File · Chu Chua NTS 093L/01
Geophysics
821222

MEMORANDUM

file: GP research

GSC logging program

TO: file

FROM: Peter Kowalczyk

March 25, 1987

RE: GSC Logging program
Equity Drill holes 86-247, 86-250

GENERAL

During the summer of 1986 the GSC conducted a program of drill hole logging at a number of ore bodies in British Columbia. These included the Sullivan deposit, the Goldstream deposit, the Equity deposit and the Chu Chua deposit. A fairly complete set of geophysical logs were run in an attempt to characterise the physical properties of these types of deposits and to explore the usage of geophysical logs as interpretive aids.

This memo reviews the work at Equity in particular. The geophysical logs provided by the GSC have been composited and merged with the assay information available. The data has then been examined statistically to try to extract patterns not readily seen in the graphic logs.

For a review of the different tools used in this logging program refer to the GSC publication paper 85-27 BOREHOLE GEOPHYSICS FOR MINING AND GEOTECHNICAL APPLICATIONS

INTERPRETATION

The hole names supplied to the GSC at Equity, and the original logs, were incorrect. The holes logged were 86-246 and 86-250. The GSC was told these were 86-247 and 86-250. This means that the geology on the GSC plots is wrong, and references to data are to 86-247 instead of 86-246. All references here are to 86-246, which might be called 86-247 by the GSC. The geology on the GSC logs is actually the geology in hole 86-247 and is not correct for the hole physically logged.

The geophysical logs allow correlations to be made between the two holes logged which are difficult to make otherwise. Figure 1 shows the similarity between the resistivity log (RHO), the IP log (IP), and the magnetic susceptibility log (LOG MS) for the two holes. On the basis of these logs, the volcanic section in ddh 86-250 from 85m to 102m is repeated in 86-246 from 26m to 130m. The geologic section over this interval can be broken into four units. Using the depths in 86-250 to describe them these are as follows. From 85m to 118m, an ash lapilli tuff characterised by pulses of increased sulphides causing local highs in the IP log which build up and down in a fairly regular manner. Resistivities are low to moderate. From 118m to 124m an electrically resistive unit exists, this is logged as a dyke in 86-250 but is probably an extrusive unit. From 124m to 179m an ash lapilli tuff unit exists which is similar to the first unit described. From 179m to 192m another electrically resistive unit exists. This is described as a gabbro, but is an extrusive unit if this interpretation is correct.

The gabbro from 177.7 to 187.9 in the geologic log for 86-250 is isolated from the gabbro

