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GEOLOGICAL SURVEY

STATISTICAL ANALYSIS OF GEOCHEMICAL DATA FROM GLACIER BAY NATIONAL MONUMENT, ALASKA

By

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INTRODUCTION

The U.S. Geological Survey collected both bedrock and stream-sediment samples in Glacier Bay National Monument during the 1966, 1975, 1976, and 1977 field seasons. The 1975 through 1977 samples were collected as part of a joint Geological Survey - U.S. Bureau of Mines mineral-resource appraisal (Brew and others, 1978). Some stream-sediment samples collected in 1966, as part of an earlier Survey project (MacKevett and others, 1971), were reanalyzed with the later samples and are included in the data set.

Johnson and others (1978) found that analytical variation was a large portion of the total variation in a geochemical sampling program of a similar area to the southeast. For this reason, duplicate samples were collected at all stream-sediment sites in Glacier Bay beginning in 1975. Analytical values were averaged for each site prior to statistical analysis. Therefore, stream-sediment locations illustrated in this report represent site means, although sites collected in 1966 are based on single samples.

At least one bedrock sample was collected for geochemical analysis at each geologic station. Approximately one station per square kilometer of outcrop was collected in the western third of the monument. Bedrock sample density thins rapidly to the east, averaging approximately one station per fifty square kilometers along the eastern boundary. Each distinct lithology at a site was sampled and particular care was taken to sample all rocks with visible alteration, staining, or ore minerals. For this reason, the total bedrock sample population is considered somewhat biased toward samples high in metals of economic interest. Since multiple rock samples at one site may represent differing lithologies, site means were not generated for bedrock samples.

All geochemical samples were analyzed by the U.S.G.S. Branch of Exploration Research for 30 elements by semiquantitative spectrographic techniques and for copper, gold, lead, mercury, and zinc by atomic absorption spectroscopy (Grimes and Marranzino, 1968; Ward and others, 1969). References to atomic absorption analyses will be preceeded by AA (Examp. AA-Cu). References to analyses with no prefix indicate semi-quantitative spectrographic techniques. Further details of sample collection, processing, and analysis can be found in Brew and others (1978). Complete analytical results for all geochemical samples are available through National Technical Information Services (Forn and others, 1978).

Data and plots reported here are supplementary to the Geochemisty section of the Glacier Bay wilderness report (Brew and others, 1978; chapter B). Included are discussions of some of the statistical methods used to obtain computer-generated plots, tables of bedrock and stream-sediment correlation coefficient groups, and maps showing locations of high geochemical values for elements of economic interest.

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Individual Element Distributions

Locations of samples with high geochemical values for individual elements are plotted on plates 1-18. Each plate consists of a computer-generated plot of locations of rock and stream-sediment samples on a 1:250,000 scale base map. These plots and others like them along with the correlation coefficient studies described below were used to compile the geochemical synthesis of Glacier Bay National Monument presented in the wilderness report (Brew and others, 1978).

Elements of economic interest for which a large number of samples show values above instrumental detection limits are plotted on individual plates. Other elements are combined, two to each plate. Individual element plots illustrate two levels of high values each for bedrock and stream-sediment samples. These levels were chosen to display approximately the highest one percent and two percent of the geochemical values. Combined two-element plots illustrate one level of high values for bedrock and one possibly different level for stream-sediment samples for each element. These levels were chosen to display approximately the highest one-to-two percent of the geochemical values. The levels illustrated on these plots are not intended to show locations of anomalous samples. Anomalous levels for bedrock and stream-sediment samples are discussed in the wilderness report and anomalous areas are defined there. Due to high statistical variance associated with sampling and analytical procedures used in this study, single high geochemical values are probably not important. Clusters of high geochemical values, however, should be of more interest (Johnson and others, 1978).

Correlation Coefficient Studies

As a part of the Survey's continuing effort to explore new techniques of data analysis, correlation coefficient matrices were generated and plotted for both bedrock and stream-sediment geochemical data sets. Bedrock and stream-sediment data sets were treated separately throughout this analysis. There were five basic steps to this procedure; (1) normalization of all elements in the data set at the 95th percentile level; (2) generation of a master correlation coefficient matrix for each data set; (3) selection of small groups of elements which have high mutual correlation coefficients; (4) generation of a sample (or site) mean for each correlation group; and (5) retrieval and plotting of each correlation group.

