO are not directly comparable with those given by Barth (1955, 1959) because of modifications to the method given by Barth (1962a) and because of approximations made by Barth for the sake of

simplifying mathematical calculations. These simplifications, such as use of approximate molecular weights, are not necessary in a computer program.

Comparison of Tables 2 and 3 points up several contrasts between the CIPW norm and the mesonorm. (The CIPW norms are calculated water-free so that totals for the two methods would be more nearly equal.) In general, the mesonorm yields lower amounts of quartz and orthoclase. The latter is due to the assignment of some potassium to biotite; however, the presence of biotite has the effect of increasing the free silica, as can be seen by comparing the norms for the three peralkaline samples (G1 through G3, Tables 2 and 3). These samples are silica deficient as represented by the CIPW norm, and quartz-bearing as represented by the mesonorm. The presence of biotite can also affect the balancing of silica in quartz-free samples, as can be seen by comparing results for sample H4 (Tables 2 and 3).

There are also small differences in the apparent degree of alumina saturation (as represented by corundum) between the two methods. Corundum values are slightly higher for quartz-bearing samples, as represented by the mesonorm. However, the mesonorm may recalculate corundum to form spinel in silica-deficient samples and, hence, corundum alone is no longer a good indicator of the degree of alumina saturation. Obviously, corundum alone is a poor criteria for alumina saturation in quartz-bearing rocks if the muscovite calculation is requested.

Both methods generate error messages for the same elements in the same samples except for sample F4 for which sodium carbonate was automatically calculated by MESO. Because sodium carbonate was not calculated as part of the CIPW norm, sample F4 contains excess CO_2 beyond that used to calculate normative minerals.

Table 2.--Chemical data and mesonorms for hypothetical chemical compositions of rocks

