Geology
GJBX - (82)-218

LA-8329-MS
Informal Report

GJBX-218(82)

GEOLOGY

**Analysis of Stream Sediment Reconnaissance Data
for Mineral Resources from the
Montrose NTMS Quadrangle, Colorado**

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LA-8329-MS
Informal Report
UC-51
Issued: June 1980

**Analysis of Stream Sediment Reconnaissance Data
for Mineral Resources from the
Montrose NTMS Quadrangle, Colorado**

By

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Assistant Secretary for Nuclear Energy
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ANALYSIS OF STREAM SEDIMENT RECONNAISSANCE DATA FOR MINERAL RESOURCES
FROM THE MONTROSE NTMS QUADRANGLE, COLORADO

by

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ABSTRACT

Multivariate statistical analysis to support the National Uranium Resource Evaluation and to evaluate strategic and other commercially important mineral resources was carried out on Hydrogeochemical and Stream Sediment Reconnaissance data from the Montrose quadrangle, Colorado. The analysis suggests that (1) the southern Colorado Mineral Belt is an area favorable for uranium mineral occurrences, (2) carnotite-type occurrences are likely in the nose of the Gunnison Uplift, (3) uranium mineral occurrences may be present along the western and northern margins of the West Elk crater, (4) a base-metal mineralized area is associated with the Uncompahgre Uplift, and (5) uranium and base metals are associated in some areas, and both are often controlled by faults trending west-northwest and north.

INTRODUCTION

The Los Alamos National Laboratory (LANL) has conducted a Hydrogeochemical and Stream Sediment Reconnaissance (HSSR) in the states of New Mexico, Colorado, Wyoming, Montana, and Alaska, as well as in parts of Arizona, Utah, and Idaho for the National Uranium Resource Evaluation of the United States Department of Energy (DOE). All data were reported by 1° x 2° National Topographic Map Series (NTMS) 1:250,000-scale quadrangles, with each quadrangle containing between 1500 and 2000 sample locations. Data were reported for uranium and 12 additional elements for each water sample and as many as 45 additional elements for each sediment sample. A typical HSSR report includes a sample location overlay; concentration overlays for uranium, thorium, and conductivity; data listings for water and sediment samples; and basic statistical measurements such as mean, median, and standard deviation for uranium in each sample type.

In its HSSR reports, Los Alamos includes a brief evaluation of areas that may have potential for further uranium exploration. These evaluations are based on comparisons of uranium concentrations and uranium-thorium (U/Th) ratios with the bedrock geology of the quadrangle. Although the data evaluations are logical first steps in identifying potential follow-up areas, incorporation of the large amount of additional analytical information available for each sample location could greatly enhance the interpretation of uranium data. These data could also be used to assess other strategic or economic mineral commodities in each of the quadrangles (Van Eeckhout, 1979). Funding and time constraints, however, eliminated the possibility of a detailed evaluation of multielement data in routine NURE HSSR reports by Los Alamos.

The goals of this study are 1) to examine how evaluations of uranium potential based on stream sediment data might be assisted through multivariate statistical analysis, and 2) to examine the use of multielement data to identify areas with potential for mineral commodities other than uranium. This study extends the methods developed in an earlier multivariate statistical analysis of HSSR data for the Craig quadrangle, Colorado (Beyth and others, 1980).

Data for the Montrose quadrangle were selected for study because two of Colorado's three major vein-type uranium districts (Marshall Pass and Cochetopa) occur within the quadrangle and because recently released HSSR data indicate that several other areas within the quadrangle have good potential for uranium exploration (Broxton and others, 1979). The large amount of exploration taking place in the quadrangle also reflects industry's belief that potential for discovery of additional uranium deposits is good in this area. Because the Colorado Mineral Belt, a major zone of base and precious metal occurrences, trends northeastward across the area, the quadrangle is also well suited for the study of mineral commodities other than uranium.

General Setting

The Montrose quadrangle covers approximately 19,200 sq km in southwestern Colorado and includes portions of the Southern Rocky Mountains and Colorado Plateau physiographic provinces. The Sawatch, West Elk, and San Juan Mountains dominate the eastern two-thirds of the quadrangle (Map 1).

Elevations range from 4393 m above sea level at Mount Harvard in the Sawatch Mountains to 1500 m above sea level in the northwestern corner of the quadrangle. Montrose is the largest city in the area, with a 1970 census population of about 5000. The climate is typical of the mountain and valley regions of the Rocky Mountains. The annual precipitation ranges from more than 600 mm in the higher elevations to less than 250 mm in the valleys. Precipitation during the sampling periods was above average, and temperatures were near seasonal averages.

The Continental Divide, which cuts through the eastern third of the quadrangle along the ridges of the Sawatch and San Juan Mountains, separates the quadrangle into the Arkansas River drainage on the east and the Gunnison River drainage on the west. The Gunnison River and its major tributaries, the North Fork and Uncompahgre Rivers, drain most of the quadrangle (Map 1).

Geology

Good general overviews of the geology and mineral occurrences of the region can be found in Tweto (1968) and Curtis (1975). A regional geologic map for the quadrangle has been compiled by Tweto (1976). The following descriptions of geology and mineral occurrences are summarized from Broxton and others, 1979.

The oldest rocks in the quadrangle consist of Precambrian X (age >1700 m.y.) quartzites, metarhyolites, greenstones, metagreywackes, and various types of gneisses and schists exposed in the Sawatch Range and along the Gunnison River. These metasedimentary and metavolcanic rocks are intruded by widespread 1700 m.y. old granitic batholiths and (in the central part of the quadrangle) by smaller Precambrian Y (about 1400 m.y.) granitic and alkali-rich mafic plutons. In the vicinity of the town of Powderhorn, the Precambrian rocks are intruded by the Iron Hill carbonatite complex, an early Cambrian alkaline pluton with associated occurrences of thorium (Map 4).

Cambrian through Mississippian marine sandstones, shales, and limestones unconformably overlie crystalline rocks of the basement complex in the northeastern and southwestern parts of the quadrangle. Pennsylvanian to Permian uplift of the Uncompahgre Highland resulted in removal of early Paleozoic strata over much of the southern and western parts of the quadrangle. Pennsylvanian and Permian arkosic redbeds in the northeastern and southwestern parts of the quadrangle represent synorogenic clastic sediments shed into the Central Colorado Trough and the Paradox Basin on the flanks of the uplifted terranes.

Triassic and Jurassic fluvial and lacustrine sediments were deposited over much of the beveled Precambrian core of the Uncompahgre Highland as well as over the flanking basin deposits. By Cretaceous time, transgressive and regressive seas covered the entire region, resulting in deposition of marine shales and sandstones interfingering with nonmarine sandstones, carbonaceous shales, and variegated mudstones. Mesozoic rocks are exposed principally in the western part of the quadrangle.

During the Late Cretaceous to Eocene Laramide orogeny in Late Cretaceous time, the northwest-trending Sawatch Anticline and Uncompahgre Plateau were

uplifted, resulting in widespread erosion of older rock units and deposition of orogenic clastic sediments in basins adjacent to the uplifts. Erosional remnants of these Laramide orogenic sediments (for example, Eocene Ohio Creek and Wasatch Formations) are preserved in the northwest part of the quadrangle. The Sawatch Anticline, which rose along the axis of the late Paleozoic Central Colorado Trough, and the Uncompahgre Plateau, a rejuvenated portion of the late Paleozoic Uncompahgre Highland, are reactivated basement blocks characterized by large vertical displacements. Intermediate to felsic volcanism (recorded in sediments of the Wasatch Formation) and intrusions accompanied the early states of Laramide deformation. Laramide volcanism and plutonism were localized along northeast-trending Precambrian shear zones and are associated with the earliest stages of mineral deposition in the Colorado Mineral Belt.

The northern part of the San Juan volcanic field, which covers most of the southern part of the quadrangle, is a deeply dissected Oligocene volcanic plateau made up of a lower sequence of mainly andesitic lavas and breccias and an upper sequence of sheets of rhyolitic and quartz latitic ash-flow tuffs. Caldera complexes, stocks, plugs, sills, and dikes represent deeply eroded volcanic centers and epizonal plutons that were sources for the volcanic rocks. North of the Gunnison River, the lower sequence of lavas and breccias of the San Juan volcanic field coalesces with volcanic deposits of similar age and composition derived from the West Elk Mountains. Numerous felsic epizonal stocks, laccoliths, dikes, and sills of Oligocene age are exposed at the north end of the West Elk volcanic field and extend northeastward into the Sawatch Range. The Mt. Princeton batholith, on the eastern side of the Sawatch Range, was emplaced at about the same time that the volcanic activity in the West Elk and San Juan volcanic fields occurred.

Epeirogenic uplift, bimodal basalt-rhyolite volcanism, and block faulting characterized late Tertiary deformation in the quadrangle. The Arkansas River Basin, a graben superimposed on the crest and eastern flank of the Laramide Sawatch Anticline, is the northernmost segment of the Rio Grande Rift. Late Tertiary orogenic sediments, represented by the Miocene Santa Fe and Dry Union Formations, fill the Arkansas River Basin.

Radioactive Mineral Occurrences

Nearly 600,000 tons of uranium ore containing between 0.11 and 1.17 percent U_3O_8 have been produced in the Montrose quadrangle (compiled from Nelson-Moore and others, 1978). Most of this production has come from mines in the Cochetopa and Marshall Pass districts. These mining districts and other uranium occurrences in the quadrangle are briefly described in Table I, and their locations are shown in Map 4. Individual uranium occurrences in Colorado are described in more detail in Nelson-Moore and others (1978).

Uranium deposits in the Cochetopa district are localized along the Los Ochos fault, where sandstones and shales of the Jurassic Morrison Formation adjoin schists and granites of Precambrian X age. The principal orebodies are associated with intensely altered areas within the fault breccia and in the adjacent wall rocks. Most orebodies are related to brecciated rocks of the Morrison Formation, though uraniferous veins also cut the Precambrian schists. Although no mines are active in this area at the present time, 486,000 tons of

ore yielding 1,351,000 lb of U_3O_8 have been produced from this district, mainly from the Los Ochos and T-2 mines (Nelson-Moore and others, 1978).

Uranium deposits in the Marshall Pass district are also structurally controlled. They are concentrated along the Chester fault, which displaces Precambrian X granites and schists against remnants of Paleozoic sedimentary formations. The uranium occurs mainly in Paleozoic rocks, particularly the Ordovician Harding Quartzite, Devonian Chaffee Formation, Mississippian Leadville Limestone, and Pennsylvanian Belden Formation. More than 105,000 tons of ore containing between 0.25 and 1.17 percent U_3O_8 have been produced from this district. Most production was from the Pitch Mine, an underground mine that was recently reopened as an open pit.

The Powderhorn thorium district is located in the south-central part of the quadrangle. Thorium, principally in the form of pyrochlore, is concentrated in veins and shear zones on the margins of the Iron Hill complex, an Early Cambrian alkaline intrusion made up of pyroxenite, uncomphagrite, ijolite, nepheline syenite, and carbonatite. Thorium levels are too low to be of economic interest under present market conditions unless the thorium is extracted as a byproduct of niobium, rare earth, or uranium deposits that may exist within the alkaline complex.

Data presented by Phair and Gottfried (1964) indicate that Precambrian granitic and metamorphic rocks as well as Laramide plutonic rocks in the Front Range, 50-100 km east and northeast of the quadrangle, are thorium-rich on a regional scale and define a distinct thorium geochemical province. Furthermore, the segment of the Front Range transected by the Colorado Mineral Belt is considered a metallogenic uranium province because of the unusual number of workable uranium deposits located there. Because of the similarities in Precambrian bedrock geology, the presence of workable uranium deposits, and the projection of the Colorado Mineral Belt through the area, portions of the quadrangle might be extensions of the thorium and uranium provinces described in the Front Range. Tweto (1968) suggests that northwest-trending faults intersecting the northeast-trending veins are important sites for uranium occurrences on the fringes of or outside the Colorado Mineral Belt.

Base and Precious Metal Occurrences

Most of the known base and precious metal mineral occurrences in the quadrangle are within the Colorado Mineral Belt, a northeast-trending zone of major metal deposits associated with Laramide and middle Tertiary plutons aligned along reactivated Precambrian shear zones. This belt extends diagonally across the quadrangle from the Mosquito Range in the northeast to the Uncompahgre and Lake City calderas in the southwestern part of the quadrangle.

The major base- and precious-metal mining districts in the quadrangle (Burbank and Luedke, 1968) are described in Table II, and their locations are shown in Map 5. In addition, the Colorado resources map (USGS, 1971) shows the locations and types of many smaller mineral deposits in the report area. An extensive catalog of mineral occurrences and mines in the quadrangle was compiled by Truebe (1979).

INTERPRETIVE TECHNIQUES

There are 1857 sediment samples and 1365 water samples in the data base for the quadrangle. Locations of these sample sites are shown on Map 3. Detailed sample coordinates, listings of field and analytical data, and descriptions of field and analytical procedures are given in Broxton and others, 1979.

Because regional background concentrations of elements vary as a function of geology and physiography, data for the quadrangle were divided into three geochemically distinct geologic or physiographic provinces: the Western Plateau area (Area A), the San Juan and West Elk volcanic fields (Area B), and the Sawatch and Gunnison crystalline terrane (Area C) (see Map 3).

The Western Plateau is an arid area of low relief, underlain by gently dipping Mesozoic formations. The San Juan-West Elk volcanic terrane is a semihumid to semiarid region of moderate to high relief, underlain primarily by mid-Tertiary intermediate and felsic volcanic rocks. The Sawatch-Gunnison crystalline terrane is a complex crystalline area underlain primarily by Precambrian igneous and metamorphic rocks and to a lesser extent by Paleozoic sediments and Tertiary felsic intrusive rocks.

All elements reported in the Montrose HSSR report were examined for potential use in this study. Of the 42 elements reported for sediment samples, 21 elements (Al, Ba, Ca, Ce, Co, Cr, Cu, Dy, Fe, Hf, K, Li, Mg, Mn, Pb, Sc, Th, Ti, U, V, and Zn) were selected for multivariate statistical analysis. Four additional elements (Ag, Au, W, and Nb) have too many values below the detection limit to be included in the statistical analysis, but were examined on a case-by-case basis to determine their usefulness in outlining mineralized areas. Uranium was the only element examined in water data. The elements selected for study in sediment and water samples were chosen because they are recognized or suggested pathfinders for uranium or could be useful in exploration for strategic minerals.

The data base for this study was compiled on a CDC-6600, 128K central memory computer. Histograms, scattergrams, correlation coefficients, and factor analysis were generated using the Statistical Package for the Social Sciences (SPSS, Nie and others, 1975). Data base management system 2000 was used to calculate simple statistical parameters such as average and standard deviation, as well as to transfer data from CDC-6600 computer disk to the SPSS system.

In factor analyses and the computation of averages, standard deviations, and correlation coefficients, a value of one-half the detection limit was assigned to elements with analytical values below the detection limit. Therefore, some statistical parameters (such as averages and medians) could be positively skewed in those elements with many values below the detection limit (Table IV; Figs. 1-21). Analyses with values below the detection limit were ignored on scattergrams and log probability plots.

Anomaly thresholds for each element (Table III) were estimated from log probability plots of frequency distribution curves using data for the entire quadrangle (Lepeltier, 1969). Separate thresholds for uranium, copper, lead, and zinc were estimated for each of the three geologic or physiographic provinces (Table IV).

