Table 3

DISTRIBUTION OF SAMPLES BY GEOLOGIC UNIT
FROM THE EDGEMONT DETAILED GEOCHEMICAL SURVEY, SOUTH DAKOTA; WYOMING

Geologic Unit	Geologic Unit Code	No. of Groundwater Samples	No. of Sediment Samples
Alluvium	QAL	1	34
Niobrara Marl and Carlile Shale	KNC	0	1
Greenhorn Limestone	KGCG	0	9
Graneros Group	KGDS	0	83
Inyan Kara Group	KFL	105	191
Unkpapa Sandstone and Morrison Formation	JMOR	0	7
Sundance Formation	JRSU	3	39
Spearfish Formation	TRSP	0	50
Minnekahta Limestone and Opeche Shale	PEMO	0	4
Minnelusa Formation	PMIN	0	1
Total		109	419

contains high uranium values in groundwater and deposits of uranium: (1) uranium has precipitated out of solution updip of the wells which are low in uranium and is not undergoing active leaching, and/or (2) a reducing environment is present which restricts the solubility of uranium in groundwater.

The correlation matrix (Table A-2) indicates a significant positive correlation coefficient of ≧0.25 for both Pearson and Spearman correlations between the logs of uranium, calcium, magnesium, potassium, strontium, uranium/specific conductance, and uranium/sulfate. There is a significant negative correlation between uranium, pH, and sodium.

Specific Conductance

The 84th percentile for specific conductance in the Edgemont project area is 3,014 μmhos/cm. Concentration of these high values for specific conductance are in two trends. One trend runs northeast-southwest from the Black Hills National Forest to south of the community of Burdock. Two of the high values in this trend are from the Sundance Formation and the others are produced from the Inyan Kara Group. The other trend is in the southern part of the project area and consists of scattered samples that run northeast-southwest from Chilson Canyon to south of the town of Edgemont. The greater than 84th percentile specific conductance values are from groundwaters of the Inyan Kara Group.

Geochemical plots for groundwater show associations of above 84th percentile values for specific conductance with calcium, lithium, magnesium, sodium, and sulfate. The correlation matrix indicates a significant positive correlation coefficient of ≧0.25 for both Pearson and Spearman correlations between the logs of specific conductance, calcium, potassium, magnesium, sodium, silicon, strontium, lithium, sulfate, and boron.

The 16th percentile for specific conductance is 1,319 μmhos/cm. The largest cluster of these "low" conductance values is between lat. 43°35' and 43°25' and roughly includes most of the groundwater samples taken along the Wyoming and South Dakota border eastward to the communities of Dewey and Burdock. These groundwaters produce from the Inyan Kara Group where it is overlain by the Graneros Group.

Related Variables

Three groups of variables are important for understanding the groundwater geochemistry and its relation to uranium in the Edgemont project area. The first group defines basic water types in the area and includes calcium, magnesium, pH, specific conductance, sulfate, and total alkalinity. High calcium and magnesium values form a trend in a northwestern to southeastern direction starting at lat. 43°30' along the northeastern edge of the sampled area. Sodium values above the 84th percentile (283.5 ppm) are located southwest of the high calcium and magnesium groundwaters. High sulfate values in groundwaters are located in two major trends running northeast to southwest. One is in the vicinity of the community of Burdock and the other is south of the town of Edgemont. The

lowest values for sulfate are located directly west of Edgemont and correspond to the groundwater samples having the highest total alkalinity. Two of the groundwaters containing higher amounts of sulfate are produced from the Sundance Formation; all others are produced from the Inyan Kara Group. The groundwater geochemical plots for uranium, calcium, and sulfate show a good areal correspondence east of the Dewey Terrace. The strong negative correlation of sodium with uranium on the correlation matrix is confirmed by the geochemical plots.

The second group of elements considered are pathfinders for uranium sandstone deposits and include arsenic, molybdenum, and selenium. Although above 84th percentile values of these elements are not always in exact coincidence with above 84th percentile values for uranium or each other, in combination with uranium and one another they define areas of favorability. Observing the areal associations of these elements in the area sampled, one area of interest is directly west and northwest of the town of Edgemont near and within the Cheyenne River Valley. Here, a cluster of high uranium groundwaters also shows high values for molybdenum and in the southwest there is a cluster of groundwaters containing the highest values for arsenic and selenium in the project area. A smaller group of high molybdenum values is on the western side of this cluster. Groundwaters containing anomalous amounts of uranium near Dewey and along Beaver Creek on the Dewey Terrace are associated with high molybdenum values. There are several smaller areas with uranium and molybdenum in association. The high uranium groundwaters that are known to be near old uranium mine operations do not necessarily have areal associations with all of these pathfinder elements. Sample 405089, a groundwater sample taken on the Doran Ranch and near an inactive uranium mine, contains only a moderately high selenium value. This is also true for most of the other samples known to be taken near uranium mines.

The final group of variables to be considered are the sulfide well waters. The main body of sulfide water is located in the south central section of the sampled area west to northwest of the town of Edgemont. Sulfide is coincident with above 84th percentile values for uranium in some of the groundwaters sampled; however, most often they are associated with the very low to nondetectable values of uranium in groundwater west of Edgemont. Gott, et al (1974) considers sulfate reduction in groundwater as a major factor in the creation of an environment favorable to uranium precipitation. The interface between groundwaters containing high sulfate and sulfide groundwaters includes favorable areas.

Summary of Groundwater Data

Geochemical data for groundwaters in the Edgemont project area show two regions of separate character. They are easily divided by their specific conductance values. Well waters on the Dewey Terrace show overall lower specific conductance values than those to the south, along with lower values for calcium, magnesium, sulfate, and total alkalinity. Uranium values in these groundwaters as well as pathfinder elements are high and the area is shown to be distinct in geochemical plots for ratios of uranium/specific conductance and uranium/sulfate. The Inyan Kara Group overlain by the Graneros Group on the Dewey Terrace and to the southwest

of the terrace appears to be favorable for uranium deposition. Uranium deposition here would probably be controlled by the Dewey Fault and Structural Zone.

Groundwater samples taken along the outcrop of the Inyan Kara Group are few. In many cases, they are near inoperative uranium mines. These groundwaters appear to reflect this with high values for uranium, occasional association with molybdenum, and consistent association with selenium.

The most interesting area geochemically is west of the town of Edgemont on the alluvial plain of the Cheyenne River. Here, very low uranium values are combined with above 84th percentiles for arsenic, molybdenum, and selenium waters low in sulfate, high in bicarbonate, and containing hydrogen sulfide. Updip are high uranium values and uranium mines.

The model of groundwater chemistry and its relation to uranium deposition proposed by Gott, et al (1974) is reflected in data collected by this project. Calcium sulfate waters appear to be confined to ares where the Inyan Kara is exposed at the surface and run in a northeast to southwest trend in the area sampled. Sodium sulfate waters are always downdip of these calcium sulfate waters. The most noticeable trend of sodium bicarbonate waters coincides with sulfide wells in the same area as mentioned in the preceding paragraph. The pH values however do not follow the exact model that Gott, et al (1974) noted for them. Calcium sulfate waters having high uranium values do not have higher pH values than other water samples. Data indicate that low pH values do exist in areas of sodium bicarbonate groundwaters with low uranium values indicating reducing conditions.

GEOCHEMICAL DISTRIBUTIONS IN STREAM SEDIMENTS

The sample site locations for stream sediments in the Edgemont detailed geochemical survey are shown on Plate 4. The symbol plot for the hot-acid-soluble uranium as determined by fluorometric analysis (U-FL) is presented on Plate 5 and in Figure B-1b. The symbol plot for thorium is presented on Plate 6 and in Figure B-4b. The number of stream sediment samples (419) which were collected from each of the major geologic and lithologic units of the survey area is presented in Table 3. Results from all stream sediment samples collected from the survey area are included in the microfiche in Appendix D.

Values for soluble uranium (U-FL), total uranium as determined by neutron activation (U-NT), thorium, arsenic, cobalt, copper, nickel, selenium, vanadium, zinc, and zirconium are listed in Table B-3. The figures in Appendix B present log frequency, lognormal probability, percentile, and areal symbol plots for the preceding variables plus U-FL/U-NT, aluminum, boron, calcium, cerium, chromium, iron, lithium, manganese, molybdenum, niobium, phosphorus, potassium, scandium, titanium, and yttrium.

