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Relationships between the groundwaters of Ash Meadows, Death Valley, Pahranagat Valley and the Nevada Test Site based on statistical analysis and modeling of trace element data

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ABSTRACT

Relationships between the groundwaters of the Nevada Test Site, Ash Meadows, Pahranagat, and Death Valley have been studied by many people over many years. Using hydrogeochemical data from these areas (sampled and analyzed by the Harry Reid Center for Environmental Studies) hydrologic subbasins were classified on the basis of trace element concentrations and compare these to previous classification systems. In addition, previously suggested flow relationships were examined on the basis of trace element concentrations, in particular those elements which are thought to behave conservatively in oxidizing environments. These efforts were made with the aid of statistical analyses such as principal component analysis and contouring within ARC/INFO (a geographic information system). The spring and well water chemistry data includes major ion and trace element chemistry and was obtained from the Harry Reid Center for Environmental Studies at UNLV. In most analyses only trace elements were examined. Results of principal component analysis yielded logical results that reflect differences in geology and location. Perched waters on the Nevada Test Site have the most unique chemistries. Waters from the Furnace Creek region of Death Valley, Ash Meadows, and Pahranagat Valley seem to have many similarities with respect to trace elements. Contour modeling reveals that at least three processes or parameters control the behaviour of trace elements within the study area.

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Acknowledgements

I have been incredibly fortunate throughout my entire life to have found wonderful people to work and surround myself with. My family has always provided amazing amounts of support. I thank my parents and siblings first for their unconditional love and unfathomable patience. I would also like to thank all of my committee members, Dr. Vernon Hodge, Dr. Evangelo Yfantis, Dr. Kevin Johannesson, and Dr. Klaus Stetzenbach for all of their time and patience. The Harry Reid Center for Environmental Studies provided both a research assistantship and the hydrogeochemical data examined in this study. Without these two important components, this study would not have materialized. I appreciate the time and resources of Jason Johnson, Kevin Campbell, Kathy Lau, and Bob Taylor (Bureau of Land Management) which were spent working in Ash Meadows. I would also like to thank Mr. Bob Puterski and the Las Vegas Valley Water District for their help in the ARC/INFO work of this thesis. I am also thankful to Dave Kreamer for his efforts to keep me out of trouble. Lastly I thank my friends, both here and at home, for their ability to listen to me and make me laugh when I need to.

CHAPTER 1:

INTRODUCTION, SIGNIFICANCE, AND RELATED STUDIES

According to Claassen (1983), "ground water chemical data can help define ground water sources and pathways when combined with hydraulic data." Ground water within the study area is thought to react with tuffaceous rocks, carbonate rocks, and or carbonate valley fill (a mixed lithology of both carbonate and tuffaceous rocks). The major ion chemistry of the ground water is determined by the lithology of the rocks through which they flow and, cosequently, the trace elements are also likely influenced by this lithology (Claassen, 1983). Concentrations of elements in solution are further controlled by speciation and complexation as well as pH (Morel and Hering, 1993). In general, waters that discharge directly from the regional carbonate aquifer have certain chemical similarities, waters from local felsic volcanic rocks have separate chemical characteristics, and water flowing through different alluvial deposits should also share common chemistry because of the processes acting on the waters.

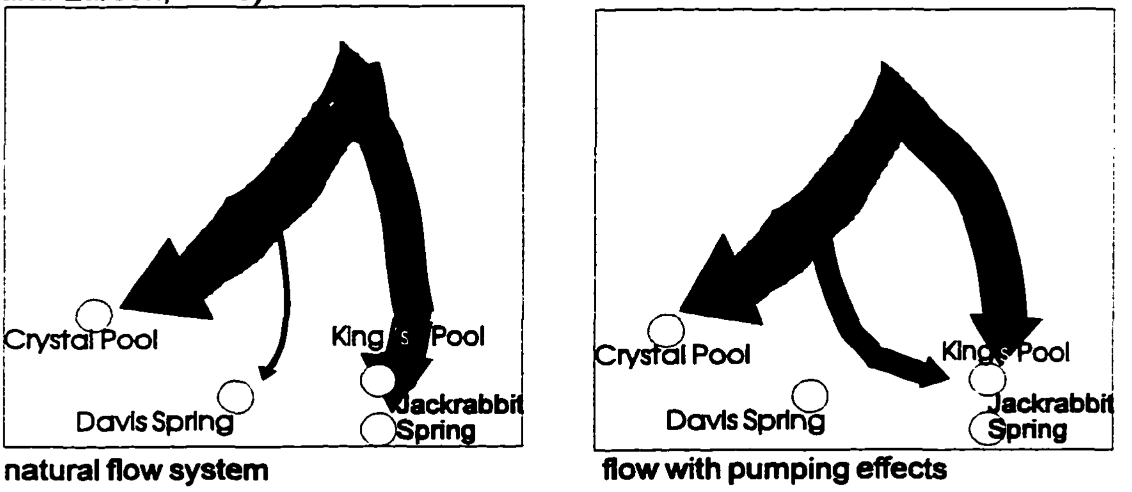
Trace element hydrochemistry is used in this study to analyze statistically how closely different springs are related and to identify differences between them. For this reason, trace element hydrogeochemistry may be used to classify hydrologic subbasins. In addition trace elements may possibly be used to support other efforts by Johannesson et al. (1996) which have hypothesized ground water mixing perhaps on both large and small scales. Ground waters of Ash Meadows, Death Valley, the Pahranagat

Valley and the Nevada Test Site (obtained from various springs and wells and named in Chapter 2) are examined in this project.

It is important to understand the pattern of ground water flow in southern Nevada and southeastern California. Much of the interest focused on the ground water of this region has been stimulated by Site Characterization studies of the high level nuclear waste site proposed for Yucca Mountain. Beyond these concerns, relationships throughout the arid basin and range province are important due to the dramatically increasing need for water. In the Las Vegas area alone the human population has grown from below 600,000 in 1985 to almost 1,000,000 in 1994 (Clark County Dept. of Comprehensive Planning). With this growth, demands on water resources have increased. As water table elevations fall, subsidence of the land surface and degradation of ground water quality may occur. Spring discharge is also affected by overtaxation of aquifers as illustrated by Figure 1 after Dudley and Larson (1976) (on page 3), posing possible problems for endangered species and other inhabitants in some subbasins.

The study by Dudley and Larson (1976) indicated that although not all springs in Ash Meadows were affected by pumping, some were. One result of Dudley and Larson's work indicated that pumping may divert flow from Davis Spring to Jackrabbit Spring. Although this example (represented in Figure 1) is at a relatively small scale, restricted to Ash Meadows, the ideas are the same at any scale.

Figure 1: Flow Lines With Possible Changes Due to Pumping (after Dudley and Larson, 1976)



In addition to the work of Claassen (1983), other authors have contributed chemistry data for the rocks and waters of southern Nevada as well as some knowledge of mechanisms involved in the alteration of ground water chemistry due to the host rock. These include: Winograd and Thordarson (1975), Raker and Jacobson, (1987), Schoff and Moore (1964), Johannesson et al. (1995), McKinley et al, (1991), and Broxton et al. (1989). Other scientists have contributed work over many years to further delineate and define ground water flow in southern Nevada. Some of these are: Dudley and Larson (1976), Hess (1992), Dettinger (1989), Burbey and Prudic (1991), Czarnecki and Waddell (1984), and Camera and Westenberg (1994).

Yelken (1996), and Farmer (1996) are concurrent research efforts at the University of Nevada, Las Vegas which is also related to ground water and rock chemisty in southern Nevada. Perfect (1994) has also defined subbasins in southern Nevada in work at the Colorado School of Mines. The work used a data set (compiled from numerous sources) including thousands of wells and springs, but seemed to classify on the basis of major elements.

Using hydrogeochemical data from these areas (sampled and analyzed by the Harry Reid Center for Environmental Studies) an attempt was made in this study to classify hydrologic subbasins on the basis of trace element concentrations and compare these to previous classification systems. In addition, previously suggested flow relationships are examined on the basis of trace element concentrations, in particular those elements which are thought to behave conservatively in oxidizing environments. These efforts were made with the aid of statistical analyses such as principal component analysis and contouring within ARC/INFO (a geographic information system). The spring and well water chemistry data includes major ion and trace element chemistry and was obtained from the Harry Reid Center for Environmental Studies at UNLV. In most analyses only trace elements were examined. As stated in the abstract the results of principal component analysis yielded logical results that reflect differences in geology and location. Perched waters on the Nevada Test Site have the most unique chemistries. Waters from the Furnace Creek region of Death Valley, Ash Meadows, and Pahranagat Valley seem to have many similarities with respect to trace elements. Contour modeling reveals that at least three processes or parameters control the behaviour of trace elements within the study area.