Statistical averages and standard deviations are also strongly positively skewed by contamination due to tailings in established mining districts. The effects of contamination on the statistical data are well illustrated by the extreme standard deviations for copper, lead, and zinc (Table III). Although averages are often used as reasonable approximations of elemental background values, use of the raw statistical data can result in estimates that are far too high. To better estimate elemental background levels for the quadrangle and for each of the three geologic or physiographic provinces, the statistical data in Table III were recalculated after removing samples above the anomaly threshold levels cited in Table IV. This procedure separated the most exotic samples (usually downstream from mine tailings) from those that better represent the bedrock geology, and it resulted in a much better estimate of background concentration for each element.

Scattergrams were plotted and correlation coefficients were calculated for all combinations of elements. Selected plots are shown in Figures 22 through 35.

Multielement correlation and R-mode factor analysis (PA1 and PA2 with Varimax orthogonal rotation) for the whole quadrangle (1857 samples) and for each of the three geologic or physiographic subdivisions (Western Plateau, 409 samples; San Juan and West Elk volcanic fields, 783 samples; Sawatch-Gunnison terrane, 665 samples) were carried out both on raw data and on log-transformed data. The results of the analyses are summarized in multielement correlation charts and factor analysis diagrams (Figs. 36-57).

Concentrations greater than the thresholds for uranium, thorium, niobium, dysprosium, cerium, hafnium, lithium, lead, copper, zinc, and scandium were plotted on 1:250,000-scale maps that were reduced as overlays.

Clusters of samples above thresholds were delineated and boundaries were drawn according to topographic drainage basins on 1:62,500-scale and 1:24,000-scale topographic maps of the U.S. Geological Survey. These clusters were then overlain on the geologic map (Tweto and others, 1976) to determine the provenance of anomalous samples (Table V).

To better define the relationships among those samples of interest, additional multielement correlation and factor analyses on log-transformed data were calculated for the anomalous samples above threshold for uranium, copper, lead, and zinc (Figs. 48-57). The basic statistics for the data set are summarized in Table VI. For comparison, elemental abundances in acid and basic rocks are given in Table VII.

Three factor score maps were plotted: the factor score for factor 3 out of 9 factors (PA1 on raw data for the whole quadrangle), which is loaded mainly by copper, zinc, and lead (Map 26); factor 9 out of 9 factors (PA1 on raw data for the Sawatch-Gunnison crystalline terrane), which is loaded mainly by uranium and less by chromium, iron, and vanadium (Map 15); and factor 2 out of 9 factors (PA1 on raw data for the whole quadrangle), which is loaded mainly by lanthanides, thorium, and hafnium, and less by uranium (Map 16). This method helps in locating the areas most favorable for the occurrence of uranium in base metals.

Using the above data and elemental concentrations, an attempt was made to determine the probable location of mineralized areas by following the pattern of concentrations in the drainage basins. In cases where it was possible to identify the source of anomalous samples, probable locations were designated by an X on the maps. All available literature was consulted in the attempt to locate mines, mining activity, and prospects.

Uranium concentrations in sediment and water samples were mapped by kriging (Planner and Campbell, 1980) (Maps 17 and 18).

The following review of information on the methods of sampling, chemical analysis, and statistical evaluation should be noted before the results of the work are discussed:

(1) The average sampling density is one sample location per 10 sq km. Many mineralized areas, especially the vein types, may not be detected at that density (Bramlett, 1979).

(2) The total elemental concentrations in the sediment samples reported by Broxton and others (1979) and used in this report are for the -100 mesh fraction.

(3) The statistical analysis of all elements except uranium was based on sediment samples only; data from both sediment and water samples were used for uranium. All concentrations are reported in parts per million (ppm) for sediment samples and parts per billion (ppb) for water samples.

(4) The data were examined for each geologic or physiographic province (Map 3) by comparing elemental data to the geology of each area.

(5) Some geochemical correlations that are almost certain to exist (such as those between lanthanides, thorium, and hafnium) are unreasonably low on raw data and are brought out better by log-transformed data (Figs. 39 and 40).

(6) There is widespread mining activity in the quadrangle (see Map 5). The tailings from the mines may produce local point-source contamination.

(7) Contouring of factor score maps generally shows the favorable areas for various combinations of elements. On the other hand, the contouring may shift the favorable location on the map; although stream sediment samples represent drainage basins, contouring ignores the boundaries of basins.

PRESENTATION OF RESULTS

The results are presented in tables, figures, and maps. Because of the large amount of data, not all results presented are completely discussed in the following section. However, all results are presented in such a way that readers can provide their own interpretation.

The use of the original 1:250,000-scale topographic maps (U.S. Geological Survey, 1962) and geologic map (Tweto and others, 1976) is recommended. Reduced copies are included in this report (Maps 1 and 2) for use with the

concentration overlays. Map 3 is a sample location map without sample numbers. Other maps are cited in the text.

Concentration overlays, a sample location overlay with sample numbers, and a listing of field data and elemental concentrations for sediment samples from the Montrose quadrangle can be found in the report by Broxton and others (1979), which should be used in conjunction with this report.

Uranium, Thorium, Lanthanides, Hafnium, Niobium, and Lithium

For the sediment samples of the entire quadrangle, the correlations between uranium, lanthanides, thorium, and hafnium are best expressed in log-transformed data (Fig. 37 and factor 2, Fig. 38). Uranium is also associated with base metals, as shown by factor 4, log-transformed data.

The five factors on log-transformed data for stream sediment samples of the quadrangle may be interpreted as follows:

The first factor, composed mainly of iron, cobalt, scandium, vanadium, titanium, and manganese, probably represents a mafic assemblage. The second factor (the lanthanides, thorium, hafnium, and some uranium) probably represents zircon and heavy resistate rare-earth minerals. The third factor, composed of potassium, aluminum, barium, and titanium, probably represents a felsic assemblage. The fourth factor, composed of copper, lead, zinc, and very little uranium, probably represents a base-metal assemblage. The fifth factor, composed of magnesium, calcium, lithium, and vanadium, probably represents limestone.

Western Plateau Area (Area A)

The average values for uranium in sediment samples in the area are low (3.7 ppm), whereas the background for uranium in water samples is very high (23 ppm, Map 7). Uranium is moderately correlated with thorium (0.39, Fig. 40).

High values of uranium in water samples, uranium values >4.0 ppm in sediment samples, and high values of lithium in sediment samples (Map 14) occur in the Mancos Shale at the margins of the Gunnison and Uncompahgre Uplifts.

No values of uranium greater than 20 ppm in sediment samples were found in Area A, but high values were found in water samples (Maps 7 and 18) associated with sediment samples having high U/Th ratios (Map 9). The most interesting anomaly, located at Waterdog Peak in the west-central part of the area, is associated with the Cretaceous to Tertiary Telluride Conglomerate. The concentrations of uranium in water samples at the location range from 13.2 ppb (sample C08057) to 209.5 ppb (sample C08055) (Map 7).

Uranium is loaded 0.50 on factor 1 with calcium, magnesium, and vanadium, and on factor 4 with thorium, lanthanides, and hafnium (Fig. 41, log-transformed data). The moderate correlation with vanadium (0.41, Fig. 40) may indicate carnotite-type minerals (factor 1, Fig. 41, log-transformed data).

About 68 percent of the total information about uranium was used in factor analysis.

Three areas with high factor 2 scores (whole quadrangle log-transformed data, Fig. 38; Map 16) were identified where all but a few samples lie along the trend of the Gunnison Uplift in the northern part of Area A (Map 16). The highest values of uranium in the northernmost area coincide with high concentrations of uranium in water samples (38.2 ppb; Map 7).

Very high factor scores are mainly due to high hafnium (Map 13) and moderate to very high uranium values. The central area has moderate to low scores and is associated with high concentrations of uranium in water. The southern area overlies the Cretaceous Dakota and Burro Canyon Formations and has very high dysprosium and cerium values (Maps 11 and 12).

San Juan and West Elk Volcanic Fields (Area B)

The statistical analysis, uranium concentrations in water samples, factor score maps, kriging maps, and high values of niobium indicate that parts of this volcanic area may be favorable for uranium occurrences, even outside the Colorado Mineral Belt. On the other hand, only two sediment samples with high uranium were found (Map 6), and the average value of uranium in sediment samples (3.8 ppm) is very low.

The correlations between uranium, the lanthanides, thorium, hafnium, and lead are moderate, and other correlations with uranium are low or negative (Fig. 43). The very few U/Th ratios greater than 1 represent samples concentrated along the Colorado Mineral Belt. There are numerous sediment samples with ratios of 0.5-1.0 in the eastern part of the area; only a few of them coincide with high concentrations of uranium in water (Map 7), although they correspond somewhat with anomalous uranium concentrations in water samples as defined by kriging (Map 18). A clearly anomalous area of uranium in sediment samples, also defined by kriging (Map 17), is located near the Bonanza King base-metal and precious-metal mines in the northeastern corner of the area (Maps 4 and 5).

Two water samples about 25 km northeast of Cochetopa Dome indicate that uranium may be associated with an east-trending fault line separating Oligocene andesitic lavas and breccias from Tertiary felsic rocks. Sample C09120, a water sample with 5.4 ppb uranium, is near a reported occurrence of uranium (point 41 on Map 4).

Sample C08415, near Lake City, illustrates the importance of evaluation by drainage basin. The sample, a sediment, contains 26.9 ppm uranium and represents uranophane in a vein-type occurrence about 1.5 km upstream (Map 4). The area of the basin is about 3 sq km.

Niobium is the only element above threshold that is associated with the uranium mine on Soap Creek, in the West Elk volcanic field (Maps 4 and 10). The high values of niobium along the western and northern margins of the West Elk crater could likewise indicate uranium occurrences; similar associations of niobium and uranium were reported from Saudi Arabia (Matzko and Nagvi, 1978).

Uranium and lithium are often associated where uranium orebodies occur in volcanic environments (Burt and Sheridan, 1980). In this study, there was a clear correlation in the West Elk volcanic field only where the Cochetopa Dome uranium occurrences (reported by Nelson-Moore and others, 1978) were detected by high lithium in sediment samples (Map 14).

In factor analysis, uranium is loaded mainly on factor 2 with thorium, hafnium, and lanthanides (0.60; Fig. 44, log-transformed data). The Bonanza King area is expressed by high factor 2 scores (Map 16). High factor 2 scores also indicate the Wasatch Formation intruded by middle Tertiary felsic intrusive rocks in the northern West Elk volcanic field. One very high score close to the West Elk crater is due to sample C08694, in which uranium, dysprosium, cerium, and thorium are high, and the U/Th ratio (0.126) is very low. Two zones of high factor 2 scores are located in the southeastern part of the area. The western zone has volcanic rocks along the eastern margin of the Colorado Mineral Belt and coincides with a high-temperature uranium mineral occurrence (Map 4). The eastern zone, associated with the Bonanza King mining area, has Precambrian X migmatites and granites and Paleozoic sedimentary rocks, and an occurrence of a low-temperature uranium mineral is reported. Most of these high factor 2 scores are associated with anomalies identified from airborne survey data (Map 4).

The kriging map of uranium in sediment samples (Map 17) indicates that values exceeding a level as low as 4 ppm may be significant for identifying areas with high background, such as the Colorado Mineral Belt, and areas of anomalous concentrations of uranium where the background is low, such as the San Juan and West Elk volcanic fields.

Sawatch and Gunnison Crystalline Terrane (Area C)

Analysis of the data for the entire quadrangle shows that Area C, the northeast part of the quadrangle, is generally the most favorable area for the occurrence of uranium. Uranium-producing properties in the area lie within the Colorado Mineral Belt.

The favorable character of Area C is suggested by the clustering of sediment samples in which uranium exceeds the quadrangle threshold of 20 ppm (Map 6), clustering of sediment samples in which the U/Th ratio is high (Map 9), and by the factor 2 score contours (Map 16). A few of the significant anomalous areas identified in this report were not listed by Nelson-Moore and others (1978), nor were they identified by the aerial gamma-ray survey carried out by geoMetrics (1979) (Map 4).

Mapping by kriging log-transformed data for uranium in sediment samples (Map 17) shows a higher background for the Colorado Mineral Belt than for the rest of the quadrangle, and kriging indicates at least 10 anomalies within area C. Most of the anomalous values correspond with high factor 9 scores on raw data (Map 15). Factor 9 on raw data for Area C is virtually a pure uranium factor with some loading of potassium (Fig. 47). Henceforth, references in the text to factor 9 will always mean this factor on raw data. All the other factors referred to are on log-transformed data.

The accuracy of locating mineralized areas can be increased by comparing anomalous areas with drainage basins in which there are anomalous concentrations of uranium in stream sediment samples.

The main cluster of anomalous values of uranium at the Mt. Princeton batholith (Map 6) coincides with the major area of lead, copper, and zinc occurrences (Maps 5, 19, 20, and 21; Table V). Some correlation also exists between uranium anomalies and isolated anomalous values of base and precious metals. The correlation between uranium and base metals is seen by comparison of factor 3 scores (Map 26) and factor 9 scores (Map 15). Correlation of the geology with the high values of uranium shows that most of the uranium anomalies are associated with Precambrian X granitic rocks and middle Tertiary felsic plutonic rocks (Table V). A smaller number of anomalous samples occurs in areas partially underlain by Precambrian X felsic, hornblendic, and biotitic gneisses.

Most of the high concentrations of lanthanides (Maps 11 and 12), thorium (Map 8), and hafnium (Map 13) in the quadrangle are located in Area C. High values of dysprosium and hafnium are mainly in Precambrian X granites of the Gore Range at the western margin of the Arkansas River graben; a few high values are in the graben fill itself. There are some high concentrations in the Sawatch Range, but except for thorium they are not in the same location as the main cluster of uranium values at the Mt. Princeton batholith. Few high values of thorium and hafnium are correlated with high values of uranium in water samples.

A regional correlation exists between factor 2 (lanthanides and uranium, Map 16) and factor 9 (uranium and potassium, Map 15).

The Marshall Pass and Cochetopa uranium districts and the Powderhorn thorium district are somewhat expressed by elevated factor 9 scores (Map 15) and much less by kriging (Map 17). The direct mapping of anomalous concentrations of uranium in water samples (Map 7), combined with kriging (Map 18), detects these districts much better. The Marshall Pass and Cochetopa districts are detectable by medium to high factor 2 and factor 9 scores that only partly overlap.

Many samples with anomalous concentrations were collected downstream from major faults, such as along the eastern margin of the Arkansas River graben, or along the line trending northwest across Crested Butte and separating the high Precambrian Sawatch Range on the east from the low Mesozoic sedimentary rocks and the volcanic basin of the West Elk volcanic field on the west. This line is associated with Tertiary felsic rocks and with base and precious metals.

The north-trending fault from Spring Creek to White River National Forest is clearly expressed by high concentrations of uranium in water (Map 7).

One of the higher concentrations of uranium in water (197.6 ppb) was found in the stream draining the area of the Marshall Pass mines. The concentrations decrease downstream to 25.6 ppb. In this case, where contamination is assumed to exist, uranium in water was a better detector than uranium in stream sediments (Map 6).

The largest clusters of anomalous samples are associated with Cambrian Iron Hill carbonatite and Precambrian Y granites and alkalalic and mafic rocks to the north. A high concentration of uranium in water could be a direct indication that some of that uranium came from leachable ore-forming minerals.

The Sawatch Uplift, Mt. Princeton batholith, and Mosquito Uplift have a few anomalous samples with high concentrations of uranium in water samples (Maps 7 and 18) which correspond partly with high concentrations of uranium in sediment samples (Map 6 and 17). Since some of the uranium in Area C may be in leachable minerals, the low background of uranium in water (3.4 ppb) could be the result of the brief contact time where streamflow is rapid in the high and rough terrain (Maxwell, 1977). This response to topography could be a reason why uranium in sediment is a better detector of uranium in the higher parts of the area, while uranium in water is a better detector in the lower southern part, where most of the mining districts are located.

