UNITED STATES DEPARTMENT OF THE INTERIOR

GEOLOGICAL SURVEY

# A HYDROGEOCHEMICAL SURVEY OF THE DEER TRAIL MOUNTAIN-ALUNITE RIDGE AREA, SOUTHWESTERN UTAH

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## ABSTRACT

A hydrogeochemical survey of the Deer Trail Mountain-Alunite Ridge study area was undertaken to examine the geochemical characteristics of the waters as related to the potential for locating mineral deposits. The study area encompassed the Pine Creek (Bullion Canyon) and Cottonwood Creek drainage basins located approximately 10 km (6 mi) southwest of Marysvale, Utah. Thirty-seven samples were collected from streams, springs, and mine waters within the study area. The data were interpreted using single element plots and Q-mode factor analysis. A three factor model was selected. Factor 1 reflects normal weathering, Factor 2 reflects weathering of base metal sulfide minerals, and Factor 3 reflects weathering of alunite and possibly pyrite. Chemical modeling was used to calculate the chemical speciation of the waters. The presence of anomalous U, Mo, Li, K, and F, factor analysis interpretation, and geological data suggest that a buried stock underlies the study area. Several areas are identified which may contain undiscovered sulfide mineralization, probably related to the emplacement of the stock.

## INTRODUCTION

A hydrogeochemical survey was conducted in and around the Pine Creek (Bullion Canyon) and Cottonwood Creek drainages, which encompasses the Deer Trail Mountain-Alunite Ridge area, during the summer of 1982. Thirty-seven stream, spring, and mine water samples were collected and analyzed for 19 constituent concentrations. The study area is located in the Tushar Mountains some 10 km (6 mi) southwest of Marysvale, Utah (fig. 1) and covers approximately 75 sq km (35 sq mi).

Geological studies conducted in the Deer Trail Mountain-Alunite Ridge area indicate the presence of a buried intrusive underlying the area (Cunningham and Steven, 1979b). Geochemical studies using rock, water, and heavy mineral concentrates of stream sediment by Tucker, R. E., and others (1980, 1981, and 1982) also gave geochemical indications of a mineralized stock underlying the study area. The detailed hydrogeochemical survey was conducted to examine the geochemical characteristics of the area with an emphasis on identifying new areas of mineral potential.

## GENERAL GEOLOGY

The study area is located in the high plateaus subprovince of the Colorado Plateau near its boundary with the Basin and Range province. The study area covers some 75 sq km (35 sq mi) within the Marysvale Volcanic field (Cunningham and Steven, 1979d). The Oligocene-Miocene Bullion Canyon Volcanics, the predominant geological unit in the study area (fig. 2), consists of intermediate composition lava flows, ash flow tuffs, and related volcanoclastic deposits. These rocks originated from numerous stratovolcanos between 35 to 22 m.y. ago (Steven, Cunningham, Naeser, and Mehnert, 1978). Along the eastern edge of the Tushar Mountains, the Bullion Canyon Volcanics unconformably overlie Paleozoic and Mesozoic limestones and sandstones.

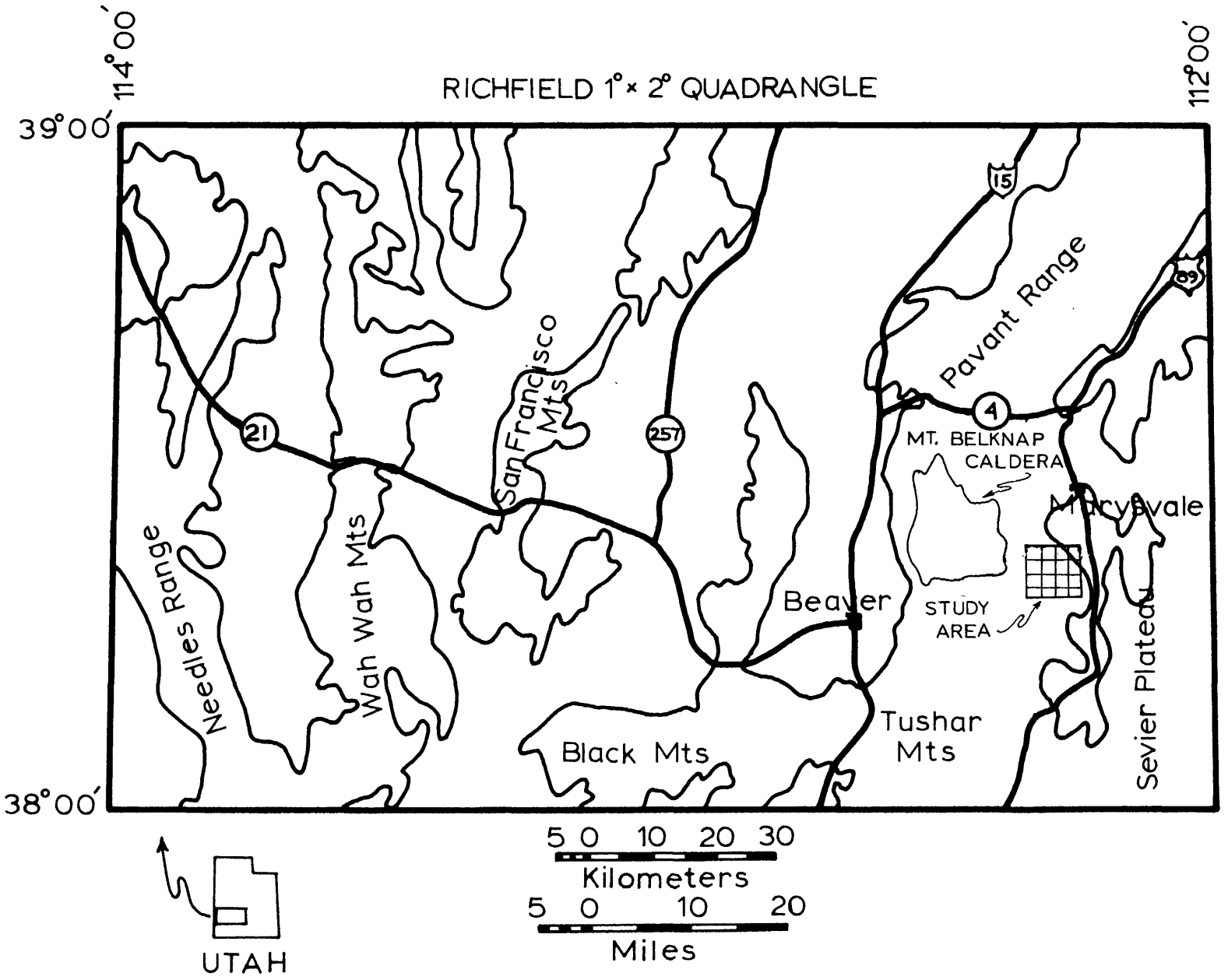


Figure 1.--Index map of the Deer Trail Mountain-Alunite Ridge study area, southwestern Utah.

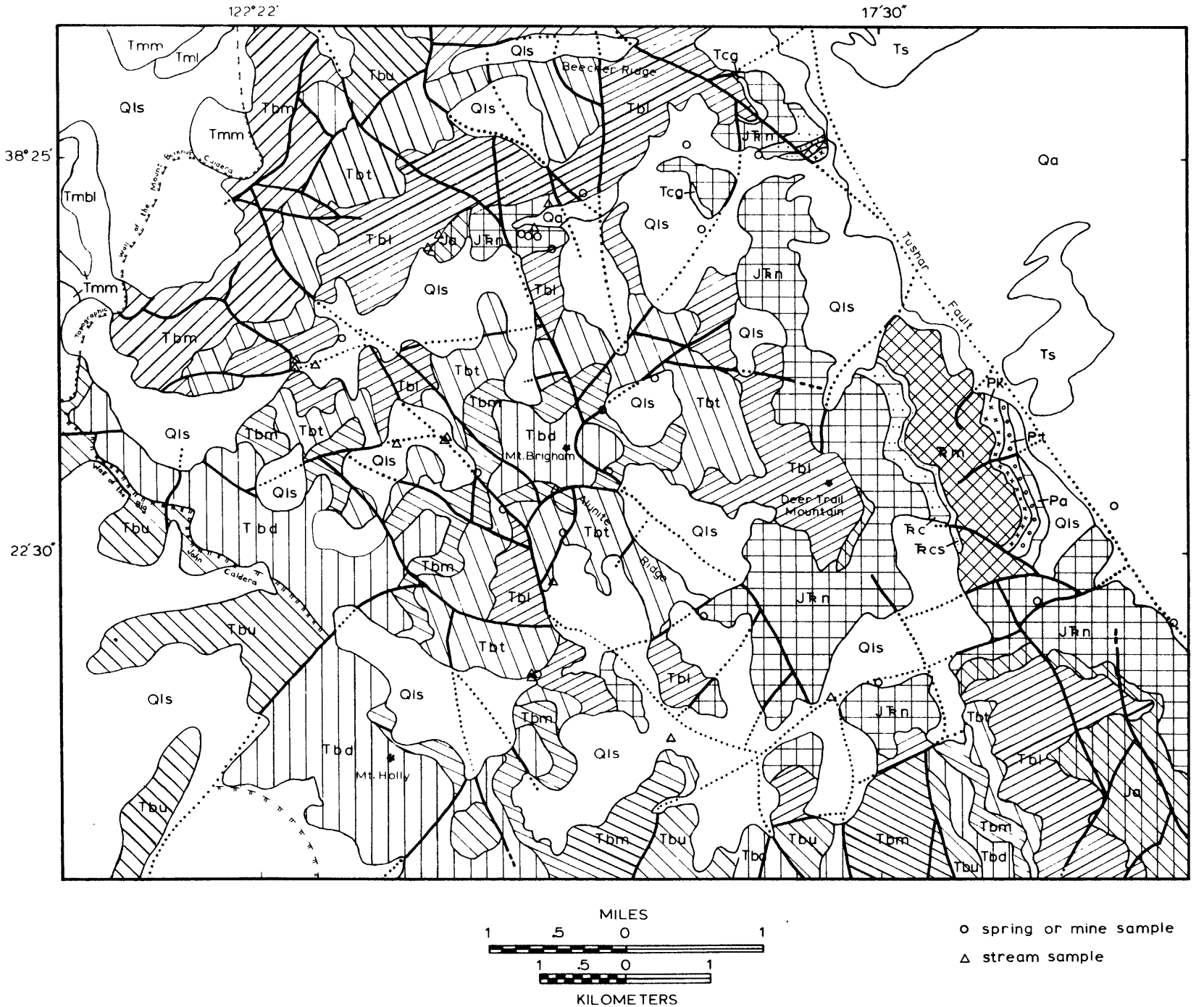


Figure 2.--Generalized geologic map of the Deer Trail Mountain-Alunite Ridge study area, southwestern Utah.

Numerous monzonitic to quartz monzonitic stocks were emplaced throughout the region during the period of volcanism which produced the Bullion Canyon Volcanics. Basin and Range extensional tectonism began approximately 22-21 m.y. ago, which coincides with the shift from the intermediate composition Bullion Canyon Volcanics to a bimodal rhyolite-basalt series (Steven and others, 1978). The Mount Belknap Volcanics are of rhyolitic composition and were erupted between 22-16 m.y. ago (Steven and others, 1978) and lie to the west of the study area. More detailed geological descriptions are given in Cunningham and Steven (1978a, 1979a, 1980), Steven (1977), and Steven and Cunningham (1980).

## DESCRIPTION OF MAP UNITS

Qa ALLUVIAL DEPOSITS (HOLOCENE)--Silts, sands, and gravels in alluvial fans, alluvial slope wash, and stream alluvium

Qls LANDSLIDE DEBRIS (QUATERNARY)--Includes talus and colluvium

Ts SEVIER RIVER FORMATION, LOWER PART (PLIOCENE AND MIOCENE)--Fluviatile gravels, sands, and silts, with interlayered ash-fall tuffs

### MOUNT BELKNAP VOLCANICS (MIOCENE)

Tmm Middle Tuff Member--Crystal-poor rhyolite welded ash-flow tuff, closely similar to that in the outflow Joe Lott Member (Tmj)

Tmbl Blue Lake Rhyolite Member--Crystal-poor rhyolite flows, closely similar to those in the Mount Baldy Rhyolite Member (Tmb)

Tml Lower Tuff Member--Moderately welded crystal-poor alkali-rhyolite ash-flow tuff lithologically similar to the Joe Lott Tuff Member (Tmj). Intracaldera facies of the Mount Belknap caldera

### BULLION CANYON VOLCANICS (MIOCENE AND OLIGOCENE)

Tbu Upper Member--Mostly rhyodacite to andesite lava flows and local ash-flow tuffs

Tbd Delano Peak Tuff Member--Densely welded crystal-rich quartz latite ash-flow tuff containing phenocrysts of plagioclase (32 percent), hornblende (9 percent), Fe-Ti oxide minerals (4 percent), and less than 1 percent each of quartz, biotite and apatite

Tbm Middle Member--Mostly light-gray and brown rhyodacite lava flows, flow breccia, and volcanic mud-flow breccia that lie between the overlying Delano Peak Tuff Member (Tbd) and underlying Three Creeks Tuff Member (Tbt)

Tbt Three Creeks Tuff Member (Oligocene)--Densely welded light-gray and brown, crystal-rich quartz latite ash-flow tuff containing phenocrysts of plagioclase (35 percent), hornblende (9 percent), biotite (3 percent), and quartz (2 percent). Fe-Ti oxide minerals, sanidine, and other accessory minerals occur in traces. K-Ar age is 27 m.y. (Steven, Cunningham, Naeser, and Mehnert, 1978)

Tbl Lower Member--Mostly volcanic mud-flow breccia, flow breccia, and tuffaceous sedimentary rock that occur below the Three Creeks Tuff Member (Tbt)

Tcg CONGLOMERATE (OLIGOCENE TO PALEOCENE)--Light-gray to buff pebble conglomerate containing rounded clasts of sandstone and limestone derived from Mesozoic and Paleozoic rocks. Locally contains tuffaceous sandstone

Ja ARAPIEN FORMATION (MIDDLE JURASSIC)--Light-gray limestone and shale and locally interbedded red to brown sandstone and intraformational limestone conglomerate layers

JTrn NAVAJO SANDSTONE (JURASSIC AND TRIASSIC?)--Fine-grained buff well-sorted, crossbedded sandstone. The crossbedding dips south

Trc CHINLE FORMATION (UPPER TRIASSIC)--Green, purple, and red sandstone, siltstone, and mudstone. Laminated and thinly bedded

Trcs Shinarump Member--Light-brown to brownish-gray crossbedded poorly sorted sandstone. Crossbedding dips northwest

Trm MOENKOPI FORMATION (MIDDLE? AND LOWER TRIASSIC)--Greenish-gray and purple, fine-grained sandstone and underlying red siltstone and shale. Includes a prominent gray limestone bed near the base

Pk KAIBAB LIMESTONE (LOWER PERMIAN)--Light- to dark-gray limestone and dolomite

Pt TOROWEAP FORMATION (LOWER PERMIAN)--Light-gray dolomite and yellowish-gray limestone, sandstone, and quartzite

Pq QUEANTOWEAP SANDSTONE OF McNAIR, 1951 (LOWER PERMIAN)--Light-tan well-sorted, crossbedded orthoquartzite

Placer gold was discovered in Bullion Canyon in 1868. Shortly afterwards, stratabound or manto-type base-metal sulfide ore deposits containing precious metal were discovered within the Paleozoic and Mesozoic sedimentary rocks. Vein-type alunite was identified on Alunite Ridge in 1910. The pink, highly crystalline alunite occurs in veins that cross-cut the host Bullion Canyon Volcanics. A hot springs-type mercury deposit was discovered on the eastern face of Deer Trail Mountain near the turn of the century (Callaghan, 1973). Detailed mining and mineral deposit descriptions are given in Butler (1913), Butler and Gale (1912), Butler and others (1920), Callaghan (1938 and 1973), Cunningham and Steven (1978b, 1979c, 1979e), Steven, Cunningham, and Rowley (1978), Steven and Cunningham (1979), Steven and others (1980), and Wyant and Stugart (1951). At present mining activity in this area is sporadic, but extensive exploration programs are in progress.

A genetic relationship between porphyry-type mineral deposits and precious metal containing base-metal sulfide has been recognized (Wallace and others, 1978; Mutschler and others, 1981; and Westra and Keith, 1981). The base metal deposits are generally found in zones removed from the porphyry-type mineralized zone due in part to thermal mobility, solution chemistry, and wall rock interactions with the upwelling fluids. In the study area the base-metal sulfide, manto-type deposits could have formed as metal-bearing hydrothermal fluids, emanating from an intrusive body, reacted with the favorable overlying sedimentary rocks.

The vein-type alunite deposits are located within the fault-bounded, most highly domed portion of Bullion Canyon Volcanics and may center over the postulated 14 m.y. old intrusive (Cunningham and Steven, 1979b). The alunite is believed to have formed as sulfur-rich hydrothermal fluids reacted with the Bullion Canyon Volcanics. There are no extrusive volcanic rocks or dikes that can be attributed to the postulated hidden stock.

## SAMPLE COLLECTION AND ANALYTICAL TECHNIQUES

Water samples were collected from 37 sites in July 1982 within the study area. Water samples were collected from 16 first order or unbranched streams, ten springs, and 11 mine drainages. Three duplicate water samples were collected and duplicate analyses were performed on five samples. The results of the chemical analyses are given in Appendix 1.

At each site a 60 ml sample was filtered into an acid-rinsed polyethylene bottle through a 0.45 μm membrane filter, and then acidified with reagent grade concentrated nitric acid to a pH less than 2. A 500 ml untreated sample was also collected in a clean polyethylene bottle. Temperature and pH were measured at each site. Calcium, Mg, Na, K, Li, $SiO_2$, Zn, Cu, Mo, Fe, Mn, Al, and As were determined on the acidified samples. Alkalinity ($HCO^-_3$), $SO_4$, Cl, F, U, and specific conductance were determined on the untreated samples. The analytical techniques are listed in Table 1 and a data summary and limits of detection are given in Table 2. Geometric means and geometric deviations are shown because the frequency distributions tend to be symmetrical on geometric (or logarithmic) scales. Samples with constituent concentrations reported to be below the detection limit of the analytical method (Table 2) are defined as qualified values. The geometric mean and geometric deviation were estimated for elements with qualified values by the censored-distribution technique of Cohen (1959). In order to utilize multivariant statistical techniques numerical values had to be substituted for the qualified values. If less than half of the values were qualified, a value of 0.7 times the lower detection limit was substituted. If more than half of the values were qualified, a value of 0.5 times the lower detection limit was substituted. A comparision of geometric means calculated using Cohens method and substitution is given in Table 3. The two methods give geometric means that compare reasonably well, suggesting the substitution scheme can be used with caution.

A charge balance was calculated for the samples to determine the accuracy of the analyses. The charge balance is calculated by the equation:

$$\frac{\frac{\text{anions}}{\text{eq. wt.*}} - \frac{\text{cations}}{\text{eq. wt.}}}{\frac{\text{anions}}{\text{eq. wt.}} + \frac{\text{cations}}{\text{eq. wt.}}} \times 100 = \pm \quad \% \text{ difference}$$

* eq. wt. = equivalent weight = molecular weight/charge

There are 33 samples with a charge balance difference of 6 percent or less. The highest deviation was 10.7 percent in sample 06. These results add confidence to the analytical results for the major cations and anions (Ca, Mg, Na, K, Alk, $SO_4$, Cl, and F).

