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RFM (relative fraction magnitude)

Program Explanation and Computer Program Listing

By

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Abstract

The RFM (relative fraction magnitude) program is proposed as an aid in the estimation of depth to ore-mineral concentration. This estimate is based on the determination of the relative position of the sampled surface plane within the zonational framework of a hydrothermal sulfide mineralization. The program requires analytical data on two sample fractions collected at the same localities. The first of these must selectively concentrate iron and manganese oxides (exclusive of magnetite) and, the other, the sulfides and their oxidized zone derivatives.

Introduction

The interpretation of a geochemical anomaly, believed to be the product of a concealed mineralization, should incorporate two inferences: 1, the type of ore minerals that might be expected at depth and 2, an estimate of depth of ore-mineral concentration.

The only definitive method of determining these parameters is by core drilling. However, reasonable estimates must and can be made on the basis of existing geologic, geophysical, and geochemcal information prior to the expensive drilling stage. Geologic information is essential in determining the type of mineralization that might be expected within a given area. Geologic information in conjunction with geophysical data can provide information as to the depth at which an ore-mineral concentration might be expected. Geochemical data, on the other hand, can add very significantly to the determination of both parameters.

Geochemical data represents measurements of quantities directly involved in the mineralization process; they, aside from drill data, therefore constitute the most valid body of information from which estimates as to type and depth of ore-mineral concentrations, might be made.

The type of mineralization can be deduced from the total elemental assemblage that has been introduced into the mineralized area as well as the relative amount of each element within this assemblage.

Elemental and intraelemental mineralogic zonations are present and geochemically measurable in most mineralizations. Using these two parameters, depths to ore-mineral concentrations can be estimated by determining the relative position, of the sampled surface, within the zonational framework.

Geologic considerations

The RFM (relative fraction magnitude) program is proposed as an aid in the estimation of depth to ore-mineral concentration. This estimation is based on the determination of the relative position of the sampled surface plane within the zonational framework of mineralization. Rather than determining the elemental zonation within this plane, for which purpose the REM (relative element magnitude) program can be utilized (VanTrump and Alminas, 1978), the RFM program is designed to determine the relative proportions of ore metal occurring in the form of base metal sulfides and oxidized zone ore minerals as opposed to the ore metal contained in iron and manganese oxides. This proportionality calculation is based on the following three premises:

1. That there is an iron and manganese oxide enrichment halo, encompassing the outer, visible alteration zones and beyond, associated with most hydrothermal sulfide mineralizations. This halo overlaps but also extends substantially beyond the ore-metal sulfide and the subsequent iron sulfide zones into essentially unaltered rocks. The outermost expression of this halo occurs in the form of metal-rich fracture coatings.

2. That the hydrothermal solutions transporting and precipitating the iron and manganese, forming the enriched halo, also contain low levels of the same ore metals to be found within the sulfide zone. These co-preciptate with the iron and manganese, imparting high trace-metal contents to the oxides, which are indicative of the composition of the sulfide zone.
3. That the ore-metal sulfide zone decreases outward gradually and progressively when viewed in terms of sulfide content per large volume of host rock. The mode of occurrence of these sulfides changes from disseminations and microveinlets in the central portions to scattered veins in the outer portions of the zone.

These premises establish two geochemically measurable trends:

1. The overall ore-metal content per unit volume of host rock progressively increases toward the central portion of the ore-metal sulfide zone and,
2. The mode of occurrence of this ore metal shifts progressively from predominantly, or even exclusively, that held in iron and manganese oxides in the outer portion of the halo to predominantly sulfide minerals within the sulfide zone.

The zonational model presented above is, of course, a gross generalization of any specific situation encountered in nature. Each given mineralization will, in fact, exhibit some elemental and mineralogic zonational irregularities as well as structural discrepancies producing some erratic values. An attempt is made to minimize the influence of these erratic values on the calculation by obtaining values for the mineralization as a whole rather than for spot locations. This is done in two ways. First, stream-sediment derived mineralogic fractions are used. As a result, the values from one sample location are representative of the totality of all structural and zonational settings within the sampled drainage basin. All the values of the individual sampled drainage basins, within the mineralized area, are composited to produce a cell value. This is representative of the mineralized area as a whole and generally encompass several square miles.