Base Metals

The central, northeastern, and southwestern parts of the quadrangle are part of the northeast-trending Colorado Mineral Belt (Map 5). The rocks making up the belt are primarily Precambrian granites and migmatites covered by Paleozoic sediments and intruded by Upper Cretaceous to Tertiary volcanic rocks. The young volcanic rocks form huge calderas and acid intrusive batholiths (Map 2). The mines and mineral occurrences indicated on Map 5 produce base metals (copper, lead, and zinc), precious metals, molybdenum, tungsten, and other metals.

As expected for this mining area, there are extremely high concentrations of lead, copper, and zinc in stream sediment samples (Figs. 2, 3, and 20). The averages and standard deviations for the different areas are also very high (Table III), and they are strongly positively skewed (Figs. 2, 3, and 20). The cumulative frequency curves for these three elements indicate that the thresholds are in the low percentiles. In some cases, such as lead, two populations are indicated (Table IV; Appendix). The basic statistics for lead, copper, and zinc values above the thresholds are summarized in Table VI, which shows 237 very high values for lead, 192 for copper, and 195 for zinc.

The base metals are not correlated as well in samples for the whole quadrangle (Fig. 37) as they are in 90 samples in which uranium exceeds the quadrangle threshold of 20 ppm (Fig. 48). Most of the 90 samples are in Area C.

The correlation and factor analyses show that copper, lead, and zinc form one distinct elemental assemblage. All are loaded on the same factor (Figs. 38, 41, 44, and 52). There is low correlation with uranium, manganese, and barium (Figs. 37, 39, 40, 42, 43, 46, 48, 50, 51, 53, 54, 56, 57). The relationships may indicate that barite and manganese minerals occur as gangue in a sulfidic vein-type base- and precious-metal environment, with possibly some associated uraninite.

The factor 3 score map (Map 26) indicates the most favorable areas for the base metals assemblage. Most of the high factor scores of this map

coincide with the Colorado Mineral Belt. The highest scores represent samples from Oligocene lavas and breccias and Tertiary felsic intrusive rocks of Mt. Princeton, where they are extruded and intruded through Precambrian basement rocks (Table V; Map 2).

The stratigraphy and tectonics in the area of high lead, copper, and zinc (Maps 19-21), summarized in Table V, support the conclusions drawn from the factor 3 score map (Map 26). Because the clusters of stream sediment samples with high concentrations are mapped accurately according to drainage basins, isolated probable mineral occurrences can be located, even when they are small. The length of the dispersion train can be estimated for a few cases in which mines or prospects are known (Map 5). Some correlation with high concentrations of gold (Map 22), silver (Map 23), and tungsten (Map 24) was found. This accurate mapping makes it likely that indications of undiscovered mineralized areas can be found.

Correlation of the factor 3 score map (Map 26) with the factor 9 (raw data) score map of Area C (Map 15) indicates that most high scores for uranium in Area C coincide with high scores for the base metals. The most impressive correlation is between the main cluster of anomalous uranium values at the southern slope of the Mt. Princeton caldera and the high factor 3 scores (mainly base metals). The factor 2 score map of the lanthanides, thorium, and hafnium (Map 16) shows that they are slightly correlated with the base metals.

Some high scores seem to be related to two main tectonic trends: west-northwest and north. The high scores following the west-northwest trend at the southeastern corner of Area B are associated with the Ruby mining district. This trend is located on the tectonic boundary between the high Precambrian structure lying east-northeast and the sedimentary basin and Middle Tertiary intrusions lying west-southwest. A small high-score cluster, composed of only two samples, was identified close to the Iron Hill carbonatite. The samples of this cluster are probably located along the main fault of the west-northwest-trending Gunnison Uplift (Map 2).

Even the large high-score cluster of the Bonanza caldera at the southeastern boundary of the quadrangle, which coincides with Oligocene andesitic lavas and breccias and Tertiary felsic intrusive rocks, seems to be controlled by faults trending northwest and north.

The northward trend is at the northwestern corner of Area C, where high factor scores coincide with the north-trending fault zone extending from Spring Creek to the White River National Forest.

There are some high-score areas in Area C that coincide with the Mancos, Mesaverde, Dakota, and Burro Canyon Formations at the Uncompahgre Uplift, especially where Jurassic formations crop out and there are north-trending faults. Therefore, it is likely that at least part of the sulfidic base-metal mineral assemblage is associated with young magmatic activity and is controlled by faults trending west-northwest and north (Table V).

Precious Metals and Tungsten

Gold and silver mining in the quadrangle was mostly in the Uncompahgre, Lake City, Gold Brick, Ruby, Tincup, Chalk Creek, Tomichi, Monarch, and Bonanza King mining areas (Map 5; Table II). Precious metals are associated with base metals in most of the mines; in the Gold Brick they are associated with molybdenum, tungsten, beryllium, lithium, niobium, and tantalum. One molybdenum and tungsten mine on Green Mountain was not detected by sample C08718.

Twenty-five samples with >0.2 ppm gold (Map 22), 41 with >6 ppm silver (Map 23), and 24 with >25 ppm tungsten (Map 24) are shown. So many samples have concentrations below the detection limits that results for these three metals were not used in the statistical analysis.

High values of gold, silver, and tungsten are concentrated along the Colorado Mineral Belt. There are a few in Area A at the Uncompahgre Uplift, on Log Hill Mesa, south of Montrose. The trends of the three metals are similar to the trends of the base metals. High values of silver occur in a group at the Mosquito Uplift, associated with intensively faulted Precambrian X granite at the northwest-trending eastern margin of the Arkansas River graben.

The importance of mapping high values according to drainage is illustrated by two isolated high values (as opposed to clusters) which identified a small mine between Stubbs Gulch and Long Gulch and prospects close to Cebolla Hot Springs. The respective samples were C09176, with 0.63 ppm gold in the -100 mesh fraction of stream sediment, located about 1.5 km from the mine, and C08401, with 0.22 ppm gold, located about 3 km from the prospects. In both cases, a stream drainage connected the sample with its source.

Regional Assemblages

Five main assemblages are inferred from Fig. 39. They show the following differences for the three geologic or physiographic provinces:

The limestone assemblage is the most important one in Area A. It contains some uranium (Fig. 41, log-transformed data), probably from the Mancos Shale and the Mesaverde Formation. Both of them contain limestone (Map 2). There are few magmatic rocks in the area, which explains why the felsic and mafic rock assemblage are not strongly defined in the factor analysis. The lanthanide assemblage includes some chromium.

In Area B, the mafic-rock assemblage includes calcium and magnesium, with no lithium (Fig. 44). The lanthanide assemblage includes some uranium. Fractionation between the cerium and ytterbium groups is indicated, because the correlation between cerium and dysprosium is only 0.42 (Fig. 43, log-transformed data). The base-metal assemblage contains a little thorium and barium. The felsic assemblage contains lithium. The fifth assemblage is partly a repetition of the first, with low loadings of vanadium, titanium, and chromium; it might represent pyroxene minerals.

The elemental assemblages of Area C are: the lanthanide assemblage; the mafic-rock assemblage, including scandium, iron, cobalt, and vanadium; the

felsic assemblage, with some titanium; the base-metal assemblage, with a little uranium; the limestone assemblage, with some titanium and vanadium; and lithium with a small amount of scandium (six assemblages; Fig. 47, log-transformed data).

CONCLUSIONS

(1) The Sawatch and Gunnison crystalline terrane is the area most favorable for uranium occurrences in the quadrangle, with uranium ore minerals the likely source of high uranium in sediment samples.

(2) The southern Colorado Mineral Belt is favorable for the occurrence of uranium minerals. Base and precious metals appear to be associated with uranium minerals such as pitchblende in vein-type occurrences in shear zones.

(3) Carnotite-type uranium mineral occurrences are likely in the Western Plateau area, mainly at the nose of the Gunnison Uplift.

(4) Base-metal minerals probably occur in an area of north-trending faults in the Uncompahgre Uplift, near Ridgway.

(5) High concentrations of niobium in sediment samples indicate possible occurrences of uranium minerals along the western and northern margins of the West Elk crater, since niobium has been reported elsewhere as a pathfinder for some kinds of uranium minerals in volcanic rocks.

(6) Clusters of anomalous values of uranium are correlated with occurrences of base and precious metals in some areas.

(7) Base-metal minerals are most likely to occur as sulfides with gold, silver, and tungsten, but they may sometimes occur with pitchblende. The gangue minerals might include manganese minerals and barite.

(8) Base-metal and uranium mineral occurrences probably are controlled by faults trending west-northwest and north along the northeast-trending Colorado Mineral Belt.

(9) Uranium in stream water samples is useful in identifying areas favorable for uranium occurrences, except in areas where streamflow is too rapid to allow the contact with rocks necessary for high concentrations of uranium to develop.

(10) A single sample can often indicate the exact location of a mineral occurrence if the relationship of the sample to the drainage basin is carefully analyzed.

(11) Some fractionation between the cerium and ytterbium groups of lanthanides may have occurred, especially in the San Juan and West Elk volcanic fields and the Western Plateau area.

(12) A combination of kriging, drainage basin, and factor score mapping may be useful in locating mineralized areas.

(13) Log transformation of geochemical data may be important where the distribution is highly skewed.

RECOMMENDATIONS

Follow-up field studies should be conducted in areas identified by this analysis as favorable for the occurrence of uranium, base metals, and precious metals. The preferred areas are the southern Colorado Mineral Belt, the nose of the Gunnison Uplift, the western and northern margins of the West Elk crater, and the Uncompahgre Uplift near Ridgway.

The statistical techniques upon which this report is based should be applied to other hydrogeochemical and stream sediment data to identify other areas in which mineral occurrences might be significant.

ACKNOWLEDGMENTS

The authors gratefully acknowledge the help of the following individuals in preparation of this report: Debbie A. Gambrell and Nancy J. Eckhoff, who typed the report; John A. Paskiewicz, who drafted the figures and maps; Mary E. Luke, who helped during all the stages of the work; and Andrea Kron, who edited the report for English usage.

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Fig. 1. Histogram and cumulative frequency distribution of uranium concentrations in sediment samples

Fig. 2. Histogram and cumulative frequency distribution of copper concentrations in sediment samples

Fig. 3. Histogram and cumulative frequency distribution of lead concentrations in sediment samples

Fig. 4. Histogram and cumulative frequency distribution of lithium concentrations in sediment samples

Fig. 5. Histogram and cumulative frequency distribution of aluminum concentrations in sediment samples

Fig. 6. Histogram and cumulative frequency distribution of barium concentrations in sediment samples

Fig. 7. Histogram and cumulative frequency distribution of calcium concentrations in sediment samples

Fig. 8. Histogram and cumulative frequency distribution of cobalt concentrations in sediment samples

Fig. 9. Histogram and cumulative frequency distribution of chromium concentrations in sediment samples

Fig. 10. Histogram and cumulative frequency distribution of iron concentrations in sediment samples

Fig. 11. Histogram and cumulative frequency distribution of hafnium concentrations in sediment samples

Fig. 12. Histogram and cumulative frequency distribution of potassium concentrations in sediment samples

Fig. 13. Histogram and cumulative frequency distribution of cerium concentrations in sediment samples

Fig. 14. Histogram and cumulative frequency distribution of magnesium concentrations in sediment samples

Fig. 15. Histogram and cumulative frequency distribution of scandium concentrations in sediment samples

Fig. 16. Histogram and cumulative frequency distribution of manganese concentrations in sediment samples

Fig. 17. Histogram and cumulative frequency distribution of thorium concentrations in sediment samples

Fig. 18. Histogram and cumulative frequency distribution of titanium concentrations in sediment samples

Fig. 19. Histogram and cumulative frequency distribution of vanadium concentrations in sediment samples

Fig. 20. Histogram and cumulative frequency distribution of zinc concentrations in sediment samples

Fig. 21. Histogram and cumulative frequency distribution of dysprosium concentrations in sediment samples

Fig. 22. Scattergram showing correlation between uranium and thorium

Fig. 23. Scattergram showing correlation between uranium and cerium

* For scattergram plot, analyses containing values below detection limit were ignored. Because 1217 values were used instead of the whole matrix of 1857, there are minor changes in the statistical parameters.

Fig. 24. Scattergram showing correlation between thorium and cerium

Fig. 25. Scattergram showing correlation between hafnium and thorium

* For scattergram plot, analyses containing values below detection limit were ignored. Because 1217 values were used instead of the whole matrix of 1857, there are minor changes in the statistical parameters.

Fig. 26. Scattergram showing correlation between copper and lead

Fig. 27. Scattergram showing correlation between lead and zinc

* For scattergram plot, analyses containing values below detection limit were ignored, except for copper and lead where detection limit was used as absolute value. Because 1217 values were used instead of the whole matrix of 1857, there are minor changes in the statistical parameters.

Fig. 28. Scattergram showing correlation between copper and zinc

Fig. 29. Scattergram showing correlation between iron and vanadium

* For scattergram plot, analyses containing values below detection limit were ignored, except for copper and lead where detection limit was used as absolute value. Because 1217 values were used instead of the whole matrix of 1857, there are minor changes in the statistical parameters.

Fig. 30. Scattergram showing correlation between iron and titanium

Fig. 31. Scattergram showing correlation between iron and cobalt

* For scattergram plot, analyses containing values below detection limit were ignored. Because 1217 values were used instead of the whole matrix of 1857, there are minor changes in the statistical parameters.

Fig. 32. Scattergram showing correlation between iron and scandium

Fig. 33. Scattergram showing correlation between cobalt and manganese

* For scattergram plot, analyses containing values below detection limit were ignored. Because 1217 values were used instead of the whole matrix of 1857, there are minor changes in the statistical parameters.

Fig. 34. Scattergram showing correlation between cobalt and chromium

Fig. 35. Scattergram showing correlation between cerium and dysprosium

* For scattergram plot, analyses containing values below detection limit were ignored. Because 1217 values were used instead of the whole matrix of 1857, there are minor changes in the statistical parameters.

Fig. 36. Multi element correlation, 1857 sediment samples, raw data

Fig. 37. Multi element correlation, 1857 sediment samples, log-transformed data

PA2 Varimax, Raw Data

PA1 Varimax, n Factor=9, Raw Data

PA2 Varimax, Log-Transformed Data

(22.0%) : Of total information, 22.0% is loaded in factor 1 using raw data

Fig. 38. Factor Analysis, 1857 sediment samples

Fig. 39. Multi element correlation, 409 sediment samples, Area A, raw data

Fig. 40. Multi element correlation, 409 sediment samples, Area A, log-transformed data

PA2 Varimax, Raw Data

PA2 Varimax, Log-Transformed Data

23.3% Of total information, 23.3% is loaded in factor 1 using raw data

Fig. 41. Factor Analysis, 409 sediment samples, Area A

Fig. 42. Multi element correlation, 783 sediment samples, Area B, raw data

Fig. 43. Multi element correlation, 783 sediment samples, Area B, log-transformed data

PA2 Varimax, Raw Data

PA2 Varimax, Log-Transformed Data

Fig. 44. Factor analysis, 783 sediment samples, Area B

Fig. 45. Multi element correlation, 665 sediment samples, Area C, raw data

Fig. 46. Multi element correlation, 665 sediment samples, Area C, log-transformed data

PA2 Varimax, Raw Data

PA1 Varimax, N Factor = 9, Raw Data

PA2 Varimax, Log-Transformed Data

26.2% - Of total information, 26.2% is loaded in factor 1 using log transformed data.

Fig. 47. Factor analysis, 665 sediment samples, Area C

Fig. 48. Multi element correlation, 90 sediment samples in which uranium is > 20 ppm, log-transformed data

30.9% - Of total information 30.9% is loaded in factor 1.