SAMPLE	A1	A2	B1	B2	C1	C2	D1	D2	E1	E2	E3	E4
SYMBOL	*	#	*	#	*	#	*	#	*	*	#	S
SiO2	75.9	75.9	73.8	73.8	52.1	52.1	72.9	72.9	48.3	48.3	48.3	48.3
Al2O3	13.8	13.8	13.3	13.3	16.6	16.6	13.5	13.5	14.8	14.8	14.8	14.3
Fe2O3	.1	.1	1.3	1.3	8.3	8.3	1.9	1.9	2.4	2.4	2.4	2.4
FeO	.68	.68	.04	.04	.8	.2	.18	.08	9.6	9.1	9.1	6.5
MgO	.11	.11	.45	.45	4.5	4.5	.36	.36	9.1	8.1	8.1	5.5
CaO	.18	.18	.44	.22	6.6	6.6	1.2	1.2	8.5	10	10	15
Na2O	3	3	2.4	2.4	3.7	3.7	3.6	3.6	1.26	1.26	1.26	1.25
K2O	7	7	5.8	5.8	2.4	2.4	4.6	4.6	.12	.12	.12	.12
LOI	.47	.47	1.5	1.5	3	3	.85	.85	3.63	3.63	3.63	3.63
TiO2	.14	.14	.21	.21	1.7	1.7	.37	.37	.68	.68	.68	.68
P2O5	.02	.02	.08	.26	.81	.81	.1	.1	.13	.13	.13	.13
MnO	.05	.05	.02	.02	.1	.1	.04	.04	.21	.21	.21	.21
ZrO2	---	---	.22	.22	---	---	---	---	---	---	---	---
CO2	.03	.03	.06	.06	.02	.02	.01	.01	---	---	---	---
SO3	---	---	---	---	---	---	---	---	---	---	---	---
Cl	.01	.01	---	---	---	---	---	---	1.4	1.4	1.53	1.4
F	---	.15	.02	.01	.03	.03	.02	.02	---	---	---	---
S	---	---	---	---	---	---	.1	.2	---	---	---	---
Cr2O3	---	---	---	---	---	.7	---	---	---	---	---	---
NiO	---	---	---	---	---	---	---	---	---	---	---	---
BaO	---	---	---	---	---	---	---	---	---	---	---	---
TOTAL	101.488	101.575	99.632	99.586	100.647	100.747	99.722	99.722	99.808	99.808	99.908	99.503
NORM												
Q	29.2	29.332	35.713	36.083	10.385	10.38	30.726	30.751	9.726	9.162	9.353	8.732
C	1.386	1.42	3.291	3.483	.08	.08	1.32	1.321	.389	---	---	---
Z	---	---	.206	.206	---	---	---	---	---	---	---	---
OR	40.159	40.222	34.458	34.617	3.945	3.943	26.97	26.991	---	---	---	---
AB	26.821	26.821	22.347	22.365	34.269	34.252	33.089	33.115	.346	.347	---	.349
AN	.085	---	.472	---	22.083	22.072	3.959	3.962	41.381	42.479	42.652	42.771
BI	1.819	1.718	1.718	1.509	17.088	17.08	1.357	1.358	1.205	1.208	1.208	1.217
NE	---	---	---	---	---	---	---	---	---	---	---	---
MS	---	---	---	---	---	---	---	---	---	---	---	---
HL	.016	.016	---	---	---	---	---	---	2.334	2.341	2.411	2.357
TH	---	---	---	---	---	---	---	---	---	---	---	---
NC	---	---	---	---	---	---	---	---	---	---	---	---
HY	---	---	---	---	---	---	---	---	40.156	29.553	29.727	---
NS	---	---	---	---	---	---	---	---	---	---	---	---
KS	---	---	---	---	---	---	---	---	---	---	---	---
WO	---	---	---	---	---	---	---	---	---	---	---	---
DI	---	---	---	---	---	---	---	---	---	---	---	11.835
RI	---	---	---	---	---	---	---	---	---	---	---	---
ACT	---	---	---	---	---	---	---	---	---	10.432	10.172	28.23
ED	---	---	---	---	---	---	---	---	---	---	---	---
OL	---	---	---	---	---	---	---	---	---	---	---	---
MT	.104	.104	.145	.145	2.16	---	.258	---	2.665	2.673	2.673	2.692
CM	---	---	---	---	---	.722	---	---	---	---	---	---
HM	---	---	.843	.843	4.527	5.964	1.184	1.357	---	---	---	---
SP	---	---	---	---	---	---	---	---	---	---	---	---
TN	.292	---	.455	---	3.664	3.662	.791	.792	1.509	1.514	1.514	1.524
PF	---	---	---	---	---	---	---	---	---	---	---	---
RU	---	.097	---	.152	---	---	---	---	---	---	---	---
AP	.042	.042	.173	.363	1.747	1.746	.214	.214	.289	.29	.29	.292
FR	---	.152	.02	---	---	---	.017	.017	---	---	---	---
PR	---	---	---	---	---	---	.089	.096	---	---	---	---
CC	.076	---	.157	---	.052	.052	.026	.026	---	---	---	---
MG	---	.076	---	.157	---	---	---	---	---	---	---	---
SD	---	---	---	---	---	---	---	---	---	---	---	---
TOTAL	100	100	100	99.924	100	99.953	100	100	100	100	100	100
SALIC	97.667	97.811	96.489	96.754	70.761	70.726	96.065	96.141	54.176	54.329	54.416	54.21
FEMIC	2.333	2.189	3.511	3.17	29.239	29.227	3.935	3.859	45.824	45.671	45.584	45.79

Table 2.--Chemical data and mesonorms for hypothetical chemical composition of rocks--continued