The RFM program determines both the overall magnitude of a mono-metal anomaly and the metal partitioning between the two mineralogic fractions. The combination of these two measurements over ore bodies of known depth permits establishment of a scale for estimating depth to sulfide zones in geochemical anomalies overlying concealed mineralizations. This has been done over several orebodies occurring in a broad region in southwestern New Mexico. Eight geochemical anomalies suspected to reflect concealed mineralizations, ranging in setting from Montana to Mexico, were also investigated. The results to date are encouraging in that they reflect the relative depths of the known ore deposits and appear to correlate with geologic and geophysical depth estimates in the case of the concealed mineralizations. In order to be utilized, as intended, this program requires analyses of two sample types derived from each sample location. One of these must selectively concentrate the iron and manganese oxide minerals and, the other, the sulfide and oxidized zone ore minerals. For past work, the senior author has used magnetic susceptibility to extract such fractions from panned concentrates as described below:

The sample material consists of the portion of pan-concentrate stream sediment having a specific gravity greater than that of bromoform (2.9). This sample material was subsequently separated magnetically into two fractions labeled magnetic (M-1) and nonmagnetic (NM-1). The magnetic (M-1) fraction is that portion of such material not magnetic at 0.1 ampere but magnetic at a 1.0-ampere setting on a Frantz Isodynamic Separator (forward slope 25°, side slope 15°). The portion that is not magnetic at a 1.0-ampere setting is labeled nonmagnetic (NM-1). The M-1 fraction is comprised dominantly of iron oxides, iron hydroxides, and manganese oxides, in addition to mafic rock-forming minerals. The iron and manganese oxides occur primarily as particles of fracture coatings and fissure fillings. The nonmagnetic (NM-1) fraction is composed of light-colored, rock-forming accessory minerals and primary and secondary ore minerals.

Program explanation

Introduction

The RFM (relative fraction magnitude) program is designed to determine the relative anomaly magnitude of a given element as expressed by two different sample media collected at the same sample sites. Calculations are performed on a cell basis (that is, on all sample locations occurring within a defined area) rather than on individial sample locations.

Only rectangular cell configurations are possible. The user determines the cell size, shape, and location by defining its corner points in terms of minimum and maximum of latitude and longitude or (x) and (y). In most instances, the cell boundaries should barely encompass the anomalous area under study.

The cell should contain a reasonable number of sample locations. The size of the actual population is a function of cell size and structural and topographic complexity of the study area. Sample-site distribution within the cell should be as uniform as possible.

Mode of calculation

The RFM values are derived on the basis of two parameters for each element in each of the two sample media. The first of these, the intensity factor, is calculated by dividing the mean of all anomalous values of one element in one sample medium, occurring within the cell area, by its respective threshold value. This step establishes an average anomaly intensity for that portion of the cell area anomalous in a given element. The division of the elemental mean value by its respective threshold value is intended to subdue the anomaly intensity factor and to permit a more reasonable interelemental comparison.

The second paramater, the area factor, is calculated by dividing the number of sample locations, anomalous in a given element within one sample medium, by the total number of sample locations within the cell. This parameter gives a rough indication of the percent of all area that is anomalous, assuming a relatively uniform sample-site distribution within the cell.

These two parameters are multiplied for each sample medium, and the product is called the fraction magnitude (FM) for that given element. This multiplication step is taken to combine the area and intensity factors of an anomaly into one value. The two FM values of the element are then added together and each FM value is divided by this total to give the proportion of the element occurring in each of the two fractions. This value is called the RFM value for that element in each fraction.