Fig. 49. Factor analysis, 90 sediment samples in which uranium is > 20 ppm, log-transformed data

Fig. 50. Multi element correlation, 192 sediment samples in which copper is >50 ppm, log-transformed data

Fig. 51. Multi element correlation, 102 sediment samples, Area C, in which copper is >50 ppm, log-transformed data

PA2 Varimax, Whole Quadrangle

30.9% -Of total information 30.9% is loaded in factor 1

PA2 Varimax, Area C

Fig. 52. Factor analysis, 192 and 102 sediment samples, whole quadrangle and Area C, in which copper is >50 ppm, log-transformed data

Fig. 53. Multi element correlation, 237 sediment samples in which lead >40 ppm, log-transformed data

Fig. 54. Multi element correlation, 123 sediment samples, Area C, in which lead >40 ppm, log-transformed data

PA2 Varimax, Whole Quadrangle

27.6% - Of total information 27.6% is loaded in factor 1

PA2 Varimax, Area C

Fig. 55. Factor analysis, 237 and 123 sediment samples, whole quadrangle and Area C, in which lead >40 ppm, log-transformed data

Fig. 56. Multi element correlation, 195 sediment samples in which zinc > 180 ppm, log-transformed data

Fig. 57. Multi element correlation, 85 sediment samples, Area C, in which zinc >180 ppm, log-transformed data

TABLE I
GENERALIZED DESCRIPTIONS OF MAJOR URANIUM AND THORIUM DISTRICTS
(Locations of specific occurrences are shown in Map 4)

<u>County</u>	<u>District or Area</u>	<u>Description</u>
Delta	Gunnison River area	The five occurrences in the area are radioactive spring deposits that are found in the Dakota Sandstone. One is associated with a fault. No uranium minerals are visible; abnormal radium contents have been reported.
San Miguel Ouray Hinsdale	Southwest Montrose quadrangle	Only 18 tons of ore averaging 0.20% U ₃ O ₈ are reported from these three counties (Nelson-Moore and others, 1978). Most uranium occurrences are in veins in Tertiary volcanic rocks; one radioactive spring deposit is known. Uranium is associated with rhyolite-latite intrusive rocks and breccia zones. The uranium minerals are mostly uranophane and pitchblende. In San Miguel County, tabular orebodies are found in the Entrada Sandstone. Average ore grade is 0.05% U ₃ O ₈ ; the uranium is closely associated with vanadium. One such occurrence is reported in the extreme southwest corner of the quadrangle.
Gunnison Chaffee Park	Northeast Montrose quadrangle	About 200 tons of ore, averaging 0.12 to 0.22% U ₃ O ₈ , were taken from deposits in the area (Nelson-Moore and others, 1978). Most uranium occurrences are vein-type in pegmatites in Precambrian granitic rocks; some are associated with veins, dikes, and fault breccias of Tertiary intrusive rocks; a few are found along fault contacts between Paleozoic quartzite and Precambrian granite. Deposits are usually small. Uranium is associated with faults, fractures, alteration zones, carbonaceous trash (especially in fault zones), and base-metal minerals. Autunite, columbite, pitchblende, brannerite, and monazite are principal uranium minerals. These types of occurrence are found throughout the quadrangle.
Gunnison	Powderhorn thorium district	Most of the thorium occurrences are radioactive anomalies in veins in Precambrian granite, schist, and gneiss. Deposits consist of thorite and minor amounts of uranium minerals, quartz, barite, hematite, and sulfides.
Saguache	Cochetopa district	The production total to 1971 for the district is about 486,000 tons of ore containing 0.11 to 0.20% U ₃ O ₈ (Nelson-Moore and others, 1978). Uranium generally occurs in fault breccia or shear zones between the Morrison Formation (or sometimes the Dakota Sandstone) and Precambrian rocks, or in veins cutting Precambrian rocks. Uranium may also be associated with malachite, azurite, or other base-metal minerals. The Morrison Formation is mainly sandstone and mudstone, whereas the Precambrian rocks are generally granite or schist. The principal uranium-bearing minerals include pitchblende, uranophane, autunite, torbernite, and zippeite.
Saguache	Periphery of Cochetopa district	Southeast and around the periphery of the Cochetopa district, several uranium occurrences are reported in the Miocene Potosi Volcanic Series, or in Cretaceous rocks that are overlain by these volcanic rocks.
Saguache Gunnison	Marshall Pass district	More than 105,000 tons of ore, ranging from 0.25 to 1.17% U ₃ O ₈ , have been produced from the district. All occurrences in the area are related to the Chester fault or the Indian Creek anticline. The principal host rocks include the Ordovician Harding Quartzite and the Pennsylvanian Belden Shale, which are in fault contact with Precambrian rocks. The Harding Quartzite is a porous, silty sandstone, whereas the Precambrian rocks include highly fractured granites, schists, and pegmatites. Uranium is associated with iron-stained, fossiliferous, and carbonaceous zones. Sulfides may be present. The uranium minerals are pitchblende, uranophane, uraninite, and minor amounts of gummite, autunite, and zippeite. Several occurrences of similar type are found southeast of the district.

TABLE II
METAL-MINING DISTRICTS HAVING GREATER THAN ONE MILLION DOLLARS CUMULATIVE PRODUCTION .
(From Burbank and Luedke, 1968)
(Mining Districts are shown on Map 5)

<u>Mining District</u>	<u>Principal Commodity</u>	<u>Deposit Setting</u>
Uncompahgre (Ouray)	Silver, gold, lead, copper, zinc	Fissure veins and bedded replacement deposits in the Dolores and Morrison Formations, Leadville Limestone, Dakota Quartzite, and Molas Formation; associated with quartz monzonite.
Lake City	Silver, lead, gold, copper, zinc	NE- and NW-trending fissure veins in andesite, rhyolite, and monzonite porphyry intrusive rocks.
Ruby (Irwin, Keystone, Forest Queen, and Mt. Emmons)	Molybdenum	Stockwork deposits associated with intermediate to felsic porphyry intrusive rocks.
Gold Brick-Quarry Creek (Ohio City, Gold Hill, and Cumberland Pass)	Silver, gold, lead	Veins trending N5°W in Precambrian granite and schist; replacement deposits in Fremont Dolomite, Leadville Limestone, and limestone beds in the Belden Shale.
	Molybdenum, tungsten	E- and NE-trending quartz veins in Precambrian quartz monzonite and Cambrian quartzite.
	Lepidolite, beryl, feldspar, columbite-tantalite	NE- and N-trending quartz veins in Precambrian schists, quartzite, metadiorite, and gneiss.
Tincup	Silver, gold, lead	Bedded replacement deposits in Leadville Limestone associated with quartz diorite and quartz monzonite, N-trending quartz veins along faults, and placer deposits.
Chalk Creek (Alpine, Romley, St. Elmo)	Gold, silver, lead, copper, zinc	N- to NE-trending quartz veins in Tertiary quartz monzonite.
Tomichi (White Pine)	Lead, zinc, silver, copper, gold	Replacement and contact deposits, fissure veins in Manitou Dolomite and Leadville Limestone, associated with quartz monzonite and granite porphyry.
Monarch (not shown on Map 5)	Silver, gold, lead, zinc, copper	Replacement deposits in limestone and dolomite of the Manitou Formation, Leadville Limestone, and Fremont Formation; NE-trending veins in Tertiary quartz monzonite.
Brown's Canyon (not shown on Map 5)	Fluorite	NW-trending fissure veins along faults in Precambrian granite and gneiss and Tertiary rhyolite porphyry.
Bonanza King (Kerber Creek)	Silver, lead, zinc, copper, gold	NW- and N-trending quartz veins in Tertiary andesite, latite, rhyolite, diorite, monzonite, and granite porphyry.

TABLE III
BASIC STATISTICS (IN PPM) FOR 21 ELEMENTS IN SEDIMENTS

Computer Code No.	Element	Whole Quadrangle					Sawatch-Gunnison Crystalline Terrane				
		Whole Area (1857 Samples)		Whole Area Below Threshold			665 Samples		Below Threshold		
		Average	Standard Deviation	Average	Standard Deviation	Samples ^b	Average	Standard Deviation	Average	Standard Deviation	Samples ^b
C228	U	6.4	9.0	4.8	3.2	1767	11.0	13.2	6.8	4.5	577
C232	Cu	43.3	121.0	26.7	9.0	1659	48.7	131.3	28.7	10.1	558
C235	Pb	64.7	407.1	14.8	10.2	1685	99.5	608.7	18.1	12.3	588
C239	Li	32.0	22.5	28.9	13.7	1758	35.8	19.2	32.3	14.2	618
C240	Al	63468.8	12869.9	62332.5	12209.9	1759	61896.1	14553.9	60761.3	13862.8	634
C242	Ba	673.4	272.8	635.0	174.6	1754	633.8	256.8	600.5	182.0	633
C243	Ca	25577.1	23756.6	-	-	-	23163.0	23340.9	-	-	-
C246	Co	11.4	5.2	10.5	3.2	1758	11.2	3.5	10.9	3.0	649
C247	Cr	40.0	26.4	37.7	19.9	1823	49.4	34.2	44.1	22.3	635
C251	Fe	27194.6	17318.5	24830.0	10929.3	1788	28938.4	18253.7	25855.2	10366.6	647
C252	Hf	12.1	13.4	10.1	5.0	1778	16.7	20.3	11.7	5.7	600
C253	K	16667.2	4311.5	-	-	-	17430.6	4884.5	-	-	-
C244	Ce	103.0	129.9	92.4	43.0	1814	137.4	197.7	115.6	56.1	631
C256	Mg	16019.6	9232.3	14696.6	5770.9	1761	17321.1	12151.9	14954.8	5922.8	610
C257	Mn	883.3	551.6	808.9	373.9	1777	947.3	569.5	853.5	337.1	630
C261	Sc	10.1	4.0	9.4	3.1	1759	11.4	4.6	10.3	3.3	603
C266	Th	14.6	27.0	12.0	6.7	1799	22.3	43.4	15.6	9.3	608
C267	Ti	4954.6	2290.8	4634.7	1679.4	1779	5172.8	2418.6	4805.8	1751.0	632
C268	V	102.1	65.7	89.2	36.9	1737	93.1	57.6	86.4	35.2	646
C270	Zn	162.4	234.3	81.0	44.8	1658	194.7	1060.5	79.7	45.5	578
C289	Dy	5.3	4.3	4.6	1.5	1751	7.0	5.9	5.5	1.9	569

TABLE III (Cont'd)

San Juan and West Elk Volcanic Fields							Western Plateau Area				
Computer Code No.	Element	783 Samples		Below Threshold		Samples ^b	409 Samples		Below Threshold		Samples ^b
		Average	Standard Deviation	Average	Standard Deviation		Average	Standard Deviation	Average	Standard Deviation	
C228	U	3.8	2.0	3.8	1.7	781	3.7	0.9	3.7	0.9	409
C232	Cu	40.2	105.8	25.1	8.1	729	40.5	130.3	26.9	8.1	372
C235	Pb	46.8	235.7	12.2	7.9	737	42.1	203.6	14.7	9.3	360
C239	Li	25.3	24.5	23.7	10.8	774	38.7	19.8	34.0	14.4	366
C240	Al	68240.2	10347.5	67887.4	9681.2	718	56891.5	10603.6	56744.4	10417.8	407
C242	Ba	756.2	304.9	700.1	152.8	716	578.9	168.7	573.8	161.2	405
C243	Ca	22121.5	12894.1	-	-	-	36117.9	35952.9	-	-	-
C246	Co	12.0	5.7	10.8	3.2	720	10.7	6.1	9.7	3.1	398
C247	Cr	30.0	18.0	29.6	16.7	780	43.7	17.7	43.2	15.5	408
C251	Fe	28959.7	17901.5	25804.3	11290.1	741	20980.1	12579.5	19749.2	9502.0	400
C252	Hf	10.0	5.7	9.6	4.2	772	8.8	5.4	8.5	4.3	406
C253	K	16875.4	4070.8	-	-	-	15027.6	3200.6	-	-	-
C244	Ce	90.3	50.7	86.7	26.1	776	71.2	70.4	67.4	22.7	407
C256	Mg	15066.5	7060.9	14375.8	5875.7	758	15728.1	6874.8	14914.7	5480.2	393
C257	Mn	982.4	525.3	918.0	362.8	746	589.7	464.1	546.9	324.1	401
C261	Sc	10.0	3.7	9.5	2.9	749	7.9	2.6	7.9	2.5	407
C266	Th	10.6	7.1	10.4	3.8	782	9.8	3.1	9.8	3.1	409
C267	Ti	5322.8	2384.9	4905.3	1638.5	739	3894.8	1409.4	3879.3	1376.1	408
C268	V	110.1	76.0	90.0	37.1	705	101.3	53.8	92.3	38.8	386
C270	Zn	146.4	365.8	84.7	44.2	717	140.5	602.8	76.0	44.5	363
C249	Dy	4.4	1.7	4.3	1.2	777	4.2	3.9	4.0	1.0	405

Values below the detection limit were calculated as half the absolute value of detection limit.

U, Cu, Pb, Li, Al, Ba, Co, Cr, Fe, Hf, and Ce are calculated below the threshold values that are summarized in Table IV.

TABLE IV

THRESHOLD VALUES ESTIMATED FROM LOG PROBABILITY PLOTS FOR 20 ELEMENTS

<u>Element</u>	<u>No. of Values Below Detection Limit</u>	<u>Threshold (in ppm)</u>	<u>Cumulative % At Which Threshold Chosen</u>	<u>Sawatch and Gunnison Terrane</u>	<u>San Juan and West Elk Volcanic Fields</u>	<u>Western Plateau</u>
U	—	20	93	Not lognormal. Threshold of 20 ppm at 93%.	Very low mean of 3.5 ppm. Minor threshold at 11 ppm.	Lognormal; very low mean of 3.5 ppm.
Cu	32	50	91	Two populations, with a lower threshold of 60 ppm; 50 ppm at 86%.	Two populations, with the lower threshold of 50 ppm at 94%.	Threshold at 91%.
Pb	227	40, 60	~88, 88	Threshold of 60 ppm at 88%; two populations.	Threshold of 40 ppm at 91%; two populations, with a boundary at 60 ppm at 93%.	Threshold of 40 ppm at 86%; two populations.
Li	15	65	96			
Al	3	80,000	96			
Ba	47	1,000	96			
Co	—	20	96			
Cr	168	120	98			
Fe	—	65,000	96			
Hf	1	30	96			Total values low, lower threshold of 16 ppm at 91%.
Ce	—	300	~98			
Mg	64	30,000	96			
Mn	—	1,800	96			
Sc	—	18	96			
Th	—	50	~97			Low values.
Ti	18	10,000	96			
V	6	200	96			
Zn	503	180	87	Two populations, with a boundary at 180 ppm at 91%.	Two populations, with a boundary at 280 ppm at 93%.	Two populations, with a boundary at 180 ppm at 85%.
Dy	6	11	~97			

*The method used for this estimation is according to Lepeltier (1969). For the log probability plots, values below detection limit, marked by a minus sign, were ignored. Therefore, absolute values of mean and threshold could be a little too high, especially in those elements that have many values below detection limit.

TABLE V

CORRELATION BETWEEN CLUSTERS OF ABOVE-THRESHOLD VALUES
FOR ELEMENTS AND THE GEOLOGY OF SEDIMENT SAMPLES

Geologic Province	Strong Assoc.	Moderate Assoc.	Minor Assoc.	Correlations With Other Elements
URANIUM:				
Sawatch- Gunnison terrane	Xg, Tmi	Xfh, Xb	XYg, MCr, MOr, TKi, Tpl, Td	Pb, Zn, Cu, and minor Ag, Au, and W in the Mt. Princeton batholith

Comments: High concentrations of uranium are principally associated with Precambrian X granites (Xg) and mid-Tertiary felsic plutons (Tmi). A lesser number of anomalous samples is associated with Precambrian X biotite and hornblende gneisses (Xb and Xfh). Many anomalous samples were collected downstream from major faults.