ARC/INFO and is included in the Geographic Information Systems section of Chapter 5 to show precise locations of each sample location.

Figure 2: Schematic of Study Area Showing Locations of Clusters of Springs and Wells

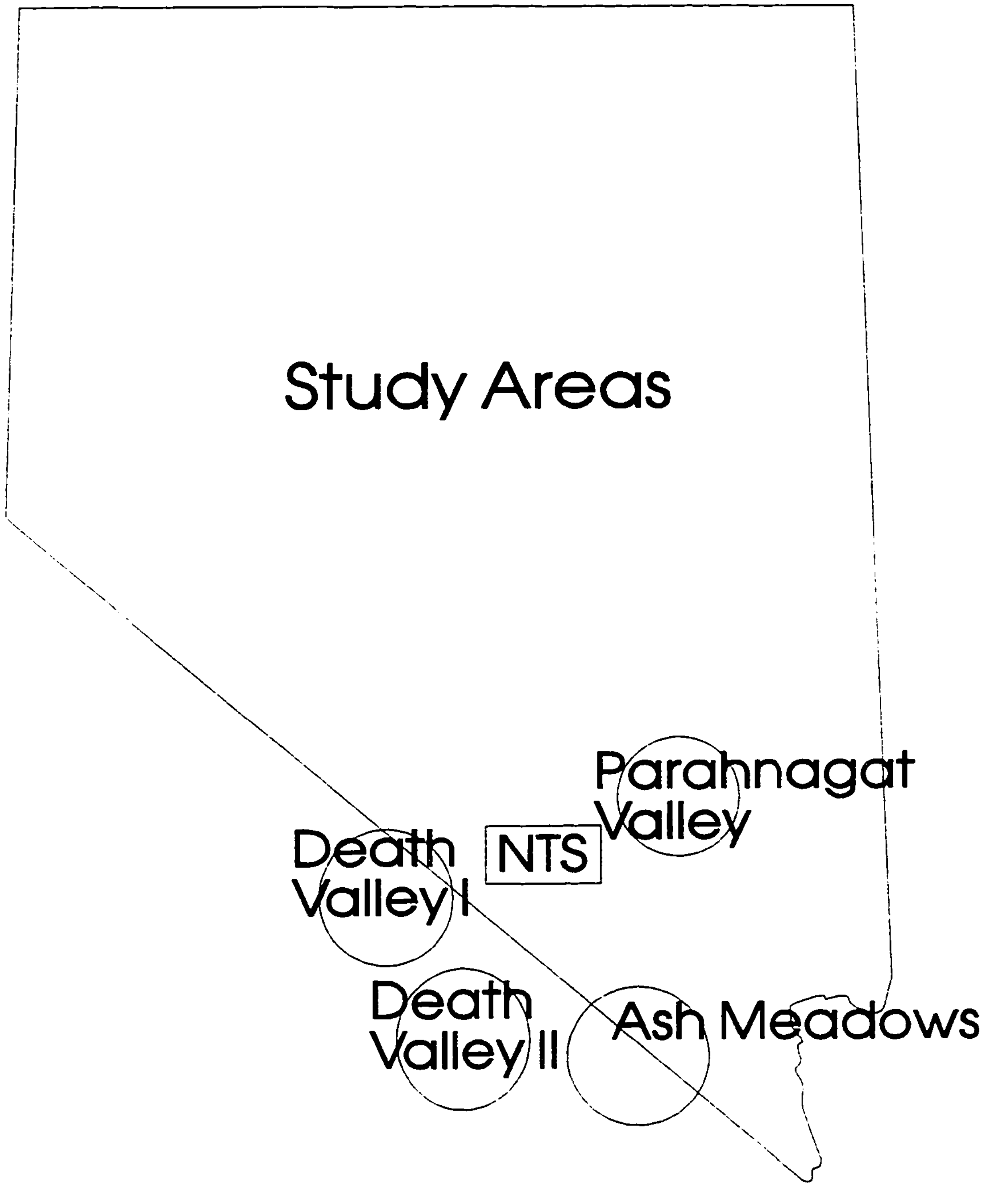


Table 1: Locations of Springs and Wells (data from Harry Reid Center for Environmental Studies, McKinley et al, 1991, Camera and Westenburg 1994)

Spring Name	Region	Decimal Latitude N	Decimal Longitude W
Big Spring	AM	36.3750	116.274
Bradford	AM	36.4012	116.303
Cold Spring	AM	36.4608	116.346
Crystal Pool	AM	36.4203	116.324
Fairbanks	AM	36.4905	116.341
Jackrabbit	AM	36.3898	116.279
Kings Pool	AM	36.4015	116.274
Longstreet	AM	36.4675	116.326
Point of Rocks NE	AM	36.4020	116.271
Point of Rocks NW	AM	36.4025	116.273
Rogers	AM	36.4810	116.328
Scruggs	AM	36.4342	116.310
Upper Grapevine	UDV	37.0242	117.384
Middle Grapevine	UDV	37.0210	117.384
Lower Grapevine	UDV	37.0203	117.388
Mesquite	UDV	36.9643	117.368
Nevares	MDV	36.5125	116.821
Saratoga	LDV	35.6818	116.422
Scotty's Castle	UDV	37.0325	117.329
Surprise	UDV	37.0002	117.339
Texas	MDV	36.4578	116.836
Travertine	MDV	36.4408	116.830
Ash	PAH	37.4633	115.192
Crystal	PAH	37.5317	115.234
Hiko	PAH	37.5985	115.216
Cane	NTS	36.7853	116.087
Well J13	NTS	36.8080	116.396
Tippipah	NTS	37.0445	116.207
Topopah	NTS	36.9392	116.271
Soda Well	LDV	35.1392	116.097
Saga Well	NTS	36.8080	116.513
Hardrock Well	SI	35.4558	115.529
Colliseum Well	SI	35.5585	115.556
Coffer Well	NTS	37.0042	116.557
Cinderlite Well	NTS	36.6967	116.503
Army Well	NTS	36.5917	116.0372
Airport Well	NTS	36.6403	116.4092
J12	NTS	36.7650	116.3900
Lathrop Well	NTS	36.6408	116.4397

Geology of Southern Nevada

Lithology

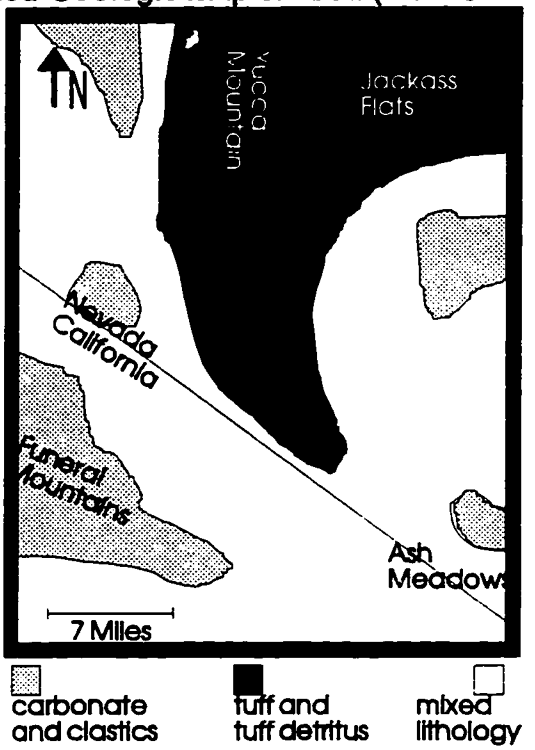
During the Precambrian and Paleozoic more than 13,000 meters of marine sediments were deposited on the ancient marine depositional slope, which through time and geological deformation became exposed continental crust and part of the region studied in this thesis (Winograd and Thordarson, 1975, Wicander & Monroe, 1989). Both Cenozoic sedimentary and volcanic rocks are common throughout the study area (see Figure 3, page 9). Table 2 simplifies stratigraphic information from Winograd and Thordarson (1975). The table describes geology from the surface downward through successively older geology. Winograd and