Normalization of all elements in each data set enhances the correlation coefficients slightly over non-normalized data and simplifies the generation of sample (or site) correlation group means. Normalization at the 95th percentile level is achieved by dividing all geochemical values for each element by the 95th percentile value for that element. The 95th percentile values for each element were determined graphically. This procedure results in resetting the range of all elements so that the 95th percentile of values equals one. Therefore, all elements are weighted equally in all subsequent steps. Without this normalization step, elements which occur in hundreds and thousands of parts per million (ppm) would overshadow those which only occur at levels of a few ppm. The 95th percentile was chosen as the normalization point instead of the 100th percentile (highest value reported) to base the subsequent analyses on the normal high values rather than on a few extremely high anomalous values.

After each element in each data set was normalized, a master correlation coefficient matrix was generated for each data set. All correlation coefficients greater than 0.30 were considered significant. Elemental pairs from each data set with significant correlation were then grouped by trial and error. Elements were added to or subtracted from each group to achieve the maximum mutual correlation within the group. Mutual correlation was determined by averaging the coefficients of all possible element pairs within the group. The final groups selected from the bedrock data set are listed along with their correlation coefficients in tables 1-4; groups selected from the stream-sediment data set are listed in tables 5-8. Tables 1-8 also include the number of samples used to calculate each correlation coefficient. These are samples with values for both elements above detection limits. Mutual correlations of approximately 0.5 are common in these groups.

High analytical values for elements in any one of the correlation groups tend to occur together in this study area. If an element occurs within a group, concentrations of that element might be found wherever any other element in the group is concentrated and particularly where multiple elements in the group are concentrated. To take advantage of this clustering effect, normalized group means were generated for each correlation group. Separate means were generated for each bedrock sample and for each stream-sediment sampling site. For a given sample (rock) or site (stream-sediment), the normalized values for each element within the group were summed and the sum divided by the number of samples within the group. For example, assume a group of two elements, A and B.

If the normalized value for element A at one site was 1.0 and the normalized value of B was 1.5, then the group mean at that site would be:

$$\frac{\text{Value A + Value B}}{\text{\# elements in group}} = \frac{1.0 + 1.5}{2} = 1.25$$

Table 1. Bedrock geochemical correlation group 1: Fe, Mg, Ti, Mn, Sc, V.

[Upper-right portion of table contains correlation coefficients; lower-left portion contains the number of sample pairs used to calculate the correlation coefficient.]

	Fe	Mg	Ti	Mn	Sc	V
Fe	----	0.56	0.63	0.56	0.69	0.63
Mg	1861	----	0.40	0.47	0.64	0.62
Ti	1690	1689	----	0.52	0.45	0.61
Mn	1859	1860	1690	----	0.47	0.50
Sc	1809	1806	1640	1804	----	0.69
V	1807	1804	1640	1802	1780	----

Average correlation coefficient = 0.56

Table 2. Bedrock geochemical correlation group 2: Co, Cr, Ni, Sc, V, AA-Cu.

[Upper-right portion of table contains correlation coefficients; lower-left portion contains the number of sample pairs used to calculate the correlation coefficient.]

	Co	Cr	Ni	Sc	V	AA-Cu
Co	----	0.48	0.68	0.73	0.51	0.52
Cr	1584	----	0.75	0.52	0.32	0.31
Ni	1696	1572	----	0.50	0.32	0.44
Sc	1767	1590	1709	----	0.69	0.46
V	1767	1600	1716	1780	----	0.32
AA-Cu	1719	1554	1667	1733	1740	----

Average correlation coefficient = 0.50

Table 3. Bedrock geochemical correlation group 3: Ba, La, Sr, Zr, AA-Zn.

[Upper-right portion of table contains correlation coefficients; lower-left portion contains the number of sample pairs used to calculate the correlation coefficient.]

	Ba	La	Sr	Zr	AA-Zn
Ba	----	0.37	0.32	0.43	0.48
La	1025	----	0.21	0.40	0.10
Sr	1510	1067	----	0.32	0.25
Zr	1479	1088	1621	----	0.33
AA-Zn	1517	1075	1640	1659	----

Average correlation coefficient = 0.32

Table 4. Bedrock geochemical correlation group 4: Mg, Ca, Mn, Sc, V.