The uranium threshold is 20 ppm.

BASE METALS:

Western Plateau area	Km, Kdb	Jmwe and N-trending faults	Kmv and E-trending faults	Au, Ag, W

Comments: Most of the anomalous base-metal values in the area occur in the Mancos (Km) and Dakota and Burro Canyon (Kdb) Formations. Many of these samples were collected downstream from N-trending faults; some are spatially related to E-trending faults.

San Juan- West Elk volcanic fields	Tpl	Taf, Tmi	TPdc, KJde, Kmv, Km, TKi	Ag

Comments: In the San Juan-West Elk volcanic fields, anomalous base-metal values are most strongly associated with areas of mid-Tertiary volcanic rocks (Tpl) and less strongly with mid-Tertiary felsic intrusions (Tmi) and ash-flow tuffs (Taf). Most of the anomalous samples occur within or marginal to the Lake City, Bonanza, and Uncompahgre calderas.

TABLE V, Continued

Geologic Province	Strong Assoc.	Moderate Assoc.	Minor Assoc.	Correlations With Other Elements

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BASE METALS, continued:

Sawatch- Gunnison terrane	Xg, Xfh, Tmi, NW-trending faults	Xb, MCr, MOr, Tpl, N-trending faults	Yam, Cam, TKi, NE- and E-trending faults	U, Ag, Au, W

Comments: Anomalous base-metal values are most strongly associated with Precambrian X granites (Xg) and hornblende gneisses (Xfh) and with mid-Tertiary felsic plutonic rocks (Tmi) at the Mt. Princeton batholith. Many of the anomalous samples occur downstream from NW-trending faults; some are spatially related to N-trending faults.

The thresholds are Cu 50, Pb 40, and Zn 180 ppm. Anomalous values generally occur in the same samples.

PRECIOUS METALS:

Western Plateau area	Kdb	Km, TKtc

Comments: Gold-bearing sediments in the Western Plateau area were sampled in streams draining the Dakota and Burro Canyon (Kdb) Formations. One silver-bearing sediment sample was collected from a stream cutting through the Mancos Shale (Km) and the Telluride Conglomerate and Cimarron Ridge Formation (TKtc).

San Juan- West Elk volcanic fields	Tpl	Taf	Cu

Comments: In the San Juan and West Elk volcanic fields, most gold- and silver-bearing sediments are located within the Colorado Mineral Belt trend. Silver-bearing sediments occur also in the Bonanza caldera in the Bonanza King mining district. The largest group of gold-bearing sediments occurs along the northwest margin of the Uncompahgre caldera in the Uncompahgre mining district.

TABLE V, Continued

Geologic Province	Strong Assoc.	Moderate Assoc.	Minor Assoc.	Correlations With Other Elements
PRECIOUS METALS, continued:				
Sawatch-Gunnison terrane	Xfh, Tmi, NW- and NE-trending faults	Xg		Pb, Zn, Cu, U

Comments: Gold in the Sawatch-Gunnison terrane is strongly associated with Precambrian metamorphic rocks (Xfh) in the Gold Brick-Quarry Creek mining district and with mid-Tertiary plutonic rocks (Tmi) of the Mt. Princeton batholith in the Chalk Creek mining district. Silver-bearing sediments are related to the Tomichi mining district in the Sawatch Range. Other gold- and silver-bearing sediments not related to known mining camps are heavily concentrated near NW-trending faults on the western margin of the Mosquito Uplift.

The thresholds are Au 0.2 and Ag 6 ppm.

Geologic units from Tweto and others (1976): Xfh = Precambrian X felsic and hornblende gneiss; Xb = biotitic gneiss; Xg = $\approx$ 1700 m.y. granitic rocks; XYg = Precambrian X and Precambrian Y granitic rocks, undivided; Yam = $\approx$ 1400 m.y. alkaline and mafic rocks; Cam = Cambrian alkaline and mafic intrusive rocks; MCr = Mississippian, Devonian, Ordovician, and Cambrian rocks; MOR = Mississippian, Devonian, and Ordovician rocks; TPdc = Dolores and Cutler Formations; Jmwe = Morrison, Wanakah, and Entrada Formations; Km = Mancos Formation; Kmv = Mesaverde Formation; Kdb = Dakota and Burro Canyon Formations; TKi = felsic Laramide intrusive rocks; TKtc = Telluride Conglomerate and Cimarron Ridge Formation; Tpl = Oligocene andesitic lavas and breccias; Tmi = middle Tertiary intrusive rocks; Taf = Oligocene ash-flow tuff; Td = late Tertiary Dry Union Formation.

TABLE VI
BASIC STATISTICS (IN PPM) FOR 21 ELEMENTS IN SEDIMENTS
FROM THE MONTROSE QUADRANGLE, COLORADO
WHERE URANIUM, LEAD, COPPER, AND ZINC ARE ABOVE THRESHOLD

Element	U >20 ppm (90 samples)		Cu >50 ppm (192 samples)		Pb >40 ppm (237 samples)		Zn >180 ppm (195 samples)	
	Average	Standard Deviation	Average	Standard Deviation	Average	Standard Deviation	Average	Standard Deviation
U	37.8	20.7	9.8	11.1	9.4	9.7	8.5	7.8
Cu	53.7	82.7	186.5	344.1	148.1	318.3	169.8	347.1
Pb	96.5	253.4	454.5	1193.0	414.4	1078.2	466.5	1182.8
Li	38.1	18.5	34.4	18.8	37.0	17.6	33.2	17.2
Al	62760.0	14771.6	61031.8	15738.5	62031.3	14705.0	61598.4	14677.0
Ba	570.2	238.5	785.7	608.3	735.4	469.0	753.6	542.3
Ca	17674.2	6850.8	22425.1	15248.0	22914.4	21166.2	22343.1	15984.8
Co	11.1	3.2	15.3	7.2	12.5	5.5	16.4	9.8
Cr	42.7	33.0	49.3	40.4	36.2	18.9	39.2	22.9
Fe	35002.8	32327.1	37321.3	20074.5	31299.8	16661.1	39419.3	25120.2
Hf	27.3	36.7	10.9	6.7	13.5	11.8	12.3	8.4
K	18907.2	5431.1	16783.2	5578.5	18099.1	5427.2	16671.3	5434.9
Ce	259.5	492.4	116.5	82.6	115.9	66.0	126.6	120.0
Mg	14458.5	6947.4	18254.7	9060.2	16016.8	6884.3	16763.7	6925.7
Mn	1193.1	642.1	1352.0	981.8	1149.2	928.8	1381.9	974.4
Sc	11.0	3.8	12.1	4.3	10.2	3.3	11.3	4.0
Th	55.0	106.9	16.3	11.8	19.2	13.7	17.0	11.7
Ti	5690.8	3317.9	5558.8	3001.3	4837.0	2061.1	5532.9	2998.8
V	107.0	95.8	131.0	91.9	108.8	69.0	135.4	108.2
Zn	233.0	522.1	794.6	2179.5	688.5	1974.0	853.6	2145.8
Dy	10.5	12.4	5.2	2.4	5.6	3.2	5.9	5.9

TABLE VII

ELEMENTAL ABUNDANCES IN ACIDIC AND BASIC ROCKS^{a,b}

Element	Acidic Rocks	Basic Rocks
U	1 - 10	0.1 - 1
Cu	15 - 20	40 - 80
Pb	20 - 50	2.7 - 4.3
Li	70 - 700 ^c	75 ^c
Ba	730 - 880	14.5 oceanic basalt 246 tholeiitic basalt 613 alkali basalt
Co	1 - 2	40 - 50 (ultrabasic 70 - 120)
Cr	16 - 22	200 - 300 (ultrabasic 2000 - 3000)
Dy	6.1	5.9
Eu	1.1	1.5
Fe	2.5% ^c	8.8% ^c
Hf	<10	2.8 - 3.3
K	38	6.1
Ca	55	16
Mn	500 ^c	1500 ^c
Sc	3 - 10	23 - 92
Sm	6.2	4.3
Th	10 - 20	0.5 - 2
Ti	2600 - 5000	22,000
V	17 - 30 ^c	56 - 320 ^c
Zn	30 - 70	80 - 120
Ni	5 - 15	50 - 500 (ultrabasic 1000 - 1450)
Nb	14 - 24	10 - 14
Au	0.002 - 0.004	0.003 - 0.004
Ag	0.05 - 0.1	0.02 - 0.08
W	1.42 - 2.5	0.5 - 1.0

a Average after Wedepohl and others (1978)

b Units are ppm unless otherwise specified

c Rankama and Sahama (1968)

APPENDIX

List of samples and values above threshold for uranium, copper, lead, cobalt, chromium, hafnium, cerium, thorium, titanium, zinc, and dysprosium

Thresholds (from Table IV)

<u>Element</u>	<u>ppm</u>
U	20
Cu	50
Pb	40 to 60
Co	20
Cr	120
Hf	30
Ce	300
Th	50
Ti	10,000
Zn	180
Dy	11

APPENDIX

LIST OF SAMPLES AND VALUES ABOVE THRESHOLD FOR URANIUM, COPPER, LEAD, COBALT, CHROMIUM, HAFNIUM, CERIUM, THORIUM, TITANIUM, ZINC, AND DYSPROSIUM

Sample Number	Latitude	Longitude	U (ppm)	Sample Number	Latitude	Longitude	U (ppm)
18415	38.062778	107.425833	26.90	19001	38.878754	106.414852	24.57
18608	38.803540	106.238022	29.40	19002	38.867680	106.429983	39.01
18609	38.812500	106.226944	27.33	19004	38.863450	106.494359	39.12
19611	38.815780	106.168011	23.60	19009	38.637193	106.359365	26.25
18627	38.542769	106.134277	27.88	19010	38.655630	106.374779	27.66
18632	38.612474	106.019947	30.04	19011	38.670057	106.376377	27.18
18646	38.660421	106.091308	20.49	19012	38.675709	106.382909	24.68
18647	38.687079	106.094325	32.52	19013	38.700725	106.339742	26.13
18669	38.540944	106.243732	34.77	19018	38.680259	106.273707	24.92
18672	38.543754	106.187869	32.03	19019	38.680421	106.268766	24.80
18673	38.575446	106.209096	33.87	19020	38.708865	106.272558	22.46
18694	38.662459	107.218778	22.36	19022	38.643821	106.253241	45.30
18696	38.713949	106.205227	21.27	19023	38.609754	106.317502	25.19
19697	38.715049	106.221762	20.64	19024	38.600996	106.286680	25.98
18699	38.707800	106.228033	53.26	19027	38.554345	106.301897	27.28
18705	38.684718	106.175321	57.94	19028	38.586111	106.329106	33.07
18707	38.671165	106.163129	34.58	19030	38.501102	106.401869	37.93
18708	38.667761	106.161039	50.59	19034	38.533869	106.490154	26.96
18709	38.649055	106.212242	60.52	19190	38.944167	106.059722	23.70
18710	38.664830	106.220586	22.58	19199	38.754263	106.130952	22.51
18712	38.529401	106.464701	20.38	19200	38.988125	106.211641	66.50
18713	38.520880	106.422475	31.40	19206	38.897162	106.122758	22.49
18714	38.518306	106.419086	38.65	19209	38.903956	106.067165	27.72
18715	38.624753	106.409178	26.20	19216	38.458351	106.268398	32.87
18717	38.604036	106.466182	22.78	19356	38.389237	106.281615	24.90
18727	38.586759	106.680597	36.99	19401	38.656183	106.573944	64.09
18935	38.441716	106.377874	28.46	19403	38.674769	106.567845	30.85
18837	38.422445	106.399855	20.70	19416	38.442172	106.357704	34.84
18840	38.457600	106.409897	33.45	19423	38.952095	106.666414	20.98
18842	38.475510	106.401820	24.32	19426	38.938348	106.676972	26.75
18844	38.436902	106.439178	21.49	19435	38.921890	106.592902	49.73
18845	38.419944	106.427744	47.21	19439	38.847775	106.551345	20.60
18846	38.405041	106.409757	40.79	19444	38.679652	106.518100	32.38
18941	38.955662	106.467155	26.84	19447	38.968334	106.564786	46.21
18942	38.983045	106.443477	23.39	19448	38.947941	106.593485	73.16
18945	38.988543	106.413905	30.04	19458	38.616305	106.566529	91.51
18949	38.813105	106.272119	64.63	19473	38.790157	106.870159	24.53
18951	38.818036	106.332584	48.43	19510	38.721254	106.602458	74.50
18957	38.764705	106.332766	27.28	19511	38.720669	106.603722	136.90
18960	38.782495	106.262031	37.61	19515	38.772071	106.811629	23.70
18967	38.756736	106.376544	38.18	19516	38.750082	106.790397	48.26
18974	38.907437	106.313461	69.77				
18976	38.871621	106.309862	55.20				
18977	38.854277	106.342249	56.09				
18978	38.867994	106.334902	74.16				
18979	38.882545	106.355206	74.71				
18988	38.845684	106.322925	61.00				
18998	38.871899	106.384318	20.80				
19000	38.907807	106.331622	21.16				

APPENDIX (continued)

Sample Number	Latitude	Longitude	Cu (ppm)	Sample Number	Latitude	Longitude	Cu (ppm)
18003	38.030274	107.155449	78	18357	38.151944	107.252500	275
18062	38.416044	107.812779	52	18363	38.093611	107.291667	194
18070	38.449147	107.855556	77	18365	38.071044	107.296667	194
18090	38.378999	107.795000	53	18367	38.077222	107.348889	215
18092	38.341944	107.775556	55	18382	38.073333	107.049444	89
18099	38.319444	107.725000	117	18384	38.092500	107.028333	79
18101	38.286349	107.762779	172	18396	38.244722	107.037222	100
18103	38.460000	107.844667	69	18399	38.248333	107.065833	88
18104	38.425000	107.917500	90	18401	38.271667	107.080000	83
18109	38.273333	107.975000	118	18418	38.022500	107.400556	263
18126	38.208756	107.633889	99	18419	38.021111	107.403056	201
18139	38.177778	107.928333	63	18420	38.019167	107.402222	43
18155	38.000278	107.659167	65	18421	38.013056	107.435556	57
18157	38.006389	107.663611	152	18422	38.011111	107.436111	146
18158	38.053511	107.824722	194	18424	38.023056	107.493611	53
18159	38.048333	107.820833	55	18432	38.352222	107.965556	71
18163	38.032500	107.793056	53	18438	38.288889	107.945556	90
18166	38.122222	107.887222	113	18441	38.258611	107.904667	74
18168	38.107772	107.901349	57	18444	38.276389	107.864444	90
18172	38.089444	107.998333	80	18445	38.319444	107.848889	60
18173	38.088056	107.998889	55	18449	38.955670	107.529444	76
18178	38.409167	107.891111	54	18490	38.976722	107.534044	61
18180	38.145278	107.772222	87	18521	38.908722	107.174733	59
18197	38.052500	107.690556	131	18595	38.984042	106.018422	100
18199	38.102722	107.737222	53	18599	38.957165	106.205736	113
18201	38.059167	107.689444	75	18635	38.561544	106.015441	64
18202	38.025278	107.666389	971	18648	38.224733	106.095369	632
18203	38.021111	107.676944	192	18669	38.540944	106.243732	67
18204	38.019722	107.676389	117	18670	38.544456	106.243253	61
18206	38.000033	107.694167	246	18673	38.579544	106.209096	64
18207	38.086944	107.601111	56	18576	38.515447	106.178694	64
18210	38.054147	107.571667	55	18677	38.507734	106.247220	51
18211	38.053333	107.574167	214	18596	38.713949	106.205227	155
18215	38.344722	107.000000	122	18697	38.715744	106.221762	64
18216	38.359444	107.021389	65	18698	38.714941	106.249778	114
18256	38.404147	107.165000	53	18699	38.707900	106.229033	63
18257	38.331389	107.157222	40	18700	38.717391	106.103975	112
18258	38.373944	107.140833	52	18705	38.584214	106.175331	66
18265	38.115833	107.517779	51	18711	38.576930	106.371131	251
18266	38.128333	107.520000	71	18712	38.529401	106.404701	244
18272	38.199444	107.553889	55	18719	38.648113	106.472136	135
18292	38.484722	107.007500	118	18720	38.642422	106.470060	132
18293	38.486467	107.005556	90	18825	38.557570	106.694149	92
18294	38.199444	107.015556	65	18830	38.544995	106.649301	59
18302	38.013056	107.310556	402	18831	38.560299	106.634049	68
18305	38.445278	107.343056	97	18845	38.419746	106.427744	52
18318	38.338333	107.225056	76	18881	38.813745	106.898220	121
18319	38.321944	107.220433	54	18893	38.497814	106.148341	53
18322	38.283440	107.113056	144	18896	38.468880	106.250626	52
18326	38.298149	107.229444	144	18899	38.476389	106.089167	66
18330	38.245833	107.250000	248	18920	38.869382	106.994654	1427
18335	38.003056	107.470000	96	18939	38.951309	106.444944	68
18337	38.019722	107.362778	155	18940	38.954444	106.462203	65
18351	38.157779	107.290833	773	18941	38.955862	106.445755	54
18353	38.163333	107.296389	163	18943	38.985255	106.449075	235
				18944	38.987620	106.409037	63