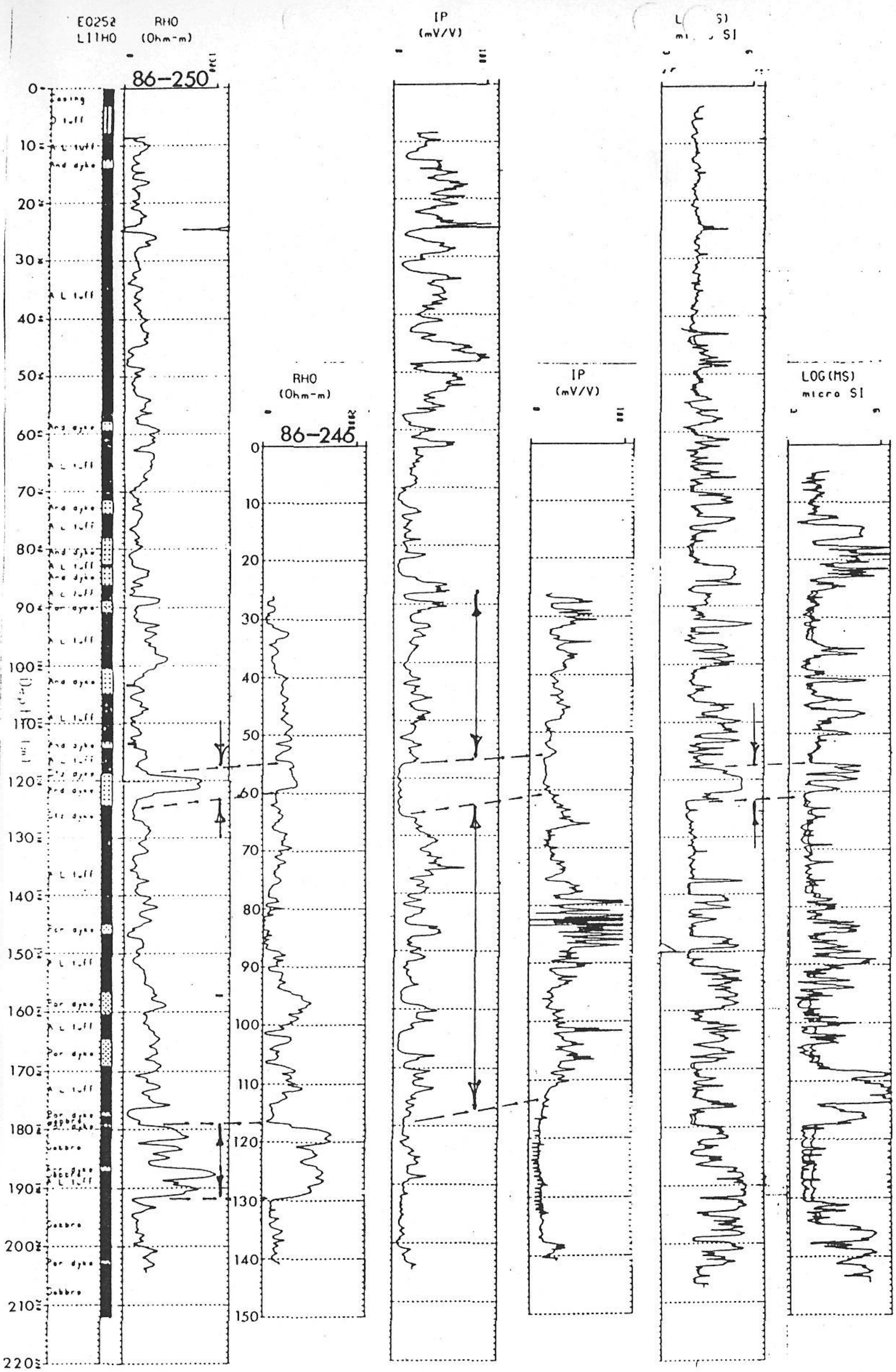

figure 1: Resistivity (RHO), IP effect (IP), and log magnetic susceptibility logs placed side by side to show correlations from hole to hole. Ddh 86-246 is to the right of ddh 86-250.

below it in the hole by a 2m thickness of lapilli tuff. It has quite a different geophysical character and is probably a different unit.

The implications of this interpretation are dramatic. The two drill holes are about 640 meters apart. The fact that the thickness of the volcanic section has changed very little suggests that it was almost flatlying during its deposition. Drill hole 86-250's collar elevation is 1313m and 86-246's is 1260m. This means the true elevation difference of the same section in the two holes is only 10 meters. The suggestion is that vertical movement since deposition is minimal and that the regional dip along the line of the two drill holes is nearly flat. Also, rocks which are interpreted as intrusive in the geologic log would be extrusive, if the geophysical interpretation is correct, and they must extend over quite large areas. Thus they would make good marker horizons.

This interpretation is in conflict with the current geologic log for these two holes. The correlation between the logs is quite dramatic and provides strong evidence in favour of it. It would be worthwhile doing some thin section work on the rock units logged as dykes and gabbro in the geologic log for 86-250 but identified as extrusive flatlying units by the geophysical logs to resolve this conflict.

STATISTICAL ANALYSIS OF GSC LOGS

In order to examine the response of the GSC logging tools to the mineralization, the GSC's digital logs were combined with the assay information existing for the holes logged. The assays were taken over 3 meter intervals. Ideally, any statistics comparing the GSC logs to the assays should be taken using 3 meter composites for the GSC logs as well. However, this was difficult to do easily, so the 3 meter assays were broken into 1 meter intervals for comparison with the geophysical logs. It should be realized that this will introduce variability into the readings, as three geophysical readings exist for each assay, and the actual variability of the assays over the 3 meters that the composite was taken over is not known.