Table 1.--Analytical methods used for water analyses, Deer Trail Mountain-Alunite Ridge study area, southwestern Utah

| Constituent | Method | Reference |
|---|---|---|
| Alkalinity | Gran's plot potentiometric titration | Orion Research, Inc. (1975). |
| Sulfate | Ion chromatography | Smee and Hall (1978). |
| Chloride | ----do | Do. |
| Fluoride | ----do | Do. |
| Calcium | Flame atomic absorption spectrophotometry | Perkin-Elmer Corp. (1976). |
| Magnesium | ----do | Do. |
| Sodium | ----do | Do. |
| Potassium | ----do | Do. |
| Lithium | ----do | Do. |
| Silica | ----do | Do. |
| Zinc | ----do | Do. |
| Copper | Flameless atomic absorption spectrophotometry- | Perkin-Elmer Corp. (1977). |
| Molybdenum | ----do | Do. |
| Iron | ----do | Do. |
| Manganese | ----do | Do. |
| Aluminum | ----do | Do. |
| Arsenic | Ion-exchange separation method | Ficklin (1983). |
| Uranium | Fluorometric | McHugh (1979). |
| Specific conductance | Conductivity bridge | Brown and others (1970). |

Table 2.--Summary of the analytical results from water samples in the Deer Trail Mountain-Alunite Ridge study area, southwestern Utah

| Constituent | Lower detection limit | Minimum | Maximum | Geometric mean | Geometric deviation | Unqualifie values* |
|---|---|---|---|---|---|---|
| | | | mg/L | | | |
| Ca | 0.1 mg/L | 4.4 | 270 | 35 | 2.1 | 37 |
| Mg | 0.01 mg/L | 0.4 | 64 | 4.3 | 2.7 | 37 |
| Na | 0.01 mg/L | 0.5 | 8.2 | 2.8 | 1.8 | 37 |
| K | 0.04 mg/L | 0.18 | 3.8 | 0.67 | 2.0 | 37 |
| $SiO_2$ | 1.0 mg/L | 3.3 | 19 | 8.2 | 1.4 | 37 |
| Alkalinity | 1.0 mg/L | <1.0 | 223 | 57 | 4.0 | 35 |
| $SO_4$ | 0.1 mg/L | 3.0 | 817 | 45 | 3.1 | 37 |
| Cl | 0.01 mg/L | 0.31 | 7.9 | 1.7 | 2.2 | 37 |
| F | 0.01 mg/L | 0.04 | 2.4 | 0.31 | 2.9 | 37 |
| | | | µg/L | | | |
| Li | 4.0 µg/L | <4 | 27 | 4.2 | 2.6 | 19 |
| Zn | 1.0 µg/L | 1.0 | 2150 | 8.1 | 5.2 | 37 |
| Cu | 1.0 µg/L | <1.0 | 99 | 1.2 | 4.2 | 21 |
| Mo | 1.0 µg/L | <1.0 | 26 | 0.79 | 4.5 | 17 |
| Fe | 1.0 µg/L | 1.0 | 1700 | 8.1 | 7.3 | 37 |
| Mn | 1.0 µg/L | <1.0 | 760 | 3.7 | 9.0 | 31 |
| Al | 1.0 µg/L | 3.0 | 2700 | 25 | 3.7 | 37 |
| As | 1.0 µg/L | <1.0 | 20 | 0.86 | 3.1 | 17 |
| U | 0.1 µg/L | <0.1 | 2.8 | 0.27 | 2.5 | 33 |

*Number of the 37 samples with concentrations greater than the lower detection limit

Table 3.--Comparison of geometric mean values calculated using Cohens Method and the substituted values

| Element | Geometric mean | | |
|---|---|---|---|
| | Cohens Technique | With substitution | Number of unqualified values |
| Li µg/L | 4.19 | 4.28 | 19 |
| Alkalinity mg/L | 56.9 | 57.0 | 35 |
| Cu µg/L | 1.20 | 1.64 | 21 |
| Mo µg/L | 0.785 | 1.09 | 17 |
| Mn µg/L | 3.71 | 4.36 | 31 |
| As µg/L | 0.864 | 0.993 | 17 |
| U µg/L | 0.273 | 0.276 | 33 |

## GEOCHEMISTRY OF THE WATERS

Hydrogeochemistry can be a powerful tool in geochemical exploration, and can best be applied to geochemical exploration when a rather large suite of ions are analyzed and computer based data analysis techniques are utilized. The geochemical characteristics or signature of the waters can be important in geochemical exploration and in understanding the processes of chemical weathering which were responsible for that signature. Some hydrogeochemical studies applied to mineral exploration can be found in Boyle and others (1971), Miller and others (1979, 1980, and 1984), Miller and McHugh (1981a, 1981b), Tucker and others (1980), Wanty and others (1981), and Chatam and others (1981).

There are some geochemical properties of the aqueous environment that must be considered when using these media exploration studies. An aqueous medium is generally homogenous due to complete mixing of the dissolved constituents, however, many constituent concentrations at a given site may vary with time due to flow rate fluxuations (Miller and Drever, 1977; Levinson, 1974). Precipitation of certain constituents due to changing pH and(or) oxidation states within a drainage may also significantly change the chemical composition of the water, which is particularly evident in adit drainages. This hydrogeochemical study was conducted in the summer when most of the stream flow is contributed by groundwater and over a short time span, which should reduce most of the complicating variability associated with the above considerations.

Small daily variations in constitutent concentrations undoubtedly occur in a dynamic hydrogeochemical system, but these fluxuations may not be readily separated from the analytical variations in this limited study. To help determine if there could be a significant daily effect on constituent concentrations within a stream, one site was chosen for sampling in the evening (sample 23) and the following morning (sample 27). The variations in the constituent concentrations between these two samples are no greater than differences observed in the analytical duplicates (Appendix 1). This indicates that geochemical significance should not be attributed to slight variations in constituent concentrations within the study area, but that an order of magnitude change may be geochemically significant.

To determine what possible effect mixing may have on a sample source, a small creek was sampled at its spring source (site 03) and then approximately 0.8 km (0.5 mi) downstream (site 05). The change in constituent concentrations is not very large for most ions (Appendix 1), however, the Fe and Mn concentrations exhibit a greater than 90 percent decrease between sites. This can be attributed to the change in pH and oxidation state of the ions and consequently the precipitation of Fe and Mn hydroxides. Uranium, Mg, alkalinity, and $SO_4$ also have marked concentration decreases between the sites. These decreases in constituent concentrations may reflect co-precipitation or other complex geochemical interactions that occur along the streams drainage.

The spatial distribution of constituent concentrations, particularly elements related to ore deposits within a study area can give an indication of the mineral potential of an area and the rock type through which the water has traveled. When examining the spatial distributions of the constituents, both

high and low concentrations were utilized. Unusually low constituent concentrations have been shown to be diagnostic in defining geochemical characteristics often associated with mineralizing events in other studies (Tucker, J. D., and others, 1981; Tucker, R. E., and others, 1980, 1981). In this study, the elemental concentrations defined three constituent suites which reflected their spatial distributions. The first suite contains Fe, Al, and Mn (figs. 3, 4, and 5, respectively). Elevated concentrations of these ions are primarily restricted to sites in the Alunite Ridge area (sites 03-06, 12-14, and 18-21). The second suite contains elevated concentrations of Mg, Ca, Na, Cl, F, U, and Mo (figs. 6-12, respectively). Elevated concentrations of these ions are predominantly found in the Pine Creek (Bullion Canyon) area (sites 22-26, 28-34, and 36-39) and the eastern margin of the study area (sites 01 and 08). The third suite contains elevated concentrations of $SO_4$, $SiO_2$, Li, K, Zn, Cu, and As (figs. 13-19, respectively). Elevated concentrations of these ions do not appear to be localized, but occur throughout the study area, often coinciding with elevated concentrations of the other ions.

One sample collected on Alunite Ridge deserves special note due to its unique geochemical signature. Sample 03 was collected from a spring near the top of Alunite Ridge and contains elevated concentrations of Fe, Al, Mn, Mg, Ca, U, Mo, $SO_4$, $SiO_2$, Li, K, and Zn. The elevated concentrations of Mg, Ca, U, Mo, and Li are intriguing because these ions do not generally occur in samples from Alunite Ridge. However, the ions U, Mo, and Li are often found in water samples associated with the manto-type mineral deposits in Pine Creek and the weathering of the Mount Belknap Volcanics (Tucker and others, 1980). Elevated concentrations of Mg and Ca are most often associated with water samples from the mineralized areas in sedimentary rocks. The high concentration of $SO_4$ and low pH suggest that sulfide minerals and(or) alunite may be weathering within the recharge systems of this spring. The suite of ions observed in sample 03 reflects the weathering of sulfide minerals. A possible source would be the manto deposits at depth and(or) a near surface extension of the metallized intrusive postulated to underlie the area.

The Pine Creek drainage can be divided into two distinct regions based on geochemical results and geological evidence. The upper or western region drains Bullion Canyon Volcanics rocks that are in the headwaters of Pine Creek (sites 15-17 and 28-33). The lowest concentrations for many of the constituent ions occur in samples from this region (Appendix 1). The lower or eastern region of Pine Creek is composed predominantly of Paleozoic and Mesozoic sedimentary rocks with some Bullion Canyon Volcanics rocks at higher elevations (sites 22-27, 34-40). Mining activity was generally restricted to this region. Samples from known mineralized areas and samples adjacent to mineralized areas have some of the highest concentrations for many constituent ions from within the study area. Because the sampling was conducted over a short time span during the summer, dilution cannot account for the observed concentration differences in the waters from the two regions. Differences in the chemical character of the rocks within the recharge basins and(or) the rate of chemical weathering of the rocks are more likely to account for the observed differences in constituent concentrations between the two regions. The geologic and geochemical data suggest that the upper region of Pine Creek has not been mineralized to any appreciable extent.

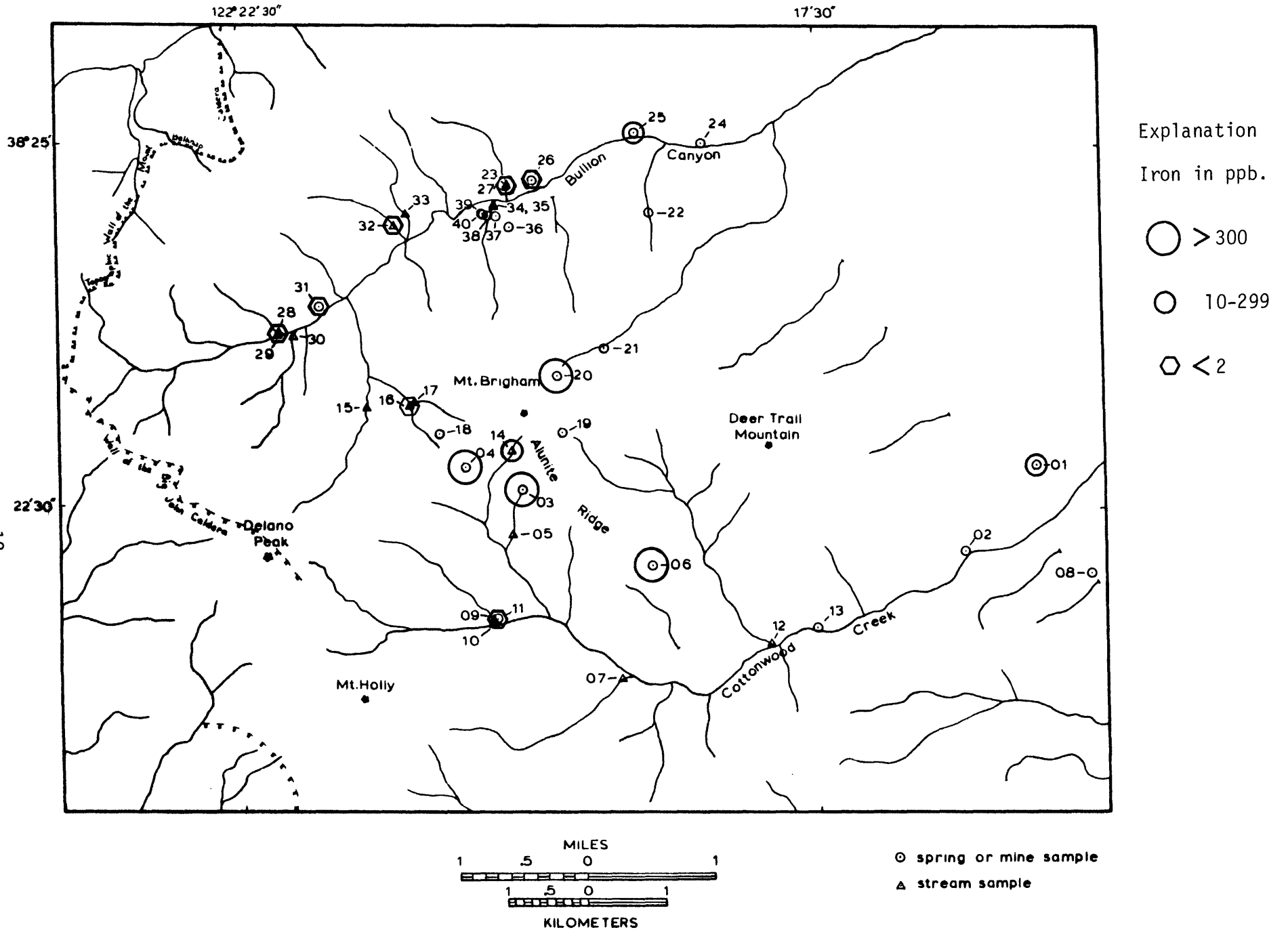


Figure 3.--Distribution of iron concentrations within the Deer Trail Mountain-Alunite Ridge area, Utah.

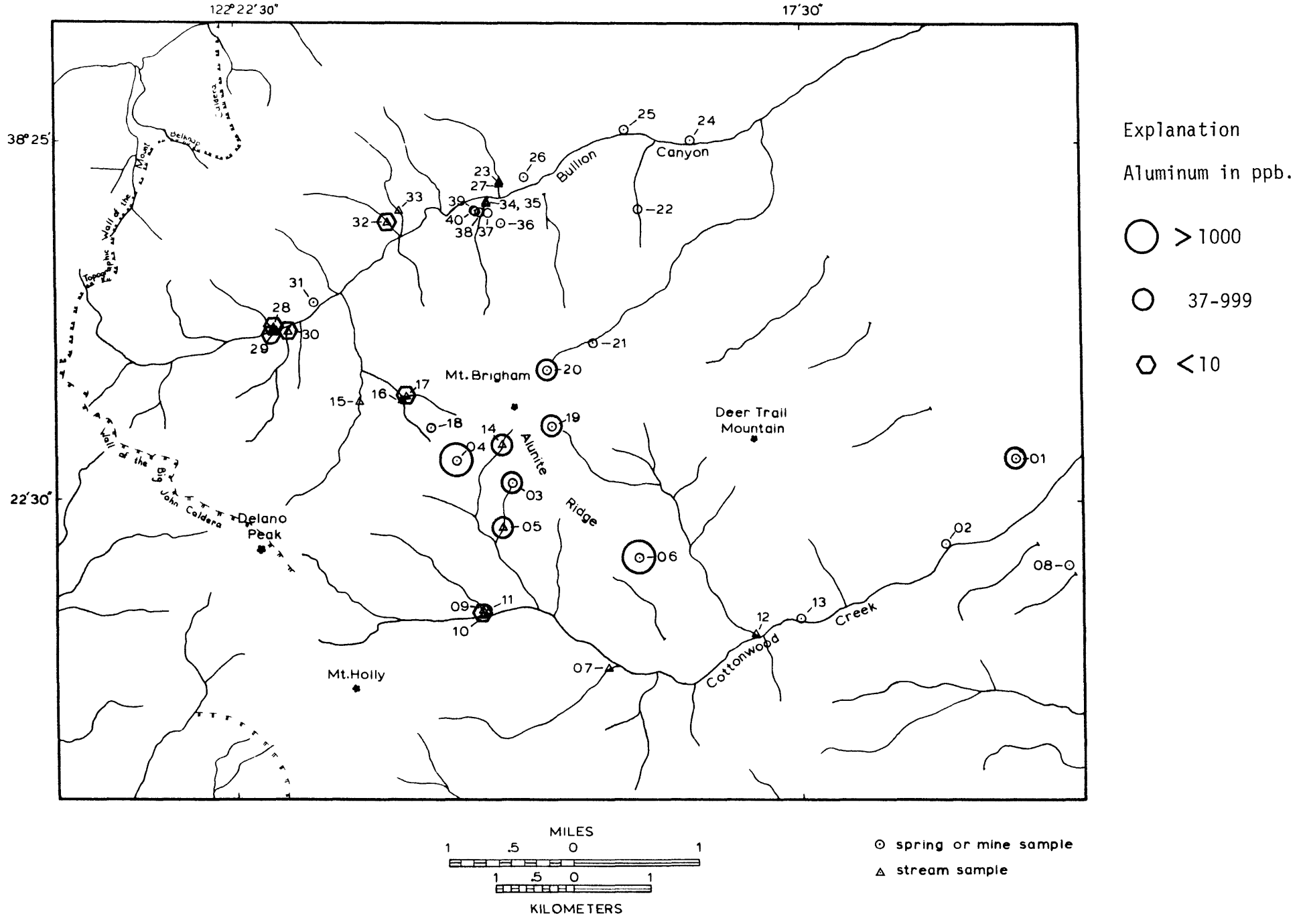


Figure 4.--Distribution of aluminum concentrations within the Deer Trail Mountain-Alunite Ridge study area, southwestern Utah.

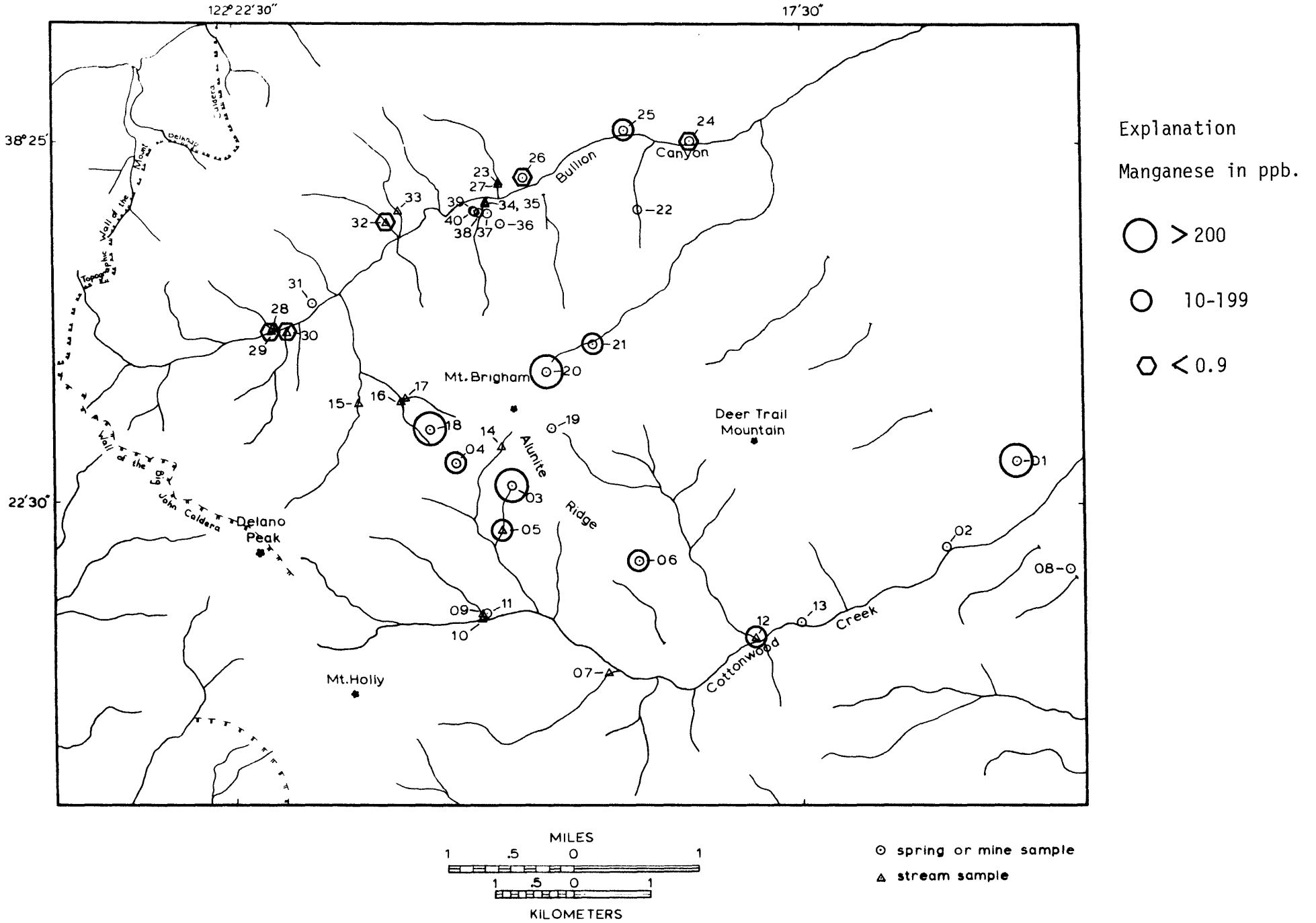


Figure 5.--Distribution of manganese concentrations within the Deer Trail Mountain-Alunite Ridge study area, southwestern Utah.