Table 2: Stratigraphy: Nevada Test Site (Winograd and Thordarson, 1975)

Age	Stratigraphic Unit	Lithology	Thickness
Quaternary	valley fill	alluvial fan fluvial fanglomerate lakebed mudflow deposits	2000 feet
Tertiary	Basalt of Kiwi Mesa, Rhyolite of Shoshone Mountain, Basalt of Skull Mountain, Piapi Canyon Group, Wahmonie Formation, Salyer Formation, Indian Trail Formation, Calico Hills tuffs, Tuff of Crater Flat, Horse Springs Formation	tuffs & flows (non-welded to welded) sandstones, limestone, basalts	$2*10^4$ feet
Cretaceous to Pennsylvanian	Granitic stocks, Tippipah Limestone,	granodiorite, limestone	>3600 feet
Mississippian to Silurian	Eleana Formation, Devil's Gate Limestone, Nevada Formation	argillite, quartzite conglomerate, limestone, dolomite	$\geq 12*10^3$ feet
Ordovician	Ely Springs Dolomite Eureka Quartzite Pahrump Group	dolomite, quartzite, limestone, claystone	≅ 3000 feet
Cambrian	Nopah Formation Dunderberg Shale Bonanza King Formation Carrera Formation Zabriskie Quartzite Wood Canyon Formation	dolomite, limestone, shale, siltstone, quartzite	≅ 10000 feet
Precambrian	Stirling Quartz Latite Johnnie Formation	quartzite, siltstone, sandstone, limestone, dolomite	≅ 5000 feet

Thordarson state that although the information is based on geology from the Nevada Test Site, it applies to a defined area which approximates the area included in this study. The lithology may prove quite important when attempting to draw conclusions from trace element data. As mentioned in Chapter 1, ground water may obtain a chemical signature from the rock it flows through (Claassen, 1983).

Figure 3: Generalized Geologic Map of Area (after Claassen, 1983)



Structure

The area of study has had a geologic history. The region was deformed during the late Mesozoic by folding, thrusting, and strike-slip faulting (Winograd and Thordarson, 1975). During the Miocene normal faulting (associated with volcanism) created the basin and range topography (Winograd and Thordarson, 1975). Figure 4 (after Stevens, et al 1991) describes in part the structural geology of the study area in very schematic fashion. The figure is not to scale nor does it include every known structural feature in the study.

Geologic structure is important in many portions of the study area because of relationships that are sometimes observed between faults and springs. Ground water is thought to be discharged along a fault line in the Paleozoic carbonates below Ash Meadows, after which it percolates up through Quaternary deposits (Dudley and Larson, 1976). This scenario is visually explained in Figure 5 by a schematic cross section after Dudley & Larson, (1976).

Figure 4: Structure in the South-Central Great Basin(after Stevens, Stone, & Belasky, 1991)

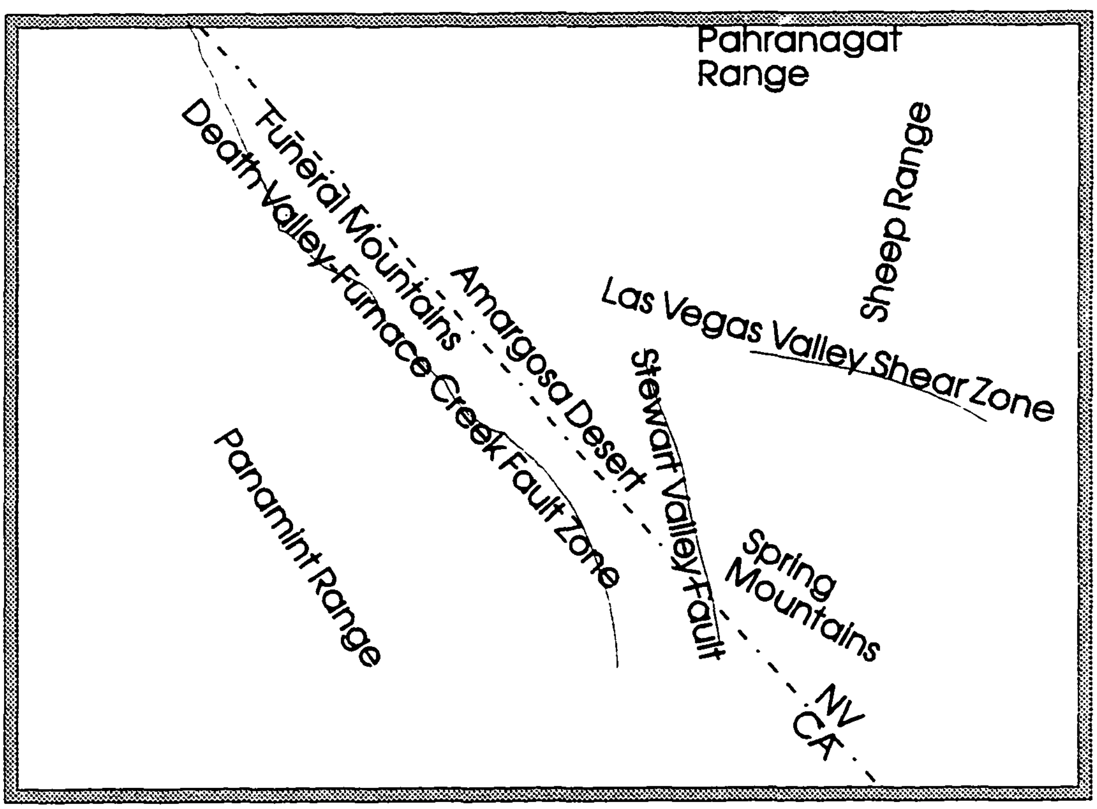
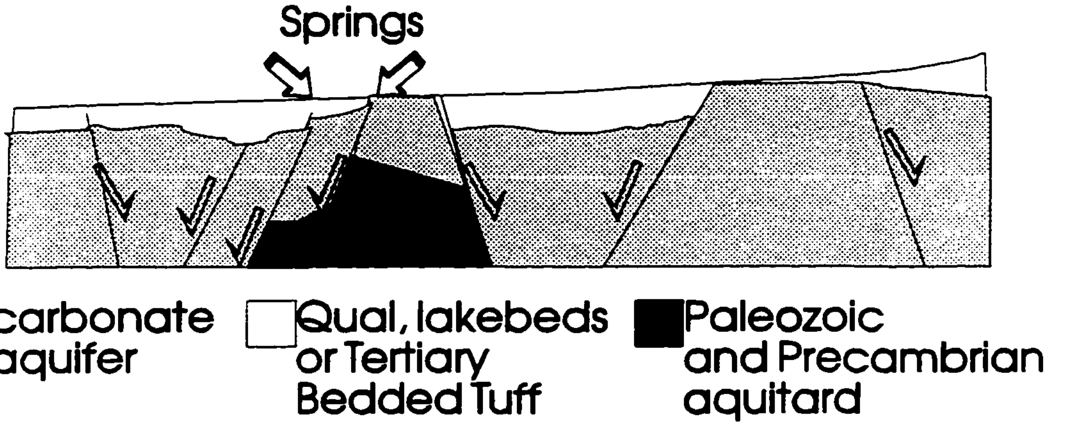


Figure 5: Control of Ash Meadows Spring Line (after Dudley & Larson, 1976)



Hydrology of Southern Nevada

Aquifers

The principal aquifers in the region are the lower carbonate and valley fill aquifers. Winograd and Thordarson (1975) discuss other aquifers, including the bedded tuff aquifer, the lava flow aquifer, and welded tuff aquifers, which are not focused on in this study.