In order to simplify the analysis a characteristic suite of logs was selected from the different logs run. For rock resistivity 2 EM conductivity logs and a galvanic resistivity log exist. A cross-plot of the conductivity logs showed the Romulus and the Geoinstruments conductivity logs did not correlate very well in the range of conductivities encountered. For rock resistivity the 10 cm micro-normal resistivity taken with the IP log was chosen. Temperature, although useful for detecting fractures, was felt to be unlikely to be related to any of the rock properties on a small scale down the hole and was discarded from the analysis. SP, IP, gamma gamma density, gamma gamma heavy element ratio (also called spectral gamma gamma), and the Geoinstruments magnetic susceptibility logs were included in the file.

As the logs are in digital form it was not necessary to keep logarithmic versions of the data, this option is available at any time in the analysis programs.

The poor response of the Romulus and Geoinstruments conductivity logs is not unexpected. These logs are useful for estimating the conductivity of massive sulphide conductors, and the range of resistivities encountered in this case is typically outside the range of these logs.

Tetrahedrite is the principal silver mineral at Equity. This explains the very high correlation coefficients for silver, antimony, and copper. The correlation between iron and silver is close to zero. This suggests that the pyrite mineralization is not related to the mineralization, but is rather characteristic of the original volcanics. This interpretation is supported by the stratigraphic correlation made with the IP logs between the two holes, which would require that the pyrite content of the volcanics be one of the original properties of the rocks.

The only geophysical log which correlates with the mineralization is the gamma gamma heavy element ratio (GGHE). The atomic weights of silver, antimony, and copper are 107, 121, & 63 versus 55 and 32 for iron and sulphur, and 27, 28 & 16 for aluminium, silicon, and oxygen. Thus, the GGHE tool, which responds to higher atomic weights, could be expected to respond quite strongly to higher silver grades. Some matrix effects could be expected for pyrite, however, the cross plot of GGHE against silver for silver grades greater than 2 ppm shows a correlation coefficient of 0.67. This is quite high, and it might be possible to improve it by making some type of matrix correction for pyrite. Even without the matrix correction, the response of the GGHE log to the silver in the tetrahedrite is remarkable as the average iron value for intervals with silver above 2 ppm is 4.6% while the average silver grade is 40 ppm (.004%) and that of antimony is 280 ppm (.028%).

The Gamma gamma log does not appear very useful in this environment. It is strongly anti-correlated with IP, which is reasonable, as density will be dependent on pyrite content in large measure. When pyrite content goes up, density goes up and the gamma gamma count will go down.

The temperature log flags open structures well and has promise as a geotechnical log, assisting in pit wall design and in assessing dewatering problems.

The magnetic susceptibility logs appear useful in assessing bulk magnetic susceptibilities of rock units and help characterize the physical properties that might be used in forward modeling problems. In detail, there is quite high local variability along the holes, and only general correspondence from hole to hole. Whether this is an intrinsic rock property, or the result of later hydrothermal alteration is unclear.

SP does not appear very useful, but is very easy to collect. In sedimentary environments it is known to be very useful in recognizing particular stratigraphic units. In this volcanic environment its meaning is not so clear.

SUMMARY

The IP and resistivity logs, along with the magnetic susceptibility log, appear to be the most useful for correlating from drill hole to drill hole in the volcanic environment at equity. The conclusion made in this case is in conflict with the present geologic interpretation of the rock units in the drill logs, although the geophysical correlation matches the regional geologic dips. It would be difficult to reconcile these interpretations without further geophysical logging to establish the stratigraphic markers more clearly and some reinterpretation of the geologic logs, including thin section work, and perhaps chemical analysis to attempt to establish the volcanic section more conclusively. Paleomagnetic measurements may be useful also, although the hydrothermal system could have reset the paleomagnetic vectors in some areas.

In any case, even if the geophysical interpretation here is in error, the characterization of the the rock types by these geophysical logs seems very practical. This should be one of the conclusions of this program of work. In this case, a program involving more than 2 holes would have provided a much clearer picture.

It is surprise how useful the IP parameter is as it was the author's opinion that the very small size of the array would cause problems in trying to characterize the macroscopic properties of the rock. However, the small array provides small scale character on the log trace which is a great help in correlating from one hole to another. In any logging program where the IP response is being used to characterize the rock properties, a small array is probably necessary. It should not be larger than 50 centimeters, and perhaps should be smaller, say 20 centimeters, or even 10 as was used in this program. In the case where the IP log has been composited to 1 meter intervals, much of the usefulness of this log in correlating from hole to hole has been destroyed.