SAMPLE	E5	E6	F1	F2	F3	F4	F5	F6	G1	G2	G3	H1
SYMBOL	S	C	*	#	S	S	#	#	W	W	W	U
SiO2	48.3	67.5	74.9	74.9	74.9	74.9	67.8	67.8	53.7	53.7	53.7	43.91
Al2O3	14.8	13.51	14.3	14.3	14.3	14.3	17.9	17.9	11.16	11.16	11.16	14.95
Fe2O3	2.4	3.38	.9	.9	.9	.9	.45	.45	3.1	2.1	3.1	2.6
FeO	4.5	2.54	.26	.26	.26	.26	.4	.8	3.21	4.01	1.21	9.23
MgO	3.5	.69	.2	.1	.1	.1	.3	.3	6.44	6.44	6.44	10.8
CaO	19	3.17	.12	.12	.12	.12	.53	.1	3.46	3.46	3.46	14.37
Na2O	1.26	3.32	7.6	7.6	7.6	7.6	.1	.33	1.67	1.67	1.67	1.95
K2O	.12	4.95	.3	.3	.3	.3	9	8.5	9.16	9.36	11.16	1.02
LOI	3.63	.08	.66	.66	.66	.66	1.78	1.78	3.41	3.41	3.41	.82
TiO2	.68	.56	.13	.13	.13	.13	.23	.23	1.92	1.92	1.92	1.07
P2O5	.13	.38	.03	.03	.03	.03	.05	.05	1.75	1.75	1.75	.1
MnO	.21	---	.02	.02	.02	.02	.02	.02	.04	.04	.04	---
ZrO2	---	---	---	---	---	---	---	---	---	---	---	---
CO2	---	.23	.02	.1	.2	.4	1.6	.6	---	---	---	---
SO3	---	---	.62	.62	.62	.62	.03	1.2	.06	.06	.06	---
Cl	1.4	---	.03	.03	.03	.03	---	.03	.03	.03	.03	---
F	---	---	---	---	---	---	---	---	.44	.44	.44	---
S	---	---	---	---	---	---	---	---	---	---	---	---
Cr2O3	---	---	---	---	---	---	---	---	.04	.04	.04	---
NiO	---	---	---	---	---	---	---	---	---	---	---	---
BaO	---	---	---	---	---	---	---	---	.81	.81	.81	---
TOTAL	99.608	100.31	100.083	100.063	100.163	100.363	100.19	100.083	100.208	100.208	100.208	100.82
NORM												
Q	11.02	23.62	29.929	29.994	29.956	30.303	31.868	34.246	6.401	6.432	8.286	---
C	---	---	2.507	2.508	2.505	2.639	9.186	9.956	---	---	---	---
Z	---	---	---	---	---	---	---	---	---	---	---	---
OR	---	26.746	1.307	1.615	1.764	1.76	54.839	52.346	41.028	40.581	47.721	---
AB	.351	30.271	63.464	63.487	63.408	62.545	---	---	7.099	5.855	---	---
AN	42.928	7.456	---	---	---	---	---	---	---	---	---	28.844
BI	1.221	4.717	.734	.243	---	---	---	.469	24.754	27.29	24.545	9.579
NE	---	---	---	---	---	---	---	---	---	---	---	.542
MS	---	---	---	---	---	---	---	---	---	---	---	---
EL	2.366	---	.047	.047	.047	.047	---	.049	.049	.049	.049	---
TH	---	---	.859	.859	.858	.856	.043	.572	.087	.087	.086	---
NC	---	---	---	---	---	.211	.213	---	---	---	---	---
HY	---	---	---	---	---	---	---	---	---	---	---	---
NS	---	---	---	---	---	---	---	---	---	.44	3.467	---
KS	---	---	---	---	---	---	---	---	---	---	1.558	---
WO	6.495	1.015	---	---	---	---	---	---	---	---	---	---
DI	31.096	---	---	---	---	---	---	---	---	---	---	3.728
RI	---	---	---	---	---	---	---	---	11.814	11.442	4.938	---
ACT	---	---	---	---	---	---	---	---	---	---	---	---
ED	---	---	---	---	---	---	---	---	---	---	---	52.774
OL	---	---	---	---	---	---	---	---	---	---	---	---
MT	2.701	3.588	.649	.649	.544	---	---	.493	.752	---	---	2.701
CM	---	---	---	---	---	---	---	---	.046	.046	.045	---
HM	---	---	.192	.192	.262	.623	.324	---	.179	---	1.578	---
SP	---	---	---	---	---	---	---	---	---	---	---	---
TN	1.53	1.188	.163	---	---	---	---	---	3.21	3.205	3.183	.43
PF	---	---	---	---	---	---	---	---	---	---	---	1.194
RU	---	---	.036	.09	.09	.09	.165	.168	.326	.326	.324	---
AP	.293	.807	.063	.063	.062	.062	.108	.11	3.821	3.814	3.788	.208
FR	---	---	---	---	---	---	---	---	.434	.433	.43	---
PR	---	---	---	---	---	---	---	---	---	---	---	---
CC	---	.591	.05	.159	.159	.159	.95	.071	---	---	---	---
MG	---	---	---	.093	.275	.274	.854	.868	---	---	---	---
SD	---	---	---	---	.07	.431	.672	.651	---	---	---	---
TOTAL	100	100	100	100	100	100	99.222	100	100	100	100	100
SALIC	56.664	88.094	98.113	98.51	98.538	98.361	96.15	97.169	54.664	53.004	56.142	29.356
FEMIC	43.336	11.905	1.887	1.49	1.462	1.639	3.073	2.831	45.336	46.996	43.858	70.614