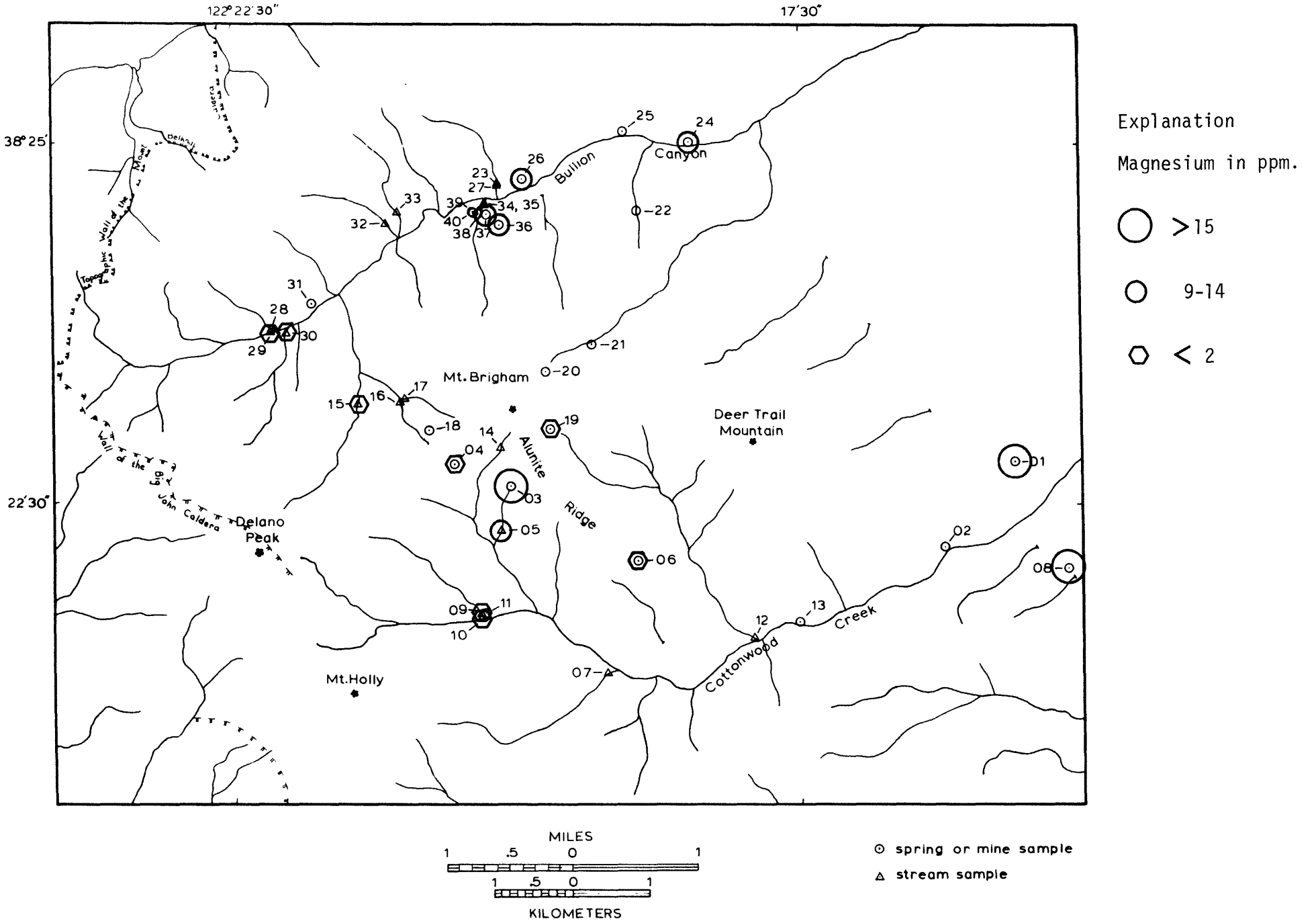


Figure 6.--Distribution of magnesium concentrations within the Deer Trail Mountain-Alunite Ridge study area, southwestern Utah.

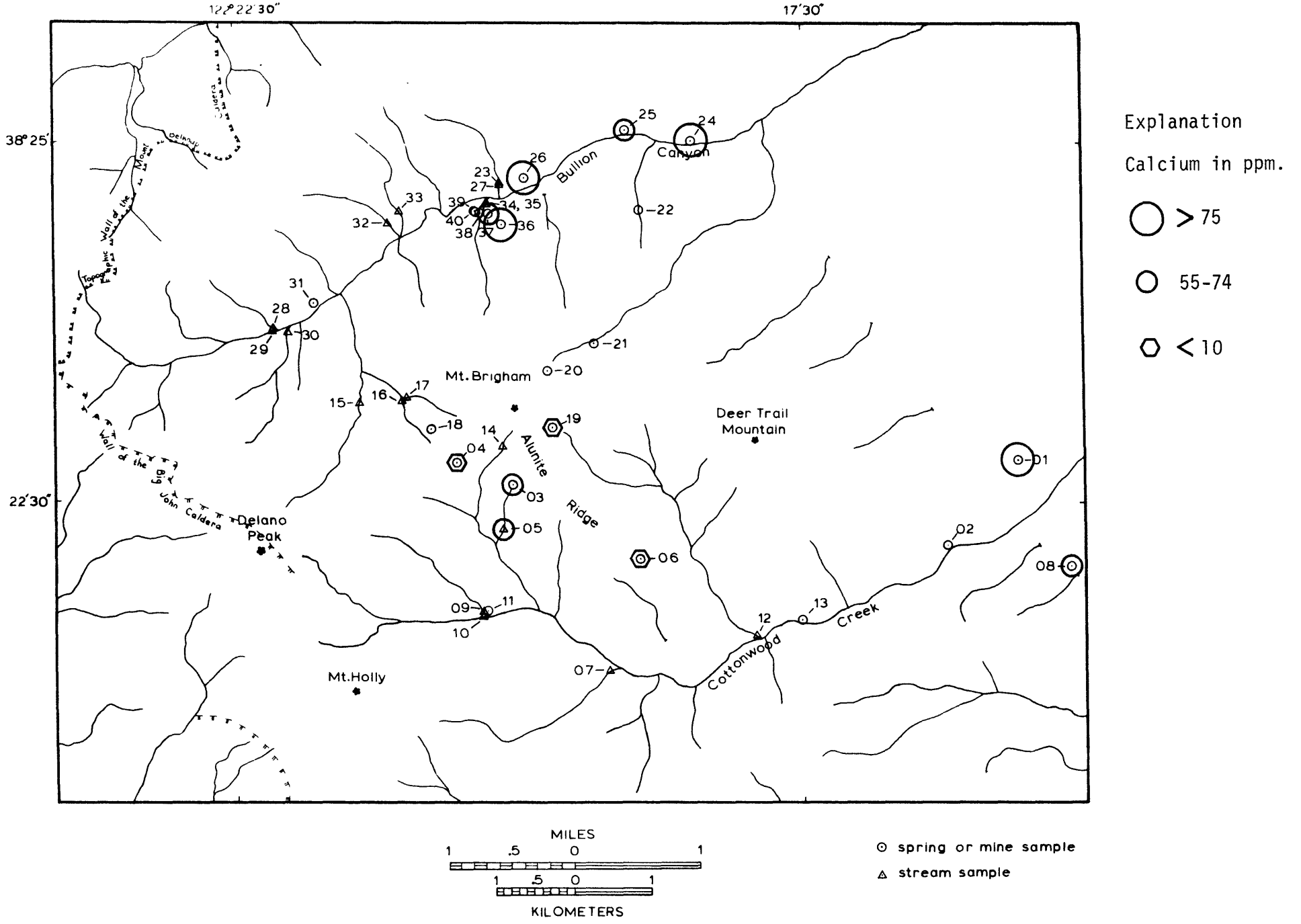


Figure 7.--Distribution of calcium concentrations within the Deer Trail Mountain-Alunite Ridge study area, southwestern Utah.

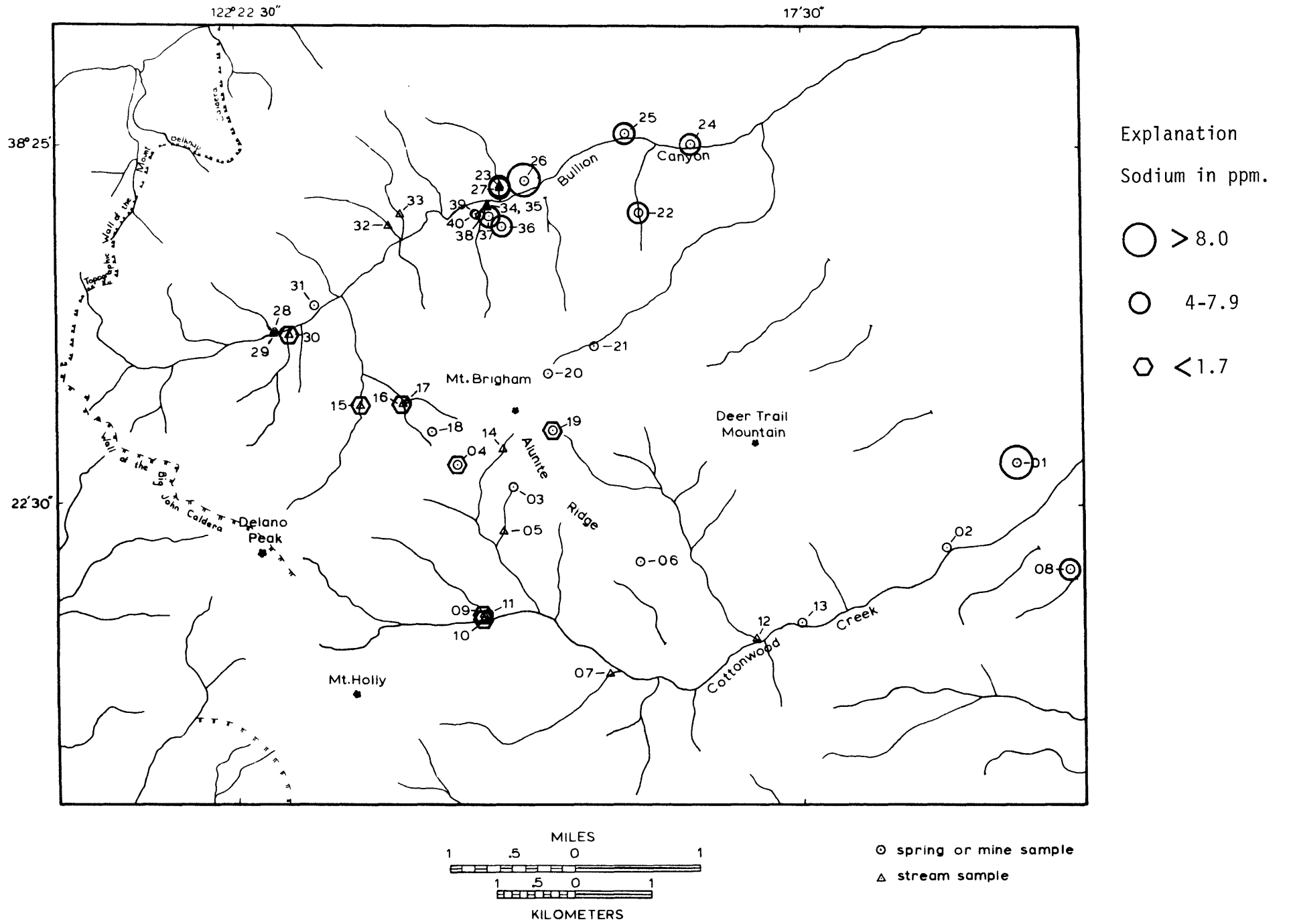


Figure 8.--Distribution of sodium concentrations within the Deer Trail Mountain-Alunite Ridge study area, southwestern Utah.

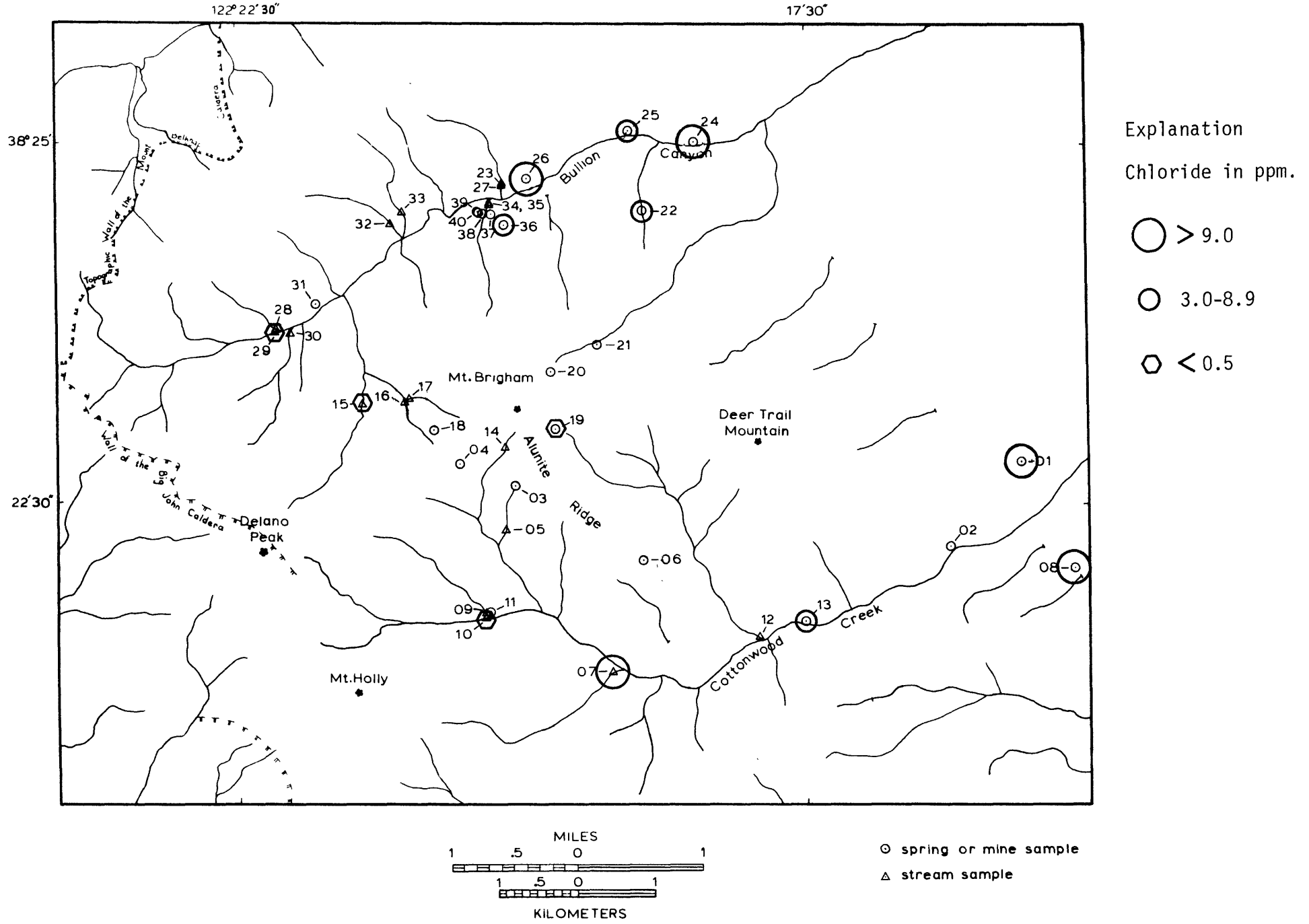


Figure 9.--Distribution of chloride concentrations within the Deer Trail Mountain-Alunite Ridge study area, southwestern Utah.

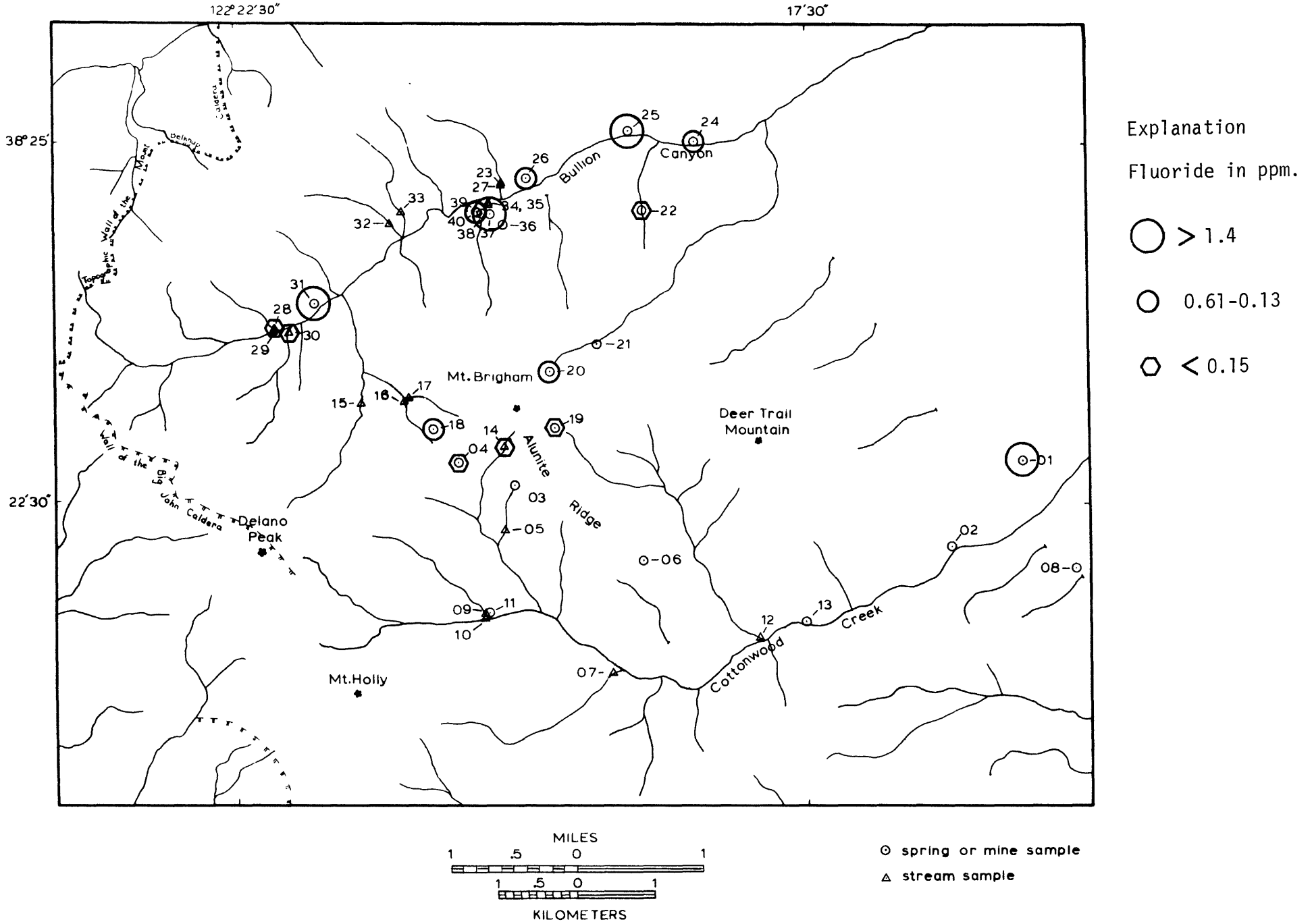


Figure 10.--Distribution of fluoride concentrations within the Deer Trail Mountain-Alunite Ridge study area, southwestern Utah.