<u>Uranium</u>

The areal distribution of uranium (Plate 5 and Figure B-1b) and U-NT (Figure B-2b) outlines four areas of uranium concentrations above the

84th percentile (5.50 ppm). In the northwestern corner of the sampled area, there are several sediment samples with uranium values above the 84th percentile. They are located near the community of Dewey, South Dakota and drain the immediate vicinity and to a small extent the western side of the Elk Mountains. The sediments are mostly from units of the Graneros Group. A trend of high uranium values that extends from near Pass Creek to Cheyenne and Dick Canyons is located in the southeast of the project area. These samples are primarily from basins draining formations of the Inyan Kara Group. From data provided by field personnel and information provided by the Tennessee Valley Authority on location of uranium mines, it appears that most of these samples are from basins draining open-pit uranium operations. The only exceptions to this are Samples 405643 and 405644 located on tributaries of Pass Creek. In the southeastern part of the survey area are two additional groups of samples with uranium values above the 84th percentile. Both clusters are located south of the Cheyenne River. One group drains the alluvium of the Cheyenne River and the Graneros Group immediately around the town of Edgemont. In the southwest of the project area, there is a cluster of high uranium values from basins draining the Graneros Group. Percentile plots for U-FL, U-NT, and U-FL/U-NT indicate that the Graneros Group contains high amounts of soluble uranium.

Less than 16th percentile (1.81 ppm) values for uranium are found in small clusters along the northern to northwestern boundary of the project area. These samples are from streams draining the Spearfish and Sundance Formations. A large cluster of uranium values below the 16th percentile are located in approximately the center of the sampled area east of the town of Burdock. These streams are in the Inyan Kara Group.

Geochemical and percentile plots for U-FL/U-NT indicate that all of the rock units within the sampled area contain high percentages of soluble uranium.

The correlation matrix (Table B-2) shows a significant positive correlation of ≥0.20 for both Pearson and Spearman correlations between the logs of U-FL, U-NT, aluminum, arsenic, cerium, chromium, cobalt, copper, iron, lithium, nickel, scandium, selenium, thorium, titanium, vanadium, yttrium, zinc, and zirconium. There is a negative correlation between U-FL and calcium.

Thorium

Geologic distribution of thorium in stream sediments is shown by the percentile plot (Figure B-4a). Values above the 84th percentile (9 ppm) are concentrated in units of the Inyan Kara Group; Graneros Group; the Niobrara, Carlile, and Greenhorn Formations; and the alluvium. These high values for thorium appear to be associated with greater than 84th percentile values for arsenic, barium, cobalt, copper, nickel, and zinc in samples from the Graneros Group. Best areal associations of greater than 84th percentile values for thorium in sediments from the Inyan Kara Group are with arsenic, iron, and titanium.

The correlation matrix (Table B-2) shows a significant positive correlation coefficient of ≧0.20 for both Pearson and Spearman correlations between the logs of thorium, U-FL, U-NT, aluminum, arsenic, boron, cerium, chromium, cobalt, copper, iron, lithium, manganese, nickel, niobium, phosphorus, potassium, scandium, titanium, vanadium, yttrium, zinc, and zirconium.

Related Variables

The correlation matrix shows positive associations between the log of the concentration of uranium and many other elements. Included among these are cerium, chromium, cobalt, copper, iron, nickel, scandium, yttrium, zinc, and zirconium. Areal plots indicate that most areas with stream sediment samples that have values greater than the 84th percentile for these elements which correspond with greater than 84th percentile values for uranium are in sediments of the Graneros Group. In most cases, percentile plots for these elements indicate the Graneros Group to have higher median values than the other rock units. In the northwestern section of the project area, where the Graneros Group crops out, the U-FL/U-NT values are moderate. Here, there is also a close areal association with thorium. These factors indicate an association of uranium with resistate minerals. In the southwest where the Graneros Group crops out, most of the same elements appear to be associated with uranium, the notable exceptions being a lesser amount of zirconium associated with uranium and the presence of phosphorus and barium. The U-FL/U-NT values are often above the 84th percentile and indicate a higher amount of soluble uranium in the southwest than in the northwest.

In the correlation matrix, arsenic, selenium, and vanadium are the most closely correlated with uranium. High uranium values in the Graneros Group correspond areally with above 84th percentile values for these three elements. However, median values are also generally higher in the Graneros Group for these elements than those of the other rock units. In the southwest, there is also a strong areal association between uranium and molybdenum.

In the Inyan Kara Group, there is an association of above 84th percentile values for molybdenum with above 84th percentile concentrations of uranium in the southern part of the survey area. Arsenic, selenium, and vanadium are also associated with high uranium values in the Inyan Kara Group.

Summary of Stream Sediment Data

Areal distribution and percentile plots for uranium in stream sediments indicate highest concentrations to be from basins draining the Graneros and Inyan Kara Groups. The ratio of U-FL/U-NT shows a high proportion of soluble uranium in the Graneros Group, with accompanying high concentrations of arsenic, selenium, and vanadium. There is also a positive association between uranium and a suite of elements that indicate the presence of resistate minerals. The anomalous uranium and pathfinder elements could possibly be associated with the bentonite beds contained in the Belle Fourche and Mowry Shales that are the dominant rock units

cropping out in the southwestern part of the project area. The Skull Creek Shale is the dominant unit of the Graneros Group cropping out in the northwest and the different units outcropping are probably the reason for the different associations of elements with uranium in this area as compared to the southwest. As shown on the geochemical distribution plot, the high uranium values that are located in the Inyan Kara Group are almost exclusively draining open-pit uranium mines. The samples which are high in uranium also are high in the pathfinder elements arsenic, selenium, and vanadium.

Greater than 84th percentile concentrations of molybdenum are associated with above 84th percentile concentrations for uranium in the southern part of the area sampled in both the Graneros and Inyan Kara Groups.

BIBLIOGRAPHY

1. Arendt, J. W., Butz, T. R., Cagle, G. W., Kane, V. E., and Nichols, C. E., *Hydrogeochemical and Stream Sediment Reconnaissance Procedures of the Uranium Resource Evaluation Project,* Union Carbide Corporation, Nuclear Division, Oak Ridge Gaseous Diffusion Plant, Oak Ridge, Tennessee, K/UR-100 (December 1979).

2. Bell, H., Gott, G. B., Post, E. V., and Schnabel, R. W., *Lithologic and Structural Controls of Uranium Deposition in the Southern Black Hills, South Dakota,* Geology of Uranium and Thorium, International Conference (1955).

3. Bell, H. and Bales, W. E., *Uranium Deposits in Fall River County, South Dakota,* U. S. Geological Survey, Trace Elements Investigations Report 297 (1954).

4. Bell, H. and Post, E. V., *Geology of the Flint Hill Quadrangle, Fall River County, South Dakota,* U. S. Geological Survey, Bulletin 1063-M (1971).

5. Braddock, W. A., *Stratigraphic and Structural Controls of Uranium Deposits on Long Mountain, South Dakota,* U. S. Geological Survey, Bulletin 1063-A (1957).

6. Braddock, W. A., *Geology of the Jewel Cave Southwest Quadrangle Custer County, South Dakota,* U. S. Geological Survey, Bulletin 1063-G (1963).

7. Brobst, D. A., *Geology of the Dewey Quadrangle, Wyoming, South Dakota,* U. S. Geological Survey, Bulletin 1063-B (1961).

8. Cagle, G. W., "The Oak Ridge Analytical Program" *Symposium on Hydrogeochemical and Stream Sediment Reconnaissance for Uranium in the United States, March 16 and 17, 1977,* United States Energy Research and Development Administration, Grand Junction, Colorado, pp 133-156 [GJBX-77(77)] (October 1977).

9. Casey, R. D. and Wescott, E. M. *Electrical Geophysical Exploration of Paleostream Channels, Edgemont Mining District, Fall River County, South Dakota,* United States Atomic Energy Commission, Division of Raw Materials (1957).

10. Cuppels, N. P., *Geologic Environment of an Oxidized Uranium Deposit in the Black Hills, South Dakota,* U. S. Geological Survey, Bulletin 1063-C (1962).

11. Darton, N. H. and Smith, W. S. T., *The Geology of the Edgemont Folio,* U. S. Geological Survey, Folio No. 108 (1904).