The saturated thickness of the Paleozoic lower carbonate aquifer varies from hundreds to thousands of feet (Winograd and Thordarson, 1975). This unit is fractured by faults as well as three sets of joints. Many caves are contained within this same unit, two of the largest ones being Devils Hole and Gypsum Cave (Winograd and Thordarson, 1975). The permeability of the carbonate unit within the area of the Nevada Test Site ranges from 0.00002 gpd/ft^2 to 0.1 gpd/ft^2, the mean being 0.01 gpd/ft^2(Winograd and Thordarson, 1975). The carbonate aquifer discharges 1,300 gpm of the 1,430 gpm flowing from springs associated with the Spring Mountains (Winograd and Thordarson, 1975). The waters of the Spring Mountains serve to highlight the importance of the carbonate aquifer in southern

Nevada since such a high percent of the flow in the springs there is from the lower Paleozoic carbonate aquifer.

The valley fill aquifer is composed of alluvial-fan, fluvial, fanglomerate, lakebed, and mudflow deposits and overlies the Paleozoic carbonate rocks in many places (Winograd and Thordarson, 1975). Because less drilling is required, most wells in Las Vegas pump water from the valley fill aquifer, but it is important to note that these waters are related through intrabasin movement of ground water (Winograd and Thordarson, 1975). The valley fill aquifer layer happens to be more than 1000 ft thick in many locations but generally, the saturated thickness is only a small percent of the aquifer(Winograd and Thordarson, 1975).

Aquitards

The most important aquitards, in terms of aerial distribution are the lower clastic aquitard and the tuff aquitard (Winograd and Thordarson, 1975). The lower clastic unit is the lower boundary for ground water in the study area, and the tuff defines water in the Cenozoic aquifer versus the water in the Paleozoic aquifers(Winograd and Thordarson, 1975). The lower clastic aquitard has permeabilities much lower than those of the carbonate and valley fill aquifers ranging from 0.0000007 gpd/ft^2 to 0.0001 gpd/ft^2 with a mean of 0.00001gpd/ft^2 (Winograd and Thordarson, 1975).

Springs

Most springs of the study area issue from bases of ridges of Paleozoic carbonate rocks, alluvium, lake beds, and tufa mounds (Winograd & Doty, 1980); although Scotty's Castle and Surprise springs emanate from volcanic tuffs as well as some springs in the vicinity of the Nevada Test Site. Spring discharge is variable in terms of flow throughout the study area and occurs through a number of different processes. In the case of Travertine and Texas Springs, ground water must flow from the carbonate and through Quaternary gravels or Tertiary lacustrine deposits before surfacing while Nevares Spring flows from a travertine mound (Winograd and Thordarson, 1975). Jackrabbit Spring, Big Spring, Crystal Pool, Longstreet, Rogers, and Fairbanks are all solution or cavern type springs, created by dissolution of soluble rock (Hughes 1966). All springs and wells included in this study are listed in Table 1 as well as Table 3 on page 14. Table 3 includes the aquifer and source material (what the spring discharges from at the surface) if known, for the spring and well locations in the study. References are indicated by number and listed below the table.

Regional Flow

Within the study area water is thought to move through the earth by three different kinds of ground water movement: movement of perched water, intrabasin movement, and interbasin movement (Winograd and Thordarson, 1975). The hydraulic gradient (change in hydraulic head per unit distance) seems to increase from the Test Site (0.3 feet per mile) to the southwest (5.9 feet per mile) (Winograd and Thordarson, 1975). It may be important to note that over larger time scales the water table has not remained constant (as climates have changed) (Winograd & Doty, 1980). From the oversimplified water table contour map in Figure 6 on page 15, one can see that the flow in the study area is generally to the south and southwest (after Burbey and Prudic, 1991).

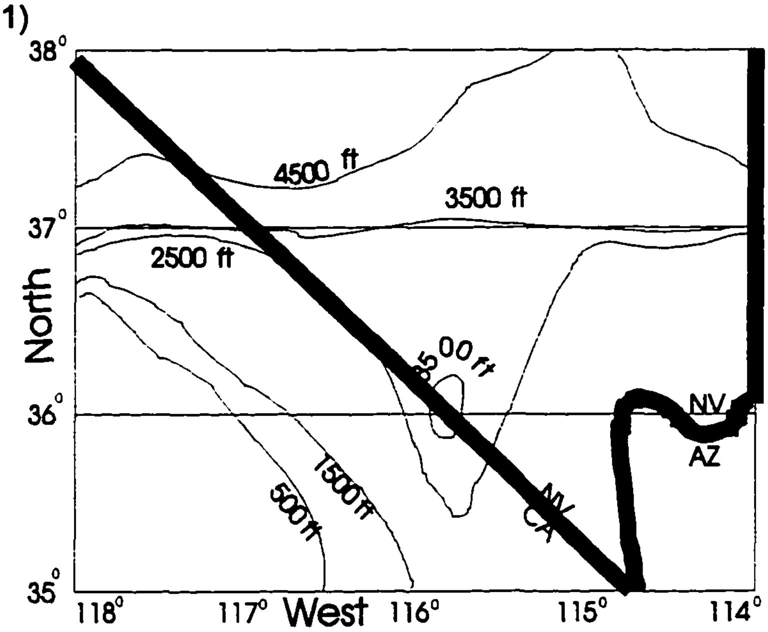
Table 3: Aquifer and Source Rock of Spring or Well

Region	Spring Name	Aquifer	Source
AM	Big Spring	carbonate[2]	lake bed or travertine[2]
AM	Bradford	carbonate[2]	lake bed or travertine[2]
AM	Cold Spring	carbonate[2]	lake bed or travertine[2]
AM	Crystal Pool	carbonate[2]	lake bed or travertine[2]
AM	Fairbanks	carbonate[2]	lake bed or travertine[2]
AM	Jackrabbit	carbonate[2]	lake bed or travertine[2]
AM	Kings Pool	carbonate[2]	lake bed or travertine[2]
AM	Longstreet	carbonate[2]	lake bed or travertine[2]
AM	Pt of Rocks NE	Aquifer	carbonate rock[2]
AM	Pt of Rocks NW	carbonate[2]	playa[7]
AM	Rogers	carbonate[2]	lake bed or travertine[2]
AM	Scruggs	carbonate[2]	playa[7]
UDV	Upper Grapevine	X	QTal
UDV	Middle Grapevine	X	QTal
UDV	Lower Grapevine	X	QTal
UDV	Mesquite	carbonate[4]	alluvium[4]
MDV	Nevares	carbonate[2]	travertine[4]
LDV	Saratoga	carbonate[1]	carbonate[1]
UDV	Scotty's Castle	carbonate[3]	Tvolcanics[3]
UDV	Surprise	carbonate[3]	Tvolcanics[3]
MDV	Texas	carbonate[2]	Qgravels,Tlacustrines[6]
MDV	Travertine A	carbonate[2]	Qgravels,Tlacustrines[6]
MDV	Travertine B	carbonate[2]	Qgravels,Tlacustrines[6]
PAH	Ash	carbonate[7]	carbonate rocks[7]
PAH	Crystal	carbonate[7]	carbonate rocks[7]
PAH	Hiko	carbonate[7]	carbonate rocks[7]
NTS	Cane	tuff[1]	tuff[1]
NTS	Well J13	tuff[1]	NA (well)
NTS	Tippipah	tuff[1]	tuff[1]
NTS	Topopah	tuff[1]	tuff[1]
LDV	Soda Well	X	NA (well)
NTS	Saga Well	X	NA (well)
IS	Hardrock Well	X	NA (well)
IS	Colliseum Well	X	NA (well)
NTS	Coffer Well	X	NA (well)
NTS	Cinderlite Well	X	NA (well)
NTS	Army Well	carbonate[3]	NA (well)
NTS	Airport Well	valley fill[7]	NA (well)
NTS	J12	volcanic[3]	NA (well)
NTS	Lathrop Well	valley fill[4]	NA (well)

Perfect, Faunt, & Steinkampf, 1994[1], Winograd and Thordarson, 1975[2], Camera & Westenburg, 1992[3], Kreamer et al, 1996[4], Winograd,1971[6], Johannesson et al, 1996[7]

Winograd and Thordarson (1975) give several reasons which support the hypothesis that waters throughout the study area are hydraulically related. The first is that the saturated zone of the lower carbonate aquifer is probably at least 4,000 feet thick and laterally extensive in the study area; therefore, movement of ground water through the aquifer from basin to basin is likely (Winograd and Thordarson, 1975). In addition, the chemistries (major ion) of the lower carbonate aquifer beneath Yucca and Frenchman Flats are similar to that of the springs in Ash Meadows (Winograd and Thordarson, 1975). Lastly, a regional potentiometric map indicates that ground water at the test site contributes flow to both Ash Meadows, Death Valley, and the Oasis Valley (Winograd and Thordarson, 1975). According to a study by Hunt, et al (1966), the waters discharging in Death Valley and Ash Meadows are also related to the waters of Pahranagat Valley, with 35% of the flow in Ash Meadows fed by this source (Winograd and Thordarson, 1975).