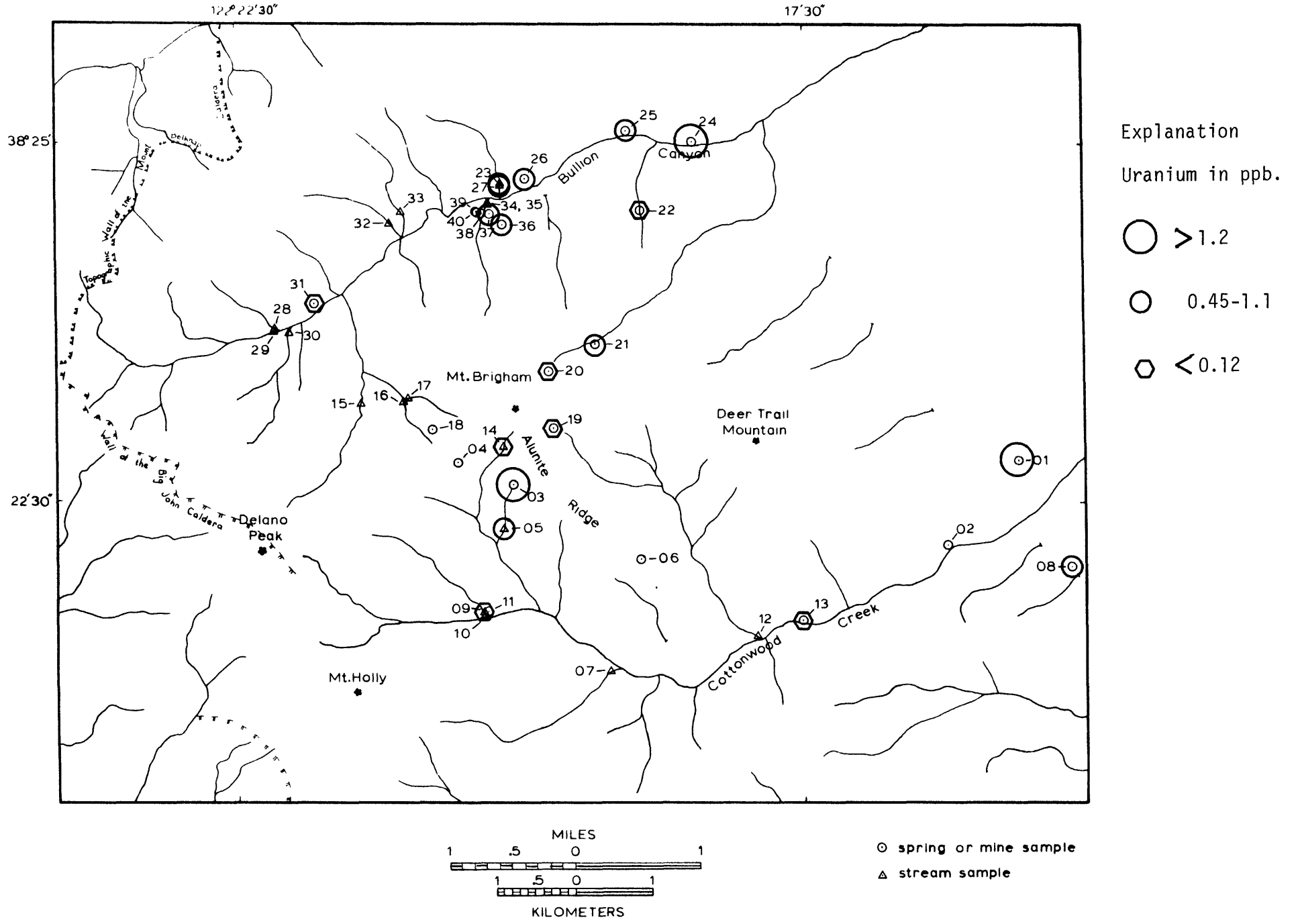


Figure 11.--Distribution of uranium concentrations within the Deer Trail Mountain-Alunite Ridge study area, southwestern Utah.

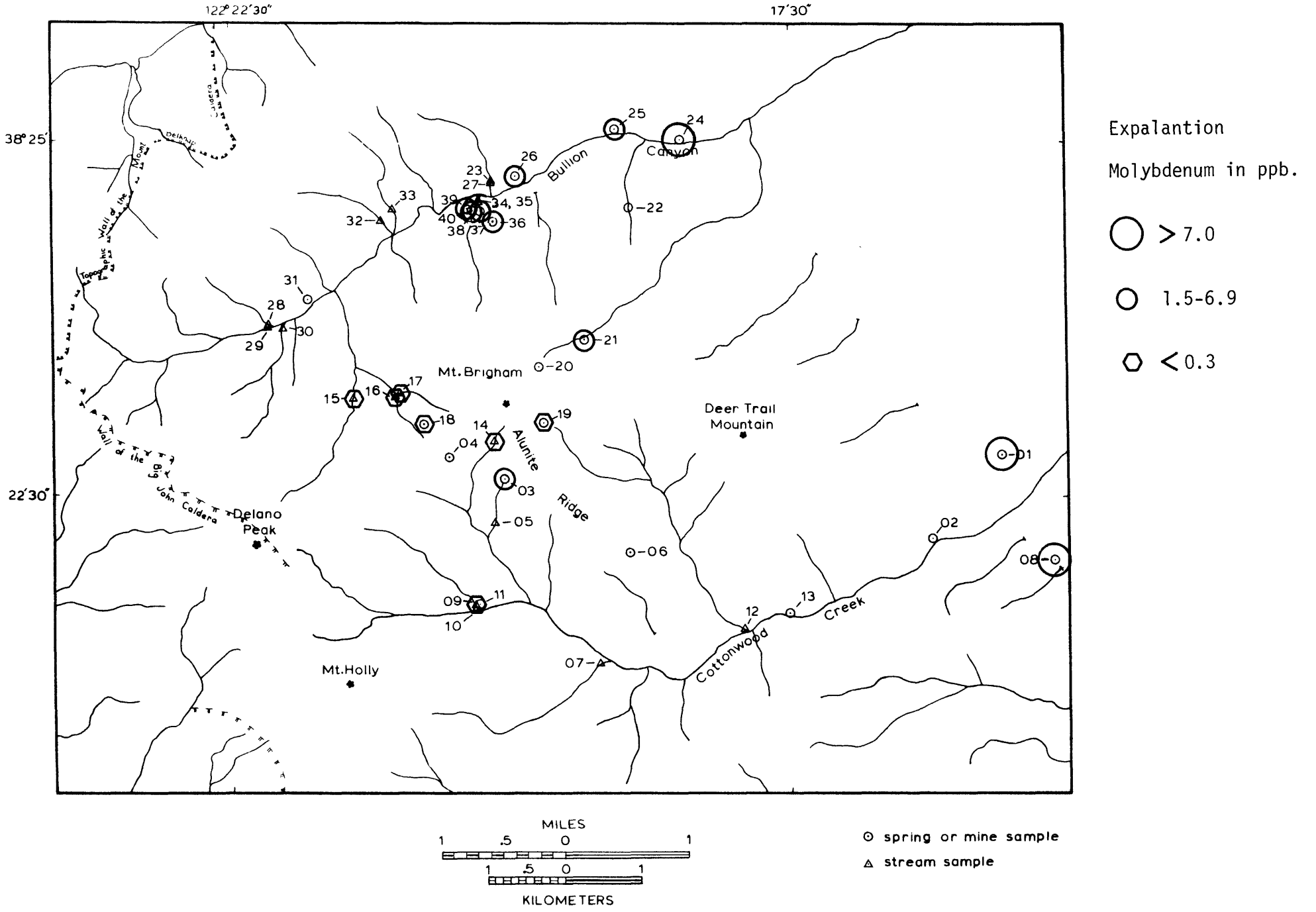


Figure 12.--Distribution of molybdenum concentrations within the Deer Trail Mountain-Alunite Ridge study area, southwestern Utah.

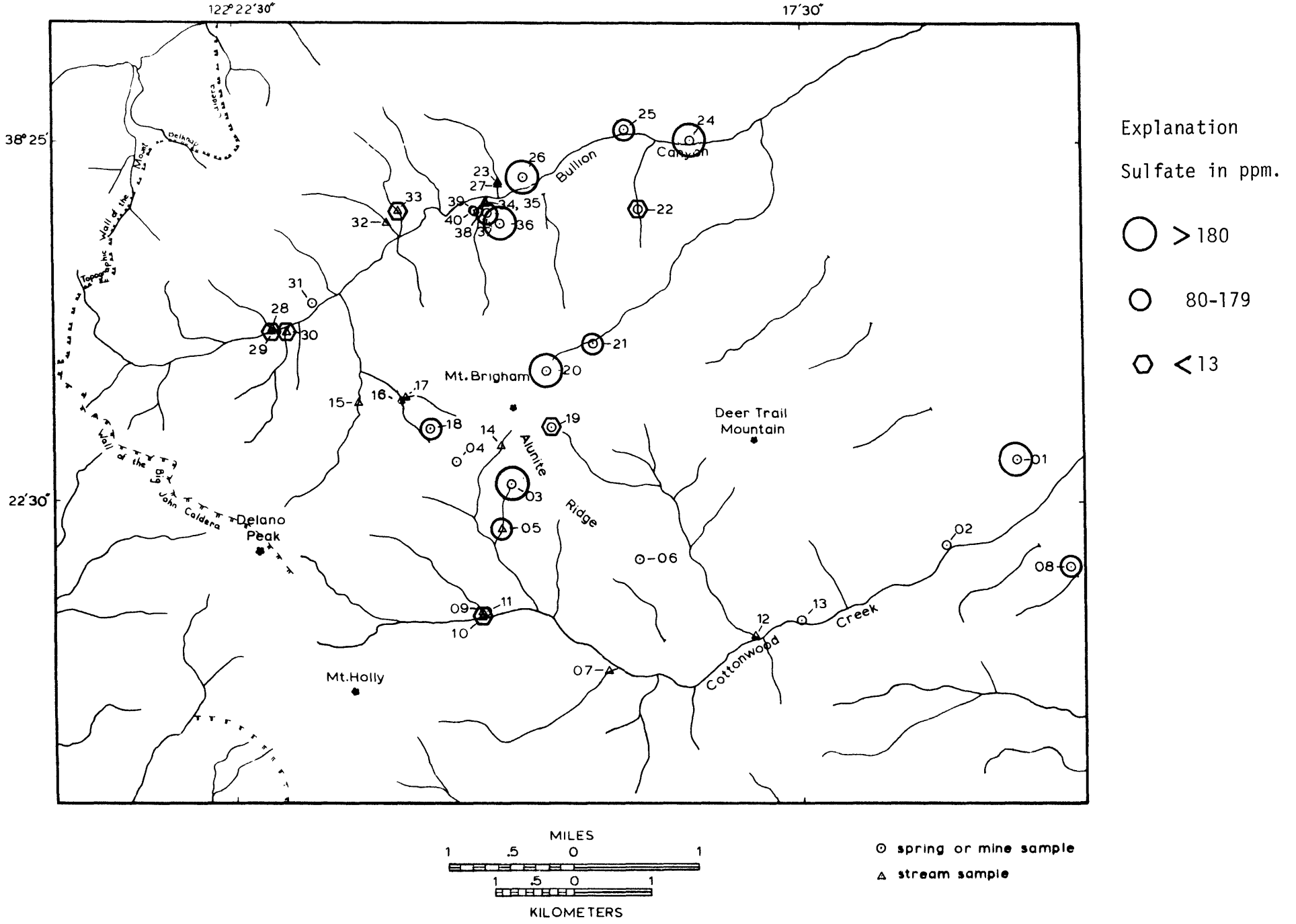


Figure 13.--Distribution of sulfate concentrations within the Deer Trail Mountain-Alunite Ridge study area, southwestern Utah.

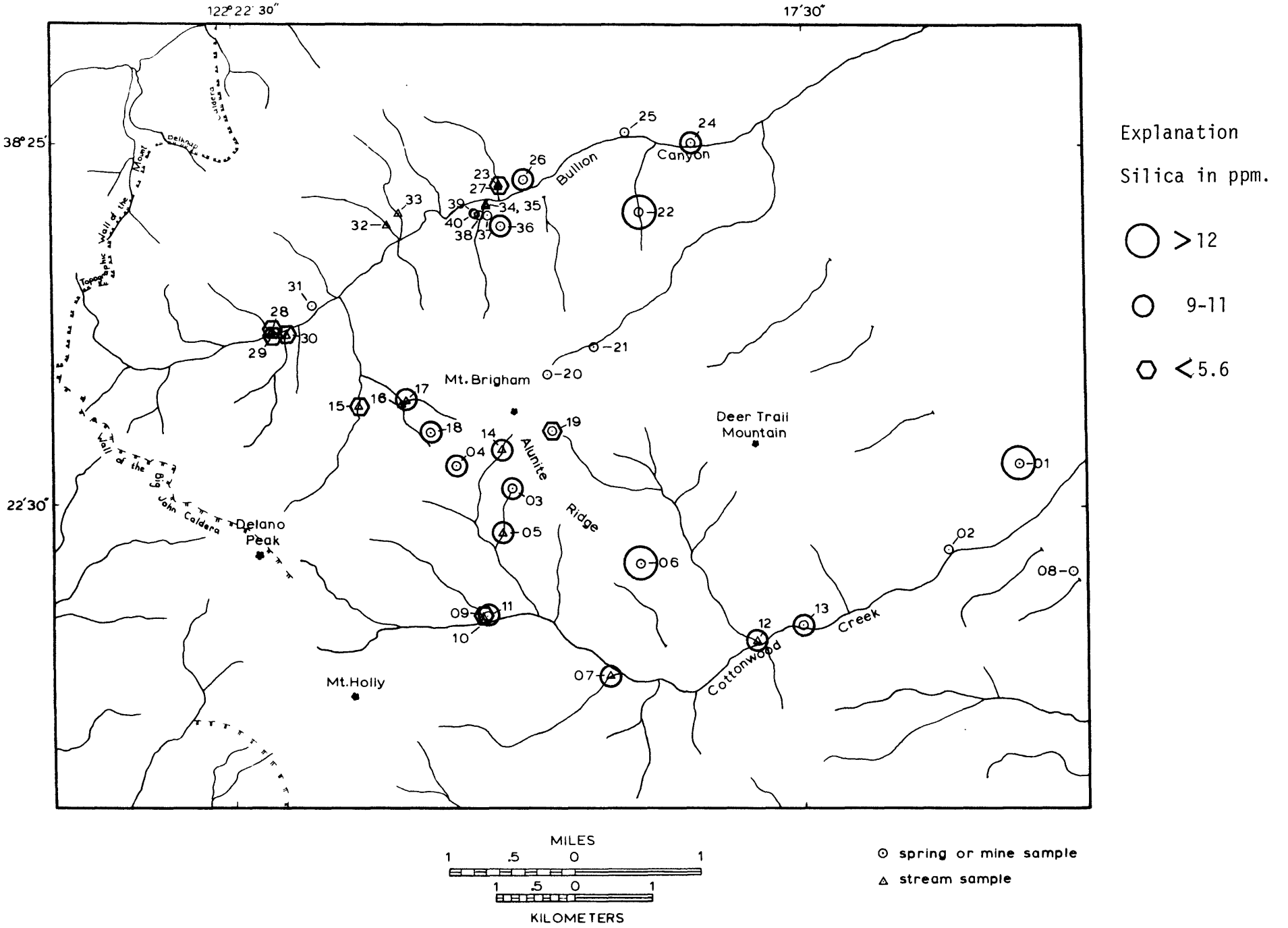


Figure 14.--Distribution of silica concentrations within the Deer Trail Mountain-Alunite Ridge study area, southwestern Utah.

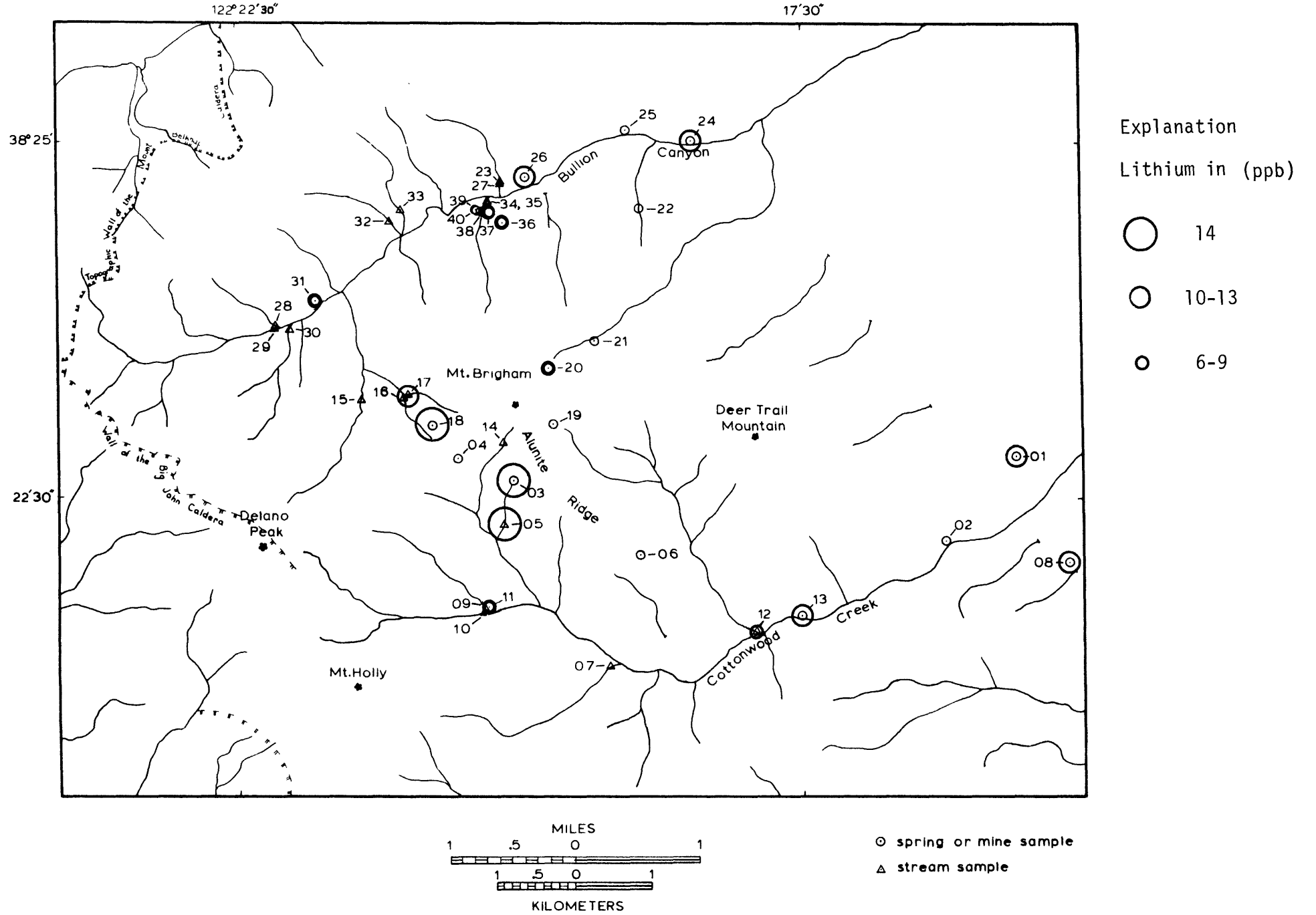


Figure 15.--Distribution oflithium concentrations within the Deer Trail Mountain-Alunite Ridge study area, southwestern Utah.

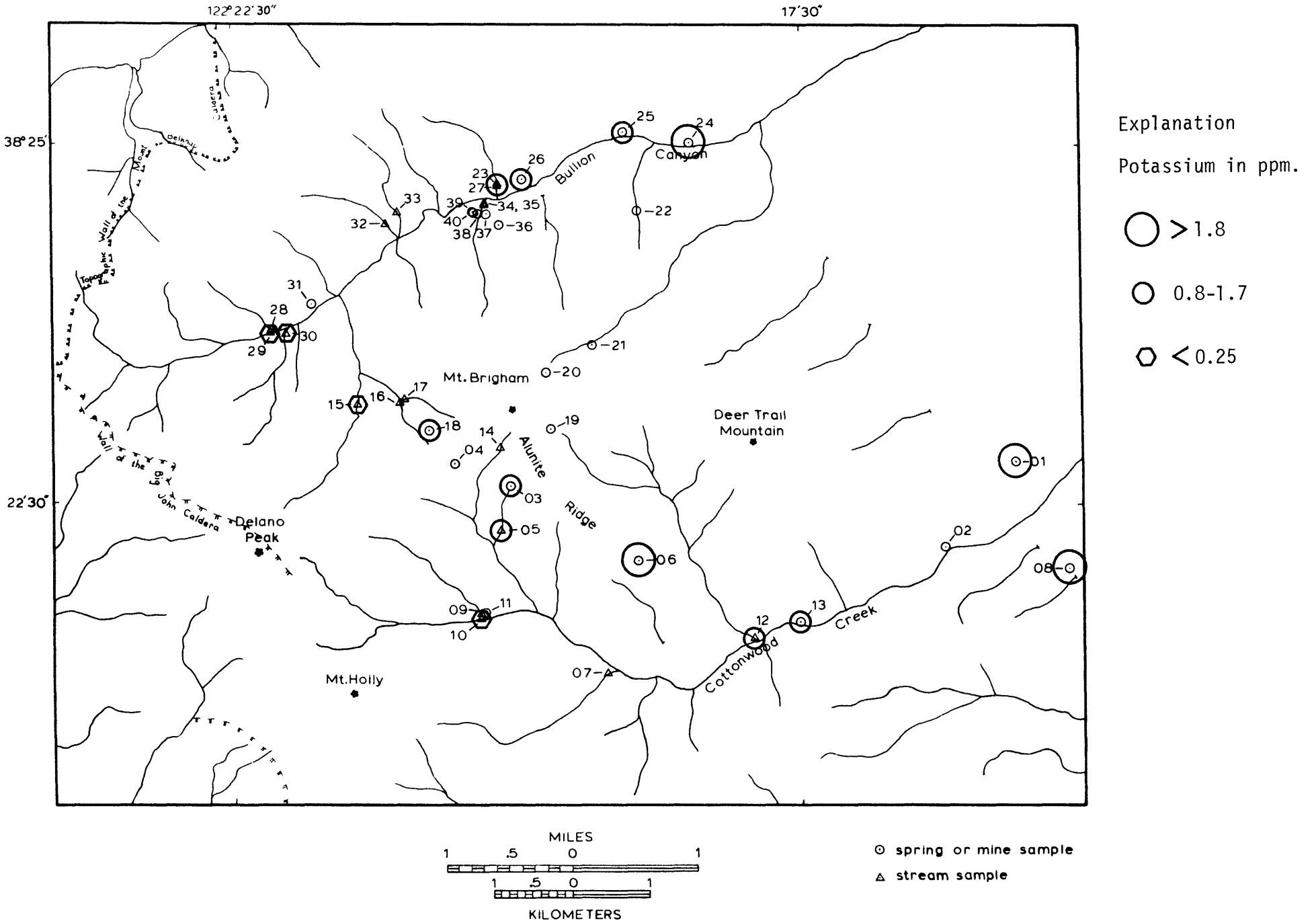


Figure 16.--Distribution of potassium concentrations within the Deer Trail Mountain-Alunite Ridge study area, southwestern Utah.