12. D'Silva, A. P., Haas, W. J., and Floyd, M. A., *Multilaboratory Analytical Quality Control Program for the Hydrogeochemical and Stream Sediment Reconnaissance*, Ames Laboratory, Iowa State University, Ames, Iowa, IS-4433 (May 1978) (Available from National Technical Information Service, U. S. Department of Commerce, 5285 Port Royal Road, Springfield, Virginia 22161).

13. Gott, G. B. and Schnabel, R. W., *Geology of the Edgemont Northeast Quadrangle, Fall River and Custer County, South Dakota*, U. S. Geological Survey, Bulletin 1063-E (1963).

14. Gott, G. B., Wolcott, D. E., and Bowles, C. G., *Stratigraphy of the Inyan Kara Group and Localization of Uranium Deposits, Southern Black Hills, South Dakota and Wyoming*, U. S. Geological Survey, Professional Paper 763 (1974).

15. Illsley, C. T., *Additional Data and Interpretations on Geochemical-Geophysical Exploration of Paleostream Channels, Edgemont Mining District, Fall River County, South Dakota*, United States Atomic Energy Commission, Division of Raw Materials (1957).

16. Illsley, C. T. and Scott, J. H., *Preliminary Report on Geochemical-Geophysical Exploration of Paleostream Channels, Edgemont Mining District, Fall River County, South Dakota*, United States Atomic Energy Commission, Division of Raw Materials (1956).

17. Jones, R. S., Frost, I. C., and Rader, L. F., Jr. *A Comparison of Plants and Soils as Prospecting Guides for Uranium in Fall River County, South Dakota*, U. S. Geological Survey, Trace Elements Investigations Report 686 (1957).

18. Kane, V. E., Baer, T., and Begovich, C. L. *Principal Component Testing for Outliers*, Union Carbide Corporation, Nuclear Division, Oak Ridge Gaseous Diffusion Plant, Oak Ridge, Tennessee, K/UR-7 (July 1977). United States Department of Energy, Grand Junction, Colorado [GJBX-71(77)].

19. Keene, J. R., *Ground-Water Resources of the Western Half of Fall River County, South Dakota*, South Dakota Geological Survey, Report of Investigations No. 109 (1973).

20. King, P. B., Beikman, H. M., and Edmonston, G. J., *Geologic Map of the United States*, U.S. Geological Survey (1974).

21. National Oceanic and Atmospheric Administration, *Climates of the States, Vol. II - Western States Including Alaska and Hawaii*, U. S. Department of Commerce, Water Information Center, Port Washington, New York, pp 861-876 (1974).

22. "Old Radiation Study May Pose New Problems for Operators of Active Yellowcake Mills," *Nuclear Fuel*, Vol. 5, No. 2, January 21 (1980).

23. Post E. V., *Geology of the Cascade Springs Quadrangle, Fall River County, South Dakota,* U. S. Geological Survey, Bulletin 1063-L (1967).

24. Ryan, J. D., *Geology of the Edgemont Quadrangle, Fall River County, South Dakota,* U. S. Geological Survey, Bulletin 1063-J (1964).

25. Schnabel, R. W., *Geology of the Burdock Quadrangle, Fall River and Custer Counties, South Dakota,* U. S. Geological Survey, Bulletin 1063-F (1963).

26. Texas Instruments, Inc. *Aerial Radiometric and Magnetic Reconnaissance Survey of Portions of Arizona, Idaho, Montana, New Mexico, South Dakota and Washington, Hot Springs Quadrangle, South Dakota,* Vol. 2-K, U. S. Department of Energy, Grand Junction, Colorado [GJBX-126(79)].

27. Texas, Instruments, Inc., *Geologic Map of the Hot Springs Quadrangle,* (1979).

28. Uranium Resource Evaluation Project, *Hydrogeochemical and Stream Sediment Reconnaissance Basic Data for Hot Springs NTMS Quadrangle, South Dakota,* Union Carbide Corporation, Nuclear Division, Oak Ridge Gaseous Diffusion Plant, Oak Ridge, Tennessee, K/UR-132 (December 31, 1979). United States Department of Energy, Grand Junction, Colorado [GJBX-27 (80)].

29. Uranium Resource Evaluation Project, *Procedures Manual for Groundwater Reconnaissance Sampling,* Union Carbide Corporation, Nuclear Division, Oak Ridge Gaseous Diffusion Plant, Oak Ridge Tennessee, K/UR-12 (March 1978). United States Department of Energy, Grand Junction, Colorado [GJBX-62(78)].

30. Uranium Resource Evaluation Project, *Procedures Manual for Stream Sediment Reconnaissance Sampling,* Union Carbide Corporation, Nuclear Division, Oak Ridge Gaseous Diffusion Plant, Oak Ridge, Tennessee, K/UR-13 (May 1978). United States Department of Energy, Grand Junction, Colorado [GJBX-84(78)].

31. Wilmarth, V. R. and Smith, R. D., *Preliminary Geologic Map of the Minnekahta Quadrangle, Fall River County, South Dakota,* U. S. Geological Survey, Mineral Investigations Field Studies Map MF-67-70 (1957).

32. Wolcott, D. E., Bowles, C. G., Brobst, D. A., and Post, E. V., *Geologic and Structure Map of the Minnekahta Northeast Quadrangle, Fall River and Custer Counties, South Dakota,* U. S. Geological Survey, Mineral Investigations Field Studies Map MF-242 (1962).

APPENDIX A

GROUNDWATER

THIS PAGE

WAS INTENTIONALLY

LEFT BLANK

APPENDIX A

GROUNDWATER

LIST OF TABLES

LIST OF FIGURES

LIST OF FIGURES, Continued

LIST OF FIGURES, Continued

LIST OF FIGURES, Continued

Table A-1

STATISTICAL SUMMARY FOR GROUNDWATER OF THE EDGEMONT DETAILED GEOCHEMICAL SURVEY, SOUTH DAKOTA; WYOMING

ELEMENT	NO. SAMPLES ANALYZED: MEASURABLE VALUES	NO. SAMPLES ANALYZED: BELOW DETECTION LIMIT	DETECTION LIMIT	MINIMUM VALUE	MAXIMUM VALUE	MEAN	MEDIAN	MODE	STANDARD DEVIATION	COEFFICIENT OF VARIATION	**LN TRANSFORMATION: MEAN	**LN TRANSFORMATION: S. D.	*ROBUST: MEAN	*ROBUST: S. D.
U	86	23	<0.20	<0.20	109.10	6.24	0.51	<0.20	14.175	2.272	0.48	1.60	-0.32	2.06
SP	109			287	5892	2073	1771	1653	962.3	0.5	7.54	0.43	7.54	0.39
U/SP	109			0.02	27.58	2.43	0.30	0.07	4.876	2.009	-0.75	1.86	-0.78	1.76
U/B	109			0.11	368.37	42.28	6.77	1.32	77.945	1.844	1.95	2.17	1.95	2.29
U/SO	109			0.03	141.30	8.60	1.34	0.17	21.720	2.525	0.53	1.79	0.50	1.76
AG	22	87	<2	<2	6	2	<2	<2	1.2	0.4	0.95	0.36		
AL	37	72	<10	<10	339	41	<10	<10	61.0	1.5	3.27	0.82		
AS	83	26	<0.5	<0.5	53.7	4.0	0.8	<0.5	9.98	2.50	0.29	1.12	-0.24	1.90
B	109			32	931	215	96	42	230.0	1.1	4.85	1.01	4.82	0.93
BA	106	3	<2	<2	91	8	5	5	12.2	1.4	1.81	0.66	1.73	0.76
BE	1	108	<1	<1	1	1	<1	<1	0.0	0.0	0.0	0.0		
CA	109			1.0	505.3	106.0	51.4	5.6	121.59	1.15	3.80	1.57	3.86	1.64
CD	41	68	<2	<2	19	3	<2	<2	2.7	0.8	1.14	0.45		
CR	11	98	<4	<4	10	5	<4	<4	2.1	0.4	1.64	0.33		
CU	12	97	<2	<2	29	6	<2	<2	7.5	1.2	1.45	0.76		
FE	98	11	<10	<10	1044	35	23	25	103.3	2.9	3.20	0.49	3.11	0.42
K	109			1.7	28.7	10.0	8.5	7.1	5.61	0.56	2.15	0.57	2.16	0.56
LI	109			18	455	113	83	56	79.3	0.7	4.56	0.56	4.54	0.58
MG	109			0.8	279.4	42.6	19.0	2.5	53.22	1.25	3.00	1.32	3.01	1.26
MN	89	20	<2	<2	9566	213	32	2	1027.1	4.8	3.77	1.51	3.26	2.07
MO	49	60	<4	<4	25	8	<4	<4	4.2	0.5	2.06	0.42		
NA	109			8.6	744.1	204.7	210.1	211.9	104.30	0.51	5.15	0.67	5.20	0.63
NI	22	87	<4	<4	32	6	<4	<4	5.8	0.9	1.72	0.45		
P	2	107	<40	<40	985	520	<40	<40	656.9	1.3	5.46	2.03		
SC	11	98	<1	<1	1	1	<1	<1	0.0	0.0	0.0	0.0		
SE	109			0.2	8.7	0.8	0.5	0.4	1.08	1.42	-0.57	0.63	-0.63	0.55
SI	108	1	<0.1	<0.1	12.5	3.6	3.3	3.3	1.67	0.47	1.16	0.52	1.17	0.61
SR	109			51	10491	2285	1204	144	2587.8	1.1	7.01	1.33	7.04	1.29
TI	26	83	<2	<2	8	4	<2	<2	2.5	0.6	1.27	0.58		
V	23	86	<4	<4	15	5	<4	<4	2.8	0.5	1.68	0.38		
Y	30	79	<1	<1	2	1	<1	<1	0.3	0.2	0.05	0.18		
ZN	94	15	<4	<4	3193	92	9	6	384.8	4.2	2.80	1.30	2.31	1.66
ZR	13	96	<2	<2	6	3	<2	<2	1.5	0.5	1.06	0.42		
T-AK	109			35	920	261	179	165	192.0	0.7	5.37	0.61	5.36	0.65
M-AK	109			33	898	261	181	174	190.2	0.7	5.37	0.60	5.37	0.64
P-AK	109			0	90	6	0	0	13.5	2.1				
CL	65	44	<10	<10	501	48	13	<10	70.0	1.4	3.38	0.90		
NA/C	109			1.39	78.64	18.51	13.24	3.31	16.738	0.904	2.49	1.00	2.50	1.00
PH	109			6.2	9.1	7.7	7.7	8.1	0.58	0.08				
SO4	109			41	2910	731	542	506	560.5	0.8	6.27	0.90	6.31	0.93