Figure 6: Water-Table Contour Map of southern Nevada (after Burbey & Prudic, 1991)



Rainfall/Evaporation

As the designation of "desert" suggests, the area has a high evaporation/precipitation ratio. The average annual rainfall over the region is three to six inches while potential evaporation ranges from sixty to eighty-two inches per year(Winograd and Thordarson, 1975). The driving force for these high potential evaporation rates is high temperatures. The average high temperatures in the area range from 40.5°C in Las Vegas, to 24.5°C in central Yucca Flat, to 49°C in Death Valley (Winograd and Thordarson, 1975). In contrast, higher elevations receive more rainfall (Linsley et al, 1992). In fact, the Spring Mountains and Sheep Range generally receive the greatest amounts of rainfall(Winograd and Thordarson, 1975).

Surface Drainage

Some precipitation in the study area is delivered as runoff to the Colorado River (Winograd and Thordarson, 1975). Both the Las Vegas Valley and the Pahranagat Valley contribute runoff to the Colorado (Winograd and Thordarson, 1975). Jackass Flats and the Amaragosa Desert are up gradient topographically from Death Valley and are drained by the Amaragosa River. Water from most of the remaining valleys in the vicinity of the Nevada Test Site (NTS) flows to playas (Winograd and Thordarson, 1975). The western Amaragosa Valley is recharged to a large extent by surface runoff and channel flow (Claassen, 1983).

Chemistry in Ground water and in Rock

Water within the study area will have reacted within tuffaceous rocks, carbonate rocks, or carbonate valley fill- a mixed lithology of both carbonate and tuffaceous rocks. The major ion chemistry of the ground water is determined by the rock types of the subsurface and surface (Claassen, 1983). For this reason some information is given in Table 4 and 4 on the chemistry of carbonate and igneous rocks.

Trends of Trace Element Concentrations in Rock

Carbonates- Limestones and Dolomites comprise approximately 1/6 of the crustal sedimentary mass (Veizer, 1983). The average trace element chemical composition of carbonates is presented in the Table 4 on page 18. An "x" indicates that the value is on the order of magnitude indicated. In general, the chemistry of sedimentary carbonates is determined by provenance or source. Trace elements become a part of the crystal lattice in minerals by substitution for Ca^{2+}, interstitial substitution, addition of trace elements at defect sites, and adsorption induced by ionic charge (Veizer, 1983).

Igneous Rocks- The chemical composition for igneous rocks vary widely; however, there are to be relationships for trace elements in different igneous rock types. Mafic rocks typically have more chromium and cobalt, whereas felsic rocks tend to be richer in barium, rubidium, lead and beryllium (Salomons and Forstner, 1984). Table 5 on page 18 gives average trace element values for the Timber Mountain-Oasis Valley Caldera Complex, Nevada (Broxton, et al, 1989). For individual values for concentrations of each unit refer to the original cited reference.

From the works of Vezier (1983) and Broxton et al. (1989) it can be seen that carbonates on average have greater amounts of strontium than some of the NTS volcanics. Both rock types have similar concentrations of vanadium and antimony. The NTS volcanics have higher concentrations of arsenic rubidium, zirconium, and barium.

Table 4: Chemistry of Carbonates (Veizer, 1983)

Element	Carbonate (ppm)	Deep Sea Carb (ppm)	Element	Carbonate (ppm)	Deep Sea Carb (ppm)
Li	5	5	Ge	0.2	0.2
B	20	55	Cd	0.035	0.0x
F	330	540	Mo	0.4	3
Na	400	2000	Sb	0.2	0.15
Mg	47000	4000	I	1.2	0.05
Al	4200	20000	Cs	0.x	0.4
Si	24000	32000	Ba	10	190
P	400	350	La	x	10
S	12000	13000	Ce	11.5	35
Cl	150	21000	Pr	1.1	3.3
K	27000	2900	Nd	4.7	14
Ca	302300	312400	Sm	1.3	3.8
Ti	400	770	Gd	1.3	3.8
V	20	20	Tb	0.2	0.6
Cr	11	11	Dy	0.9	2.7
Mn	1100	1000	Ho	0.3	0.8
Fe	3800	9000	Tm	0.04	0.1
Ga	4	13	Yb	0.5	1.5
As	1	1	Lu	0.2	0.5
Se	0.08	0.17	Hf	0.3	0.41
Br	6.2	70	Ta	0.0x	0.0x
Rb	3	10	W	0.6	0.x
Sr	610	2000	Hg	0.04	0.0x
Y	30	42	Pb	9	9
Zr	19	20	Th	1.7	x
Nb	0.3	4.6	U	2.2	0.x

Table5 : Trace Element Chemistry: Timber Mountain-Oasis Valley Caldera Complex (concentrations are in parts per million for trace elements and percent masses for oxides)(after Broxton, et al, 1989)

V	18	TiO_2	.21
Co	.97	MnO	.069
As	3.4	SiO_2	72
Rb	170	MgO	.27
Sr	200	CaO	.81
Zr	260	Na_2O	3.6
Sb	.40	K_2O	4.9
Cs	5.2	FeO_T	1.3
Ba	810	U	120

Chemistry in Ground water of Southern Nevada

In general, waters that discharge directly from the carbonate aquifer have certain chemicalsimilarities, waters from volcanic rocks have separate chemical characteristics, and water flowing through different alluvial units probably have some common chemistry. Other parameters such as the regional flow pattern or the effects of man may then overprint these chemistries. Winograd and Thordarson (1975) expanded a classification scheme designed by Schoff and Moore (1964) and list five hydrostratigraphic facies of ground water in and around the NTS in southern Nevada (Table 6).

Table 6: Ground water Classification Scheme by Major Ions (Winograd&Thordarson, 1975)

Class	Characteristic Source	Examples
Calcium magnesium bicarbonate facies	lower carbonate aquifer or valley fill aquifer where carbonate rich	Spring Mountains, Pahranagat Valley
Sodium potassium bicarbonate	tuff, rhyolite, valley fill where rich in volcanics	Yucca Flat, Frenchman Flat, Jackass Flats, west and northwest of NTS
Calcium magnesium sodiumm bicarbonate	lower carbonate aquifer	Ash Meadows, eastern NTS
playa	where ground water is removed by evapotranspiration, rather than by fluid flow discharge	
Sodium sulfate bicarbonate	Furnace Creek Wash and west-central Amargosa Desert	

Some water within the study area may be significantly impacted by contact with volcanic tuffs due to dissolution of metastable glass as it alters to other minerals (where tuffs are present). A study by White, Claassen, and Benson (1980) indicates that in the Rainier Mesa area deeper water, both interstitial and in fractures, is richer in sodium and depleted of calcium and magnesium with respect to shallower waters. For the most part, these increasingly sodium rich waters move through the tuff through the porosity and are changed chemically through the processes of dissolution, precipitation, sorption, and ion exchange (White, et al, 1980). It is possible that these same processes are important for all ground water in the study area. Table 7 shows major ion chemistry for ground water in Rainier Mesa (White et al, 1980). Concentrations are in millimoles per liter and are averages of numerous values (all from units of the Rainier Mesa) in the original cited references.

Table 7: Chemistry of Tuff Waters of Rainier Mesa (concentrations are in millimoles/Liter) (White et al, 1980)

Na	1.5	Bicarbonate	1.6
K	0.12	Sulfate	0.15
Ca	0.21	Chloride	0.24
Mg	0.06	Flouride	0.01

CHAPTER 3:

SPRING AND WELL HYDROGEOCHEMISTRY DATA DOCUMENTATION

Reconnaissance and Sampling for Trace Elements

On reconnaissance sampling excursions different physical and chemical parameters were measured. Latitude and longitude were determined using a Panasonic brand global positioning satellite system. Other measurements taken in the field included: pH, TDS, conductance, and temperature. Four liters of spring water were collected in acid washed polyethylene bottles, after they were filtered through a 0.45 µm polysulfane filter. Samples were analyzed within one week for trace element chemistry determinations and within 2 to 4 days for anion results. The above sampling procedure is described in Stetzenbach et al. (1994). Waters were sampled for trace element concentrations on the dates shown in Table 8.