Table 2.--Chemical data and mesonorms for hypothetical chemical composition of rocks-(continued)

SAMPLE	H3	H4	H5	H6	H7	H8	H9	H10	H11
SYMBOL	X	W	W	W	A	U	U	U	A
SiO2	37.51	31.17	34.98	34.48	53.9	50.25	49.61	50.14	38.8
Al2O3	2.41	6.25	10.8	10.8	20.5	4.53	12.26	11.06	22.7
Fe2O3	1.83	3.22	1.42	1.42	2.65	1.38	1.74	1.99	6.13
FeO	8.95	9.64	21.33	21.33	1.59	15.77	9.9	9.1	7.8
MgO	48.59	19.9	19.3	19.8	1.87	20.07	13.79	12.94	4.11
CaO	.07	17.76	.43	.43	3.98	5.95	9.22	11.2	11.8
Na2O	.05	2.03	.17	.17	9.04	.42	1.46	1.48	1.42
K2O	.05	2.51	5.42	5.42	4.26	.14	.19	.13	2.64
LOI	.13	2.49	1.28	1.28	.39	.78	.55	.59	1.41
TiO2	.33	2.96	5.18	5.18	.76	.3	.7	.6	3.42
P2O5	.17	1.69	---	---	.17	---	---	---	.56
MnO	.17	---	---	---	.2	.15	.22	.2	.22
ZrO2	---	---	---	---	.13	---	---	---	1.1
CO2	---	---	---	---	.01	---	---	---	.03
SO3	---	---	---	---	---	---	---	---	---
Cl	---	---	---	---	---	---	---	---	---
F	---	---	---	---	.11	---	---	---	.11
S	---	---	---	---	---	---	---	---	---
Cr2O3	---	---	---	---	---	---	.2	.18	---
NiO	---	---	---	---	---	---	.04	.05	---
BaO	---	---	---	---	.1	---	---	---	.08
TOTAL	100.26	99.62	100.31	100.31	99.604	99.74	99.88	99.56	102.284
NORM									
Q	---	---	---	---	---	---	---	---	---
C	---	---	5.127	2.323	---	---	---	---	1.355
Z	---	---	---	---	.113	---	---	---	1.018
OR	---	---	---	---	19.31	---	---	---	---
AB	---	---	1.54	1.537	34.493	---	7.778	7.504	10.631
AN	---	.526	---	---	2.668	10.112	26.32	23.275	43.522
BI	.417	23.607	51.702	51.584	7.785	1.33	1.794	1.235	25.556
NE	.238	---	---	---	26.089	---	---	---	1.456
MS	---	---	---	---	---	---	---	---	---
HL	---	---	---	---	---	---	---	---	---
TH	---	---	---	---	---	---	---	---	---
NC	---	---	---	---	---	---	---	---	---
HY	---	---	.464	---	---	51.873	34.114	17.536	---
NS	---	---	---	---	---	---	---	---	---
KS	---	---	---	---	---	---	---	---	---
WO	---	10.879	---	---	4.856	---	---	---	---
DI	---	---	---	---	---	---	---	---	---
RI	---	---	---	---	---	---	---	---	---
ACT	---	3.661	---	---	---	16.387	9.47	28.167	---
ED	---	58.038	---	---	---	12.126	17.025	18.733	---
OL	95.377	8.159	35.166	34.381	---	6.094	---	---	---
MT	1.687	3.35	1.498	1.495	2.661	1.45	1.818	2.091	6.564
CM	---	---	---	---	---	---	.22	.199	---
HM	---	---	---	---	---	---	---	---	---
SP	3.284	---	---	4.189	---	---	---	---	1.212
TN	---	---	1.292	1.289	1.526	.63	1.461	1.26	7.319
PF	---	4.103	---	---	---	---	---	---	---
RU	.203	---	3.211	3.203	---	---	---	---	---
AP	.098	3.516	---	---	.341	---	---	---	1.199
FR	---	---	---	---	.133	---	---	---	.09
PR	---	---	---	---	---	---	---	---	---
CC	---	---	---	---	.024	---	---	---	.078
MG	---	---	---	---	---	---	---	---	---
SD	---	---	---	---	---	---	---	---	---
TOTAL	101.304	115.84	100	100	100	100	100	100	100
SALIC	.238	.526	6.668	3.86	82.673	10.112	34.098	30.779	57.982
FEMIC	101.066	115.314	93.332	96.14	17.327	89.888	65.902	69.221	42.018