NOTE: Refer to Table 1, Page 25 and Table C-1, Page C-4 for concentration units and symbol definitions.

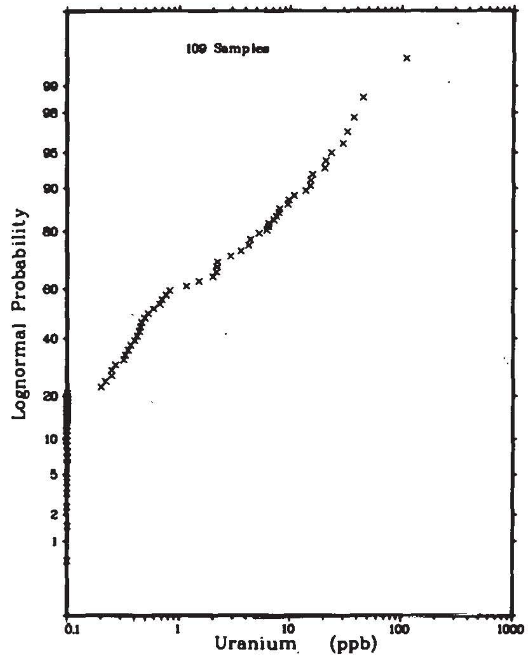
Table A-2

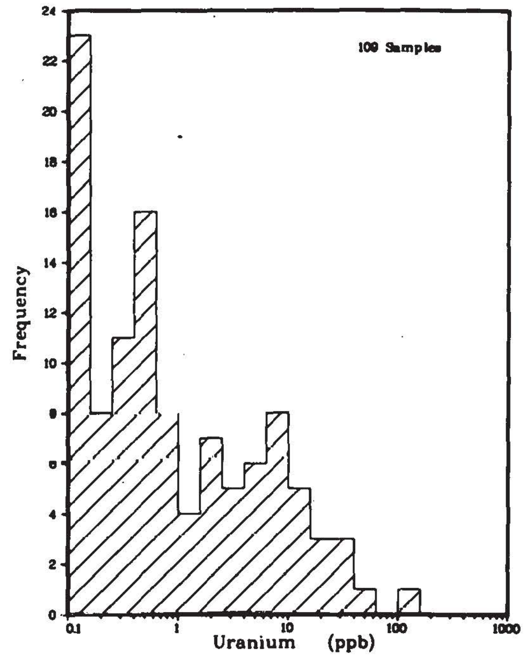
CORRELATION MATRIX FOR GROUNDWATER
OF THE EDGEMONT DETAILED GEOCHEMICAL SURVEY, SOUTH DAKOTA; WYOMING