Program execution

The RFM program uses one or two STATPAC data sets (VanTrump and Miesch, 1977) as input and prompts the user, interactively, for the required information. The program execution may be divided into three sections:

1. Input.
2. Verification.
3. Output.

Input section

This section explains the information required to initiate the program. An example of the required input, keyed numerically to an explanation of the information required, is shown below:

INPUT SECTION

```
RFM (1)
ARE YOU GOING TO USE 2 FILES ? Y (2)
(3) 1ST-FILE NAME : LHNM1 (a)
    DATA SET NAME : LHNM1 (b)
(4) 2ND-FILE NAME : LHM1 (a)
    DATA SET NAME : LHM1 (b)
ENTER LAT-LONG COL NOS : 1,2 (5)
ENTER LOC VALUES (XMIN,XMAX,YMIN,YMAX) : 32.75,32.78,107.76,107.79 (6)
                                          (a)                (b)
ENTER 1ST VARIABLE NO & THRESHOLD VALUE : 20,10 (7)
ENTER 2ND VARIABLE NO & THRESHOLD VALUE : 20,10 (8)
```

1. Typing of lower case RFM will initiate this program.
2. The number of STATPAC binary files containing the desired data (maximum two files).
3. a. The file name of the first STATPAC binary file.
   b. The STATPAC data-set name in the first file.
4. a. The file name of the second STATPAC binary file, if required.
   b. The STATPAC data-set name in the second file.
5. The column numbers of the latitude (x) and longitude (y). If more than one file is used, the column numbers for latitude and longitude must be the same in all files.
6. This step defines the location and size of the selected rectangular cell. The minimum and maximum latitude (x) and longitude (y) values defining the selected area are entered in decimal form.
7. a. The column number of the first selected variable.
   b. The threshold value of the first selected variable. The program will consider all values $\geq$ to this value.
8. a. The column number of the second selected variable.
   b. The threshold value of the second selected variable. The program will consider all values $\geq$ to this value.

Verification section

This repeat section of the program shows input parameters on which the program will make its calculations. An example of this section, keyed numerically to an explanation of the information provided, is shown below:

VERIFICATION SECTION

```
WINDOW AREA:      MINIMUM     MAXIMUM
     LATITUDE     32.7500     32.7800 (1)
    LONGITUDE    107.7600    107.7900

VARIABLES:
   1ST-VAR =  20 (S-MO    ), THRESHOLD VALUE =      10.000 (2)
   2ND-VAR =  20 (S-MO    ), THRESHOLD VALUE =      10.000
      (a)      (b)   (c)                              (d)
```

1. The minimum and maximum latitude (x) and longitude (y) values defining the area to be used.
2. A list of the variables on which calculations will be made. The following information is provided for each:
    a. Numerical identification of the variable.
    b. Column number of the variable.
    c. Element identification of the variable.
    d. Threshold value for that variable.

Output section

The output section of the program gives the results of the calculations. An example of the output, keyed numerically to the type of information provided, is shown below:

OUTPUT SECTION

(southern cell)

GENERAL STATS:

VAR NM	TOTAL	ANOM	SUM	MEAN	INTENSITY	AREA (7)	FM (8)	RFM (10)
1	13	1	50.0	50.000	5.00	7.69	38.46	18.2
2	13	8	225.0	28.125	2.81	61.54	173.08	81.8
(1)	(2)	(3)	(4)	(5)	(6)	TOTAL (9)	211.54	

OUTPUT SECTION

(northern cell)

GENERAL STATS:

VAR NM	TOTAL	ANOM	SUM	MEAN	INTENSITY	AREA	FM	RFM
1	14	6	2270.0	378.333	37.83	42.86	1621.43	94.5
2	16	4	150.0	37.500	3.75	25.00	93.75	5.5
						TOTAL	1715.18	

1. Numerical identifications of the two variables.
2. The total numbers of sample locations containing information on each of the two variables within the selected cell.
3. The number of sample locations at which each variable occurs in anomalous ($\geq$ threshold) concentrations within the cell.
4. The sum of all anomalous values of each variable occurring within the cell.
5. The mean of all anomalous values within the cell for each variable.
6. The mean of each variable divided by its respective threshold value. This is the intensity factor of each variable.
7. The quotients of the number of anomalous sample locations of each variable divided by the respective total number of samples within the cell. These values are called the area factors and are expressed in percent.
8. The products of the intensity and area factors of each variable. This is the fraction magnitude (FM) for each variable.
9. The sum of both fraction magnitudes termed the anomaly magnitude.
10. Each individual FM value divided by the anomaly magnitude and expressed in percent. These values show the proportional occurrence of the element in anomalous concentrations in the two sample media and are termed relative fraction magnitudes (RFM).