The gamma gamma heavy element tool is surprisingly sensitive and might be quite useful as an assay tool if the matrix effects were understood. This problem might be attacked by compositing over 3 meter lengths in this data set so that a 1 to 1 relationship exists with the assay data.

One tool not used in this program is the spectral radiometric probe. Potassium is known to be associated with many alteration systems, and with careful control of logging rates and calibration it can be assayed quite accurately with a radiometric log.

Overall, the program of work at Equity has demonstrated the usefulness of logging techniques quite clearly, and helped define the logs which might be most useful in this type of environment. For correlation of volcanic units, these appear to be resistivity, IP and magnetic susceptibility. For geotechnical information the temperature log appears useful. For the definition of the mineralization the IP log and the gamma gamma heavy element have worked well, although the pyrite which the IP log has principally responded to is in this case often not related to silver mineralization. In the case where more massive mineralization might be expected an EM conductivity log would be appropriate as the range of resistivities would be more in the range of these instruments.

Peter Kowalczyk.

Peter Kowalczyk

cc Patrick Killeen, GSC
Rob Pease, Equity
Ken Witherley, Utah
for circulation to GSC logging program participants

```
file: equity_log250                CONRvsCONG     .OL . =1   LOGY =0
                                    ----    ----

          +--------+--------+--------+--------+
    -4.4  +                                   +-4.4      PLOT SUMMARY
          |                                   |            168 X-Y PAIRS
          |                                   |              0 VALUES>MAX
          |                                   |              0 VALUES<MIN
y   -5.2  +                                   +-5.2        168 PLOTTED
          |                                   |              X  MINMAX  Y
a         |                        1          |           0.6034 -8.2309
x         |                                   |            0.744 -5.4342
i   -6.0  +                                   +-6.0      REGRESSION LINE
s         |                  1                |          A = -3.3690
:         |                                   |          B =  20.393
          |       1            1              |          VARIANCE
C   -6.8  +                 1                 +-6.8          0.12434
O         |       1                           |          STD. DEVIATION
N         |   1   1 1   1  1                 -|              0.35262
G         |     13111  11 121    1    -    -  |          CORRELATION COEF
    -7.6  +   1 132 234345632    -            +-7.6          0.21735
          |1 24 33612517543                   |
          |-  1 34163233 58 1                 |          PLOT INCREMENTS
          |1     131212112                    |          X:  0.92309e-03
    -8.4  +          1  1                     +-8.4      Y:  0.20000
          +--------+--------+--------+--------+
        0.60     0.62     0.63     0.64     0.65
               x axis: CONR
```

Figure 2 crossplot of conductivities for the Romulus tool (CONR) versus those for the Geoinstruments tool (CONG). The correlation between these tools is poor for the range of conductivities encountered

```
file: equity_log250               MAGR  vs  MAGG    LOGX =1  LOGY =1   REPVAL
                                  ----      ----

            +--------+--------+--------+--------+
  1500000   +                                  -+6.2     PLOT SUMMARY
            |                                   |          202 X-Y PAIRS
            |                              -    |            0 VALUES>MAX
            |                                   |            0 VALUES<MIN
y  515273   +                          1        +5.7       202 PLOTTED
            |                  1     2 3        |            X  MINMAX  Y
a           |                 1   1             |         6.4475    7175
x           |             2 111   11 1          |         45.64   548376
i  177004   +           2111 1 1-               +5.2     REGRESSION LINE
s           |     1     12121311                |        A =  2.2837
:           |       1 2 122 11 1 1    1         |        B =  2.1254
            |  1  11 1 1 1   - 1                |        VARIANCE
M   60804   +  1 22122 2  2       1             +4.8         0.83796e-01
A           |     1 1     1 1                   |        STD. DEVIATION
G           |    12  2 -  1      1              |            0.28948
G           |  1  34 12    1    1               |        CORRELATION COEF
    20887   +1 14311 12 1                       +4.3         0.82018
            |   932 1 1 1                       |
            |  9*224122   1                     |        PLOT INCREMENTS
            |-2**12 111 1                       |        X:  0.30448e-01
     7175   + 122    1                          +3.9     Y:  0.11601
            +--------+--------+--------+--------+
           6.4     12.1     22.8     42.8     80.4
                  x axis: MAGR
```

Figure 3: Crossplot of the magnetic susceptibilities measured with the Romulus tool (MAGR) versus those measured with the Geoinstruments tool (MAGG). The correlation is quite good, for this study the Geoinstruments tool was used.