	L-U	LUSP	LUSO	L-NA	L-V	L-CA	L-MG	L-SR	L-K	PH	L-SI	L-SP
L-U	1.00 (86)											
LUSP	0.96*** 0.95*** (86)	1.00 (109)										
LUSO	0.87*** 0.83*** (86)	0.93*** 0.90*** (109)	1.00 (109)									
L-NA	-0.48*** -0.48*** (86)	-0.63*** -0.61*** (109)	-0.58*** -0.46*** (109)	1.00 (109)								
L-V	0.50** 0.55** (15)	0.61*** 0.52** (23)	0.55*** 0.40* (23)	-0.64*** -0.47** (23)	1.00 (23)							
L-CA	0.54*** 0.54*** (86)	0.43*** 0.42*** (109)	0.16* 0.17* (109)	-0.48*** -0.57*** (109)	0.33 0.26 (23)	1.00 (109)						
L-MG	0.52*** 0.52*** (86)	0.38*** 0.39*** (109)	0.16* 0.15 (109)	-0.42*** -0.51*** (109)	0.30 0.30 (23)	0.95*** 0.98*** (109)	1.00 (109)					
L-SR	0.44*** 0.43*** (86)	0.32*** 0.33*** (109)	0.07 0.07 (109)	-0.29*** -0.39*** (109)	0.13 0.14 (23)	0.93*** 0.93*** (109)	0.93*** 0.94*** (109)	1.00 (109)				
L-K	0.29*** 0.29*** (86)	0.26*** 0.28*** (109)	0.04 0.02 (109)	-0.34*** -0.50*** (109)	0.24 0.19 (23)	0.81*** 0.81*** (109)	0.85*** 0.84*** (109)	0.83*** 0.82*** (109)	1.00 (109)			
PH	-0.42*** -0.45*** (86)	-0.42*** -0.42*** (109)	-0.34*** -0.32*** (109)	0.47*** 0.45*** (109)	-0.54*** -0.36* (23)	-0.61*** -0.60*** (109)	-0.65*** -0.66*** (109)	-0.60*** -0.62*** (109)	-0.47*** -0.54*** (109)	1.00 (109)		
L-SI	0.17 0.13 (85)	0.07 0.06 (108)	0.10 0.06 (108)	-0.17* 0.00 (108)	0.42** 0.08 (23)	0.20** 0.33*** (108)	0.22** 0.31*** (108)	0.21** 0.31*** (108)	0.09 0.11 (108)	-0.23** -0.19** (108)	1.00 (108)	
L-SP	0.13 0.08 (86)	-0.20** -0.21** (109)	-0.30*** -0.25*** (109)	0.34*** 0.30*** (109)	-0.49** -0.22 (23)	0.39*** 0.43*** (109)	0.51*** 0.49*** (109)	0.54*** 0.52*** (109)	0.35*** 0.34*** (109)	-0.16* -0.18* (109)	0.26*** [illegible] (108)	1.00 (109)
L-LI	0.11 0.09 (86)	-0.08 -0.06 (109)	-0.25*** -0.23** (109)	0.16* 0.08 (109)	-0.13 -0.01 (23)	0.55*** 0.58*** (109)	0.62*** 0.60*** (109)	0.63*** 0.66*** (109)	0.52*** 0.53*** (109)	-0.20** -0.26*** (109)	0.22*** 0.35*** (108)	0.72*** 0.72*** (109)
LSO4	0.28*** 0.26** (86)	0.12 0.09 (109)	-0.22** -0.21** (109)	0.02 -0.08 (109)	-0.08 -0.05 (23)	0.70*** 0.72*** (109)	0.72*** 0.72*** (109)	0.79*** 0.76*** (109)	0.63*** 0.63*** (109)	-0.27*** -0.28*** (109)	0.09 0.29*** (108)	0.66*** 0.76*** (109)
L-MO	0.06 -0.33 (37)	-0.11 -0.15 (49)	-0.15 -0.15 (49)	0.24* 0.21 (49)	-0.36* -0.37* (11)	0.13 0.01 (49)	0.15 0.04 (49)	0.10 0.06 (49)	0.04 -0.01 (49)	-0.07 -0.03 (49)	-0.05 0.11 (49)	0.21 0.06 (49)
L-CO	-0.08 -0.33 (30)	0.04 0.04 (41)	-0.00 0.03 (41)	-0.28* -0.28* (41)	0.25 0.22 (15)	0.18 0.14 (41)	0.22 0.13 (41)	0.06 0.01 (41)	0.10 0.08 (41)	-0.17 -0.17 (41)	-0.05 0.05 (41)	-0.04 0.03 (41)
L-MN	-0.20* -0.09 (74)	-0.12 -0.04 (89)	-0.21* -0.12 (89)	-0.05 -0.12 (89)	-0.03 0.06 (17)	0.35*** 0.35*** (89)	0.36*** 0.35*** (89)	0.32*** 0.35*** (89)	0.31*** 0.30*** (89)	-0.20* -0.32*** (89)	-0.26*** -0.26*** (88)	0.21* 0.14 (89)
L-ZN	0.11 0.35 (73)	0.01 -0.11 (94)	-0.05 -0.09 (94)	-0.25** -0.05 (94)	0.44** -0.10 (21)	0.25** 0.20* (94)	0.29*** 0.23** (94)	0.22** 0.13 (94)	0.22** 0.11 (94)	-0.19* -0.01 (94)	-0.03 -0.00 (93)	0.13 0.36*** (94)
LTAK	-0.13 -0.17 (86)	-0.24** -0.28*** (109)	0.02 -0.01 (109)	0.31*** 0.35*** (109)	-0.15 -0.29 (23)	-0.57*** -0.37*** (109)	-0.37*** -0.28*** (109)	-0.42*** -0.29*** (109)	[illegible] -0.19* (109)	0.11 0.13 (109)	0.16* 0.01 (108)	0.16* 0.24** (109)
L-CL	-0.19 -0.26* (48)	-0.29** -0.30** (65)	0.04 0.10 (65)	0.42*** 0.36*** (65)	-0.44* -0.40* (16)	-0.57*** -0.51*** (65)	-0.36*** -0.42*** (65)	-0.47*** -0.48*** (65)	-0.49*** -0.51*** (65)	0.17 0.08 (65)	0.10 0.15 (65)	0.15 0.16 (65)
L-B	0.00 -0.00 (86)	-0.22** -0.23** (109)	-0.08 -0.03 (109)	0.21** 0.25*** (109)	-0.36* -0.36* (23)	-0.13 [illegible] (109)	0.05 0.11 (109)	-0.02 0.07 (109)	-0.16 -0.05 (109)	-0.01 0.10 (109)	0.42*** 0.44*** (108)	0.54*** 0.55*** (109)
L-BA	0.34 0.05 (84)	0.02 -0.02 (106)	0.22** 0.19* (106)	-0.10 -0.04 (106)	0.04 -0.01 (23)	-0.24** -0.05 (106)	-0.13 -0.04 (106)	-0.26*** -0.13 (106)	-0.22** -0.18* (106)	-0.01 -0.05 (106)	0.33*** 0.29*** (105)	-0.05 0.13 (106)
L-SE	0.32*** 0.17 (86)	0.10 -0.02 (109)	0.24** 0.16* (109)	-0.15 0.04 (109)	-0.13 -0.09 (23)	-0.06 -0.03 (109)	0.05 0.01 (109)	0.00 -0.01 (109)	-0.01 -0.04 (109)	-0.17* -0.12 (109)	0.26*** 0.22** (108)	0.16 0.27*** (109)
L-AL	-0.23 -0.09 (27)	-0.16 -0.12 (37)	0.04 0.05 (37)	-0.02 -0.05 (37)	-0.18* -0.08* (8)	-0.30* -0.01 (37)	-0.18 0.02 (37)	-0.27 -0.09 (37)	-0.24 -0.02 (37)	-0.11 -0.28* (37)	0.00 0.10 (36)	0.01 0.21 (37)
L-AS	-0.28** -0.22* (67)	-0.20* -0.17 (83)	-0.01 -0.00 (83)	0.21* 0.37*** (83)	0.13 0.12 (17)	-0.56*** -0.36*** (83)	-0.39*** -0.31*** (83)	-0.47*** -0.35*** (83)	-0.55*** -0.41*** (83)	0.12 0.14 (83)	0.12 0.11 (82)	-0.00 0.13 (83)

NOTE: (1) Pearson correlation/Spearman correlation/(sample size). If either element has a concentration below the laboratory detection limits, it is omitted from the pairwise computations.
(2) Significance levels: *-10%, **-5%, ***-1%.

	L-LI	LSO4	L-MO	L-CU	L-MN	L-ZN	LTAK	L-CL	L-B	L-BA	L-SE	L-AL	L-AS
L-LI	1.00 (109)												
LSO4	0.71*** 0.71*** (109)	1.00 (109)											
L-MO	0.32** 0.31** (49)	0.18 0.04 (49)	1.00 (49)										
L-CU	0.08 0.01 (41)	0.05 0.02 (41)	-0.03 0.12 (15)	1.00 (41)									
L-MN	0.19* 0.18* (89)	0.37*** 0.26** (89)	0.05 0.11 (42)	0.59*** 0.32* (28)	1.00 (89)								
L-ZN	0.17* 0.28*** (94)	0.16* 0.24** (94)	0.06 0.05 (42)	0.36** 0.18 (37)	0.29** 0.06 (73)	1.00 (94)							
LTAK	-0.15 -0.11 (109)	-0.46*** -0.25** (109)	-0.07 -0.21 (49)	-0.14 -0.04 (41)	-0.26** -0.11 (89)	-0.18* 0.04 (94)	1.00 (109)						
L-CL	-0.19 -0.19 (65)	-0.56*** -0.44*** (65)	0.01 -0.09 (31)	-0.06 -0.01 (20)	-0.38*** -0.24 (43)	-0.00 0.29** (60)	0.77*** 0.69*** (65)	1.00 (65)					
L-B	0.35*** 0.30*** (109)	-0.05 0.06 (109)	0.26* 0.20 (49)	0.01 0.04 (41)	-0.10 -0.05 (89)	0.03 0.26** (94)	0.50*** 0.39*** (109)	0.70*** 0.72*** (65)	1.00 (109)				
L-BA	-0.15 -0.02 (106)	-0.43*** -0.21** (106)	-0.07 0.02 (48)	0.27* 0.35** (39)	-0.26** -0.07 (87)	0.14 0.38*** (92)	0.39*** 0.25*** (106)	0.59*** 0.58*** (64)	0.48*** 0.56*** (106)	1.00 (106)			
L-SE	0.00 0.02 (109)	-0.19** -0.07 (109)	-0.18 -0.19 (49)	-0.16 -0.16 (41)	-0.23** -0.15 (89)	0.02 0.17* (94)	0.44*** 0.58*** (109)	0.46*** 0.55*** (65)	0.52*** 0.45*** (109)	0.31*** 0.43*** (106)	1.00 (109)		
L-AL	-0.38 0.13 (37)	-0.33** -0.00 (37)	0.05 0.01 (18)	0.17 0.22 (20)	0.45** 0.31 (27)	0.09 0.13 (35)	0.34** 0.14 (37)	0.34* 0.30 (27)	0.33** 0.31* (37)	0.32* 0.27 (35)	0.14 0.23 (37)	1.00 (37)	
L-AS	-0.16 -0.37 (83)	-0.43*** -0.31*** (83)	0.06 0.01 (36)	0.18 0.14 (26)	-0.06 -0.05 (67)	-0.01 0.11 (69)	0.55*** 0.25** (83)	0.51*** 0.26** (52)	0.44*** 0.05 (83)	0.31*** 0.22** (81)	0.12 0.01 (83)	0.56*** 0.33 (21)	1.00 (83)