Interpretation of RFM values

Molybdenum RFM values calculated for two different portions of the same linear geochemical anomaly (Alminas and Watts, 1978) are shown in the program output section. The anomaly is produced by a north-south trending mineralization (Royal Mine and Noon Day Peak areas) which occurs at a depth measured in tens of feet in the northern cell and at a depth of >1,000 ft in the southern cell. The two cells are separated by approximately 3 miles. The rapid increase in depth to mineralization southward is due to a series of rapidly thickening premineralization volcanic rocks.

The molybdenum RFM value for the sulfide fraction in the northern (shallow) cell is 94.5 percent and the overall molybdenum anomaly magnitude is 1,715. By contrast, the molybdenum RFM value for the sulfide fraction in the southern (deep) cell is 18 percent and the overall molybdenum anomaly magnitude is only 212. These figures indicate two differences between the northern and southern cells:

1. Substantially more molybdenum has been introduced in the northern cell and,
2. 94.5 percent of the molybdenum in the northern cell occurs in the form of sulfide or oxidized-zone ore mineral, whereas 82 percent of the molybdenum in the southern cell is present in iron and manganese oxides.

Fitting these conclusions into the earlier mentioned trends, it becomes evident that northern cell is located essentially within the sulfide zone whereas the southern cell is at some distance outside of it--almost exclusively in the iron and manganese halo.

Other base metals behave in a manner similar to molybdenum (table below):

	Northern cell			Southern cell		
	Sulfide	Oxide	Total	Sulfide	Oxide	Total
	percent		Magnitude	percent		Magnitude
Pb----90.5	9.5		15,278	44	56	141
Cu----62.8	37.2		129	0	100	8
Zn----97.2	2.8		3,692	14	86	273

The elemental RFM value differences are interpreted to be the result of elemental zonation.

References cited

Alminas, H. V., and Watts, K. C., 1978, Molybdenum in stream sediments, Hillsboro and San Lorenzo quadrangles, Sierra and Grant Counties, New Mexico: U.S. Geological Survey Miscellaneous Field Studies Map MF-900E.

VanTrump, Jr., George, and Miesch, A. T., 1977, The U.S. Geological Survey RASS-STATPAC System for management and statistical reduction of geochemical data: Computers and Geoscience, v. 3, p 475-488.

VanTrump, Jr., George, and Alminas, H. V., 1978, REM. (relative element magnitude) program explanation and computer program listing: U.S. Geological Survey Open-File Report 78-1014.