Table 8: Sampling Dates (Harry Reid Center for Environmental Studies)

Ash Meadows springs	July 1992, January, May, October 1993, March 1994
Death Valley springs	June 1992, March, July, November 1993, March 1994
Pahranagat Valley springs	September 1993
Nevada Test Site springs	December 1994, January, February 1995
wells	May, June 1994

Analytical Procedures

Major anions were analyzed by ion chromatography and major cations by atomic absorption spectrophotometry (Harry Reid Center for Environmental Studies). Rare earth elements (REEs) and trace elements were analyzed by inductively coupled plasma- mass spectrometry(Harry Reid Center for Environmental Studies). Concentrations as low as parts per trillion were determined by ICP-MS (Harry Reid Center for Environmental Studies). The ICP-MS machine used is the Perkin Elmer Sciex Elan 5000 ICP- MS with an active film multiplier detector. The samples entered the ICP- MS via an ultrasonic nebulizer. Further specifics may be obtained from the Harry Reid Center for Environmental Studies.

CHAPTER 4:

METHODS OF INVESTIGATION & PROBLEM SOLUTION

Data Selection

Although approximately 55 elements were analyzed to produce the data set obtained by HRC, only a portion of this data was used. One reason that only a portion of the data set is used is that trace elements were to be the focus of this study. A second reason is that some element concentrations were found to be nondetect values more often than not. Others were not measured in all locations. Lastly it is widely held that certain elements are most difficult to obtain concentration values for because of problems inherent to sampling. For example iron, copper, lead, zinc, and cadmium concentrations have historically been difficult to measure (Windom et al, 1991, Runnells et al, 1992). For the majority of the research presented in this thesis, the following chemical element concentrations were utilized: selenium, vanadium, arsenic, tungsten uranium, molybdenum, rhenium, manganese nickel, gallium, rubidium, cobalt, strontium, cadmium, cesium, barium, thallium, tin, antimony, titanium, germanium, tantalum, lithium, chromium, and zirconium. Measured elemental concentrations used not only meet internal quality control standards of the Harry Reid Center for Environmental Studies but also were selected on the basis of the number of nondetects. Generally if an element was analyzed as a nondetect or not measured more often than not then the element was generally excluded from analysis. Some elements which were measured many times as non detects were included to represent columns of the periodic table with minimal weighting of each column in the periodic table. Only the three lightest REEs consistently have discrete measured values. Since the heavier REEs could not be represented in analysis, no REEs were considered. In Chapter Five, exploratory analysis shows that exemption of REEs does not hide differences between waters.

As mentioned previously the author obtained data from the Harry Reid Center for this study. The data are trace element concentrations from springs in Ash Meadows National Wildlife Refuge, Death Valley National Park, Pahranagat Valley and wells and springs on the Nevada Test Site as well as wells in Shadow and Ivanpah Valley. Because the data has already been collected, the thesis research did not include development of any experimental model. It is likely that a better understanding of the regional groundwater system could be obtained if more sampling and analysis were done at appropriate locations.

Principal Component Analysis

The author analyzed the data statistically. The statistical analysis included Principal Component Analysis (PCA) of the entire data set, as well as other analyses (such as correlation plots, dendograms, and icicle plots). Different scales and kinds of analysis were performed and are described in this paragraph. In the principal component analysis the elemental concentrations are variables and the cases are the spring or well water names. In the most inclusive analyses all springs and wells were included and the largest number of variables were considered. The most exclusive analyses considered a limited number of both cases (springs) and variables (chemical elements). Different kinds of analyses were conducted so that smaller geographical scales could be focused on, and the importance of waters which were thought to be perched could be minimized (since perched waters are probably less important to regional flow). These methods were used in an attempt to gain a better understanding of the physical parameters of the study area. Relationships between springs and differences between springs were noted if there there were any trends of changing trace element concentrations with changing season by making simple time vs. concentration plots for different springs. The results were then discussed.

Factor analyses like principal component analysis (PCA) has been used for numerous geological problems in the past (Joreskog, et al., 1976). Examples are: (1) using trace elements in sediments to determine the sediment origins; (2) using chemistry and structure of ore bodies to find likely sites for additional ore bodies; (3) and using the relationships between sediments samples and measurements of organism populations to determine preferences of organisms for certain kinds of sediments (Joreskog, et al., 1976). Okuda,et al (1995) used principal component analysis to classify pyroclastics based on chemical composition and make inferences about age and spatial correlations. Nash, et al (1993) clustered soils using principal component analysis into groups with two factors which explained from 53-60% of the variance within the sample.

PCA is a statistical method which is capable of reducing an unmanageable number of variables into a smaller number of composite variables called factors. The method is based on linear algebra and the use of matrix manipulation. Principal component analysis is a form of multivariate statistical theory which makes the assumption of normal distributions; however, principal component analysis is considered robust enough mathematically to be appropriate for this study (Yfantis, 1996). A good factor analysis solution will weight variables fairly, explain observations with a minimum number of factors, be meaningful, be simple, and will be interpretable (Norusis, 1994). Using commands to extract factors, PCA determines orthogonal factors based on an uncorrelated matrix and create linear combinations of the variables (Norusis, 1994). For example, the first principal component might be described by the linear equation "$Y_1 = a_{11}X_1 + \ldots + a_{p1}X_p$" if the covariance matrix is used (Morrison, 1967). In this case the first term of the equation represents the product of the vector and the scalar values of the first variable's contribution to the first principal component. The first principal component explains the largest amount of variance in the data set; additional principal components account for smaller amounts of variance. One should note that for this research, correlation matrices were used which likely define relationships in a similar fashion but require a much more complex equation to express principal components; however, the relationship between the vector portion of the first term is easy to define (s=variance, z = new vector term for principal component created using correlation matrix).

z_{ij} = (xij - $xmean_j$) / s_j (Morrison, 1967)

Both Statistical Products and Service Solutions (SPSS) (Chicago, Illinois,1994) and Statistica (Statsoft, 1993) were used for the Principal Component Analysis (since both software packages are based on the same fundamental principles, the results should be the same). Principal Component Analysis has a general procedure outlined below (based on procedure as user progresses through analysis as performed by SPSS (Norusis, 1994)). First the operator must decide how to deal with problem of missing values. Missing values can be dealt with by exclusion of cases, variables, or replacement. Next the user determines the number of factors necessary to explain a certain amount of variance. This can be done by examining the scree plot. A scree plot is a two dimensional graph relating the percent of variance explained (or sometimes indicated by an eigenvalue) to the number of factors that explains the variance in the principal component analysis. The option of rotating data may be considered. The software can then generate a correlation matrix and provide the user with factor scores. These factor scores are measures of how the data are now described by the principal components. For example, Case A may originally have been described by four variables with values of 1, 2, 3, and 4. After principal component analysis, Case A may be described with two principal components with values of 2 and 5. These factor scores can then be graphed in scatterplots with orthogonal axes which correspond to the different principal components.

The possibility exists that as many principle components as variables can be generated; however in this study 3 was the largest number of principle components needed to explain ≅50% of the variance in the sample (39 cases, 23 variables for entire working data set). For ease of display only the first two principal components were illustrated in two dimensional scatterplots. In addition, the factor analysis was not rotated and the factor scores were computed by regression. For the majority of analyses, the mean value of each element was used to fill empty cells in the original data sets (empty cells due to non detects). These means are calculated from the chemical concentrations of the same element in all other cases.