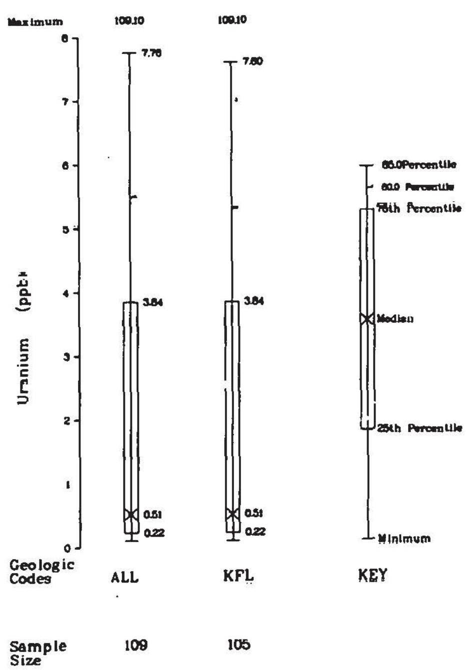
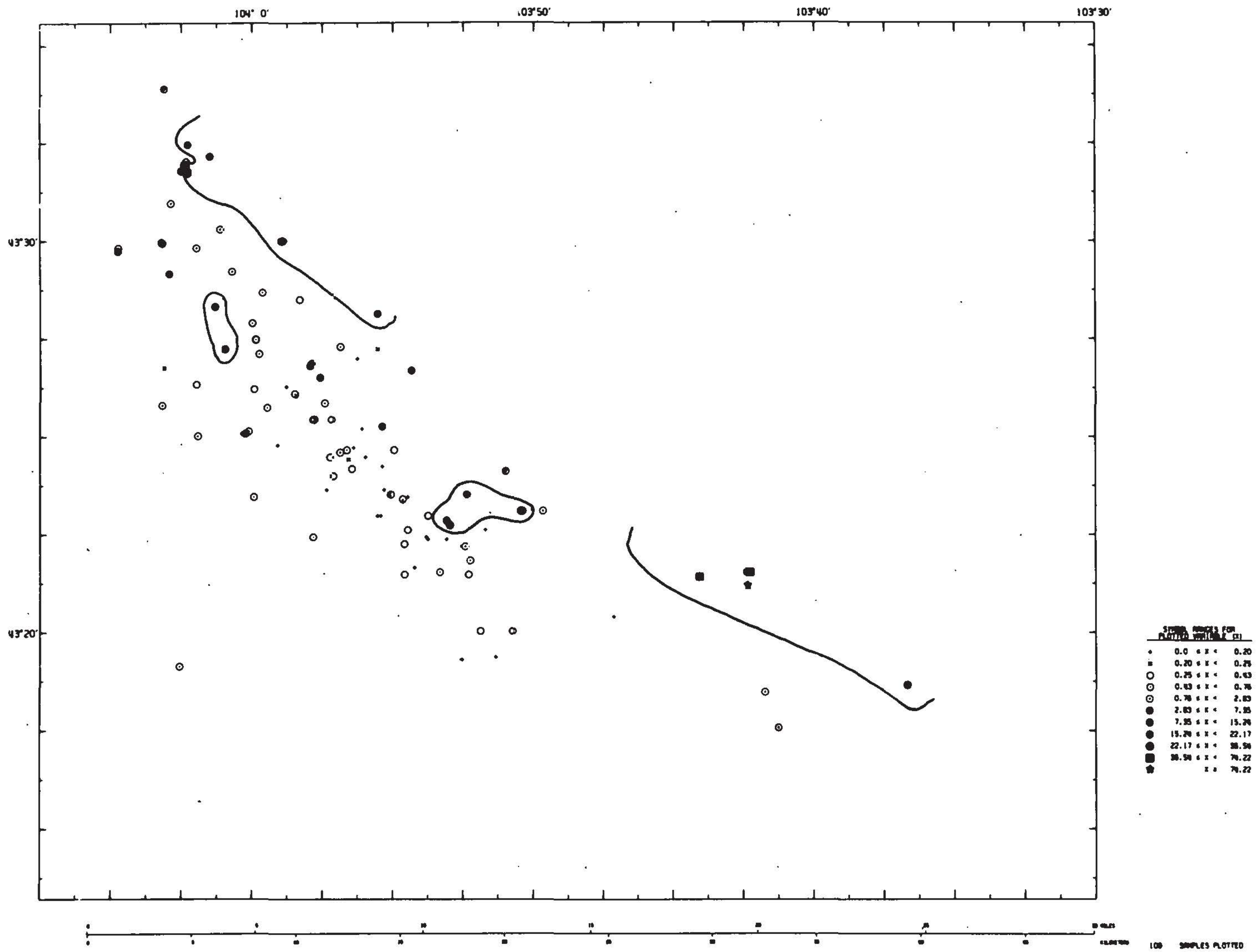


Figure A-1a

PROBABILITY, FREQUENCY, AND PERCENTILE PLOTS FOR URANIUM (PPB)
IN GROUNDWATER OF THE EDGEMONT DETAILED GEOCHEMICAL SURVEY, SOUTH DAKOTA; WYOMING



Approximate
Contour
≤7.35 ppb

Figure A-1b

GEOCHEMICAL DISTRIBUTION OF URANIUM (PPB) IN GROUNDWATER
OF THE EDGEMONT DETAILED GEOCHEMICAL SURVEY, SOUTH DAKOTA; WYOMING