Relative Fraction Magnitude Program

```
c      * * * * Relative Fraction Magnitude Program (rfm) - Statpac * * *
c                              U.S. Geological Survey
c                        Geologic Division, Denver, Colorado
c                          written by George VanTrump, Jr.
c                                 for Henry V. Alminas
c                                  on March 14, 1978
c      * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * *
c          This program is proposed as an aid in the estimation of depth
c      to ore mineral concentration. This estimate is based on the deter-
c      mination of the relative position of the sampled surface plane
c      within the zonational framework of a hydrothermal mineralization.
c      The program requires analytical data on two sample fractions
c      collected at the same localities. The first of these must selec-
c      tively concentrate iron and manganese oxides (exclusive of magnet-
c      ite) and, the other, the sulfides and oxidized zone ore-minerals..
c          The program uses a STATPAC data set as input and prompts the
c      user, interactively, for the required information.
c          The following subroutines, referenced within this program but
c      not listed, perform the following:
c          ioa_$nnl - prompts the user with a character string and holds
c             the cursor at the end of the string so that the reply to
c             the query is on the same line as the question.
c          openf    - attachs and opens a STATPAC binary file.
c          closef   - closes and detachs a STATPAC binary file.
c          searches - finds the required data set in the input STATPAC
c             binary file.
c          getlst   - reads a record(sample) from a STATPAC data set.
c      ------------------------------------------------------------------
c
1          external ioa_$nnl (descriptors), openf(descriptors)
2          character*4 inm(2)
3          character*32 file1,file2
4          dimension values(2),x(199),ia(199),sum(2),numan(2),area(2),num(2),
4         1 rfm(2),ierr(2),prod(2)
5          real mean(2),int(2)
6          common /numeric/ nnn(1),itp(2),icd(2),n(2),m(2),iselv(3,2),loc(2)
7          common /alpha  / iap(1),id(2,2),ivid(199,2),irid(4),ids(2,2)
8          data iyes/"y"/,iblk/" "/,inm/"1st","2nd"/,ibbb/"B"/
     c     ------------------------------------------------------------------
     c ... Initialize arrays.
     c     ------------------------------------------------------------------
9          do 100 i=1,17
10     100 nnn(i)=0
11         do 110 i=1,408
12     110 iap(i)=iblk
13         itp(1)=10
14         itp(2)=11
15         call ioa_$nnl ("^/Are you going to use 2 files ? ")
16         read 300,ians
```

```
17          if (ians.ne.iyes) go to 130
18          call ioa_$nnl ("^/^3a-file name : ",inm(1))
19          read 160,file1
      c     ------------------------------------------------------------
      c ... Read input parameters.
      c     ------------------------------------------------------------
20          call openf (itp(1),file1,"sqi ")
21        120 call ioa_$nnl ("Data Set Name : ")
22          read 170,id(1,1),id(2,1)
23          call searches (icd(1),itp(1),id(1,1),n(1),m(1),ivid,$120)
24          go to 150
25        130 call ioa_$nnl ("^/File Name     : ")
26          read 160,file1
27          call openf (itp(1),file1,"sqi ")
28        140 call ioa_$nnl ("Data Set Name : ")
29          read 170,id(1,1),id(2,1)
30          call searches (icd(1),itp(1),id(1,1),n(1),m(1),ivid,$140)
31          icd(2)=icd(1)
32          itp(2)=itp(1)
33          id(1,2)=id(1,1)
34          id(2,2)=id(2,1)
35          n(2)=n(1)
36          m(2)=m(1)
37          go to 180
38        150 call ioa_$nnl ("^/^3a-file name : ",inm(2))
39          read 160,file2
40        160 format (a32)
41          call openf (itp(2),file2,"sqi ")
42          call ioa_$nnl ("Data Set Name : ")
43          read 170,id(1,2),id(2,2)
44        170 format (2a4)
45          call searches (icd(2),itp(2),id(1,2),n(2),m(2),ivid,$150)
46        180 call ioa_$nnl ("^/Enter Lat-Long Col Nos : ")
47          read 210,iselv(1,1),iselv(2,1)
48          iselv(1,2)=iselv(1,1)
49          iselv(2,2)=iselv(2,1)
50          call ioa_$nnl ("^/Enter loc values (xmin,xmax,ymin,ymax) : ")
51          read 210,xmin,xmax,ymin,ymax
52        200 call ioa_$nnl ("^/Enter ^3a variable no & threshold value : ",
52           1 inm(1))
53          read 210,iselv(3,1),values(1)
54          call ioa_$nnl ("Enter ^3a variable no & threshold value : ",
54           1 inm(2))
55          read 210,iselv(3,2),values(2)
56        210 format (v)
      c     ------------------------------------------------------------
      c ... Begin computations.
      c     ------------------------------------------------------------
57        220 do 230 i=1,2
```