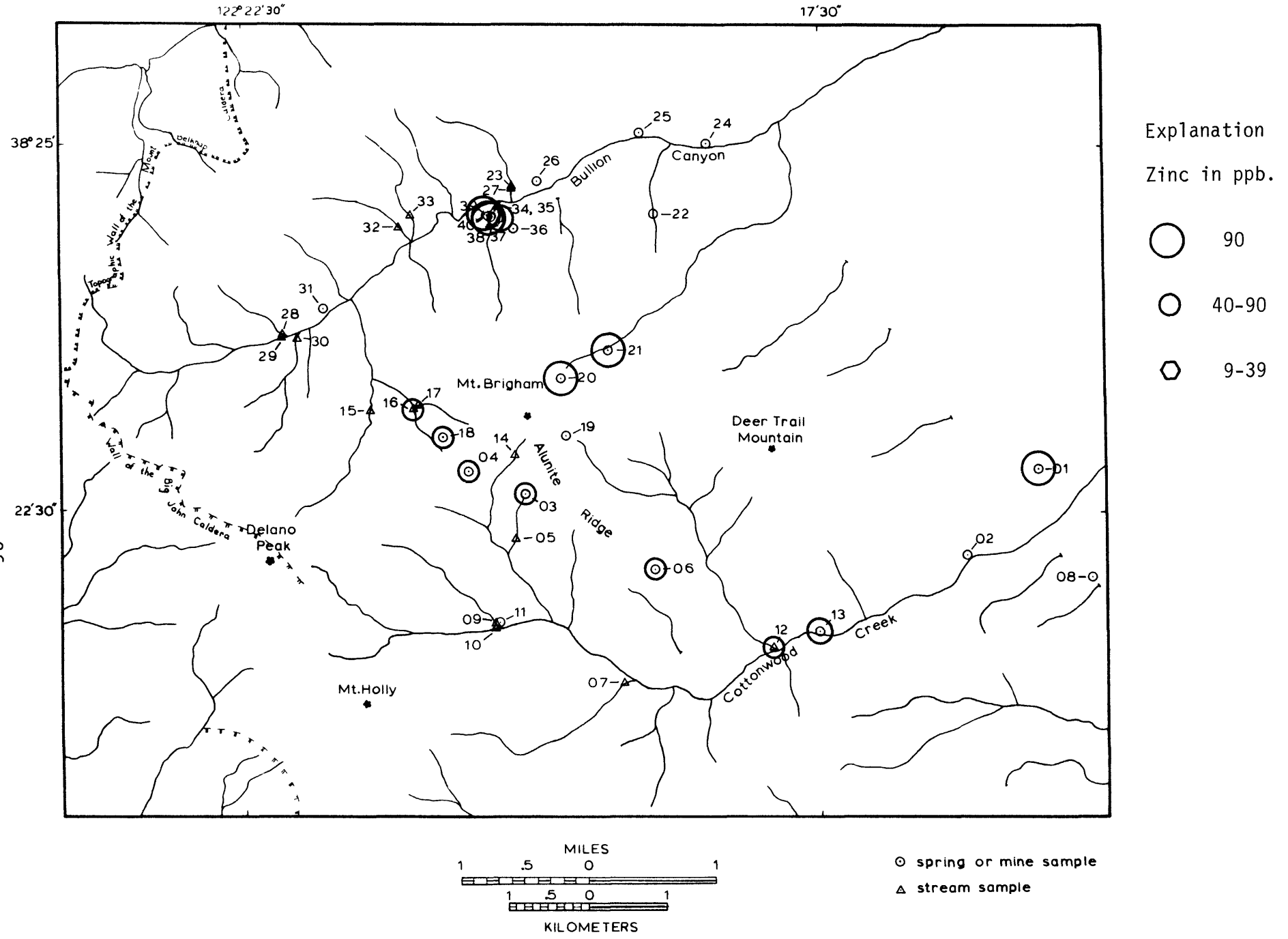


Figure 17.--Distribution of zinc concentrations within the Deer Trail Mountain-Alunite Ridge study area, southwestern Utah.

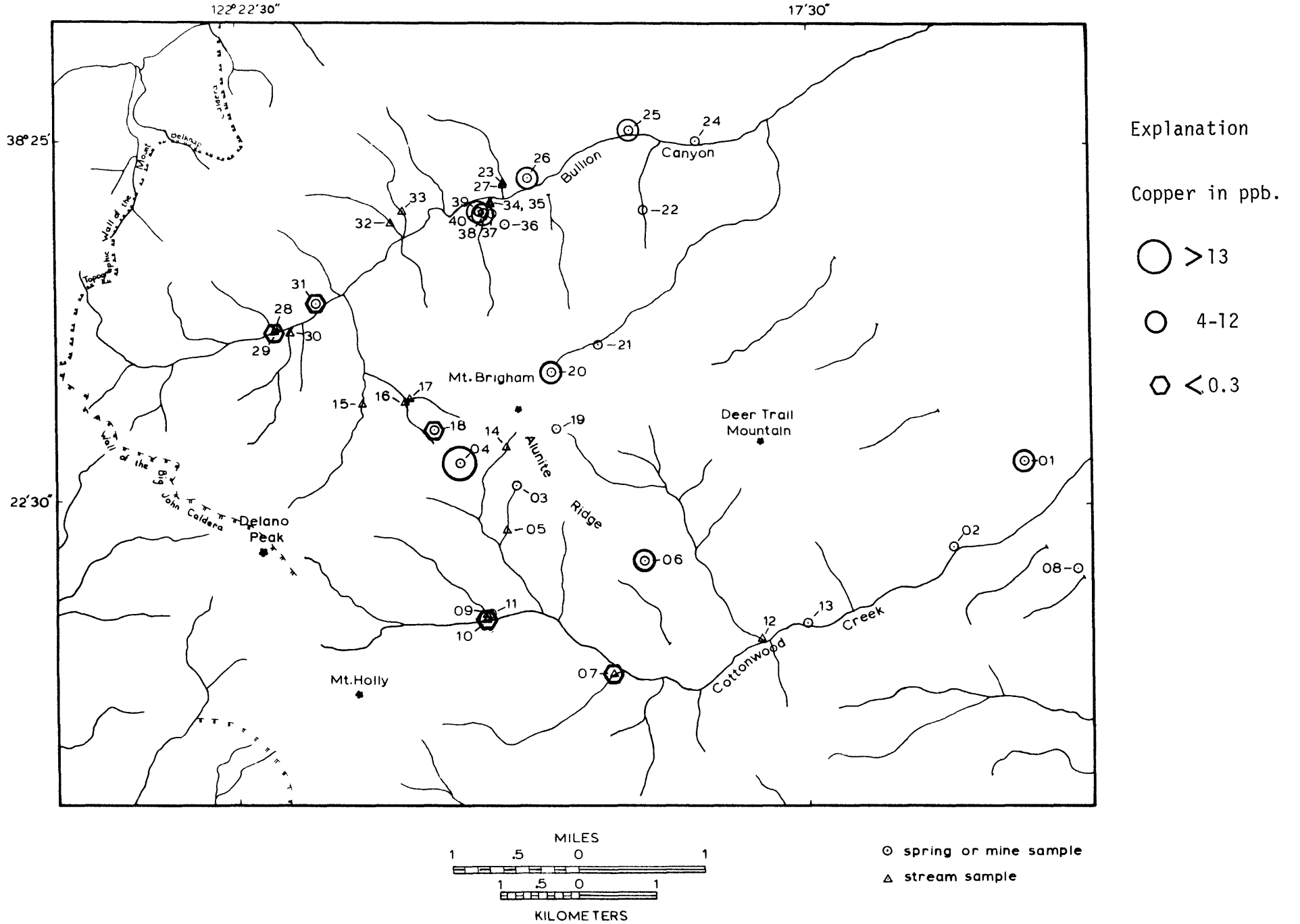


Figure 19.--Distribution of copper concentrations within the Deer Trail Mountain-Alunite Ridge study area, southwestern Utah.

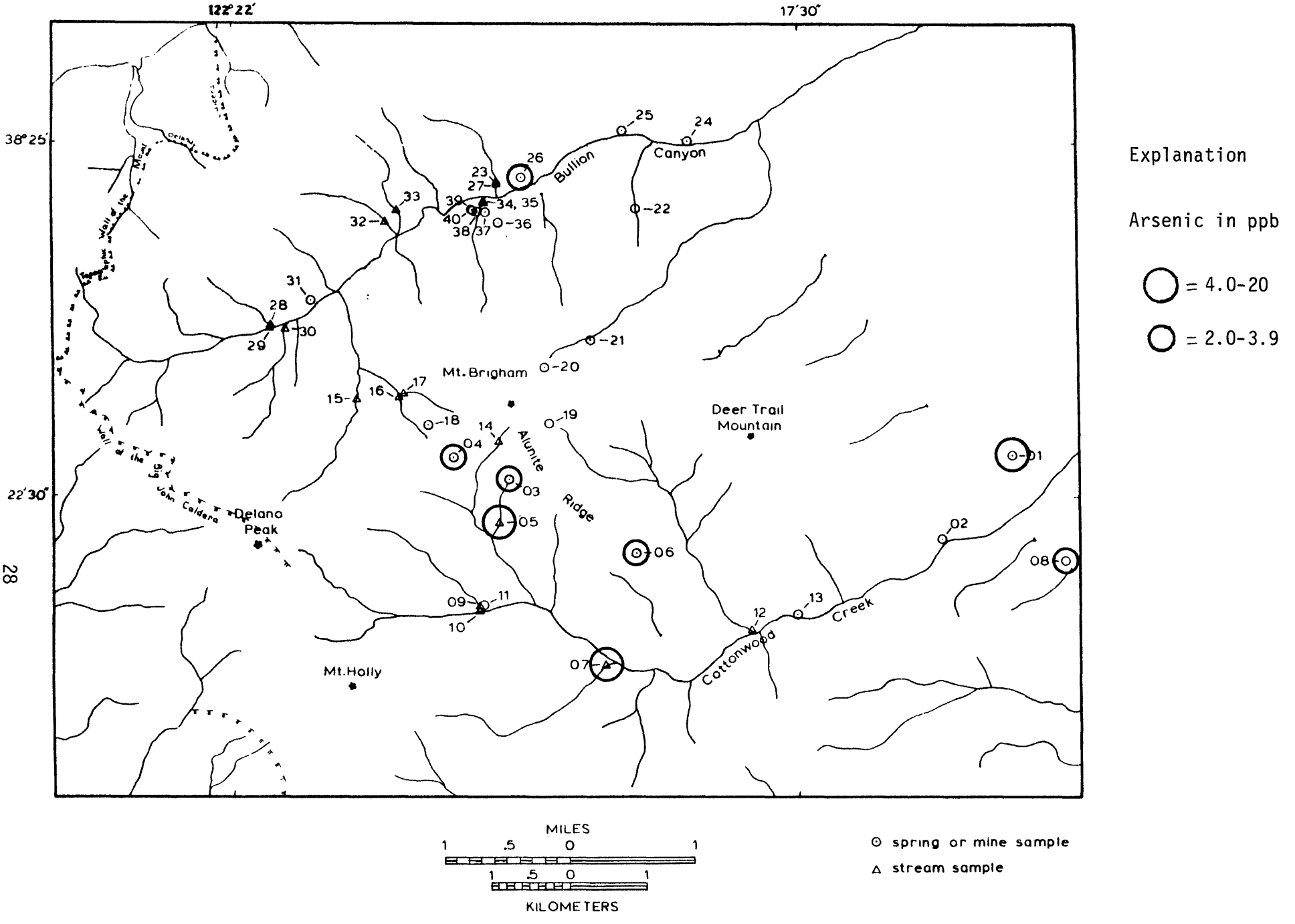


Figure 19.--Distribution of arsenic concentrations within the Deer Trail Mountain-Alunite Ridge study area, southwestern Utah.

The mineral deposits in the lower region of Pine Creek are predominantly manto-type, precious metal containing base-metal sulfide deposits, located within the Toroweap Formation (Callaghan, 1973). Samples 36, 37, 38, and 39 are from mine drainages within the lower region of Pine Creek. The chemical weathering of the rocks within these deposits can be characterized by a suite containing elevated concentrations of Mg, Ca, Na, $SiO_2$, $SO_4$, F, Zn, Cu, Mo, As, and U. However, not all of the samples have all of these ions and the absolute concentrations vary. Samples 24, 25, and 26 are from springs within lower Pine Creek region. Site 24 is located on the north side of Pine Creek below several adits and prospects on the hillside. Sites 25 and 26 are located to the east of the present mining area. All three of these springs exhibit a geochemical signature that is similar to the mine drainages mentioned above. Additional geochemical and geological study is warranted in the recharge basins of these springs.

Sample 08 was collected from a spring located approximately one km (0.6 mi) south of the Deer Trail Mine. This sample has elevated concentrations of Mg, Ca, Na, Cl, U, Mo, $SO_4$, $SiO_2$, Li, K, and As. This suite of ions is similar to the geochemical suite that is characterized in the mines in Bullion Canyon and sample 01, which is from the Deer Trail Mine.

The rocks above the spring at site 08 are predominantly Navajo Sandstone, which is not generally recognized as being the host rock for the precious metal containing base-metal sulfide deposits (Callaghan, 1973). Several rock samples were collected from the hillside directly above the spring in March of 1983 (fig. 20). The analyses (Appendix 2) indicate that the source of the ions observed in sample 08 cannot readily be attributed to the chemical weathering of the overlying rocks. It is interesting to note that the temperature of the spring source was 14°C even though the air temperature was below freezing and snow had persisted on the slopes for several months.

This spring is located along the Tushar Fault, which may act as a conduit for solutions rising from depth or moving laterally. The rocks in the immediate vicinity have been mapped as a subsided block of the sedimentary sequences that are exposed to the north (Cunningham and Steven, 1979b) and suggests that the recognized mineral deposit host, the Toroweap Formation lies buried under the present basin fill. The geochemical signature of the water from site 08 suggests that weathering of metal sulfide minerals is occurring at depth and that these ions are traveling to the surface, possibly along the Tushar Fault.

## Q-MODE FACTOR ANALYSIS

The geologic environment within the study area indicates that several alteration and mineralization sequences have been superimposed on the original compositions of the host rocks. Alteration and(or) mineralization of the original host rock along with subsequent chemical weathering of these rocks can produce differing geochemical signatures within the waters. This explains to some degree the often complex geochemical signatures or suites of ions observed in the water samples. Q-mode factor analysis was used to help define or group some of the complex geochemical relationships within the data set into discrete suites of constituents which are represented as factors.

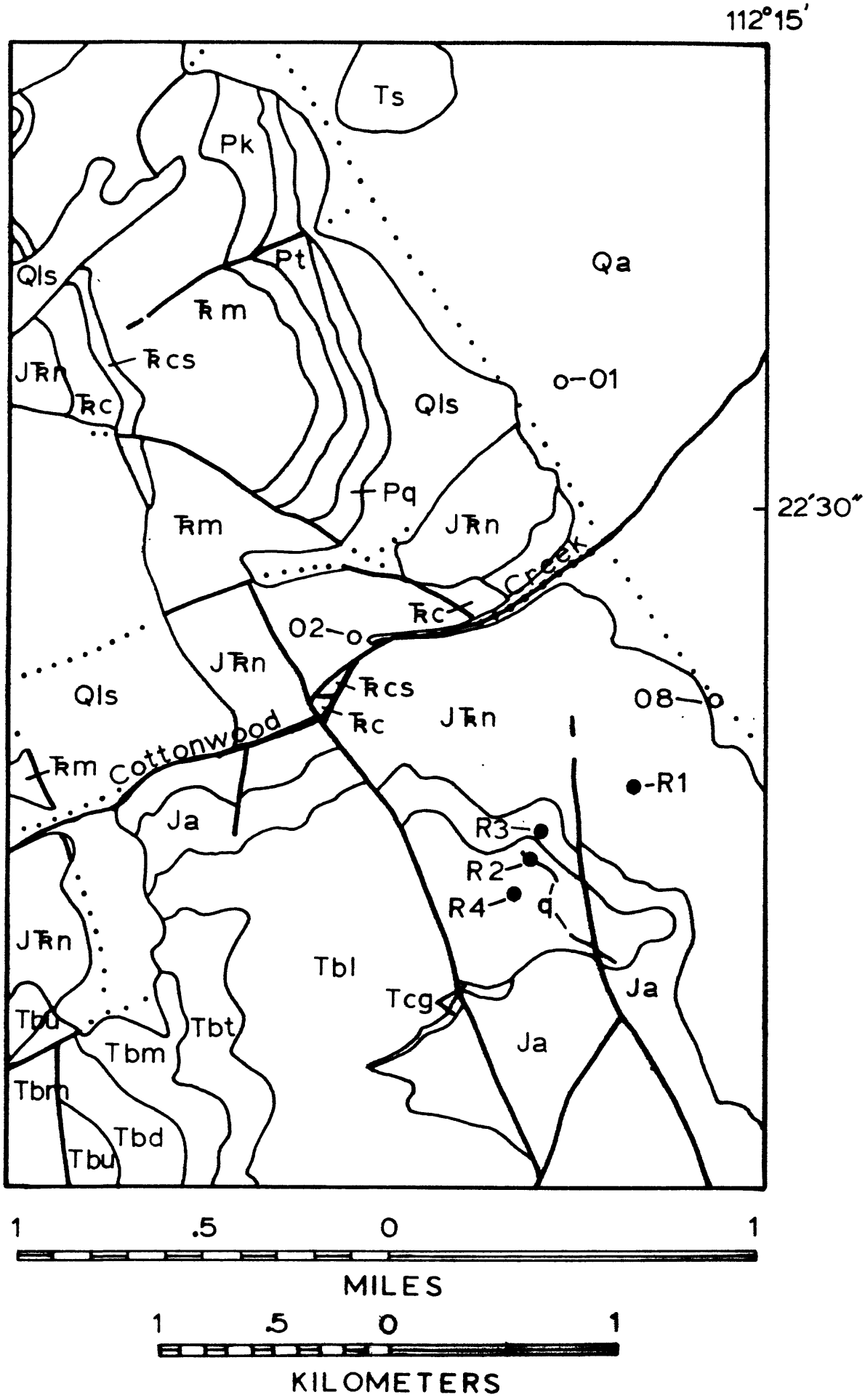


Figure 20.--Site location map for the rock samples taken above site 08 in the Deer Trail Mountain-Alunite Ridge study area, southwestern Utah. See figure 2 for units.

Q-mode factor analysis is a mathematical technique that can be used to estimate various end-member compositions based on constituent relationships within the samples. The relative importance a constituent has in defining the end-member compositions are given by factor scores. The individual samples are then compared to the end-member compositions. The measure of how well a sample compares to the end-member composition is defined by the factor loading.