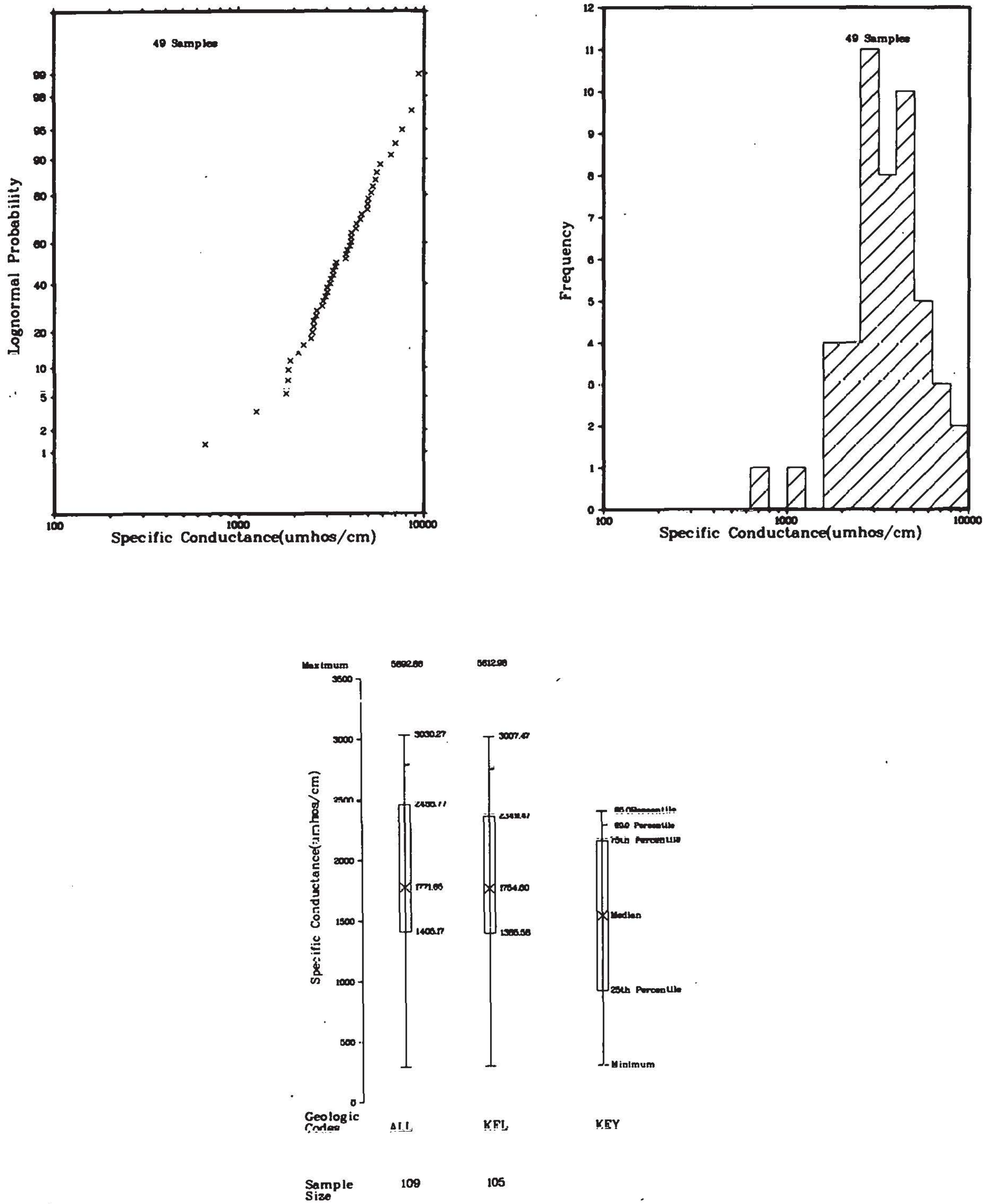
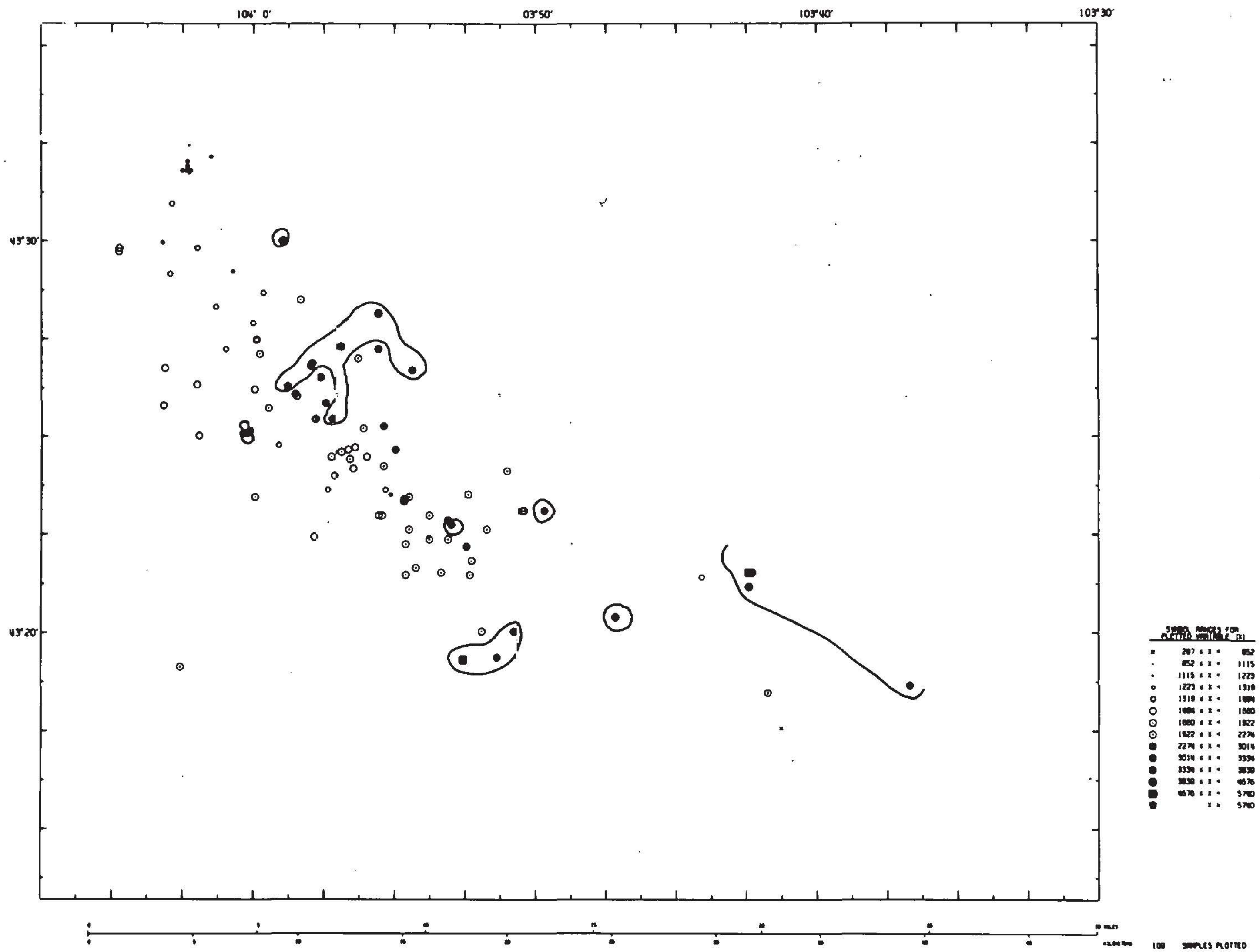


Figure A-2a

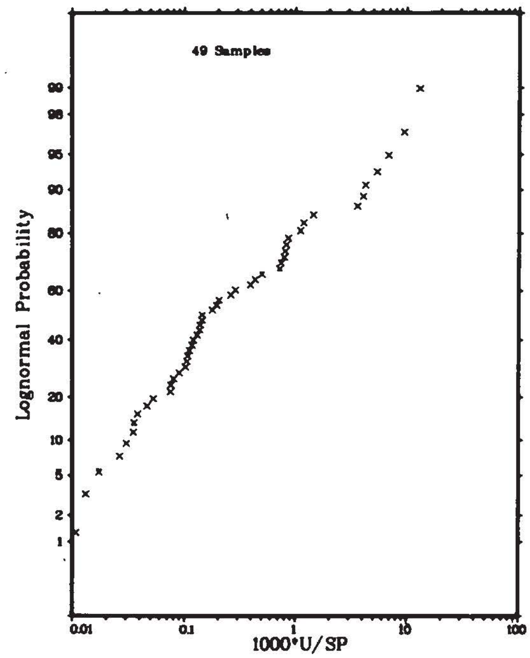
PROBABILITY, FREQUENCY, AND PERCENTILE PLOTS FOR SPECIFIC CONDUCTANCE (μMHOS/CM) IN GROUNDWATER OF THE EDGEMONT DETAILED GEOCHEMICAL SURVEY, SOUTH DAKOTA; WYOMING

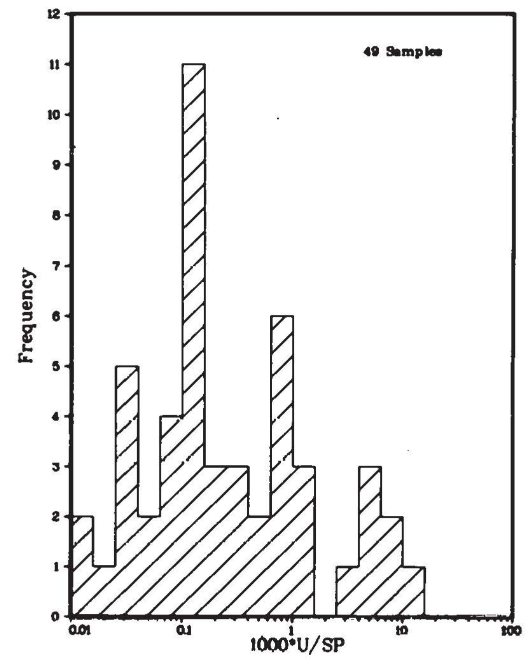


Approximate Contour ≤3,014 μmhos/cm

Figure A-2b

GEOCHEMICAL DISTRIBUTION OF SPECIFIC CONDUCTANCE (μMHOS/CM) IN GROUNDWATER OF THE EDGEMONT DETAILED GEOCHEMICAL SURVEY, SOUTH DAKOTA; WYOMING