APPENDIX (continued)

Sample Number	Latitude	Longitude	Cu (ppm)
18945	39.988543	104.413905	55
18947	39.955842	104.409874	55
18952	38.814027	106.334882	62
18956	38.843734	104.451442	51
18957	38.764705	104.332765	59
18960	38.792495	104.262031	134
18961	38.770994	104.411149	66
18965	38.739800	106.430869	75
18967	38.748953	104.446641	331
18968	38.702709	104.494999	200A
18970	38.780694	105.481475	54
18971	38.776748	104.459164	237
18973	38.821705	104.497899	122
18979	38.968545	106.255205	58
18990	38.803722	104.454544	68
18991	38.791774	105.447221	56
18993	38.780243	104.429915	61
19011	38.670057	104.376177	71
19012	38.675709	104.363909	338
19013	39.700725	104.339742	97
19014	38.703145	104.350907	1482
19015	38.698916	106.349043	2054
19017	38.714594	106.311719	74
19018	38.680259	104.273707	94
19019	38.680421	106.269766	65
19020	38.708935	104.272358	74
19023	38.609754	106.317502	123
19026	38.549154	104.297843	77
19027	38.554345	104.301893	650
19028	38.586331	104.339106	282
19035	38.562133	104.464111	98
19036	38.539710	104.438704	203
19037	38.539753	104.430959	375
19038	38.550293	104.389577	511
19092	38.176901	104.039224	94
19094	38.138773	104.039813	72
19095	38.126351	104.050099	63
19097	38.133449	104.100925	57
19165	38.330407	104.761431	47
19171	38.350061	104.860601	53
19172	38.373911	104.863639	54
19218	38.419080	104.125931	63
19226	38.373222	104.242343	57
19228	38.254167	104.127774	790
19229	38.269722	104.150833	144
19230	38.278899	104.146199	1109
19236	38.306647	104.144722	924
19237	38.316954	104.142554	618
19243	38.290270	104.040933	66
19242	38.375702	104.029613	71
19264	38.359579	104.042547	255
19255	38.353518	104.078881	211
19356	38.349237	104.216115	54
19359	38.391335	104.259454	67
19374	38.524167	106.620278	55
19375	38.506294	104.600517	55

Sample Number	Latitude	Longitude	Cu (ppm)
19376	38.612011	104.595821	67
19377	38.583673	104.604137	74
19378	38.566091	104.591029	52
19379	38.566495	104.623930	51
19391	38.542159	106.514764	77
19392	38.590225	106.516734	104
19399	38.627159	106.583177	68
19401	38.656193	105.573944	52
19421	38.970406	105.648525	74
19456	38.767795	105.621512	63
19497	38.908754	107.028214	81
19498	38.906939	107.055052	190
19499	38.931992	107.051583	66
19500	38.957494	107.084806	63
19501	38.978245	107.065604	219
19502	38.957206	107.061626	71
19509	38.869147	107.034667	1593
19520	38.894034	107.003027	66
19543	38.526727	107.651543	58
19700	38.040591	104.035503	94
19763	38.458694	104.934933	62
19768	38.416892	104.924808	64
19770	38.381283	106.884395	58
19783	38.361971	106.932684	73
19841	38.329367	106.596867	51

APPENDIX (continued)

Sample Number	Latitude	Longitude	Pb (ppm)	Sample Number	Latitude	Longitude	Pb (ppm)
14059	38.489722	107.740278	97	18294	38.199444	107.015556	479
14062	38.416944	107.812778	232	18295	38.136667	107.008889	239
14063	38.417778	107.812222	44	18302	38.013056	107.310556	4751
14064	38.488889	107.823889	275	18305	38.445778	107.343056	259
14067	38.470333	107.501389	148	18322	38.283889	107.113056	599
14070	38.449167	107.855556	124	18326	38.298889	107.229444	624
14077	38.355556	107.836111	42	18330	38.245833	107.260000	687
14080	38.378889	107.795000	76	18335	38.003056	107.470000	147
14082	38.341944	107.775556	64	18336	38.021111	107.385556	137
14089	38.319444	107.725000	179	18337	38.019722	107.362778	244
14091	38.318333	107.799722	54	18338	38.018056	107.357500	62
14098	38.239444	107.764444	42	18339	38.006722	107.361111	65
14101	38.286389	107.762778	323	18348	38.206389	107.384444	101
14102	38.287778	107.760556	53	18351	38.157778	107.290833	967
14103	38.460000	107.846667	86	18353	38.163333	107.296389	505
14104	38.425000	107.917500	108	18357	38.151944	107.252500	956
14109	38.273333	107.975000	103	18363	38.093611	107.291667	1069
14117	38.276667	107.717500	86	18365	38.071944	107.296667	1040
14123	38.187500	107.859444	219	18367	38.077222	107.348889	1091
14126	38.208056	107.833889	90	18416	38.050000	107.404722	53
14122	38.080000	107.658333	271	18418	38.027500	107.400556	53
14149	38.177778	107.028333	83	18419	38.021111	107.403056	1387
14156	38.000778	107.659167	187	18420	38.019167	107.402722	148
14157	38.006389	107.663611	504	18421	38.013056	107.435556	128
14158	38.053611	107.824722	126	18422	38.011111	107.436111	102
14159	38.048333	107.820833	89	18429	38.387056	107.956111	57
14160	38.071944	107.807778	125	18431	38.379167	107.953333	68
14163	38.032500	107.793056	126	18432	38.352222	107.965556	110
14165	38.062222	107.815278	125	18436	38.341944	107.911111	44
14166	38.122222	107.887222	449	18438	38.288889	107.945556	143
14168	38.107222	107.901389	114	18441	38.258811	107.906667	104
14169	38.115833	107.933333	177	18444	38.276389	107.864444	132
14170	38.104722	107.956389	332	18445	38.319444	107.848889	71
14172	38.089444	107.998333	113	18449	38.555670	107.528444	243
14173	38.088056	107.998889	113	18522	38.907544	107.148117	57
14178	38.409167	107.891111	82	18564	38.961444	107.139056	62
14180	38.145278	107.772222	95	18600	38.936463	106.188889	42
14181	38.121667	107.783333	48	18601	38.901316	106.176780	43
14183	38.171111	107.772222	63	18603	38.863250	106.241409	55
14197	38.052500	107.690556	185	18623	38.617497	106.121980	47
14198	38.133333	107.733889	50	18624	38.596883	106.086472	48
14199	38.102222	107.737222	45	18625	38.582107	106.093441	65
18200	38.085556	107.702778	51	18626	38.578179	106.093380	62
18201	38.059167	107.689444	360	18633	38.549853	106.008194	47
18202	38.025278	107.666389	162	18634	38.545039	106.070875	88
18203	38.021111	107.676944	181	18635	38.561548	106.015841	210
18204	38.019722	107.676389	114	18638	38.641043	106.085821	50
18205	38.020278	107.665833	178	18639	38.630676	106.070074	52
18206	38.000833	107.694167	3056	18640	38.667810	106.057030	41
18207	38.086944	107.601111	108	18641	38.674601	106.025150	44
18208	38.065278	107.586667	55	18645	38.656935	106.095990	62
18210	38.054167	107.571667	89	18648	38.224733	106.095369	562
18211	38.053333	107.574167	610	18649	38.540964	106.243732	164
18292	38.484722	107.007500	1456	18670	38.544465	106.243253	231
18293	38.486667	107.005556	977	18674	38.538926	106.193661	137
				18679	38.520473	106.118476	48

APPENDIX (continued)

Sample Number	Latitude	Longitude	Pb (ppm)	Sample Number	Latitude	Longitude	Pb (ppm)
18691	38.569915	106.077851	55	19021	38.714055	106.262632	56
18692	38.566196	106.116889	43	19022	38.643871	106.253241	79
18693	38.602789	106.084900	55	19023	38.609754	106.317502	111
18694	38.695390	106.043569	44	19025	38.524694	106.270111	45
18695	38.768160	106.092683	118	19026	38.549154	106.297840	272
18696	38.736667	106.171944	116	19027	38.554345	106.301893	787
18697	38.713949	106.205227	735	19028	38.586331	106.339106	387
18698	38.715048	106.221762	111	19029	38.526424	106.323001	90
18699	38.714941	106.249778	521	19030	38.501107	106.401869	44
18700	38.717391	106.103975	561	19031	38.502965	106.414107	41
18702	38.704641	106.139533	49	19035	38.562133	106.464111	816
18703	38.699143	106.129372	42	19036	38.539719	106.436706	898
18711	38.576930	106.371131	4671	19037	38.539753	106.430958	5832
18712	38.529401	106.404701	939	19038	38.550083	106.399577	11481
18714	38.518306	106.419086	107	19047	38.848590	107.988845	85
18720	38.642820	106.470060	44	19048	38.847541	107.986878	48
18830	38.544995	106.648301	231	19201	38.600917	106.153595	128
18831	38.560299	106.636049	239	19205	38.668297	106.136470	41
18837	38.422446	106.399855	42	19218	38.419080	106.126831	88
18841	38.475944	106.406930	85	19228	38.254167	106.127778	650
18846	38.405041	106.409757	48	19229	38.269722	106.150833	1357
18872	38.953876	106.773001	56	19230	38.278889	106.146199	1164
18881	38.813745	106.898220	91	19236	38.306667	106.144722	1468
18906	38.375000	106.093611	69	19237	38.316956	106.142554	597
18919	38.853900	106.952674	69	19264	38.269573	106.042547	164
18920	38.865382	106.994658	388	19265	38.253518	106.078881	510
18922	38.511525	107.825635	480	19266	38.352479	106.035160	60
18939	38.551308	106.444944	44	19375	38.604256	106.600817	58
18943	38.985255	106.449075	89	19376	38.612011	106.595821	624
18945	38.988543	106.413905	44	19377	38.583673	106.604137	647
18947	38.955882	106.409874	46	19378	38.568091	106.591029	71
18952	38.814027	106.334882	44	19379	38.566405	106.623930	281
18958	38.777262	106.302793	56	19386	38.512146	106.551558	44
18965	38.739800	106.430869	77	19393	38.601317	106.530889	118
18967	38.748953	106.488641	338	19394	38.629460	106.545204	166
18968	38.702709	106.494998	3053	19395	38.611036	106.524308	144
18971	38.776748	106.489164	143	19398	38.571203	106.556627	64
18973	38.821705	106.497899	55	19402	38.662393	106.563886	41
18976	38.871671	106.309863	44	19416	38.442172	106.357704	88
18979	38.868545	106.254206	73	19417	38.458729	106.341490	47
18981	38.598652	106.261578	42	19421	38.970406	106.648526	55
18982	38.983890	106.289778	42	19422	38.951579	106.630850	90
18987	38.932713	106.372983	44	19423	38.952095	106.666414	147
19009	38.637193	106.359365	155	19424	38.958098	106.711180	1366
19010	38.655630	106.374779	64	19425	38.939312	106.679083	66
19011	38.670057	106.376377	309	19428	38.920905	106.603941	184
19012	38.675709	106.363909	1927	19434	38.905614	106.726468	47
19013	38.700725	106.339742	584	19460	38.824591	106.725926	170
19014	38.703165	106.350907	5154	19468	38.819338	106.735659	452
19015	38.698818	106.349043	3588	19469	38.817271	106.735240	70
19016	38.707488	106.290451	116	19470	38.750626	106.766499	244
19017	38.714596	106.211719	118	19471	38.782887	106.781789	277
19018	38.680259	106.273707	141	19473	38.790157	106.870159	45
19019	38.680421	106.268766	53	19474	38.826852	106.849014	41
19020	38.708863	106.272558	101	19479	38.830824	106.844719	65
				19496	38.910374	107.025881	46

APPENDIX (continued)

Sample Number	Latitude	Longitude	Pb (ppm)
19497	38.508955	107.028216	255
19498	38.508980	107.055052	1920
19499	38.531892	107.051583	81
19500	38.957406	107.084806	110
19501	38.978244	107.085606	416
19502	38.957206	107.061676	75
19508	38.878534	107.053517	121
19509	38.869167	107.036667	1531
19520	38.854036	107.003027	165
19522	38.826057	107.088441	47
19616	38.866202	107.025998	72
19713	38.898723	106.892264	45
19827	38.456321	106.615431	50
19830	38.415172	106.677187	87
19867	38.726135	106.774799	232

Sample Number	Latitude	Longitude	Co (ppm)
18003	38.030278	107.158889	21.7
18005	38.040279	107.132222	32.5
18021	38.375833	107.495833	54.7
18022	38.387778	107.485278	21.2
18025	38.298056	107.486389	31.1
18027	38.297500	107.465000	23.5
18028	38.297778	107.462222	29.4
18029	38.268611	107.433889	27.2
18032	38.262500	107.478611	21.9
18033	38.218611	107.465000	32.2
18034	38.219444	107.462778	26.0
18039	38.153611	107.448333	25.8
18040	38.186667	107.457222	20.4
18041	38.310000	107.427500	25.3
18043	38.248333	107.407222	21.0
18050	38.450556	107.548611	30.4
18099	38.235833	107.733611	23.2
18101	38.286389	107.762778	20.5
18117	38.226667	107.717500	20.3
18157	38.006889	107.663611	25.2
18158	38.053611	107.824722	27.0
18159	38.048333	107.820833	21.0
18163	38.032500	107.793056	24.1
18201	38.059167	107.689444	22.9
18204	38.019722	107.676389	20.6
18206	38.000833	107.694167	46.0
18212	38.393889	107.016667	21.4
18215	38.344722	107.000000	22.3
18216	38.359444	107.021389	23.5
18220	38.362778	107.051111	21.2
18221	38.392778	107.050556	27.2
18222	38.424444	107.049444	21.6
18223	38.425000	107.044722	20.4
18243	38.495000	107.030556	22.0
18244	38.237222	107.168889	21.7
18261	38.080000	107.481111	22.3
18262	38.105000	107.474167	36.1
18263	38.130833	107.482722	22.5
18265	38.115833	107.517778	33.9
18266	38.128333	107.520000	39.8
18267	38.166667	107.520000	25.9
18269	38.158056	107.504722	21.1
18270	38.136667	107.556389	28.6
18271	38.154444	107.527500	31.5
18272	38.199444	107.553889	56.4
18277	38.262500	107.543889	24.4
18285	38.358611	107.558889	22.6
18291	38.411944	107.526667	21.2
18318	38.338333	107.278056	26.2
18327	38.254722	107.246944	24.9
18330	38.245833	107.280000	24.1
18334	38.007778	107.468889	23.1
18351	38.157778	107.290833	22.1
18353	38.163333	107.296389	23.7
18354	38.163333	107.324722	26.1
18355	38.163333	107.342222	29.6