Q-mode factor analysis demonstrates that certain end-member compositions or factors exist, however, the interpretation of the factors and their geochemical significance is a subjective process that relies on the individual's knowledge of geochemical and geological processes and their relationships. Background information regarding Q-mode factor analysis can be found in Davis (1973) and Klovan and Imbrie (1971). Geochemical studies that have applied this technique to mineral exploration can be found in Miller and others (1979 and 1980) and Tucker, R. E., and others (1980, 1981, and 1982).

Prior to Q-mode factor analysis calculations the three duplicate site samples and the analytical duplicates were removed from the data set and the data for 17 constituents was logarithmically transformed. The factor scores and factor loading are given in Tables 4 and 5, respectively. The data were interpreted using a three-factor model that explains 93.7 percent of the total variance within the data set.

## Factor 1

Factor 1 explains 40.8 percent of the total variance. Factor 1 is defined by positive scores for the ions alkalinity ($HCO^-_3$), Ca, Al, $SiO_2$, and $SO_4$, and negative scores for the ions F, U, Mn, K, and Mo. Samples 30, 20, 28, 32, and 10 have high loadings for factor 1 (Table 5) and are located in unmineralized Bullion Canyon Volcanics rock. This factor can be depicted as representing the chemical weathering of unmineralized rocks. The spatial distribution of high factor loadings are given in figure 21.

The high factor score for alkalinity reflects its contribution in defining the end-member composition, because carbonic acid is the predominant acid in most natural waters. This complements the geochemical interpretation of the factor. The high factor scores for Ca, Al, and $SiO_2$ are interpreted as reflecting the chemical weathering of felspars found within the Bullion Canyon Volcanics rock. Samples with lower factor loadings generally occur in sites from the mineralized areas.

## Factor 2

Factor 2 explains 38.6 percent of the total variance. This factor can be defined by high factor scores for the ions $SO_4$, alkalinity, Mg, Mn, F, Ca, Zn, Mo, Li, U, Na, and K (Table 4). This suite contains ions that may reflect the chemical weathering of metal sulfide mineralization ($SO_4$, Mn, F, Zn, and Mo), the chemical weathering of carbonate rocks (alkalinity, Mg, and Ca), and ions possibly associated with the weathering of minerals characteristically related to felsic intrusions (F, Mo, Li, U, Na, and K). The samples that best reflect this large geochemical suite are from sites 01, 37, 25, 08, and 24 (Table 5). These samples are from known or suspected metal sulfide mineralized areas. Figure 22 gives the areal distribution of high factor 2 loadings.

Table 4.--Factor score matrix for the constituent ions in the Deer Trail Mountain-Alunite Ridge study area, southwestern Utah

| Constituent | Factor 1 score | Constituent | Factor 2 score | Constituent | Factor 3 score |
|---|---|---|---|---|---|
| Alkalinity | 0.54 | $SO_4$ | 0.41 | Fe | 0.57 |
| Ca | 0.34 | Alkalinity | 0.37 | Al | 0.46 |
| Al | 0.24 | Mg | 0.35 | Mn | 0.32 |
| $SiO_2$ | 0.22 | Mn | 0.32 | Zn | 0.23 |
| $SO_4$ | 0.17 | F | 0.31 | Cu | 0.14 |
| Na | 0.03 | Ca | 0.28 | $SO_4$ | 0.12 |
| Li | 0.02 | Zn | 0.26 | $SiO_2$ | 0.11 |
| Fe | -0.03 | Mo | 0.22 | Li | 0.03 |
| Zn | -0.04 | Li | 0.21 | Ca | 0.02 |
| Cl | -0.05 | U | 0.19 | Cl | 0.01 |
| Mg | -0.08 | Na | 0.18 | K | -0.00 |
| Cu | -0.09 | K | 0.18 | Na | -0.06 |
| Mo | -0.15 | Cl | 0.12 | Mg | -0.07 |
| K | -0.26 | $SiO_2$ | 0.09 | Mo | -0.08 |
| Mn | -0.27 | Cu | 0.08 | U | -0.16 |
| U | -0.35 | Al | 0.06 | F | -0.25 |
| F | -0.40 | Fe | 0.05 | Alkalinity | -0.39 |

Table 5.--Factor loadings by sample site for the Deer Trail Mountain-Alunite Ridge study area, southwestern Utah.

| sample | comm. | | | |
|---|---|---|---|---|
| M01 | 0.964 | 0.210 | 0.430 | 0.857 |
| M02 | 0.969 | 0.749 | 0.193 | 0.609 |
| M03 | 0.891 | 0.305 | 0.511 | 0.733 |
| M04 | 0.932 | 0.077 | 0.946 | 0.179 |
| M05 | 0.961 | 0.477 | 0.364 | 0.778 |
| M06 | 0.921 | 0.111 | 0.930 | 0.211 |
| M07 | 0.976 | 0.784 | 0.280 | 0.532 |
| M08 | 0.918 | 0.510 | 0.167 | 0.794 |
| M09 | 0.974 | 0.818 | 0.279 | 0.476 |
| M10 | 0.959 | 0.838 | 0.222 | 0.456 |
| M11 | 0.978 | 0.746 | 0.174 | 0.625 |
| M12 | 0.977 | 0.577 | 0.413 | 0.688 |
| M13 | 0.909 | 0.602 | 0.352 | 0.651 |
| M14 | 0.974 | 0.659 | 0.578 | 0.452 |
| M15 | 0.960 | 0.824 | 0.282 | 0.448 |
| M16 | 0.958 | 0.741 | 0.267 | 0.582 |
| M17 | 0.930 | 0.668 | 0.189 | 0.669 |
| M18 | 0.849 | 0.356 | 0.335 | 0.781 |
| M19 | 0.867 | 0.621 | 0.694 | 0.030 |
| M20 | 0.935 | 0.300 | 0.688 | 0.609 |
| M21 | 0.919 | 0.537 | 0.350 | 0.713 |
| M22 | 0.905 | 0.752 | 0.312 | 0.492 |
| M23 | 0.954 | 0.643 | 0.215 | 0.703 |
| M24 | 0.871 | 0.494 | 0.057 | 0.790 |
| M25 | 0.929 | 0.481 | 0.254 | 0.796 |
| M26 | 0.920 | 0.592 | 0.078 | 0.750 |
| M28 | 0.972 | 0.861 | 0.129 | 0.464 |
| M29 | 0.939 | 0.892 | 0.200 | 0.321 |
| M30 | 0.932 | 0.913 | 0.170 | 0.265 |
| M31 | 0.936 | 0.714 | 0.092 | 0.646 |
| M32 | 0.988 | 0.852 | 0.050 | 0.509 |
| M33 | 0.946 | 0.763 | 0.196 | 0.570 |
| M34 | 0.969 | 0.707 | 0.221 | 0.648 |
| M36 | 0.978 | 0.614 | 0.169 | 0.757 |
| M37 | 0.973 | 0.454 | 0.205 | 0.851 |
| M38 | 0.885 | 0.562 | 0.313 | 0.686 |
| M39 | 0.848 | 0.499 | 0.290 | 0.718 |
| | variance | 40.75 | 14.31 | 38.62 |

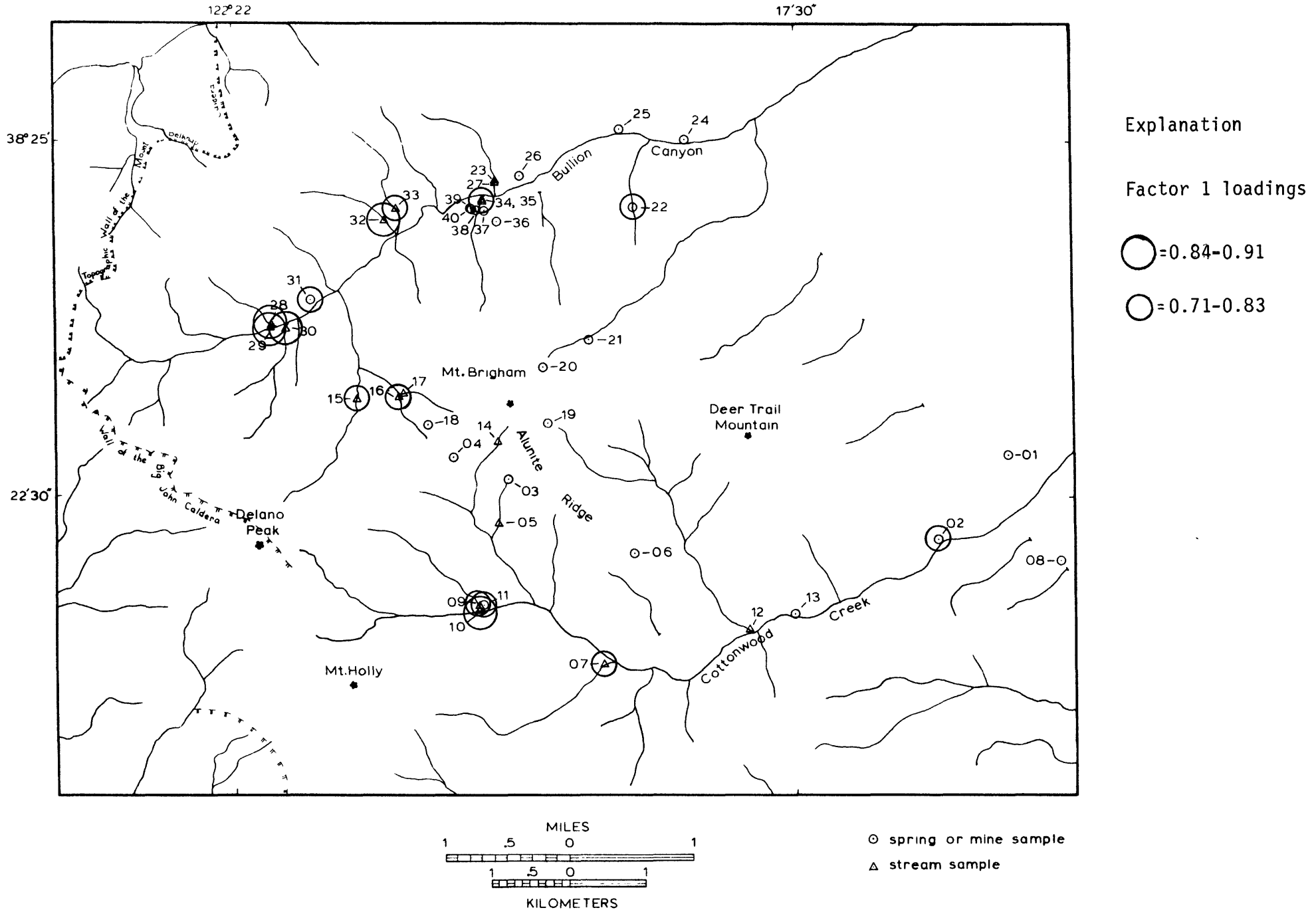


Figure 21.--Distribution of Factor 1 loadings within the Deer Trail Mountain-Alunite Ridge study area, southwestern Utah.

This factor contains two features which are geochemically interesting. The first feature is the very low factor loadings for those sites that have very high factor loadings in factor 1 (Table 5). The factor loadings decrease in sites removed from the mineralized areas of Bullion Canyon. This suggests that very large pervasive halos of metal sulfide minerals were imprinted on the country rock, possibly in response to the implacement of the postulated mineralized stock. Examples of sites in which this halo or subtle mineralization can be observed, occur in samples 31, 32, and 33 within the Pine Creek drainage, and in samples 02, 11, 12, and 13 within the Cottonwood Creek drainage (fig. 22 and Table 4).

The second feature of this factor is the definition of areas which suggest metal sulfide mineralization is present but where no mining activity is present. Sample 08 has the fourth highest factor loading in this factor. As discussed previously, this sample contains anomalous concentrations of many ions characteristic of the chemical weathering of metal sulfide minerals. The presence of sample 08 in this factor is geochemically interesting in terms of defining new target areas for mineral exploration. Sample 03 has the tenth highest factor loading in this factor, which adds credence to the previously discussed significance of this site. Sample 07, 16, and 33 deserve mention also, for they have rather high factor loadings. These sites are located in areas contiguous to known mineral deposits. These high factor loadings may reflect areas where the chemical weathering of metal sulfide minerals is occurring and(or) the extent of pervasive alteration related to the postulated stock implacement.

### Factor 3

Factor 3 explains 14.3 percent of the total variance. This factor is defined by positive factor scores for Fe, Al, and Mn and negative factor scores for alkalinity, F, and U. The ion Zn may also be useful in defining this factor (Table 5). This geochemical suite or factor is somewhat similar to factor 2 and presents some difficulty in its interpretation. This factor may reflect the chemical weathering of alunite and possibly pyrite but samples with the highest factor loadings are restricted to drainages from Alunite Ridge (fig. 23).

The high loadings for sample 03 in factors 2 and 3 is interesting. The factor loadings suggest that chemical weathering of two rather distinctive rock or mineral types is occurring in the recharge region for this spring, which creates the geochemical signature observed in this sample. This further supports the speculation that water from this spring is migrating upwards from a deeper source and(or) that an upper level expression of the proposed metallized hidden stock is near the surface in this area.

## WATEQ3 MODELING

The computer modeling program WATEQ3 (Ball and others, 1981) uses thermodynamic data and assuming chemical equilibrium among dissolved species, calculates the probable activities, metal complexes and ionic speciation in the water. The Eh for a sample was calculated from the $Fe(OH)_3 + 3H^+ + e^- \quad Fe^{2+} + 3H_2O$ couple (Miller and McHugh, 1981b). This couple is assumed to control the Eh of a solution due to the rapid reactivity of $Fe^{2+}$ in an oxidizing environment and the relative abundance of iron in contact with an aqueous system.

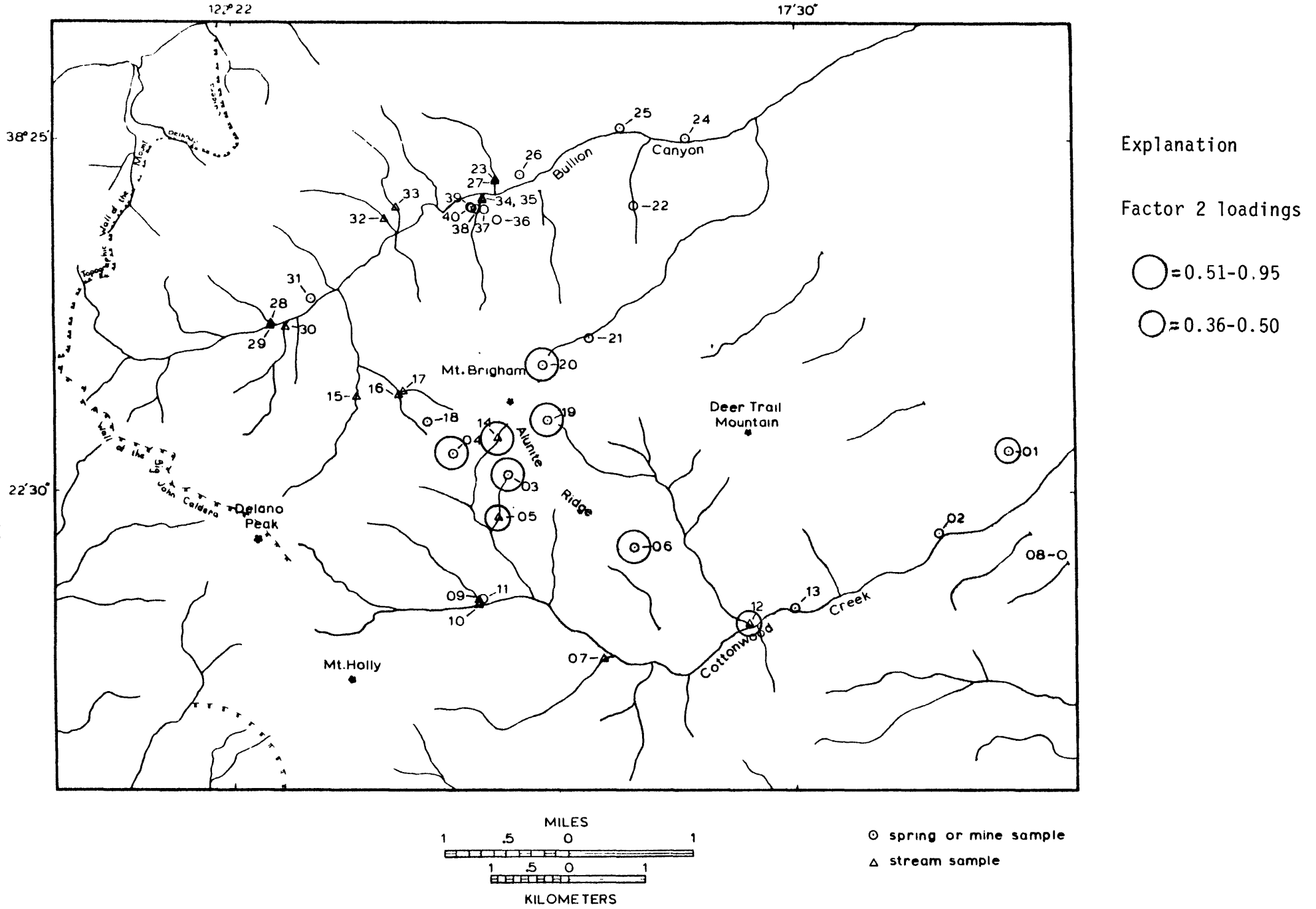


Figure 22.--Distribution of Factor 2 loadings within the Deer Trail Mountain-Alunite Ridge study area, southwestern Utah.

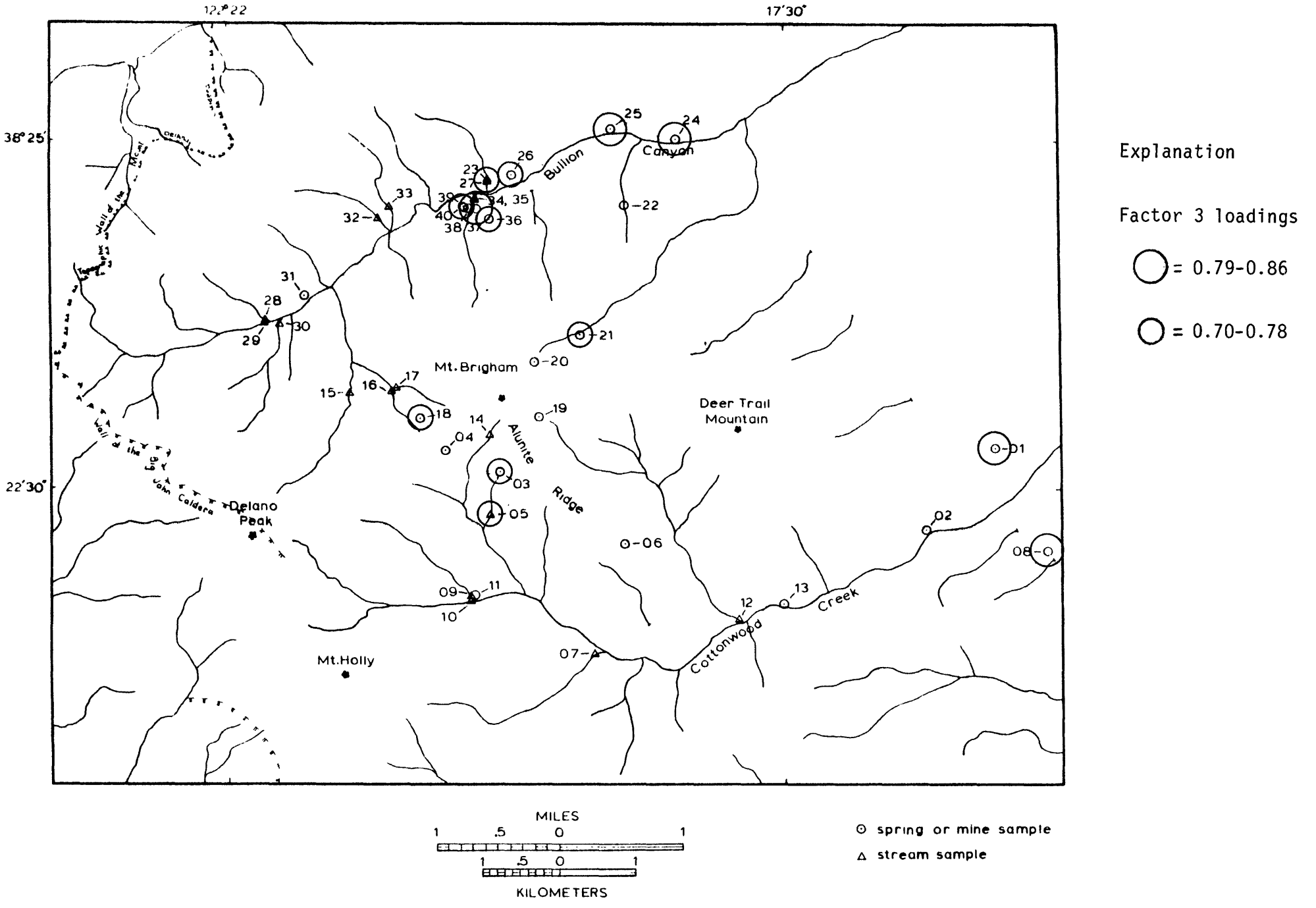


Figure 23.--Distribution of Factor 3 loadings within the Deer Trail Mountain-Alunite Ridge study area, southwestern Utah.