[Upper-right portion of table contains correlation coefficients; lower-left portion contains the number of sample pairs used to calculate the correlation coefficient.]

	Mg	Ca	Mn	Sc	V
Mg	----	0.54	0.47	0.64	0.62
Ca	1840	----	0.34	0.43	0.30
Mn	1860	1839	----	0.47	0.50
Sc	1806	1798	1804	----	0.69
V	1804	1793	1802	1780	----

Average correlation coefficient = 0.50

Table 5. Stream-sediment geochemical correlation group 1: B, Cu, Ni, AA-Pb, AA-Zn.

[Upper-right portion of table contains correlation coefficients; lower-left portion contains the number of sample pairs used to calculate the correlation coefficient.]

	B	Cu	Ni	AA-Pb	AA-Zn
B	----	0.42	0.45	0.55	0.53
Cu	1866	----	0.69	0.37	0.27
Ni	1859	1869	----	0.36	0.31
AA-Pb	1606	1606	1599	----	0.68
AA-Zn	1816	1824	1817	1615	----

Average correlation coefficient = 0.46

Table 6. Stream-sediment geochemical correlation group 2: Fe, Mg, Ti, Co, Cu, Ni, Sc, V, Y.

[Upper-right portion of table contains correlation coefficients; lower-left portion contains the number of sample pairs used to calculate the correlation coefficient.]

	Fe	Mg	Ti	Co	Cu	Ni	Sc	V	Y
Fe	----	0.46	0.36	0.62	0.40	0.34	0.48	0.68	0.49
Mg	1888	----	0.34	0.44	0.48	0.52	0.53	0.51	0.34
Ti	1434	1432	----	0.33	0.36	0.39	0.54	0.56	0.52
Co	1889	1888	1433	----	0.59	0.63	0.68	0.51	0.42
Cu	1881	1880	1425	1882	----	0.69	0.56	0.40	0.37
Ni	1874	1873	1418	1875	1869	----	0.54	0.37	0.28
Sc	1888	1887	1432	1889	1882	1874	----	0.56	0.56
V	1889	1888	1433	1889	1882	1874	1889	----	0.59
Y	1889	1888	1433	1889	1881	1874	1888	1889	----

Average correlation coefficient = 0.49

Table 7. Stream-sediment geochemical correlation group 3: Co, Cr, Cu, Ni.

[Upper-right portion of table contains correlation coefficients; lower-left portion contains the number of sample pairs used to calculate the correlation coefficient.]

	Co	Cr	Cu	Ni
Co	----	0.50	0.59	0.63
Cr	1861	----	0.45	0.66
Cu	1882	1859	----	0.69
Ni	1875	1850	1869	----

Average correlation coefficient = 0.59

Table 8. Stream-sediment geochemical correlation group 4: Ba, La, Sr, Zr.

[Upper-right portion of table contains correlation coefficients; lower-left portion contains the number of sample pairs used to calculate the correlation coefficient.]

	Ba	La	Sr	Zr
Ba	----	0.44	0.51	0.61
La	1468	----	0.40	0.39
Sr	1837	1439	----	0.38
Zr	1862	1458	1838	----

Average correlation coefficient = 0.46

Combining the values of four to nine mutually correllative elements into a single group mean should significantly reduce the total sampling and analytical variance from the individual elements. Therefore, a plot of locations of samples with high correlation group means should be a useful tool in an attempt to define areas of geochemical interest. Plots of each of the correlation groups given in tables 1-8 appear on plates 19-26. The approximate 80th and 98th percentile values were determined graphically for each correlation group mean and different symbols are used on the plates to indicate locations where the means are less than the 80th percentile, between the 80th and 98th percentile, and greater than the 98th percentile.

Plots resulting from this type of correlation coefficient analysis are a useful addition to the geochemical-anomaly definition portion of mineral resource appraisal studies. In some cases, correlation groups can be related to geologic processes such as hydrothermal alteration, mineralization, contact metamorphism, etc. In these areas, plots of normalized correlation group means help define the geographic limits of the geologic process.

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