Table 3.—CIPW norms, expressed in weight percent, for chemical compositions presented in Table 2.

SAMPLE SYMBOL	A1 *	A2 *	B1 *	B2 *	C1 *	C2 *	D1 *	D2 *	E1 *	E2 *	E3 *	E4 S
Q	30.522	30.781	37.045	37.669	4.22	4.216	31.953	31.953	10.128	10.441	10.513	11.135
C	1.082	1.288	2.639	3.134	---	---	.717	.717	---	---	---	---
Z	---	---	.334	.334	---	---	---	---	---	---	---	---
OR	40.943	40.913	34.926	34.943	14.524	14.509	27.493	27.493	.737	.737	.737	.739
AB	25.056	25.035	20.695	20.704	32.053	32.03	30.81	30.81	.319	.319	---	.32
AN	.567	---	1.209	---	22.119	22.096	5.214	5.214	41.45	41.45	41.576	41.537
LC	---	---	---	---	---	---	---	---	---	---	---	---
NE	---	---	---	---	---	---	---	---	---	---	---	---
KP	---	---	---	---	---	---	---	---	---	---	---	---
HL	.016	.016	---	---	---	---	---	---	2.4	2.4	2.463	2.435
TH	---	---	---	---	---	---	---	---	---	---	---	---
NC	---	---	---	---	---	---	---	---	---	---	---	---
AC	---	---	---	---	---	---	---	---	---	---	---	---
NS	---	---	---	---	---	---	---	---	---	---	---	---
KS	---	---	---	---	---	---	---	---	---	---	---	---
WO	---	---	---	---	1.41	---	---	---	.631	3.862	3.787	14.661
EN	.271	.203	1.142	1.003	11.477	11.466	.907	.907	23.564	20.975	20.953	14.272
FS	1.018	1.017	---	---	---	---	---	---	15.505	14.551	14.536	9.607
FO	---	---	---	---	---	---	---	---	---	---	---	---
FA	---	---	---	---	---	---	---	---	---	---	---	---
CS	---	---	---	---	---	---	---	---	---	---	---	---
MT	.144	.143	---	---	---	---	---	---	3.618	3.618	3.614	3.626
CM	---	---	---	---	---	.96	---	---	---	---	---	---
HM	---	---	1.325	1.325	8.5	8.491	1.922	1.922	---	---	---	---
IL	.263	.263	.13	.13	1.949	---	.232	---	1.343	1.343	1.341	1.345
TN	---	---	---	---	1.753	4.123	---	---	---	---	---	---
PF	---	---	---	---	---	---	---	---	---	---	---	---
RU	---	---	.146	.146	---	.057	.252	.374	---	---	---	---
AP	.047	.047	.193	.403	1.965	1.963	.24	.24	.32	.32	.32	.321
FR	---	.212	.027	---	---	---	.023	.023	---	---	---	---
PR	---	---	---	---	---	---	.189	.204	---	---	---	---
CC	.058	---	.139	---	.047	.047	.023	.023	---	---	---	---
MG	---	.057	---	.117	---	---	---	---	---	---	---	---
SD	---	---	---	---	---	---	---	---	---	---	---	---
TOTAL	100.002	99.975	100	99.909	100.026	99.962	99.975	99.38	100.016	100.016	99.945	100.016
SALIC	98.192	98.034	96.899	96.734	72.925	72.851	96.188	96.183	55.034	55.347	55.394	56.134
FEMIC	1.81	1.942	3.101	3.125	27.101	27.112	3.787	3.592	44.982	44.669	44.552	43.882