The saturation index (SI) is a measure of the thermodynamically calculated stability of a mineral in the aqueous environment. The SI is the logarithm of the ratio of the apparent ion activity product (Kap) to the equilibrium solubility product (Kt). An SI >0 indicates that the system is supersaturated with respect to a certain mineral phase and that precipitation should occur. An SI <0 indicates the solution is undersaturated with respect to a certain mineral phase and that dissolution may be taking place. The use of this technique has been applied to the investigation of known sandstone-type uranium deposits (Langmuir and Chatham, 1980; Runnells and others, 1981) and in exploration studies for roll front-type uranium deposits (Miller and others, 1980; Miller and McHugh, 1981a and b; Chatham and others, 1981; Wanty and others, 1981). The utility of the WATEQ3 program in this study was primarily to define the speciation within 10 selected water samples and to determine the calculated stability of certain mineral phases that may be related to mineralization processes. These samples were chosen on the basis of factor analysis results and their potential contribution to the geochemical understanding of the study area. Samples 01, 37, and 38 were from mines and have high factor 2 scores. Samples 29 and 30 are from unmineralized areas and have high factor 1 scores. Samples 02, 08, and 20 may reflect areas containing undetected metallization and have high factor 2 scores. Samples 03 and 05 were chosen because of their unique geochemical signature and high factor 2 scores.

Two general water types occur within the study area. Type I waters are characteristic of unmineralized areas (samples 29 and 30) and type II waters are characteristic of metal sulfide mineralized areas (samples 1, 37, 39, and possibly 02, 03, 08, 20). There is not a distinct difference in the metal complexes between the water types, however, type I waters are generally characterized by $HCO^-_3$ and $OH^-$ complexes for Mg and Fe (Table 6). This would suggest that carbonic acid is the predominant agent responsible for initiating chemical weathering of the rocks. Type II waters are characterized by a predominance of, or nearly equal calculated activities of $SO_4^{2-}$ and $HCO^-_3$ complexes for Mg and predominantly $SO_4^{2-}$ complexes of Fe. Sulfate is the predominant complexing anion in samples from known metal sulfide mineralized areas which indicates the oxidation of sulfide minerals is responsible for a majority of the chemical weathering. Streams and springs in areas contiguous to known metal sulfide mineralization tend to have nearly equal activities of $SO_4^{2-}$ and $HCO^-_3$ in Mg and Fe complexes which would indicate that pervasive metal sulfide metallization has occurred over large areas surrounding the known metal sulfide deposits. This evidence further supports the hypothesis that a metallized stock was implaced in the area.

The geochemical signature of a water will be affected by the various minerals that are being dissolved and(or) precipitated within the recharge basin (Miller and Dreaver, 1977; Garrells and Christ, 1965). The SI calculated for certain minerals from the study area samples are given in Table 7. Alunite, anorthite, and gypsum have negative SI's, indicating these minerals are thermodynamically unstable and would be dissolving. This would account for the elevated concentrations of $SO_4$, Ca and $SiO_2$ in waters with high loadings on factor 2. The SI for kaolinite and some montmorillinite clays are positive for all samples, except for samples 29 and 30, suggesting that these minerals may be presently forming in the recharge basins.

Table 6.--Predominant complexing ions for selected metals from 10 representative water samples in the Deer Trail Mountain-Alunite Ridge study area, southwestern Utah

| | | ions | | | | | |
|---|---|---|---|---|---|---|---|
| Site | pH | $UO_2$ | Ca | Mg | Al | Fe | Cu |
| M01 | 6.52 | $CO_3^{2-}$ | $SO_4^{2-}$ | $SO_4^{2-}$ | $F^-$ | $SO_4^{2-}$ | $CO_3^{2-}$, $HCO_3^-$ |
| M02 | 7.37 | $CO_3^{2-}$ | $SO_4^{2-}$ | $SO_4^{2-}$, $HCO_3^-$ | $OH^-$ | $OH^-$ | $OH^-$, $CO_3^{2-}$ |
| M03 | 6.53 | $CO_3^{2-}$ | $SO_4^{2-}$ | $SO_4^{2-}$ | $OH^-$ | $SO_4^{2-}$ | $HCO_3^-$, $CO_3^{2-}$ |
| M05 | 7.73 | $CO_3^{2-}$ | $SO_4^{2-}$ | $SO_4^{2-}$ | $OH^-$ | $SO_4^{2-}$, $OH^-$ | $OH^-$ |
| M08 | 6.80 | $CO_3^{2-}$ | $SO_4^{2-}$ | $SO_4^{2-}$, $HCO_3^-$ | $OH^-$ | $SO_4^{2-}$, $OH^-$ | $CO_3^{2-}$, $HCO_3^-$, $OH^-$ |
| M20 | 6.91 | --- | $SO_4^{2-}$ | $SO_4^{2-}$ | $OH^-$ | $SO_4^{2-}$ | $OH^-$ |
| M29 | 7.70 | $CO_3^{2-}$ | $SO_4$, $HCO_3$ | $HCO_3^-$, $SO_4^{2-}$ | $OH^-$ | $OH^-$ | --- |
| M30 | 7.76 | $CO_3^{2-}$ | $SO_4$, $HCO_3$ | $HCO_3^-$, $SO_4^{2-}$ | $OH^-$ | $OH^-$ | --- |
| M37 | 8.02 | $CO_3^{2-}$ | $SO_4$ | $SO_4^{2-}$ | $OH^-$ | $OH^-$ | $HCO_3^-$ |
| M38 | 7.96 | $CO_3^{2-}$ | $SO_4$ | $SO_4^{2-}$, $HCO_3^-$ | $OH^-$ | $SO_4^{2-}$, $OH^-$ | $OH^-$ |

Table 7.--Saturation indexes for selected minerals from 10 representative water samples in the Deer Trail Mountain-Alunite Ridge study area, southwestern Utah

| Sample | Water type | Calculated Eh | Alunite | Anorthite | Calcite | Fluorite | Gypsum | Kaolinite |
|---|---|---|---|---|---|---|---|---|
| M01 | 3 | 0.2475 | -1.30 | -6.39 | -0.54 | 0.35 | -0.19 | 1.10 |
| M02 | 1, 3 | 0.2143 | -5.31 | -6.06 | -0.74 | -1.36 | -1.86 | 1.21 |
| M03 | 2, 3 | 0.2145 | -1.06 | -7.53 | -1.36 | -1.10 | -1.20 | 1.55 |
| M05 | 3 | 0.1200 | -3.61 | -3.42 | -0.22 | -1.16 | -1.35 | 2.50 |
| M08 | 3 | 0.2910 | -1.29 | -5.49 | -0.85 | -1.15 | -1.26 | 2.04 |
| M20 | 2 | 0.1517 | -2.61 | -7.56 | -2.30 | -0.90 | -1.35 | 1.37 |
| M29 | 1 | 0.1363 | -9.75 | -6.83 | -1.07 | -2.51 | -3.08 | -0.01 |
| M30 | 1 | 0.1553 | -9.68 | -7.26 | -0.97 | -3.70 | -2.86 | -0.29 |
| M37 | 3 | 0.0906 | -6.76 | -4.60 | 0.32 | 0.36 | -1.32 | 1.12 |
| M38 | 1, 3 | 0.1040 | -7.37 | -5.64 | -0.13 | -1.76 | -1.60 | 0.68 |

The SI for calcite is positive in sample 37 and the SI for fluorite is positive in samples 01 and 37. This suggests that these minerals may be precipitating at these sites. If a major complexing ion ($F^-$ or $HCO_3^-$) is being removed from the system, and given a source of sulfide ion, supergene-type mineralization may be occurring in these sites. The presence of copper carbonate minerals in some of the mines in Bullion Canyon may be a reflection of the over saturation of carbonate ion which supports the theoretical calculations.

The WATEQ3 speciations and SI calculations have been able to illucidate subtle geochemical characteristics within the waters that could otherwise have been missed. For example, the high activity of sulfate as a complexing anion suggests that a large area has been pervasively mineralized with metal sulfide minerals. This supports the geologic evidence suggesting a mineralized stock was implaced in the area. The oversaturation of fluorite at sites 01 and 37 may indicate secondary or supergene-type minerals are forming. This zone would be the most favorable for the concentration of ore metals and warrants further geochemical investigation.

## CONCLUSIONS

A hydrogeochemical survey was conducted in the Pine Creek (Bullion Canyon) and Cottonwood Creek drainages. This area includes the Deer Trail Mountain-Alunite Ridge area believed to overlie a hidden intrusive (Cunningham and Steven, 1979b). The geological and geochemical make-up of the rocks in the study area appear to have been subjected to a series of mineralizing events which may encompass a large portion of the study area. The hydrogeochemical study was undertaken to characterize the geochemical signature of mineralized areas and apply this information as an exploration tool for locating new target areas of mineral potential. Single element data analysis indicated the sites 03, 08, 24, 25, and 26 have interesting geochemical signatures and may indicate that metal sulfide minerals are weathering within their respective recharge basins.

The use of more sophisticated data analysis techniques, particularly Q-mode factor analysis and WATEQ3 water speciation programs, were valuable in data interpretation. Q-mode factor analysis was useful in separating the hydrogeochemical data into factors which could be interpreted as reflecting certain geochemical processes. A three factor model accounted for 93.7 percent of the total variance. Factor 1 was interpreted as representing the normal chemical weathering of unaltered Bullion Canyon Volcanics rock. Factor 2 was interpreted as reflecting the chemical weathering of metal sulfide mineralized rocks. Factor 3 was rather difficult to interpret, but may reflect the chemical weathering of rocks containing alunite and(or) pyrite.

The WATEQ3 water speciation program defined two water types based on the major metal complexing ions. Waters from unmineralized areas contained predominantly $HCO_3^-$ and $OH^-$ complexes for Mg and Fe. The waters from mineralized areas contain predominantly $SO_4^{2-}$ complexes for Mg and Fe. The saturation index (SI) for many minerals was also calculated. The results of note occur in sites 01 and 37 where fluorite is stable, which suggests certain supergene minerals may be precipitating from the metal rich solutions.

The hydrogeochemical data compliments the geologic data and further supports the hypothesis that a hidden metallized stock underlies the study area. The geochemical signature in some of the water samples and the Q-mode factor analysis interpretation suggest that certain areas may contain metal sulfide mineral potential. Site 03 may in part be recharged from a deep source and(or) may reflect the chemical weathering of an upper level extension of the suspected metallized hidden stock. Site 08 has a geochemical signature, a high factor 2 loading and geologically favorable environment which suggests precious metal containing base-metal sulfide mineral deposits may exist in the subsided section that is buried under basin fill. The elevated factor 2 loadings and proximity to known mineralized areas suggest that sites 07, 16, 24, 25, and 33 may be draining basins in which metal sulfide minerals may occur. These areas represent favorable targets for mineral exploration and warrant further geochemical and geologic study.

## REFERENCES


Ball, J. W., Jenne, E. A., and Cantrell, M. W., 1981, WATEQ3 geochemical model with uranium added: U.S. Geological Survey Open-File Report 81-1183, 81 p.

Boyle, R. W., Hornbrook, E. H. W., Allan, R. J., Dyck, W., and Smith, A. V., 1971, Hydrogeochemical methods--Application in the Canadian Shield: Canadian Institute of Mining and Metallurgy Bulletin, v. 64, p. 60-71.

Brown, Eugene, Skougstad, M. W., and Fishman, J. J., 1970, Methods for collection and analysis of water samples for dissolved minerals and gases: U.S. Geological Survey Techniques of Water Resources Investigations TWI 5-A1, 160 p.

Butler, B. S., 1913, Geology and ore deposits of the San Francisco and adjacent districts, Utah: U.S. Geological Survey Professional Paper 80, 212 p.

Butler, B. S., and Gale, H. S., 1912, Alunite, a newly discovered deposit near Marysvale, Utah: U.S. Geological Survey Bulletin 511.

Butler, B. S., and others, 1920, Ore deposits of Utah: U.S. Geological Survey Professional Paper 111, 672 p.

Callaghan, E., 1938, Preliminary report on the alunite deposits of the Marysvale region, Utah: U.S. Geological Survey Bulletin 886-D, p. 91-134.

_____1973, Mineral resource potential of Piute County, Utah and adjoining area: Utah Geological and Mineralogical Survey Bulletin 102, 135 p.

Chatham, J. R., Wanty, R. B., and Langmuir, D., 1981, Groundwater prospecting for sandstone-type uranium deposits--the merits of mineral-solution equilibria versus single element tracer methods: Colorado School of Mines, prepared for the U.S. Department of Energy GJO 79-360-E, 197 p.

Cohen, A. C., Jr., 1959, Simplified estimators for the normal distribution when samples are singly censored or truncated: Technometrics, v. 1, no. 3, p. 217-237.

Cunningham, C. G., and Steven, T. A., 1978a, Geologic map of the Delano Peak NW quadrangle, west-central Utah: U.S. Geological Survey Miscellaneous Field Studies Map MF-967, scale 1:24,000.

_____1978b, Postulated model of uranium occurrence in the central mining area, Marysvale district, west-central Utah: U.S. Geological Survey Open-File Report 78-1093, 19 p.

_____1979a, Geologic map of the Delano Peak NE quadrangle, west-central Utah: U.S. Geological Survey Miscellaneous Field Studies Map MF-1105, scale 1:24,000.

_____1979b, Geologic map of the Deer Trail Mountain-Alunite Ridge mining area, west-central Utah: U.S. Geological Survey Miscellaneous Geologic Investigations Map I-230, scale 1:24,000.

_____1979c, Environments favorable for the occurrence of uranium within the Mount Belknap caldera, Beaver Valley and Sevier River Valley, west-central Utah: U.S. Geological Survey Miscellaneous Open-File Report 79-434, 15 p.

_____1979d, Mount Belknap and Red Hills calderas, and associated rocks, Marysvale Volcanic field, west-central Utah: U.S. Geological Survey Bulletin 1468, 34 p.

_____1979e, Uranium in the Central mining area, Marysvale district, west-central Utah: U.S. Geological Survey Miscellaneous Geologic Investigations Map I-1177, scale 1:24,000.

_____1980, Geologic map of the Beaver NE quadrangle, Utah: U.S. Geological Survey Miscellaneous Field Studies Map MF-1191, scale 1:24,000.

Davis, J. C., 1973, Statistics and data analysis in geology: New York, John Wiley and Son, Inc., 550 p.

Ficklin, W. H., 1983, Separation of arsenic (III) and arsenic (VI) in groundwater by ion-exchange: Talanta (in press).

Garrels, R. M., and Christ, C. C., 1965, Solutions, minerals and equilibria: Harper and Row, 450 p.

Klovan, J. E., and Imbrie, J., 1971, An algorithm and Fortran-IV program for large scale Q-mode factor analysis and calculation of factor scores: Journal of the International Association of Mathematical Geology, v. 3, no. 1, p. 61-77.

Langmuir, D., and Chatham, J. R., 1980, Groundwater prospecting for sandstone-type uranium deposits--a preliminary comparison of the merits of mineral-solution equilibria, and single-element tracer methods: Journal of Geochemical Exploration, v. 13, p. 201-219.

Levinson, A. A., 1974, Introduction to exploration geochemistry: Applied Publishing Ltd., 924 p.

McHugh, J. B., 1979, Portable field kit for determining uranium in water: U.S. Geological Survey Open-File Report 79-249, 14 p.

Miller, W. R., and Drever, J. I., 1977, Chemical weathering and related controls on surface water chemistry in the Absaroka Mountains, Wyoming: Geochimica et Cosmochimica Acta, v. 41, p. 1693-1702.

Miller, W. R., and McHugh, J. B., 1981a, Favorable environments for the occurrence of sandstone-type uranium deposits, Milford basin, Utah: U.S. Geological Survey Open-File Report 81-501, 36 p.

_____1981b, Application of mineral-solution equlibria to the search for sandstone-type uranium deposits in the Beaver basin, Utah: U.S. Geological Survey Open-File Report 81-120, 14 p.

Miller, W. R., McHugh, J. B., and Ficklin, W. H., 1979, Possible uranium mineralization, Mineral Mountains, Utah: U.S. Geological Survey Open-File Report 79-1354, 44 p.

_____1980, Possible uranium mineralization, Beaver basin, Utah: U.S. Geological Survey Open-File Report 80-508, 35 p.

Miller, W. R., Wanty, R. B., and McHugh, J. B., 1984, Application of mineral-solution equilibria to geochemical exploration for sandstone-hosted uranium deposits in two basins in west-central Utah: Economic Geology, v. 79, no. 2, p. 266-283.

Mutschler, F. E., Wright, E. G., Ludington, S., and Abbott, J. T., 1981, Granite molybdenum systems: Economic Geology, v. 76, p. 874-897.

Orion Research, Inc., 1975, Orion Research analytical methods guide, 7th ed.: Cambridge, Massachusetts.

Perkin-Elmer Corporation, 1976, Analytical methods for atomic absorption spectrophotometry: Norwalk, Connecticut, Perkin-Elmer Corp., 586 p.

_____1977, Analytical methods for atomic absorption spectrophotometry, using the HGA graphite furnace: Norwalk, Connecticut, Perkin-Elmer Corp., 286 p.

Runnells, D. D., Lindberg, R., Lueck, S. L., and Markos, G., 1981, Applications of computer modeling to the genesis, exploration, and in situ mining of uranium and vanadium deposits: New Mexico Bureau of Mines Memoirs on the Grants Mineral Belt.

Smee, B. W., and Hall, G. E. M., 1978, Analysis of fluoride, chloride, nitrate, and sulphate in natural waters, using ion chromatography: Journal of Geochemical Exploration, v. 10, no. 3, p. 245-248.

Steven, T. A., 1977, Geologic map of the Sevier SW quadrangle, west-central Utah: U.S. Geological Survey Miscellaneous Field Studies Map MF-962, scale 1:24,000.

Steven, T. A., and Cunningham, C. G., 1979, Uranium potential of the Big John caldera, Beaver County, Utah: U.S. Geological Survey Open-File Report 79-527, 16 p.

_____1980, Geologic map of the Sevier SE quadrangle, west-central Utah: U.S. Geological Survey Miscellaneous Field Studies Map MF-1109, scale 1:24,000.

Steven, T. A., Cunningham, C. G., and Machette, M. N., 1980, Integrated uranium systems in the Marysvale volcanic field, west-central Utah: U.S. Geological Survey Open-File Report 80-524, 39 p.

Steven, T. A., Cunningham, C. G., Naeser, C. W., and Mehnert, H. H., 1978, Revised stratigraphy and radiometric ages of volcanic rocks and mineral deposits in the Marysvale area, west-central Utah: U.S. Geological Survey Bulletin 1469, 40 p.

Steven, T. A., Cunningham, C. G., and Rowley, P. D., 1978, Geology and mineralization in the Marysvale mining area, west-central Utah, in Guidebook to mineral deposits of southwestern Utah: Utah Geological Association Publication 7, p. 67-70.

Tucker, J. D., Miller, W. R., Motooka, J. M., and Hubert, A. E., 1981, A rock and stream sediment concentrate survey over a known Mo-Sn anomaly in the southern Wah Wah Mountains, Utah: U.S. Geological Survey Open-File Report 81-576, 70 p.

Tucker, R. E., Miller, W. R., and McHugh, J. B., 1980, Geochemical results from a natural water study in the Mount Belknap caldera and vicinity, Utah: U.S. Geological Survey Open-File Report 80-1051, 53 p.