Agglomerative Cluster Analysis

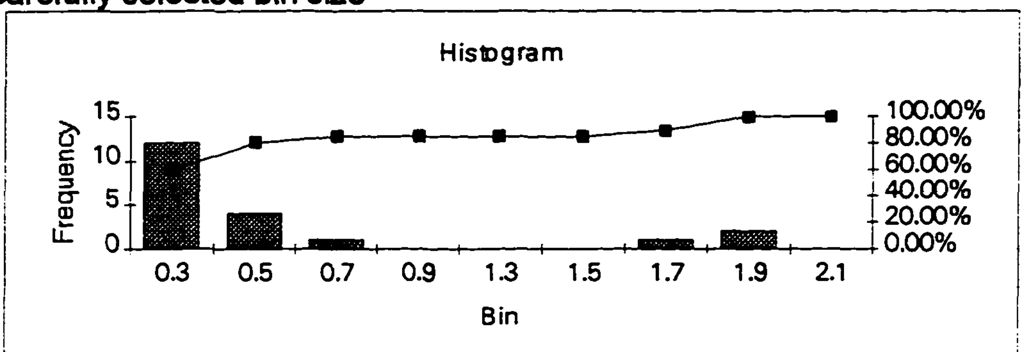
Another way of analyzing data is to perform a cluster analysis. In SPSS the squared Euclidean distance (sum of the squared differences of each elem over all of the variables) coefficient matrix is the first element of forming clusters. The Euclidean distance coefficient matrix is determined by calculating differences between corresponding variables between each combination of cases, such that the differences between each variable are weighted equally (Norusis, 1994). Plots are then generated to illustrate relative similarities between waters. Some software normalizes Euclidean Distances to a certain value, but some do not. Both Dendograms and Icicle Plots can be generated after the Euclidean matrix is created. Both dendograms and icicle plots are useful, but do express some common information. Icicle plots are read from the bottom up and best exhibit (spring to spring) which cases are most similar.

Histograms

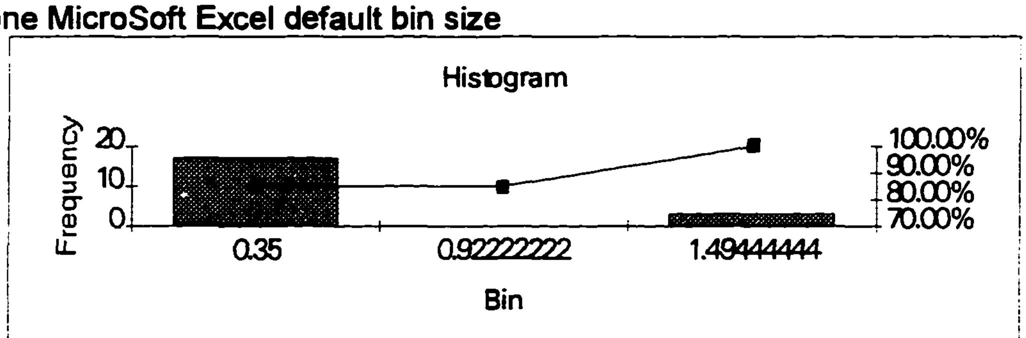
Histograms were constructed by using Microsoft Excel 4.0 and SPSS Exploratory Analysis. In Excel the histograms were assigned bin sizes after examination of the ranges in the chemical concentration data. In this case bins are divisions in concentration axis of concentration histograms. Excel was used to make sets of histograms with common bin sizes so that different subbasins may be compared. The histograms created in SPSS Exploratory are in "leaf and stem" format so that readers can verify frequencies without any effect of bin size. In this study frequency refers to the number of springs or wells having concentrations that have a given concentration. The leaf and stem format allows for reconstruction of the data set from which the histogram was built. If simple histograms alone are created and analyzed, there may be problems related to bin size. Software may choose bin sizes for the scientist. The default selection may not be appropriate for the study and may hide certain things to a small extent. Figure 7 is an example which illustrates how this problem might affect representations of data from this study.

Figure 7: Effects of Default Bin Size on Histograms

a) carefully selected bin size



b)one MicroSoft Excel default bin size

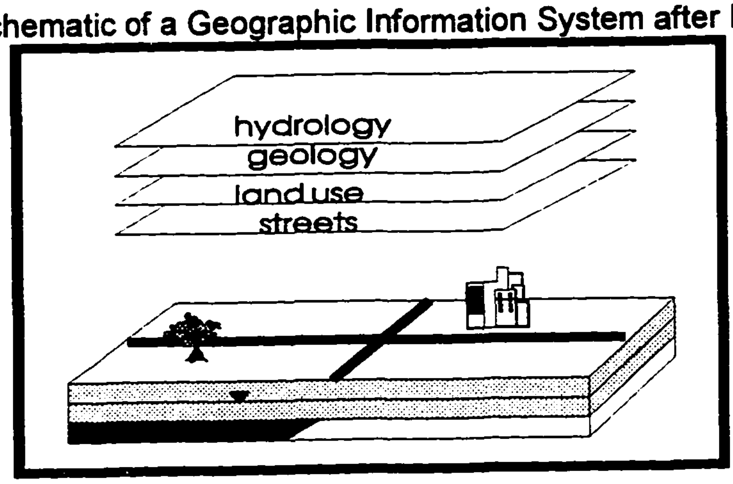


Geographic Information Systems

Geographic Information Systems (GIS) is a kind of spatial database which can be used for modeling and analyzing spatial data in a variety of ways. Environmental Systems Research Institute (ESRI) has developed a software package for use with personal computers and UNIX systems entitled *ARC/INFO*. The ARC part of the program is responsible for locating the features, for example, springs; the INFO part handles the information and descriptions of each spatial feature (ESRI, 1990). GIS is described in simple terms as an a database with two components. Part is an information database containing descriptive information, and the other part is responsible for locations in X-Y space of data points which corresponds to the descriptive information in the information part of the database.

GIS is superior to other forms of spatial analysis because it allows spatial operations on the data set. Refer to Figure 8 on page 31 when reading the following explanation. GIS can answer many important questions. The system can define what features or conditions exist at certain locations prompted by queries regarding a certain location. The system can identify changes over time as well as spatial patterns. In addition ARC/INFO is able to perform these previously mentioned tasks after certain elements of the spatial database are changed (ESRI, 1990). The ability to answer queries, and perform calculations, means that GIS is much more than just a map making tool. It may be used to present chemical data in such a form as to make certain relationships more clear and even to manipulate the data. From these capabilities, more information will be found which will either support or counter previous efforts to define ground water flow through southern Nevada.

Figure 8: Schematic of a Geographic Information System after ESRI, 1990



ARC/INFO can be a powerful tool for analysis of spatial data. For a variety of reasons only a minute portion of the software's capabilities were utilized in this study for many reasons. Foremost among these reasons is the disparate distribution of data points in the study area. For this reason the data was contoured using the kriging method available in ARC/INFO. Kriging is based on the idea that when one considers the value of a data point to determine nearby values, one should also consider the values of neighboring points. Kriging is based on the idea of a regionalized variable with three components: drift (trend), spatially correlated randomness, and noise (Clarke, 1990).

The first step in the spatial analysis was to prepare the database. INFO was used to create a template data file (chemcov) containing the concentrations of: arsenic, antimony, cesium, cobalt, selenium, vanadium, uranium, molybdenum, rhenium, rubidium, nickel, thallium, gallium, tungsten, and germanium in groundwaters from springs and wells in southern Nevada. The table was then filled from an ascii file using the ADD FROM command.

Using the ARC command PROJECT the locations of all data points were converted to a standard of Nevada State Plane (Fipszone 2702, GRS80, Datum NAD83) from the latitudes and longitudes obtained from the Harry Reid Center. The ARC command GENERATE was used to create the point coverage <location>. The location.pat file was joined to the file chemcov to form the database all work in this section is based on.

The next step was to create a map with the truest representation of space possible. This map is included in the GIS section of Chapter 5. Springs and wells are labeled to correlate with a listing at the bottom of the map. In areas such as Ash Meadows and the Grapevine springs locale, the numbers may overprint one another due to their proximity. While this does make identification of individual springs in these areas difficult, coordinates for each data point are included in Chapter 2.

ARC/INFO has several tools for modeling surfaces and contouring spatial parameters: TIN, GRID, and kriging. TIN and kriging are examined in this study. The macros used to generate the TINS and kriged contours (Appendix E). The macros are written in ARC Macro Language and are all designed to be run from the ARC prompt.

Typing the command Kriging at the ARC prompt initiates dialog to establish the conditions of the model. A contour interval is specified (different for different elements) and the name of the contour coverage and variance coverage are defined. In each analysis, the entire study area was kriged. For this analysis the spherical distribution (default) was selected for kriging technique because neither the gaussian nor universal kriging techniques is necessarily appropriate for these models. The contour coverage created will preserve the integrity of the original data set as modeling with TIN does.