APPENDIX (continued)

Sample Number	Latitude	Longitude	Co (ppm)
18382	38.073333	107.049444	21.7
18383	38.070756	107.041667	22.8
18384	38.092500	107.028333	22.9
18388	38.115278	107.035833	21.8
18390	38.155886	107.048056	31.3
18391	38.175833	107.038056	23.8
18392	38.175278	107.051667	20.1
18396	38.244722	107.037222	20.5
18399	38.248333	107.065833	21.9
18401	38.271667	107.080000	25.4
18412	38.054722	107.445278	24.9
18422	38.011111	107.436111	26.1
18423	38.023611	107.491944	21.8
18490	38.976722	107.534045	23.9
18529	38.500427	107.407702	20.7
18546	38.559775	107.497240	26.4
18622	38.612474	106.019947	20.1
18743	38.770633	107.791967	49.7
18767	38.626840	107.133015	20.8
18769	38.631588	107.245314	20.3
18771	38.675588	107.219238	21.3
18801	38.587783	107.063046	20.1
18813	38.627087	107.085238	26.0
18825	38.557570	106.694148	23.6
18920	38.869382	106.994658	55.9
18968	38.702709	106.494998	28.2
19092	38.126361	106.050099	22.0
19096	38.147765	106.087769	20.6
19165	38.230407	106.761431	36.9
19243	38.250278	106.040833	24.4
19337	38.013134	106.878634	22.5
19531	38.503333	107.272500	24.3
19537	38.567288	107.294865	21.8
19540	38.584422	107.361890	23.4
19558	38.788801	107.937946	47.8
19570	38.561565	107.327834	20.9
19581	38.695944	107.637573	37.2
19585	38.748088	107.734278	36.3
19589	38.698247	107.662387	64.6
19590	38.697047	107.680173	35.5
19631	38.688150	107.126541	20.4
19652	38.658891	107.582463	21.7
19753	38.361871	106.932684	22.5

Sample Number	Latitude	Longitude	Cr (ppm)
18677	38.507736	106.247220	121
18399	38.248333	107.065833	123
19776	38.333788	106.901242	125
18003	38.030278	107.159889	125
19216	38.498153	106.268398	129
18989	38.786115	106.380171	130
18223	38.425900	107.044722	131
18222	38.424444	107.049444	131
18953	38.807309	106.362937	131
19215	38.344722	107.000000	132
18952	38.814027	106.334892	133
18384	38.092500	107.028333	138
18220	38.362778	107.051111	142
19368	38.490744	106.642707	142
18955	38.832709	106.412857	143
18439	38.488343	106.427899	145
18401	38.271667	107.080000	145
18391	38.175833	107.038056	149
18218	38.347222	107.026944	151
18859	38.396369	106.463691	155
18221	38.392778	107.059554	163
19992	38.791978	106.439989	175
19783	38.361871	106.932684	188
18896	38.468580	106.750626	204
18898	38.489444	106.222778	208
18632	38.612474	106.019947	210
18216	38.359444	107.021389	213
18490	38.976722	107.534045	217
18212	38.393889	107.018667	250
19769	38.421982	106.944880	268
18825	38.557570	106.694148	281

APPENDIX (continued)

Sample Number	Latitude	Longitude	Hf (ppm)	Sample Number	Latitude	Longitude	Hf (ppm)
18383	38.078046	107.041657	45.0	19198	38.802075	106.090033	47.5
18387	38.124147	107.036667	35.0	19199	38.794263	106.130952	54.9
18390	38.155456	107.048056	30.5	19200	38.998125	105.211641	141.3
18500	38.902243	107.574472	24.7	19201	38.900917	106.153595	41.5
18566	38.937279	107.910695	51.0	19202	38.967441	106.140875	41.2
18597	38.843999	106.075383	39.6	19203	38.954103	106.135912	57.1
18601	38.901116	106.176780	55.0	19204	38.924221	106.133212	61.0
18606	38.836192	106.188095	37.6	19205	38.868292	106.136470	71.4
18607	38.805508	106.249767	50.1	19206	38.897142	106.122754	150.2
18611	38.815740	106.168011	51.2	19208	38.901424	106.084350	41.1
18616	38.753022	106.030091	51.5	19209	38.903756	106.067165	261.6
18617	38.762043	106.045849	109.7	19210	38.888307	106.114525	21.6
18621	38.602344	106.174589	45.7	19211	38.881657	106.090027	54.9
18624	38.596543	106.086472	54.9	19333	38.046542	106.612093	21.0
18629	38.638932	106.028294	42.9	19379	38.566405	106.623930	45.3
18632	38.612474	106.019947	69.6	19397	38.587777	106.533322	41.2
18633	38.549453	106.008194	17.3	19408	38.764242	106.641946	32.4
18637	38.590790	106.049119	57.0	19420	38.964748	106.650414	33.9
18641	38.474401	106.025159	49.5	19422	38.951579	106.630850	49.0
18642	38.679709	106.026349	47.0	19428	38.920909	106.601941	31.7
18643	38.648514	106.034626	35.9	19429	38.903560	106.619743	55.4
18644	38.651318	106.034195	80.0	19430	38.898032	106.625957	41.3
18646	38.660421	106.091308	121.0	19439	38.847775	106.551345	129.0
18647	38.647974	106.094325	44.4	19440	38.857010	106.572992	61.5
18671	38.559443	106.244073	30.4	19441	38.853915	106.574662	50.1
18685	38.699194	106.054329	36.0				
18696	38.695300	106.043568	121.0				
18697	38.716112	106.048079	54.6				
18698	38.734531	106.059185	69.5				
18699	38.761971	106.074971	120.6				
18692	38.764415	106.099002	44.4				
18694	38.662459	107.219779	54.2				
18713	38.520860	106.422474	34.7				
18716	38.600075	106.464979	34.9				
18826	38.599321	106.679007	32.5				
18835	38.441216	106.377874	58.3				
18840	38.497400	106.409897	40.8				
18842	38.475510	106.401820	38.6				
18920	38.869342	106.994654	41.5				
18948	38.995824	106.170819	33.3				
18940	38.966128	106.261844	47.3				
18986	38.930190	106.349032	39.3				
18994	38.816435	106.437739	35.8				
19015	38.698414	106.349043	35.2				
19083	38.934467	107.856376	50.1				
19091	38.141907	106.011214	44.6				
19092	38.176901	106.039225	49.4				
19143	38.018142	106.681539	35.6				
19165	38.330407	106.761431	30.6				
19167	38.356040	106.793074	35.2				
19190	38.944167	106.059722	30.4				
19195	38.840407	106.012319	33.7				
19196	38.822240	106.057996	166.3				
19197	38.919248	106.078835	49.3				

APPENDIX (continued)

Sample Number	Latitude	Longitude	Ce (ppm)
18003	38.030778	107.158889	414
18382	38.073333	107.049444	333
18384	38.092500	107.028333	521
18396	38.244772	107.037222	329
18399	38.248333	107.065833	484
18401	38.271657	107.080000	621
18601	38.301316	108.176780	305
18606	38.836397	105.188095	319
18611	38.815780	106.165011	366
18620	38.617745	106.237955	309
18632	38.612474	106.019947	632
18637	38.590290	106.048119	415
18646	38.660421	106.091309	326
18647	38.687978	106.094325	330
18694	38.662454	107.215775	1004
18713	38.520880	106.422475	301
18835	38.441216	106.377574	437
19091	38.141907	106.011214	343
19092	38.176091	106.039225	391
19190	38.944167	106.059722	374
19196	38.422740	106.057996	396
19197	38.819258	106.079835	414
19199	38.794243	106.137957	315
19200	38.988175	106.211441	4599
19201	38.900917	106.153595	372
19202	38.967851	106.140975	316
19204	38.924721	106.133232	314
19205	38.868777	106.136470	369
19206	38.897162	106.122758	504
19207	38.924414	106.105449	585
19209	38.901974	106.094350	376
19209	38.903954	106.067165	584
19409	38.764787	106.681946	452
19422	38.951579	106.630850	509
19428	38.926900	106.603941	397
19429	38.903660	106.619743	610
19430	38.898032	106.625957	426
19439	38.847775	106.551345	482
19444	38.879552	106.518100	314
19516	38.750092	106.790397	565
19535	38.748068	107.734278	1394
19589	38.598267	107.662387	304
19736	38.119359	106.412813	312

Sample Number	Latitude	Longitude	Th (ppm)
18601	38.901316	106.176780	51.3
18606	38.836392	106.188095	55.6
18607	38.805508	106.248767	42.0
18608	38.803540	106.238922	101.3
18609	38.812500	106.276944	69.1
18611	38.815780	106.168011	99.7
18613	38.757344	106.183400	50.3
18621	38.602388	105.178589	65.4
18622	38.623028	106.140813	71.0
18624	38.596489	106.086472	84.4
18632	38.612474	106.019947	191.9
18633	38.549853	106.008194	57.2
18637	38.590290	106.048119	102.7
18646	38.660421	106.091309	64.2
18647	38.687978	106.094325	68.0
18685	38.699195	106.054379	55.3
18692	38.764414	106.099002	119.7
18694	38.662454	107.215775	174.1
18697	38.715048	106.221762	62.1
18699	38.707800	106.228033	62.5
18701	38.709567	106.142210	78.5
18705	38.684718	106.175331	84.0
18708	38.657761	106.141039	52.1
18709	38.645055	106.212242	98.3
18713	38.520880	106.422475	60.8
18835	38.441214	106.377574	95.9
18840	38.447800	106.409897	86.6
18959	38.783430	106.247149	51.9
19015	38.698914	106.349043	52.0
19016	38.707498	106.290451	50.9
19019	38.680421	106.269766	51.0
19020	38.708845	106.272558	59.5
19021	38.714055	106.262632	52.5
19022	38.643871	106.253241	67.6
19024	38.650996	106.286640	67.3
19030	38.501102	106.401869	47.0
19190	38.944167	106.059722	88.9
19196	38.822740	106.057996	66.3
19199	38.794243	106.137957	115.1
19200	38.988175	106.211441	999.0
19202	38.967851	106.140975	83.1
19203	38.954193	106.135912	60.7
19204	38.924221	106.133232	63.3
19205	38.868777	106.136470	71.6
19206	38.897162	106.122758	130.3
19207	38.924414	106.105449	188.1
19208	38.901974	106.094350	64.3
19209	38.903954	106.067165	116.2
19210	38.888302	106.114525	58.2
19407	38.764090	106.678996	55.7
19408	38.764787	106.681946	55.7
19417	38.458729	106.341490	55.4
19422	38.951579	106.630850	72.6
19428	38.920970	106.603941	58.2

APPENDIX (continued)

Sample Number	Latitude	Longitude	Th (ppm)
19429	38.903540	106.619743	92.9
19430	38.898037	106.625957	88.8
19439	38.947774	106.551345	84.1
19516	38.750027	106.790397	146.3

Sample Number	Latitude	Longitude	Ti (ppm)
18003	38.030278	107.158489	11110
18005	38.040278	107.132222	12440
18021	38.375933	107.495833	15600
18025	38.298754	107.486389	10620
18027	38.297500	107.465000	10420
18039	38.153611	107.448333	10610
18041	38.310000	107.427500	10090
18043	38.248333	107.407222	10370
18050	38.450556	107.549611	10190
18244	38.237222	107.168889	11890
18249	38.195278	107.143333	11240
18262	38.105000	107.474167	12910
18265	38.115933	107.517778	12690
18266	38.128333	107.520000	11220
18271	38.154444	107.557500	10270
18272	38.199444	107.553889	13760
18355	38.163333	107.342222	11040
18382	38.073333	107.049444	14430
18383	38.078056	107.061667	10700
18384	38.092500	107.028333	14160
18390	38.155456	107.048056	12800
18396	38.244722	107.037222	16690
18399	38.248333	107.065833	13560
18401	38.271467	107.090000	13530
18422	38.011111	107.436111	13570
18529	38.500427	107.407202	12720
18546	38.559775	107.497240	15770
18597	38.843909	106.075383	11630
18607	38.905978	106.244767	12750
18616	38.753077	106.030091	10650
18617	38.762783	106.045840	10910
18642	38.679709	106.026349	12550
18644	38.651399	106.038195	11020
18646	38.650421	106.091309	13240
18659	38.540452	107.089821	12060
18663	38.739713	107.062965	10920
18665	38.703894	107.001104	12150
18677	38.507736	106.247220	10450
18686	38.695390	106.063569	12070
18687	38.716112	106.049079	10930
18688	38.734931	106.059194	13480
18690	38.751971	106.078973	10530
18694	38.662458	107.218775	15220
18767	38.626940	107.133014	10290
18802	38.549950	107.052487	10410
18814	38.625493	107.085801	11520
18909	38.352793	106.021320	11400
18956	38.943734	106.451442	10400
18992	38.781978	106.439989	10220
18998	38.871889	106.384318	10070
18999	38.861019	106.351849	10750
19001	38.878294	106.414852	10210
19091	38.141807	106.011214	14360
19092	38.176901	106.039225	13370

APPENDIX (continued)

Sample Number	Latitude	Longitude	Ti (ppm)
19095	38.126361	104.050099	10540
19096	38.147755	106.097769	14400
19165	38.330407	106.761431	16340
19196	38.822260	106.057996	15060
19197	38.819254	106.078835	14920
19198	38.802055	106.090033	11770
19200	38.988125	106.211641	11950
19201	38.906917	106.153595	10310
19206	38.897167	106.122758	10560
19208	38.901824	106.084350	11960
19211	38.891557	106.090027	11450
19242	38.296073	106.072060	11530
19348	38.575276	106.975407	10110
19422	38.951579	106.630850	12190
19429	38.903660	106.619743	10320
19439	38.847775	106.551345	23340
19441	38.853915	106.578662	10210
19449	38.816719	106.517339	11760
19531	38.503311	107.272500	12690
19540	38.584422	107.361690	14390
19541	38.625709	107.363836	11110
19566	38.565255	107.327497	10490
19570	38.561545	107.327434	11110
19624	38.738241	107.142170	10600