SAMPLE SYMBOL	E5 S	E6 S	F1 *	F2 *	F3 S	F4 S	F5 *	F6 *	G1 *	G2 *	G3 *	G1 U
Q	11.569	23.5	32.25	32.535	32.652	32.537	33.443	35.33	---	---	---	---
C	---	---	2.218	2.319	2.317	2.312	8.152	8.85	---	---	---	---
Z	---	---	---	---	---	---	---	---	---	---	---	---
OR	.739	29.184	1.733	1.783	1.782	1.778	54.043	51.096	55.919	57.14	52.945	2.232
AB	.32	28.023	60.374	60.336	60.326	60.205	.66	---	6.619	5.469	---	---
AN	41.537	7.325	.274	---	---	---	---	---	---	---	---	29.027
LC	---	---	---	---	---	---	---	---	---	---	---	2.937
NE	---	---	---	---	---	---	---	---	---	---	---	8.939
KP	---	---	---	---	---	---	---	---	---	---	---	---
HL	2.435	---	.05	.05	.05	.05	---	.05	.051	.051	.051	---
TH	---	---	1.106	1.107	1.105	1.103	.051	.703	.11	.11	.11	---
NC	---	---	---	---	---	---	---	---	---	---	---	---
AC	---	---	---	---	---	---	---	---	5.47	5.277	9.265	---
NS	---	---	---	---	---	---	---	---	---	.319	.302	---
KS	---	---	---	---	---	---	---	---	---	---	1.437	---
WO	23.294	1.853	---	---	---	---	---	---	2.21	2.21	1.383	17.374
EN	9.082	1.715	.501	.166	---	---	---	---	14.535	11.659	9.43	10.97
FS	5.731	.945	---	---	---	---	---	---	1.811	3.06	---	5.315
FO	---	---	---	---	---	---	---	---	1.39	3.434	4.963	11.151
FA	---	---	---	---	---	---	---	---	.19	.999	---	5.951
CS	---	---	---	---	---	---	---	---	---	---	---	---
MT	3.625	4.869	.53	.53	.383	---	---	---	1.401	---	---	3.77
CM	---	---	---	---	---	---	---	---	.051	.051	.051	---
HM	---	---	.54	.54	.54	.903	.457	.458	---	---	---	---
IL	1.346	1.051	.243	.243	.243	.243	.444	.444	3.757	3.757	2.637	2.232
TN	---	---	---	---	---	---	---	---	---	---	1.395	---
PF	---	---	---	---	---	---	---	---	---	---	---	---
RU	---	---	---	---	---	---	---	---	---	---	---	---
AP	.321	.896	.071	.071	.071	.071	.12	.12	4.282	4.282	4.282	.237
FR	---	---	---	---	---	---	---	---	.603	.603	.603	---
PR	---	---	---	---	---	---	---	.515	---	---	---	---
CC	---	.522	.046	.146	.144	.144	.342	.052	---	---	---	---
MG	---	---	---	.071	.21	.21	.538	.538	---	---	---	---
SD	---	---	---	---	.073	.264	.36	.412	---	---	---	---
TOTAL	100.016	100.02	100.002	100.002	100.002	99.874	99.213	99.335	99.469	99.469	99.469	100.035
SALIC	55.553	88.137	98.065	98.231	98.231	98.034	96.362	96.585	62.699	62.77	63.105	43.185
FEMIC	43.448	11.863	1.936	1.771	1.771	1.84	2.851	2.75	36.77	36.699	36.363	56.85