_____1981, Geochemical results from a rock geochemical survey in the Mount Belknap caldera vicinity, Utah: U.S. Geological Survey Open-File Report 81-576, 97 p.

Tucker, R. E., Miller, W. R., and Motooka, J. M., 1982, A geochemical survey using heavy mineral concentrates in the Mount Belknap caldera vicinity, Utah: U.S. Geological Survey Open-File Report 82-602, 132 p.

Wallace, S. R., Mackenzi, W. B., Blair, R. G., and Muncaster, N. K., 1978, Geology of the Urad and Henderson molybdenite deposits, Clear Creek County, Colorado, with a section on a comparison of these deposits with those at Climax, Colorado: Economic Geology, v. 73, p. 325-368.

Wanty, R. B., Langmuir, D., and Chatham, J. R., 1981, Groundwater prospecting for sandstone-type uranium deposits--the merits of mineral-solution equilibria versus single element tracer methods: Colorado School of Mines, prepared for the U.S. Department of Energy, v. II, GJO 79-360-E, 91 p.

Westra, G., and Keith, S. B., 1981, Classification and genesis of stockwork molybdenum deposits: Economic Geology, v. 76, p. 844-873.

Wyant, D. G., and Stugard, F., Jr., 1951, Indian Creek uranium prospects, Beaver County, Utah: U.S. Geological Survey Trace Element Memorandum Report 212, 7 p.

Appendix 1.--Analytical results for the water samples from the Deer Trail Mountain-Alunite Ridge study area, southwestern Utah.

| Sample | latitude | longitud | Ca(mg/L) | Mg(mg/L) | Na(mg/L) | K(mg/L) | Li(ug/L) | SiO2(mg/ | alk(mg/L | SO4(mg/L |
|---|---|---|---|---|---|---|---|---|---|---|
| 01 MINE | 38 22 48 | 112 15 37 | 270.0 | 64.0 | 8.1 | 1.90 | 11 | 12.0 | 223.0 | 817.0 |
| 02SPRING | 38 22 13 | 112 16 14 | 39.0 | 4.7 | 2.6 | .61 | <4 | 8.0 | 92.0 | 37.0 |
| 02ANADUP | 38 22 13 | 112 16 14 | 36.0 | 4.8 | 2.6 | .60 | <4 | 9.3 | 102.0 | 33.0 |
| 03SPRING | 38 22 38 | 112 20 3 | 69.0 | 16.0 | 3.6 | 1.60 | 27 | 9.2 | 113.0 | 125.0 |
| 04 MINE | 38 22 47 | 112 20 32 | 7.4 | .9 | 1.3 | .72 | 4 | 10.0 | .0 | 36.0 |
| 05STREAM | 38 22 19 | 112 20 8 | 58.0 | 11.0 | 3.2 | 1.50 | 16 | 9.2 | 86.0 | 99.0 |
| 06 MINE | 38 22 7 | 112 18 55 | 9.4 | 1.5 | 2.4 | 3.80 | <4 | 19.0 | .0 | 66.0 |
| 07STREAM | 38 21 19 | 112 19 12 | 30.0 | 3.9 | 2.9 | .40 | 4 | 10.0 | 78.0 | 25.0 |
| 08SPRING | 38 22 4 | 112 15 9 | 70.0 | 18.0 | 5.4 | 1.90 | 10 | 8.5 | 139.0 | 115.0 |
| 09STREAM | 38 21 44 | 112 20 19 | 21.0 | 1.6 | 1.5 | .29 | <4 | 5.6 | 54.0 | 19.0 |
| 09ANADUP | 38 21 44 | 112 20 19 | 21.0 | 1.6 | 1.5 | .29 | <4 | 7.0 | 54.0 | 18.0 |
| 10STREAM | 38 21 42 | 112 20 19 | 20.0 | 1.3 | 1.7 | .20 | 4 | 6.6 | 54.0 | 13.0 |
| 11 MINE | 38 21 45 | 112 20 17 | 48.0 | 5.0 | 3.3 | .37 | 8 | 11.0 | 140.0 | 45.0 |
| 12STREAM | 38 21 34 | 112 17 55 | 31.0 | 6.9 | 2.8 | 1.20 | 6 | 11.0 | 56.0 | 69.0 |
| 13SPRING | 38 21 41 | 112 17 30 | 23.0 | 7.6 | 2.8 | 1.30 | 12 | 11.0 | 44.0 | 59.0 |
| 14STREAM | 38 22 53 | 112 20 8 | 18.0 | 2.5 | 2.2 | .60 | <4 | 10.0 | 15.0 | 45.0 |
| 15STREAM | 38 23 12 | 112 21 24 | 23.0 | 1.2 | 1.6 | .25 | <4 | 5.6 | 43.0 | 26.0 |
| 16STREAM | 38 23 12 | 112 21 1 | 33.0 | 2.5 | 1.6 | .37 | <4 | 6.5 | 52.0 | 56.0 |
| 17STREAM | 38 23 14 | 112 20 59 | 36.0 | 5.2 | 2.5 | .65 | 12 | 9.0 | 60.0 | 52.0 |
| 18 MINE | 38 23 1 | 112 20 46 | 46.0 | 8.9 | 2.3 | 1.10 | 24 | 10.0 | 76.0 | 109.0 |
| 19SPRING | 38 23 2 | 112 19 42 | 4.4 | .4 | .5 | .35 | <4 | 3.3 | 1.8 | 3.0 |
| 20 MINE | 38 23 25 | 112 19 44 | 39.0 | 6.2 | 2.1 | .47 | 7 | 8.2 | 10.0 | 132.0 |
| 21 MINE | 38 24 43 | 112 20 9 | 47.0 | 6.2 | 2.3 | .51 | <4 | 7.7 | 94.0 | 92.0 |
| 21ANADUP | 38 24 43 | 112 20 9 | 48.0 | 6.2 | 2.4 | .50 | <4 | 7.4 | 96.0 | 83.0 |
| 22SPRING | 38 23 37 | 112 19 19 | 27.0 | 4.9 | 5.7 | .72 | <4 | 17.0 | 125.0 | 5.1 |
| 23STREAM | 38 24 46 | 112 19 56 | 49.0 | 4.6 | 4.5 | 1.00 | 4 | 5.6 | 138.0 | 50.0 |
| 27SD23 | 38 24 46 | 112 19 56 | 51.0 | 4.6 | 4.3 | .83 | <4 | 6.0 | 130.0 | 44.0 |
| 24SPRING | 38 24 44 | 112 20 9 | 87.0 | 11.0 | 7.4 | 1.90 | 12 | 10.0 | 181.0 | 147.0 |
| 25SPRING | 38 25 1 | 112 18 27 | 68.0 | 7.5 | 7.4 | 1.20 | <4 | 8.4 | 170.0 | 84.0 |
| 26SPRING | 38 25 6 | 112 19 2 | 86.0 | 12.0 | 8.2 | 1.10 | 10 | 10.0 | 179.0 | 130.0 |
| 28STREAM | 38 23 43 | 112 22 9 | 32.0 | 2.2 | 2.0 | .40 | <4 | 5.5 | 82.0 | 19.0 |
| 29STREAM | 38 23 41 | 112 22 10 | 14.0 | 1.2 | 2.0 | .22 | <4 | 5.3 | 45.0 | 4.6 |
| 29ANADUP | 38 23 41 | 112 22 10 | 14.0 | 1.2 | 2.0 | .22 | <4 | 4.5 | 45.0 | 4.6 |
| 30STREAM | 38 23 42 | 112 22 2 | 16.0 | .9 | 1.7 | .18 | <4 | 5.0 | 57.0 | 6.9 |
| 31SPRING | 38 23 54 | 112 21 49 | 39.0 | 3.4 | 3.9 | .46 | 8 | 7.0 | 116.0 | 31.0 |
| 32STREAM | 38 24 27 | 112 21 8 | 34.0 | 2.5 | 2.3 | .44 | <4 | 6.1 | 91.0 | 22.0 |
| 33STREAM | 38 24 32 | 112 21 2 | 32.0 | 2.2 | 2.1 | .48 | <4 | 6.6 | 87.0 | 11.0 |
| 34STREAM | 38 24 35 | 112 20 16 | 43.0 | 4.8 | 2.7 | .65 | <4 | 7.2 | 90.0 | 66.0 |
| 35SD34 | 38 24 35 | 112 20 16 | 43.0 | 4.8 | 2.7 | .64 | <4 | 6.9 | 97.0 | 53.0 |
| 35ANADUP | 38 24 35 | 112 20 16 | 42.0 | 4.8 | 2.7 | .64 | <4 | 6.6 | 97.0 | 59.0 |
| 36 MINE | 38 24 27 | 112 20 8 | 82.0 | 11.0 | 5.4 | .78 | 9 | 9.1 | 155.0 | 150.0 |
| 37 MINE | 38 24 31 | 112 20 15 | 73.0 | 11.0 | 5.3 | .77 | 7 | 8.7 | 144.0 | 90.0 |
| 38 MINE | 38 24 31 | 112 20 19 | 44.0 | 5.0 | 2.8 | .68 | <4 | 8.2 | 97.0 | 62.0 |
| 39 MINE | 38 24 32 | 112 20 22 | 44.0 | 4.8 | 2.7 | .66 | <4 | 7.5 | 95.0 | 64.0 |
| 40SD39 | 38 24 32 | 112 20 22 | 43.0 | 4.8 | 2.7 | .67 | <4 | 6.5 | 94.0 | 61.0 |

Appendix 1.--Analytical results for the water samples from the Deer Trail Mountain-Alunite Ridge area, southwestern Utah.--continued

| Sample | Cl(mg/L) | F(mg/L) | Zn(ug/L) | Cu(ug/L) | Mo(ug/L) | As(ug/L) | Fe(ug/L) | Mn(ug/L) | Al(ug/L) | U(mg/L) | Cond |
|---|---|---|---|---|---|---|---|---|---|---|---|
| 01 MINE | 6.10 | 2.30 | 2,150 | 4.5 | 14.0 | 6.9 | 250 | 760 | 100 | 2.80 | 1,500 |
| 02SPRING | 1.30 | .41 | 4 | 2.5 | <1.0 | 1.4 | 2 | 1 | 22 | .20 | 246 |
| 02ANADUP | 1.70 | .37 | 3 | 2.5 | <1.0 | N | 3 | <1 | 23 | N | 245 |
| 03SPRING | 2.00 | .46 | 9 | <1.0 | 2.1 | 2.9 | 800 | 460 | 61 | 1.20 | 510 |
| 04 MINE | .76 | .04 | 10 | 99.0 | <1.0 | 1.8 | 1,700 | 55 | 1,900 | .38 | 244 |
| 05STREAM | 1.90 | .48 | 6 | 2.8 | 1.0 | 4.0 | 7 | 34 | 55 | .62 | 415 |
| 06 MINE | 1.70 | .06 | 10 | 11.0 | <1.0 | 2.2 | 1,400 | 15 | 2,700 | .24 | 420 |
| 07STREAM | 1.00 | .23 | 6 | <1.0 | <1.0 | 20.0 | 7 | <1 | 24 | .16 | 250 |
| 08SPRING | 7.90 | .54 | 4 | <1.0 | 13.0 | 2.1 | 6 | 2 | 28 | .82 | 510 |
| 09STREAM | .59 | .22 | 4 | <1.0 | <1.0 | <1.0 | 3 | 2 | 14 | .12 | 125 |
| 09ANADUP | .73 | .31 | 3 | <1.0 | <1.0 | N | 6 | 1 | 15 | N | 123 |
| 10STREAM | .50 | .18 | 3 | <1.0 | <1.0 | 1.2 | 2 | 2 | 10 | .18 | 116 |
| 11 MINE | 2.10 | .37 | 5 | 1.7 | <1.0 | <1.0 | 2 | 1 | 25 | .22 | 310 |
| 12STREAM | 1.80 | .27 | 12 | 1.2 | <1.0 | <1.0 | 9 | 13 | 27 | .14 | 250 |
| 13SPRING | 3.70 | .45 | 40 | <1.0 | <1.0 | <1.0 | 5 | 2 | 34 | <.10 | 210 |
| 14STREAM | .73 | .08 | 4 | 1.7 | <1.0 | <1.0 | 22 | 6 | 41 | <.10 | 132 |
| 15STREAM | .39 | .18 | 5 | 1.5 | <1.0 | <1.0 | 3 | 1 | 13 | .18 | 192 |
| 16STREAM | .83 | .35 | 9 | <1.0 | <1.0 | <1.0 | 2 | 2 | 22 | .18 | 215 |
| 17STREAM | 1.10 | .33 | 4 | <1.0 | <1.0 | <1.0 | 4 | 3 | 3 | .20 | 260 |
| 18 MINE | 1.40 | .81 | 18 | <1.0 | <1.0 | <1.0 | 3 | 580 | 16 | .36 | 350 |
| 19SPRING | 6.40 | .05 | 6 | <1.0 | <1.0 | <1.0 | 14 | 1 | 37 | <.10 | 12 |
| 20 MINE | .90 | .66 | 115 | 3.0 | 1.0 | <1.0 | 880 | 250 | 64 | <.10 | 295 |
| 21 MINE | 1.80 | .19 | 93 | <1.0 | 1.6 | <1.0 | 5 | 13 | 31 | .78 | 320 |
| 21ANADUP | 1.40 | .18 | 92 | <1.0 | 1.6 | N | 5 | 13 | 31 | N | 320 |
| 22SPRING | 3.70 | .11 | 3 | 1.3 | <1.0 | 1.8 | 9 | 2 | 31 | .12 | 224 |
| 23STREAM | 3.30 | .37 | 3 | 2.1 | <1.0 | <1.0 | 8 | 2 | 12 | .80 | 318 |
| 27SD23 | 1.90 | .56 | 2 | <1.0 | 1.3 | 1.5 | 2 | 1 | 15 | .78 | 320 |
| 24SPRING | 7.30 | 1.10 | 2 | 2.1 | 26.0 | 1.4 | 3 | <1 | 24 | 1.40 | 540 |
| 25SPRING | 4.50 | 1.40 | 2 | 3.0 | 4.0 | <1.0 | 11 | 14 | 30 | .56 | 420 |
| 26SPRING | 5.10 | .70 | 3 | 6.2 | 1.6 | 2.3 | 2 | <1 | 14 | .78 | 540 |
| 28STREAM | 1.60 | .08 | 2 | 1.3 | 1.0 | <1.0 | 1 | 1 | 10 | .18 | 193 |
| 29STREAM | .31 | .17 | 2 | <1.0 | <1.0 | <1.0 | 4 | <1 | 7 | .20 | 32 |
| 29ANADUP | .40 | .08 | 2 | 1.1 | <1.0 | N | 5 | 1 | 9 | N | 33 |
| 30STREAM | 1.90 | .04 | 1 | <1.0 | <1.0 | 1.5 | 3 | <1 | 6 | .31 | 97 |
| 31SPRING | .95 | 1.80 | 3 | <1.0 | 1.0 | 1.1 | 2 | 1 | 15 | .12 | 255 |
| 32STREAM | 1.10 | .16 | 2 | <1.0 | 1.1 | <1.0 | 1 | <1 | 7 | .24 | 207 |
| 33STREAM | 2.30 | .51 | 2 | 2.5 | <1.0 | <1.0 | 3 | 2 | 10 | .14 | 194 |
| 34STREAM | 1.50 | .22 | 2 | 1.7 | 1.2 | <1.0 | 3 | 3 | 14 | .30 | 295 |
| 35SD34 | 2.70 | .22 | 3 | <1.0 | 1.2 | <1.0 | 3 | 4 | 10 | .30 | 295 |
| 35ANADUP | .92 | .21 | 3 | <1.0 | 1.2 | N | 4 | 4 | 9 | N | 295 |
| 36 MINE | 3.00 | .46 | 8 | <1.0 | 2.5 | <1.0 | 3 | 2 | 24 | .52 | 500 |
| 37 MINE | 2.40 | 2.40 | 42 | 1.9 | 7.5 | 1.5 | 4 | 7 | 19 | .46 | 450 |
| 38 MINE | 1.20 | .24 | 175 | 5.1 | 2.8 | 1.4 | 4 | 3 | 16 | .26 | 290 |
| 39 MINE | 1.10 | 1.00 | 283 | 7.8 | 3.0 | 1.8 | 5 | 2 | 17 | .28 | 290 |
| 40SD39 | 1.40 | .25 | 284 | 7.5 | 3.0 | 1.5 | 4 | 2 | 22 | .28 | 290 |

Appendix 1.--Analytical results for the water samples from the Deer Trail Mountain-Alunite Ridge study area, southwestern Utah.--continued

| Sample | pH | Temp(C) |
|---|---|---|
| 01 MINE | 6.52 | 17.0 |
| 02SPRING | 7.37 | 8.0 |
| 02ANADUP | 7.37 | 8.0 |
| 03SPRING | 6.53 | 5.0 |
| 04 MINE | 3.09 | 6.8 |
| 05STREAM | 7.73 | 13.0 |
| 06 MINE | 3.10 | 3.5 |
| 07STREAM | 7.79 | 10.4 |
| 08SPRING | 6.80 | 14.9 |
| 09STREAM | 7.77 | 13.6 |
| 09ANADUP | 7.77 | 13.6 |
| 10STREAM | 7.85 | 9.5 |
| 11 MINE | 7.19 | 3.8 |
| 12STREAM | 8.16 | 15.7 |
| 13SPRING | 6.79 | 7.0 |
| 14STREAM | 7.03 | 8.0 |
| 15STREAM | 7.65 | 9.0 |
| 16STREAM | 7.79 | 8.4 |
| 17STREAM | 7.91 | 9.5 |
| 18 MINE | 6.90 | 4.4 |
| 19SPRING | 6.44 | 3.3 |
| 20 MINE | 6.91 | 1.5 |
| 21 MINE | 7.67 | 2.5 |
| 21ANADUP | 7.67 | 2.5 |
| 22SPRING | 7.10 | 10.0 |
| 23STREAM | 8.67 | 15.3 |
| 27SD23 | 8.72 | 13.2 |
| 24SPRING | 7.52 | 12.8 |
| 25SPRING | 8.09 | 13.3 |
| 26SPRING | 7.58 | 9.0 |
| 28STREAM | 7.70 | 12.0 |
| 29STREAM | 7.70 | 9.8 |
| 29ANADUP | 7.70 | 9.8 |
| 30STREAM | 7.66 | 8.5 |
| 31SPRING | 7.36 | 8.2 |
| 32STREAM | 8.17 | 11.8 |
| 33STREAM | 8.13 | 12.5 |
| 34STREAM | 8.17 | 13.4 |
| 35SD34 | 8.17 | 13.4 |
| 35ANADUP | 8.17 | 13.4 |
| 36 MINE | 7.81 | 9.8 |
| 37 MINE | 8.02 | 8.3 |
| 38 MINE | 7.96 | 5.5 |
| 39 MINE | 7.98 | 6.5 |
| 40SD39 | 7.98 | 6.5 |

Appendix 2.--Analytical results for rock samples collected near site 08 in the Deer Trail Mountain-Alunite Ridge study area, southwestern Utah.

| | * Fe 0.05% | Mg 0.02% | Ca 0.05% | Ti 0.002% | Mn 10ppm | B 10ppm | Ba 20ppm | Be 1ppm | Co 5ppm | Cr 10ppm | Cu 5ppm | La 20ppm | Mo 5ppm |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 01 Navajo Sandstone | N | <.02 | N | .007 | N | 10 | N | N | N | N | N | N | N |
| 02 Quartz vein | <.05 | <.02 | N | .005 | <10 | 10 | N | N | N | N | <5 | N | N |
| 03 Arapien Formation | .3 | .05 | N | .05 | N | <10 | 150 | <1 | N | <10 | N | N | 15 |
| 04 Bullion Canyon Vol. | 7 | 2 | .5 | 1 | 700 | <10 | 700 | <1 | 50 | 500 | 50 | 50 | N |

| | Ni 5ppm | Pb 10ppm | Sr 100ppm | V 10ppm | Y 10ppm | Zr 10ppm |
|---|---|---|---|---|---|---|
| 01 | N | N | N | <10 | N | N |
| 02 | N | N | N | <10 | N | N |
| 03 | N | N | N | 10 | N | <10 |
| 04 | 200 | 10 | 300 | 100 | 20 | 200 |

These elements were not detected

* Ag 0.5ppm
As 200ppm
Au 10ppm
Bi 10ppm
Cd 20ppm
Nb 20ppm
Sb 100ppm
Sn 10ppm
W 50ppm
Zn 200ppm
Th 100ppm

* The concentration listed is the detection limit for the element.