Sample Number	Latitude	Longitude	Zn (ppm)
18021	38.375933	107.495833	265
18041	38.310090	107.427400	181
18044	38.398849	107.496667	197
18050	38.450556	107.548611	192
18070	38.449167	107.855556	319
18089	38.319444	107.725000	448
18101	38.286189	107.762778	527
18104	38.425000	107.917500	215
18109	38.273333	107.975000	344
18123	38.187500	107.659444	246
18126	38.208056	107.633889	313
18132	38.080000	107.658333	221
18137	38.240000	107.931389	202
18139	38.177778	107.928333	282
18156	38.000278	107.659167	442
18157	38.006389	107.663611	596
18158	38.053611	107.824722	271
18159	38.048333	107.820833	295
18163	38.032500	107.793056	455
18165	38.062222	107.815278	329
18166	38.122222	107.997222	271
18168	38.107222	107.901389	244
18170	38.104722	107.956389	191
18173	38.088056	107.994889	270
18178	38.409167	107.891111	285
18180	38.145278	107.772222	199
18183	38.171111	107.772222	211
18197	38.052500	107.690556	382
18200	38.085556	107.707778	470
18201	38.059167	107.699444	430
18202	38.025278	107.666389	213
18203	38.021111	107.676944	261
18204	38.019722	107.676389	388
18205	38.020278	107.665833	311
18206	38.000933	107.694167	11930
18207	38.086944	107.601111	327
18211	38.053333	107.574167	990
18243	38.495000	107.030556	215
18262	38.105000	107.474167	209
18265	38.115833	107.517778	198
18266	38.124333	107.520000	257
18272	38.199444	107.553889	334
18286	38.368333	107.547222	184
18292	38.484722	107.007500	235
18293	38.486467	107.005556	256
18294	38.199444	107.015556	275
18295	38.136667	107.008889	189
18302	38.013056	107.310556	2300
18305	38.445278	107.343056	542
18322	38.283889	107.113056	1022
18326	38.298889	107.229444	1090
18330	38.245833	107.240000	1046
18334	38.007778	107.468889	190
18337	38.019722	107.362778	442

APPENDIX (continued)

Sample Number	Latitude	Longitude	Zn (ppm)	Sample Number	Latitude	Longitude	Zn (ppm)
18351	38.157778	107.290833	1548	18942	38.943045	106.443477	190
18353	38.163333	107.296389	642	18943	38.945755	106.449075	294
18355	38.163333	107.342222	108	18945	38.988543	106.411905	205
18357	38.151944	107.252500	1177	18952	38.814027	106.334892	203
18363	38.093611	107.291667	963	18958	38.777242	106.302793	222
18365	38.071944	107.296667	966	18961	38.770994	106.411149	212
18367	38.077222	107.348889	1018	18965	38.739000	106.430869	314
18401	38.271667	107.080000	147	18966	38.761919	106.428363	217
18412	38.054722	107.445278	206	18967	38.748953	106.486641	491
18418	38.022500	107.400556	263	18968	38.702709	106.494999	1943
18419	38.021111	107.403056	933	18971	38.776744	106.489164	264
18420	38.019167	107.402222	109	19009	38.637193	106.359365	293
18422	38.011111	107.436111	241	19010	38.655619	106.174779	222
18423	38.023611	107.491944	189	19011	38.670057	106.376377	347
18432	38.352722	107.965556	294	19012	38.675709	106.363909	3494
18438	38.288999	107.945556	363	19013	38.700775	106.139742	444
18441	38.258511	107.905667	315	19014	38.703165	106.350907	4904
18444	38.276399	107.864444	318	19015	38.698814	106.349043	24789
18445	38.319444	107.848889	285	19016	38.707489	106.290451	214
18485	38.279167	107.048611	241	19017	38.714596	106.311719	183
18489	38.955970	107.528448	2568	19018	38.680259	106.273707	269
18528	38.520790	107.397347	198	19020	38.708844	106.272559	202
18546	38.559775	107.497240	184	19023	38.609754	106.317502	406
18597	38.843999	106.075383	197	19026	38.549154	106.297840	956
18598	38.857228	106.104405	223	19027	38.554345	106.301893	2055
18605	38.890583	106.173213	184	19028	38.596331	106.339106	2691
18624	38.596453	106.084472	215	19035	38.562133	106.466111	954
18635	38.561548	106.015841	340	19036	38.539719	106.436706	1409
18648	38.224733	106.095369	2966	19037	38.539753	106.430949	3482
18657	38.708953	107.435076	216	19038	38.550083	106.389577	1921
18669	38.540964	106.243732	689	19092	38.176901	106.019225	293
18670	38.544685	106.243253	845	19165	38.330477	106.761431	188
18673	38.579544	106.209094	278	19201	38.900917	106.153595	224
18674	38.538976	106.193661	472	19228	38.254167	106.127778	4154
18679	38.520473	106.118476	217	19229	38.249722	106.150833	4730
18691	38.768140	106.092683	195	19230	38.278999	106.144199	2491
18695	38.736447	106.171944	230	19236	38.306647	106.144722	1034
18696	38.713949	106.205227	1248	19237	38.316954	106.142554	3594
18698	38.714941	106.249779	1093	19240	38.259944	106.058647	265
18700	38.717391	106.101975	541	19243	38.270774	106.060933	203
18711	38.576939	106.371131	2880	19264	38.364573	106.062547	1006
18712	38.529401	106.404701	995	19265	38.353518	106.074881	1114
18714	38.518306	106.419086	189	19266	38.352479	106.035180	291
18743	38.770633	107.791947	292	19358	38.490744	106.542707	239
18786	38.586929	107.195041	183	19375	38.604256	106.403917	233
18795	38.500789	107.099979	219	19376	38.612911	106.495821	491
18801	38.587762	107.063045	217	19377	38.583573	106.404137	244
18807	38.592374	107.012752	293	19388	38.504234	106.578429	262
18813	38.627062	107.095238	198	19395	38.611736	106.524309	252
18830	38.544995	106.649301	189	19399	38.627149	106.583177	211
18831	38.560289	106.635049	251	19406	38.624943	106.525487	201
18881	38.813744	106.898220	1926	19416	38.442172	106.357704	199
18906	38.375020	106.093611	192	19419	38.975073	106.685814	193
18920	38.469387	106.994659	2235	19420	38.964748	106.650414	229

APPENDIX (continued)

Sample Number	Latitude	Longitude	Zn (ppm)
19421	38.970404	104.649524	373
19422	38.951579	104.630850	220
19423	38.952004	104.644414	234
19424	38.958978	104.711140	559
19425	38.939317	104.679983	273
19428	38.920700	104.603341	838
19460	38.824591	104.725974	225
19470	38.750424	104.766499	199
19479	38.939824	104.844719	420
19497	38.908955	107.078214	692
19498	38.906990	107.055052	2396
19499	38.931497	107.051583	303
19500	38.957494	107.084806	632
19501	38.978244	107.085604	764
19502	38.957704	107.061626	239
19503	38.893582	107.105471	209
19509	38.869147	107.036667	3577
19520	38.894834	107.003027	559
19522	38.928057	107.088951	187
19540	38.584422	107.361690	243
19558	38.788601	107.937944	259
19581	38.695944	107.637571	297
19592	38.736943	107.708142	419
19585	38.748058	107.734274	1284
19599	38.698747	107.662387	460
19590	38.697047	107.690173	364
19616	38.866207	107.025994	602
19736	38.119159	104.412813	277
19823	38.435934	104.521344	317
19830	38.415177	104.577187	225
19848	38.546123	104.759017	203
19857	38.726135	104.774799	190
19873	38.681597	104.854687	193

Sample Number	Latitude	Longitude	Dy (ppm)
18382	38.073333	107.049444	12.8
18384	38.092500	107.024333	11.7
18396	38.244722	107.037222	12.9
18484	38.421399	107.112778	19.3
18521	38.908722	107.174743	11.6
18597	38.843999	104.075383	13.0
18601	38.901316	104.175780	14.4
18602	38.876798	104.210071	12.4
18606	38.836392	104.188095	15.6
18607	38.805508	104.248767	12.6
18611	38.815760	104.164011	15.9
18614	38.795947	106.050275	11.1
18615	38.796604	104.033885	13.3
18616	38.753022	104.030091	13.0
18617	38.762099	104.045840	15.7
18619	38.598056	106.196111	16.1
18620	38.612749	104.237956	16.6
18621	38.602368	104.175584	14.9
18629	38.638977	104.028244	13.4
18640	38.667810	104.057030	11.7
18641	38.674491	104.075190	14.9
18642	38.679709	104.026349	29.6
18643	38.648514	104.034624	16.9
18644	38.651399	104.038195	26.7
18645	38.660421	104.091308	16.2
18647	38.687979	104.094325	12.5
18682	38.566196	104.116489	13.2
18683	38.695399	104.043569	27.3
18687	38.716117	104.044079	24.7
18688	38.734531	104.059184	14.1
18690	38.761971	104.078973	19.0
18694	38.652459	107.218778	31.5
18713	38.520940	104.422475	16.7
18836	38.413833	104.408634	19.6
18841	38.475944	104.406930	13.0
18846	38.405741	104.409757	11.1
18859	38.396349	104.463681	27.4
18863	38.660792	104.713459	12.6
18864	38.645703	104.747819	19.1
18866	38.734199	104.735977	13.1
18968	38.747098	104.689449	14.7
18969	38.729195	104.749947	12.2
18949	38.813105	104.272119	13.6
18952	38.814027	104.334932	12.1
18956	38.843734	104.451442	12.1
18977	38.854277	104.342249	11.4
18978	38.867994	104.334992	25.2
18987	38.932713	104.372983	11.4
18988	38.845684	104.322926	12.6
19000	38.907807	104.331632	11.7
19001	38.878254	104.414852	11.4
19030	38.501102	104.401869	13.0
19034	38.533849	104.490154	11.8
19091	38.141807	104.011214	12.0
19092	38.174901	104.039225	12.4

APPENDIX (continued)

<u>Sample Number</u>	<u>Latitude</u>	<u>Longitude</u>	<u>Dy (ppm)</u>
19190	38.944167	104.059722	15.1
19195	38.840507	104.012319	15.6
19196	38.822240	104.057994	19.2
19197	38.819258	104.078335	16.0
19199	38.794263	104.130952	13.7
19200	38.988125	104.211641	117.5
19201	38.900917	104.153595	17.3
19202	38.957851	104.140875	11.6
19203	38.954103	104.135912	15.5
19204	38.924221	104.133232	17.6
19205	38.868292	104.136470	13.3
19206	38.897142	104.122754	14.6
19207	38.924614	104.105442	21.3
19208	38.901424	104.084350	16.2
19209	38.903956	104.067165	13.5
19211	38.891657	104.090027	15.7
19357	38.393947	104.249013	11.5
19407	38.764090	104.678996	17.7
19408	38.764282	104.681946	29.6
19416	38.442172	104.357704	14.9
19417	38.458229	104.341492	12.6
19420	38.964748	104.650414	11.2
19422	38.951570	104.630450	14.9
19425	38.939112	104.679983	11.4
19428	38.920200	104.603941	12.3
19429	38.903640	104.619743	15.1
19430	38.898232	104.625957	15.8
19439	38.847775	104.551345	19.3
19444	38.879452	104.519100	13.6
19458	38.819305	104.566522	11.2
19516	38.750052	104.700307	24.3
19559	38.788421	107.937945	12.4
19585	38.744259	107.734273	25.4
19589	38.698247	107.682387	22.8
19590	38.697047	107.680173	11.7
19862	38.687417	104.754016	12.9

Map 1. Topographic map of the Montrose NTMS quadrangle, Colorado.

After Tweto, et al, 1976

Map 2. Geological map of the Montrose NTMS quadrangle, Colorado.

A Western Plateau Area

B San Juan-West Elk Volcanic Fields

C Sawatch-Gunnison Crystalline Terrane

Map 3. Location of samples and physiographic-geologic provinces of the Montrose quadrangle, Colorado.

Map 4. Radioactive mineral occurrences and airborne anomalies of the Montrose quadrangle, Colorado.

- HOST ROCKS FOR OCCURRENCES AFTER NELSON-MOORE
ET AL. 17 1978
- SANDSTONE, ARGILLITE, CONGLOMERATE, BUTTONE, LAKE SEDIMENTS
  - COAL, SHALE, LIMESTONE
  - ▲ SPRING DEPOSITS, GROUND WATER
  - ▲ IGNEOUS, METAMORPHIC
  - ◆ UNDETERMINED
  - (1) OCCURRENCE NUMBER FROM TEXT
- URANIUM ANOMALY AFTER AERIAL GAMMA RAY SURVEY BY GEOMETRICS (1979)

x Mine or quarry from 1:24,000 and
1: 63,500 scale U.S.G.S. topographic maps

x Prospect Pit

**Map 5. Base and precious metal mineral occurrences
in the Montrose quadrangle, Colorado.**

Map 6. Concentrations of total uranium (ppm) above the threshold of 20 ppm for sediment samples (-100 mesh) in the Montrose quadrangle, Colorado.

• 56.5 Concentrations in ppm

Clusters delineated according to drainage basins,
dashed where approximated

Possible location of mineralized area

Map 8. Concentrations of total thorium (ppm) above threshold of 50 ppm for sediment samples (-100 mesh) in the Montrose quadrangle, Colorado.

SYMBOLS

RATIOS

0.0 — 0.25

0.26 — 0.50

0.51 — 1.0

>1.0

Map 9. U/Th ratios (ppm) from sediment samples (-100 mesh)
of the Montrose quadrangle, Colorado.

• 33 Concentrations in ppm

○ Clusters delineated according to drainage basins,
dashed where approximated

■ Possible location of mineralized area

× Mine or quarry

Map 10. Concentrations of total niobium (ppm) above the threshold of 25 ppm for sediment samples (-100 mesh) in the Montrose quadrangle, Colorado.

Map 11. Concentrations of total dysprosium (ppm) above the threshold of 11 ppm for sediment samples (-100 mesh) in the Montrose quadrangle, Colorado.

Map 13. Concentrations of total hafnium (ppm) above the threshold of 30 ppm for sediment samples (-100 mesh) in the Montrose quadrangle, Colorado.

Factor 9 score
coefficients

U	.80278
Cu	-.03987
Pb	.08685
Li	.07702
Al	-.04275
Ba	-.15944
Ca	-.05237
Co	.04318
Cr	.16082
Fe	.19195
Hf	-.24593
K	.25779
Ce	-.04419
Mg	.14838
Mn	.10262
Sc	-.24342
Th	.08359
Ti	-.30578
V	.21117
Zn	-.14595
Dy	-.10727

Map 15. Factor 9 (uranium) score map for sediment samples
in Area C, Montrose quadrangle, Colorado.

Map 19. Concentrations of total lead (ppm) above the threshold of 40 ppm for sediment samples (-100 mesh) in the Montrose quadrangle, Colorado.

Map 21. Concentrations of total zinc (ppm) above the threshold of 180 ppm for sediment samples (-100 mesh) in the Montrose quadrangle, Colorado.

• 2.67 Concentrations in ppm

Clusters delineated according to drainage basins,
dashed where approximated

c(?) Contamination suspected

Map 22. Concentrations of total gold (ppm) above the threshold of 0.2 ppm
for sediment samples (-100 mesh) in the Montrose quadrangle, Colorado.

- 7 Concentrations in ppm
- Clusters delineated according to drainage basins
- Possible location of mineralized area
- c(?) Contamination suspected

Map 23. Concentrations of total silver (ppm) above the threshold of 6 ppm for sediment samples (-100 mesh) in the Montrose quadrangle, Colorado.

Map 24. Concentrations of total tungsten (ppm) above the threshold of 25 ppm for sediment samples (-100 mesh) in the Montrose quadrangle, Colorado.

Map 25. Concentrations of total scandium (ppm) above the threshold of 18 ppm for sediment samples (-100 mesh) in the Montrose quadrangle, Colorado.

Factor 3 score
coefficients

U	-.16328
Cu	.37928
Pb	.38033
Li	.01983
Al	-.00146
Ba	-.03690
Ca	-.03454
Ce	-.00568
Cr	-.01347
Fe	.00844
Hf	.04582
K	.05615
Ce	-.00582
Mg	.06469
Mn	-.00906
Sc	-.01543
Th	.01093
Ti	-.02481
V	-.02295
Zn	.39642
Dy	-.00055

Map 26. Factor 3 (base metals) score map of sediment samples
in the Montrose quadrangle, Colorado.