Table 3.—CIPW norms, expressed in weight percent, for chemical compositions presented in Table 2—continued

SAMPLE SYMBOL	H2 U	H3 X	H4 W	H5 W	H6 W	H7 A	H8 U	H9 U	H10 U	H11 A
Q	---	---	---	---	---	---	---	---	---	---
C	---	2.271	---	3.91	3.91	---	---	---	---	---
Z	---	---	---	---	---	.195	---	---	---	1.622
OR	---	---	---	---	---	25.373	.836	1.13	.775	9.258
AB	---	---	---	---	---	27.975	3.591	12.437	12.641	---
AN	34.339	---	.544	2.154	2.154	2.798	10.167	26.515	23.368	47.354
LC	3.5	---	---	21.007	17.807	---	---	---	---	4.867
NE	13.605	.229	9.58	.787	.787	26.612	---	---	---	6.453
KP	---	.168	8.678	3.154	5.474	---	---	---	---	---
HL	---	---	---	---	---	---	---	---	---	---
TH	---	---	---	---	---	---	---	---	---	---
NC	---	---	---	---	---	---	---	---	---	---
AC	---	---	---	---	---	---	---	---	---	---
NS	---	---	---	---	---	---	---	---	---	---
KS	---	---	---	---	---	---	---	---	---	---
WO	13.667	---	---	---	---	6.431	8.209	8.156	13.661	2.744
EN	3.433	---	---	---	---	4.694	41.565	27.191	27.992	1.826
FS	1.429	---	---	---	---	---	22.952	12.582	12.49	.717
FO	7.771	79.963	32.412	34.013	34.395	---	6.268	5.175	3.18	5.831
FA	1.498	10.701	7.318	22.96	22.96	---	3.815	2.639	1.564	2.524
CS	2.29	---	24.393	---	---	---	---	---	---	---
MT	3.312	2.65	4.807	2.079	2.079	3.57	2.022	2.54	2.912	8.811
CM	---	---	---	---	---	---	---	.297	.268	---
HM	---	---	---	---	---	.209	---	---	---	---
IL	3.197	.526	5.788	9.934	9.934	1.455	.576	1.838	1.15	6.439
TN	---	---	---	---	---	---	---	---	---	---
PF	---	---	---	---	---	---	---	---	---	---
RU	---	---	---	---	---	---	---	---	---	---
AP	.83	.126	4.121	---	---	.405	---	---	---	1.315
PR	---	---	---	---	---	.196	---	---	---	.122
PR	---	---	---	---	---	---	---	---	---	---
CC	---	---	---	---	---	.023	---	---	---	.068
MG	---	---	---	---	---	---	---	---	---	---
SO	---	---	---	---	---	---	---	---	---	---
TOTAL	100.81	96.732	97.64	100	100	99.939	100.002	100.001	100.001	99.952
SALIC	51.594	2.567	18.802	31.013	30.132	82.954	14.595	40.083	36.785	69.555
FEMIC	43.416	94.365	78.838	68.987	69.868	16.984	85.407	59.918	63.216	30.397

There is excess F of .044 wt % in sample A2.

There is excess P_2O_5 of .095 wt % in sample B2.

There is excess Cr_2O_3 of .064 wt % in sample C2.

There is excess S of .093 wt % in sample D2.

There is excess Cl of .092 wt % in sample E3.

There is excess CO_2 of .128 wt % in sample F4.

There is excess CO_2 of .79 wt % in sample F5.

There is excess CO_2 of .093 wt % in sample F6.

There is excess P_2O_5 of .117 wt % in sample H3.

There is a deficiency of SiO_2 in sample H3 equivalent to excess FeO and MgO of .446 and 2.71 wt %.

There is a deficiency of SiO_2 in sample H4 equivalent to excess FeO and MgO of .533 and 1.917 wt %.