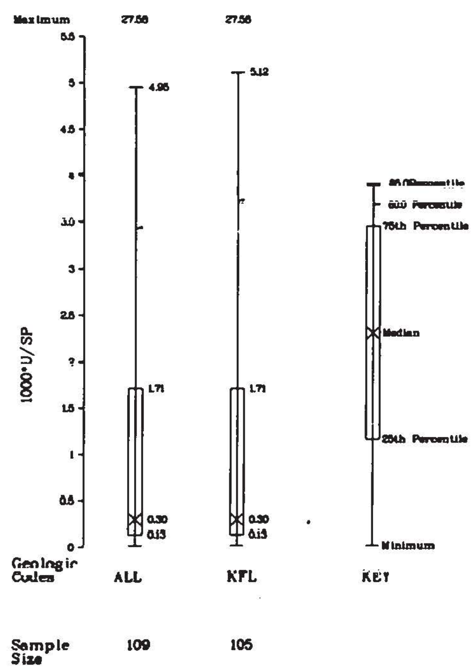
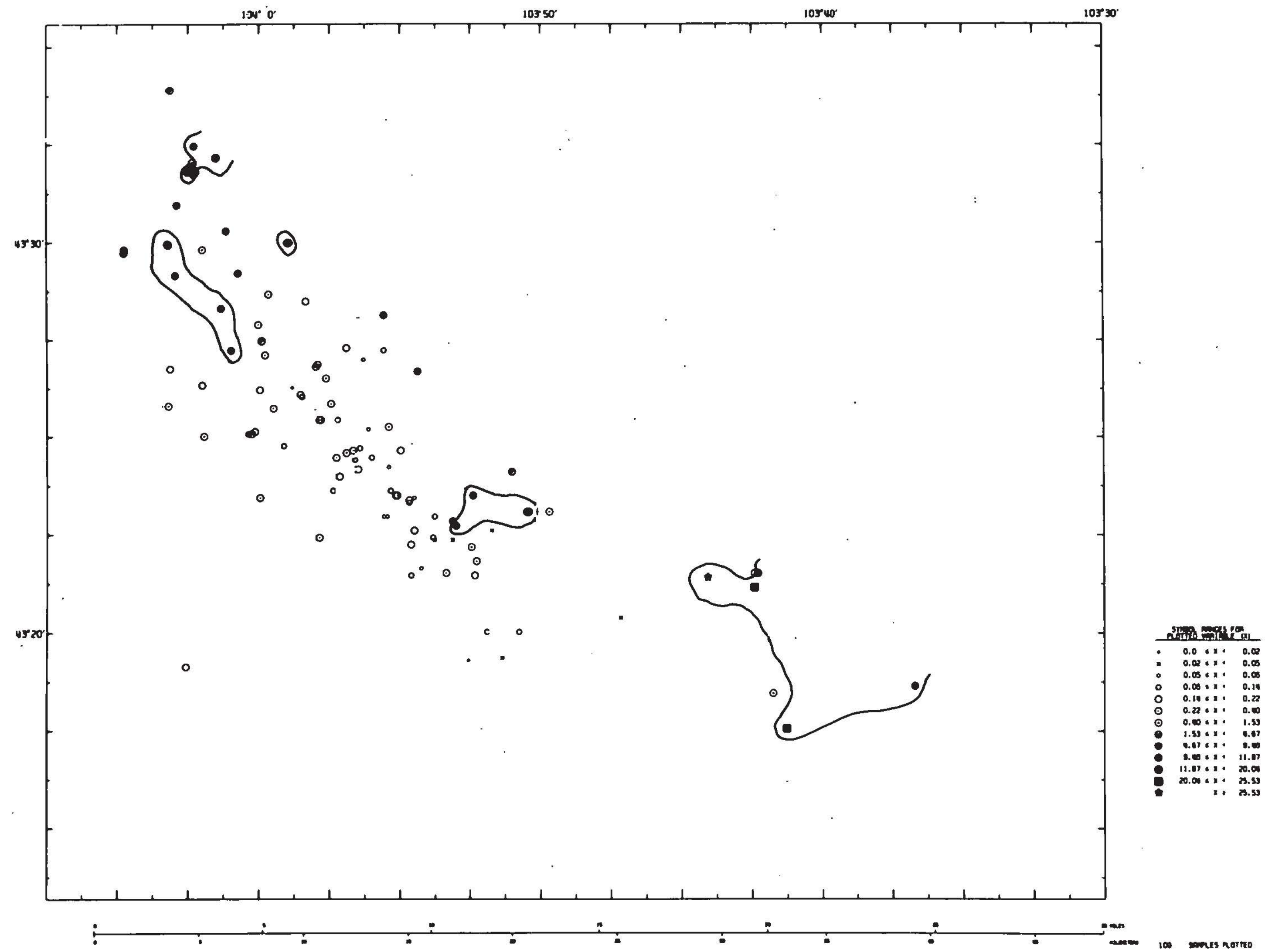


Figure A-3a

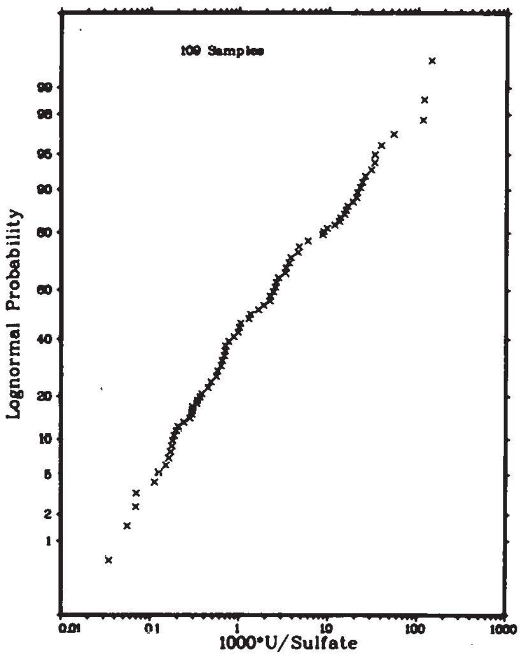
PROBABILITY, FREQUENCY, AND PERCENTILE PLOTS FOR 1,000·URANIUM/SPECIFIC CONDUCTANCE IN GROUNDWATER OF THE EDGEMONT DETAILED GEOCHEMICAL SURVEY, SOUTH DAKOTA; WYOMING

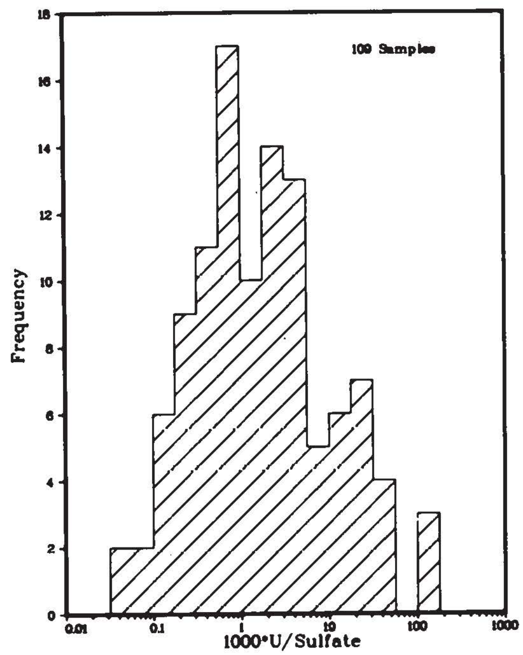


Approximate
Contour
≤4.67

Figure A-3b

GEOCHEMICAL DISTRIBUTION OF 1,000·URANIUM/SPECIFIC CONDUCTANCE IN GROUNDWATER OF THE EDGEMONT DETAILED GEOCHEMICAL SURVEY, SOUTH DAKOTA; WYOMING





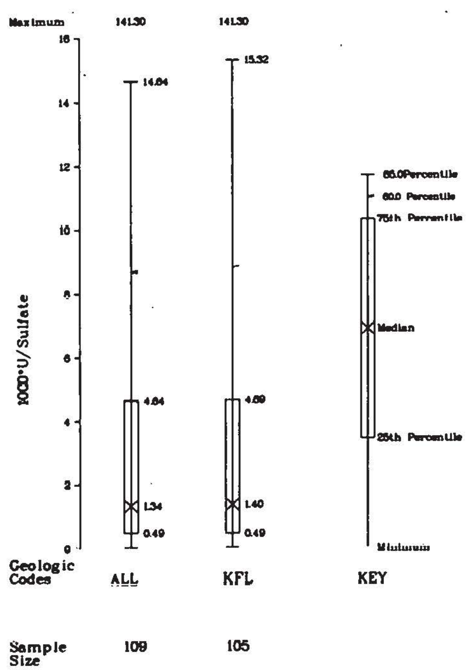


Figure A-4a

PROBABILITY, FREQUENCY, AND PERCENTILE PLOTS FOR 1,000·URANIUM/SULFATE IN GROUNDWATER OF THE EDGEMONT DETAILED GEOCHEMICAL SURVEY, SOUTH DAKOTA; WYOMING