Appendix A

A Computer Listing of the RFM program.

```
 58          itt=itp(i)
 59          call searches (icd(i),itt,id(1,i),n(i),m(i),ivid,$320)
 60          sum(i)=0.0
 61          num(i)=0
 62          numan(i)=0
 63          nn=n(i)
 64          mm=m(i)
 65          ix=iselv(1,i)
 66          iy=iselv(2,i)
 67          iz=iselv(3,i)
 68          ids(1,i)=ivid(iz,1)
 69          ids(2,i)=ivid(iz,2)
 70          zval=values(i)
 71          do 230 j=1,nn
 72          call getlst (itt,ir,irid,loc,x,ia,mm,$320)
 73          if (ia(iz).eq.ibbb) go to 230
 74          if (x(ix).lt.xmin.or.x(ix).gt.xmax) go to 230
 75          if (x(iy).lt.ymin.or.x(iy).gt.ymax) go to 230
 76          num(i)=num(i)+1
 77          if (ia(iz).ne.iblk) go to 230
 78          if (x(iz).lt.zval) go to 230
 79          sum(i)=sum(i)+x(iz)
 80          numan(i)=numan(i)+1
 81      230 continue
 82          sums=0.0
 83          do 250 i=1,2
 84          ierr(i)=1
 85          if (numan(i).ne.0.and.num(i).ne.0) ierr(i)=0
 86          mean(i)=1.0e15
 87          int(i)=1.0e15
 88          area(i)=1.0e15
 89          prod(i)=1.0e15
 90          if (numan(i).eq.0) go to 240
 91          mean(i)=sum(i)/numan(i)
 92          int(i)=mean(i)/values(i)
 93      240 if (num(i).eq.0) go to 250
 94          area(i)=100.0*numan(i)/num(i)
 95          prod(i)=area(i)*int(i)
 96          sums=sums+prod(i)
 97      250 continue
     c       ------------------------------------------------------------------
     c   ... Print results.
     c       ------------------------------------------------------------------
 98          print 260,xmin,xmax,ymin,ymax,(inm(i),iselv(3,i),ids(1,i),ids(2,i)
 98         1 ,values(i),i=1,2)
 99      260 format (/"Window Area:     Minimum    Maximum"/5x,"Latitude",2f10.4/
 99         1 4x,"Longitude",2f10.4//"Variables:"/(3x,a3,"-Var = ",i3,
 99         2 " (",2a4,"), Threshold Value = ",f10.3))
100          rfm(1)=1.0e15
```

```
      rfm(2)=1.0e15
      if (ierr(1)+ierr(2).ne.0) go to 270
      denom=(int(1)*area(1)+int(2)*area(2))
      rfm(1)=100.0*prod(1)/denom
      rfm(2)=100.0*prod(2)/denom
  270 print 280,(inm(i),num(i),numan(i),sum(i),mean(i),int(i),area(i),
     1 prod(i),rfm(i),i=1,2)
  280 format (/"General Stats:"/1x,"Var Nm   Total  Anom",
     1 t27,"Sum",t35,"Mean",t42,"Intensity",t53,"Area",t63,"FM",
     2 t70,"RFM"/(4x,a1,3x,2i6,f10.1,1x,f9.3,1x,f7.2,2x,f6.2,1x,f9.2,2x,
     3 f5.1))
      print 290,sums
  290 format (t52,"Total",f10.2)
c     ------------------------------------------------------------------
c ... Inquiry about changing existing parameters and recycle.
c     ------------------------------------------------------------------
      call ioa_$nnl ("^/Do you want another set of cols ? ")
      read 300,ians
  300 format (a1)
      if (ians.eq.iyes) go to 200
      call ioa_$nnl ("^/Do you want to change location values ? ")
      read 300,ians
      if (ians.ne.iyes) go to 310
      call ioa_$nnl ("^/Enter new loc vals(xmin,xmax,ymin,ymax) : ")
      read 210,xmin,xmax,ymin,ymax
      go to 220
c     ------------------------------------------------------------------
c ... Close files.
c     ------------------------------------------------------------------
  310 call closef (itp(1))
  320 if (itp(1).ne.itp(2)) call closef (itp(2))
c
      stop
      end
```