CORMAT: RUN ON 87:04:14 AT 10:41:36

Data from file: gsc/logs

GSC EQUITY GEOPHYSICAL LOGS, DDHS 246,250

Correlation matrix for 361 records with 13 variables

	SP	RES	IP	MAGG	GGD	GGHE	CU	ZN	SB	AG	AU	AS	FE
LOG:	1	1	1	1	1	1	1	1	1	1	1	1	1
SP	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
RES	0.000	1.000	-0.425	0.108	0.195	0.098	-0.006	-0.162	0.075	-0.014	-0.044	-0.090	-0.377
IP	0.000	-0.425	1.000	-0.321	-0.615	0.307	0.329	0.264	0.249	0.254	0.320	0.454	0.476
MAGG	0.000	0.108	-0.321	1.000	-0.098	0.128	-0.025	-0.052	-0.034	-0.042	-0.070	-0.103	0.109
GGD	0.000	0.195	-0.615	-0.098	1.000	-0.052	-0.318	-0.185	-0.273	-0.325	-0.188	-0.191	-0.085
GGHE	0.000	0.098	0.307	0.128	-0.052	1.000	0.555	0.163	0.550	0.464	0.561	0.510	0.187
CU	0.000	-0.006	0.329	-0.025	-0.318	0.555	1.000	0.335	0.766	0.807	0.778	0.582	0.102
ZN	0.000	-0.162	0.264	-0.052	-0.185	0.163	0.335	1.000	0.184	0.186	0.277	0.191	0.323
SB	0.000	0.075	0.249	-0.034	-0.273	0.550	0.766	0.184	1.000	0.804	0.797	0.501	0.081
AG	0.000	-0.014	0.254	-0.042	-0.325	0.464	0.807	0.186	0.804	1.000	0.823	0.455	-0.005
AU	0.000	-0.044	0.320	-0.070	-0.188	0.561	0.778	0.277	0.797	0.823	1.000	0.525	0.283
AS	0.000	-0.090	0.454	-0.103	-0.191	0.510	0.582	0.191	0.501	0.455	0.525	1.000	0.277
FE	0.000	-0.377	0.476	0.109	-0.085	0.187	0.102	0.323	0.081	-0.005	0.283	0.277	1.000

Number of data pairs contributing to correlation

	SP	RES	IP	MAGG	GGD	GGHE	CU	ZN	SB	AG	AU	AS	FE
SP	115	113	113	115	115	115	115	115	115	115	115	115	115
RES	113	310	310	310	310	310	310	310	310	310	310	310	310
IP	113	310	310	310	310	310	310	310	310	310	310	310	310
MAGG	115	310	310	344	344	344	344	344	344	344	344	344	344
GGD	115	310	310	344	345	345	345	345	345	345	345	345	345
GGHE	115	310	310	344	345	345	345	345	345	345	345	345	345
CU	115	310	310	344	345	345	355	355	355	355	355	355	355
ZN	115	310	310	344	345	345	355	355	355	355	355	355	355
SB	115	310	310	344	345	345	355	355	355	355	355	355	355
AG	115	310	310	344	345	345	355	355	355	355	355	355	355
AU	115	310	310	344	345	345	355	355	355	355	355	355	355
AS	115	310	310	344	345	345	355	355	355	355	355	355	355
FE	115	310	310	344	345	345	355	355	355	355	355	355	355

Figure 5 Correlation table for parameters considered in this study. Note that all variables have been log transformed prior to calculating the correlation coefficients.

P L A C E R   D E V E L O P M E N T   L T D

Placer Data Analysis System - STATS

run on 87:04:14 at 10:41:36

Current directory: /usr.MC68020/pdl_servl/plk

GSC EQUITY GEOPHYSICAL LOGS, DDHS 246,250

Summary of data from file : gsc/logs

This data file contains an internal header: (5 records)
Data grouped into 16 fields
with format: (1A6,5F5.0,F8.0,F6.0,F5.2,7F6.2)

Character ID fields:
DH

Coordinate fields:
FROM TO

Other data fields:
SP RES IP MAGG GGD GGHE CU ZN SB AG AU AS
FE

Missing data indicated by NULL value -999.000

BASIC STATISTICS OF SELECTED DATA FIELDS:

NAME	NDATA	NULLS	MINIMUM	MAXIMUM	MEAN	STD. DEV.	GEOM. MEAN	DISPERSION		
SP	115	246	-463.000	-120.000	-264.757	56.8724	0.100000e-02	0.100000e-02	0.100000e-02	
RES	310	51	19.0000	1394.00	347.910	240.671	284.127	148.403	543.979	
IP	310	51	4.00000	114.000	27.7484	17.3441	23.0245	12.2457	43.2912	
MAGG	344	17	3877.00	0.158589e+07	88140.6	180519.	30510.0	7791.56	119470.	
GGD	345	16	8204.00	17297.0	10452.2	1059.54	10406.7	9511.48	11386.2	
GGHE	345	16	1.53000	2.02000	1.67235	0.912856e-01	1.66994	1.58325	1.76139	
CU	355	6	0.100000e-01	0.450000	0.499156e-01	0.880051e-01	0.221822e-01	0.740146e-02	0.664800e-01	
ZN	355	6	0.100000e-01	0.510000	0.383381e-01	0.549349e-01	0.279809e-01	0.141173e-01	0.554587e-01	
SB	355	6	0.100000e-01	0.230000	0.204789e-01	0.316771e-01	0.134535e-01	0.664532e-02	0.272366e-01	
AG	355	6	1.00000	317.000	23.6845	54.5608	4.12861	0.752711	22.6454	
AU	355	6	0.200000e-01	3.01000	0.282648	0.497903	0.128344	0.415285e-01	0.396649	
AS	355	6	0.	0.170000	0.165352e-01	0.226268e-01	0.853266e-02	0.236759e-02	0.307512e-01	
FE	355	6	0.380000	18.0000	4.87107	2.29230	4.30206	2.44968	7.55514	

Figure 4 Simple statistics for the parameters considered in this study. Note that the assay information represents 3 meter assay intervals broken into 1 meter assay intervals and the geophysical logs represent 1 meter composites of continuous logs.

```
file: gsc/ag-hi                    AG     vs   GGHE     LOGX =1   LOGY =1    REPVAL
                                   ----        ----
           +--------+--------+--------+--------+
      2.4 +                                    +0.38       PLOT SUMMARY
           |                                    |             202 X-Y PAIRS
           |                                    |               0 VALUES>MAX
           |                                    |               0 VALUES<MIN
 y    2.2 +                                    +0.34          202 PLOTTED
           |                                    |               X  MINMAX  Y
 a         |                                    |               2.0     1.53
 x         |                                    |               317     2.02
 i    2.0 +                    11              +0.30       REGRESSION LINE
 s         |                   1               -|           A = 0.19649
 :         |        1   2   1      1       -    |           B = 0.25794e-01
           |                      21 1          |           VARIANCE
 G    1.8 +           11 1 1113      -         +0.26            0.36987e-03
 G         |        1   1 3 11113               |           STD. DEVIATION
 H         |4   8  351 3 2  - 5212              |               0.19232e-01
 E         |   3   1  -2  1  2 1                |           CORRELATION COEF
      1.7 +   3     1 13 1  2    1             +0.22            0.67515
           |42 7 2 1 2 12    1                  |
           |*7 *3422 3 213                      |           PLOT INCREMENTS
           |*6 5  1  3 1                        |           X:  0.10000e+00
      1.5 +3           1                       +0.18       Y:  0.10000e-01
           +--------+--------+--------+--------+
          2.0      15.8      126     1000     7943
                 x axis: AG
```

Figure 6 Crossplot of gamma gamma heavy element ratio (GGHE) versus Silver (AG) for silver values above 2 ppm. Note that each high silver value is repeated three times. This is a result of splitting the 3 meter assay composites into 1 meter intervals to combine them with the geophysical composites.