ARC/INFO makes analysis of spatial variance relatively simple by using the kriging command. Variance in this study is a measure of how each water sample concentration for each element varies from the mean of the mean for that element for all waters in the study. Kriging in this software creates a coverage of variance which can then also be contoured which in essence provides a map of variance of the data. Areas of higher variance are areas where more data points are needed to improve the quality of the chemical concentration contour map. It is probably obvious that many more data points would be useful in this analysis just from looking at the location map.

It is important to note that contouring any parameter is to some degree affected by the technician's individual choices. All of the results obtained are based on contour intervals, techniques, and base contours defined by the operator; however, in ARC/INFO one should always obtain the same result, provided the parameters defined in the kriging dialog remain constant.

Chapter 5:

EXPLORATORY EFFORTS AND DISCUSSION

ELEMENTAL CONCENTRATION PLOTS

The elemental concentration plots are simple X-Y and 3D bar graphs which illustrate concentrations of elements in different springs and wells. They are particularly useful to provide a visual foundations for some of the results of principal component analysis and hierarchical analysis of spring and well waters. Simple bar charts can also be used to illustrate change over time. Examples illustrating these statements follow.

Simple plots of elemental concentrations of the different water samples are useful to illustrate the actual concentrations of the elements which seem to provide the most variance between subbasins (as indicated in following principal component analysis section). Figures 9-13 on pages 36-38 compare springs and wells on the basis of several different element concentrations: uranium, rhenium, molybdenum, antimony, and cesium. From inspection of these simple plots of concentrations, one can observe that there are distinct groups of waters which consistently are different from the rest. Death Valley generally has lower concentrations of rhenium. Usually the perched springs of the NTS have either higher or lower concentrations of elements compared to other waters.

Figure 9:

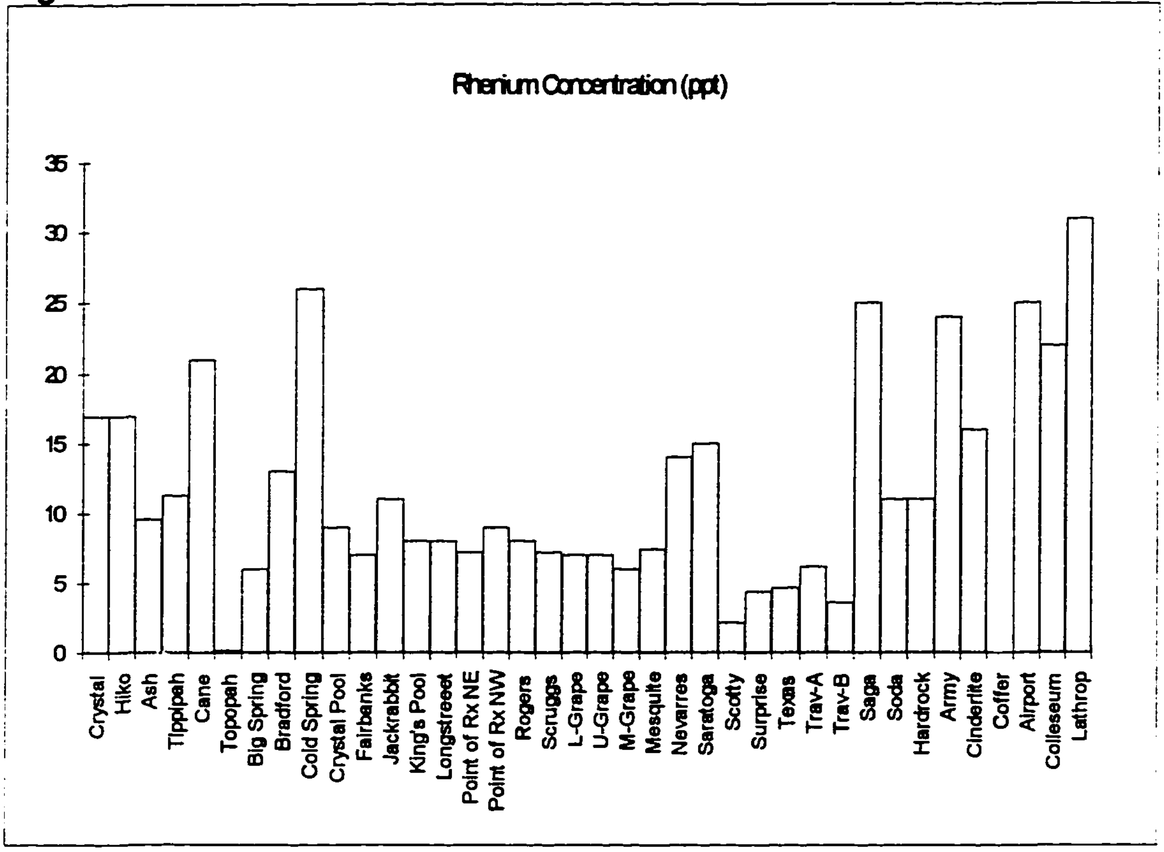


Figure 10:

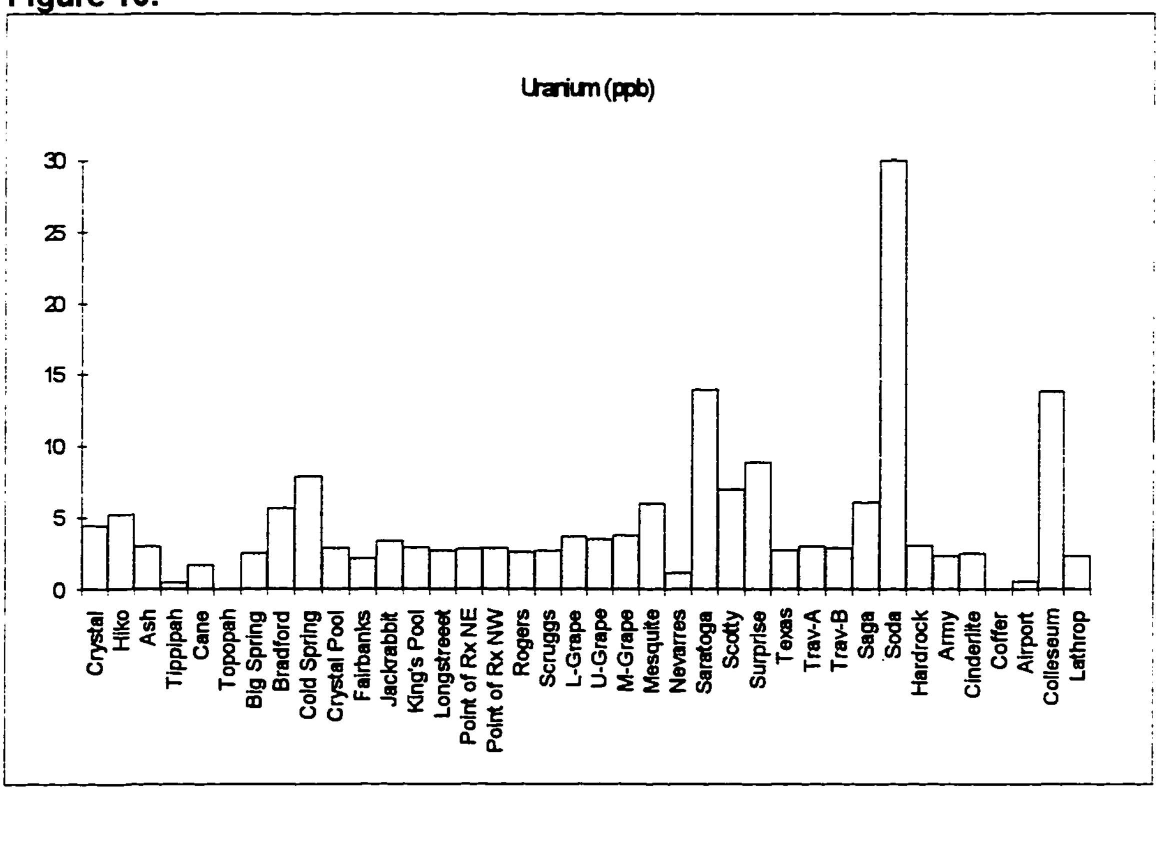


Figure 11:

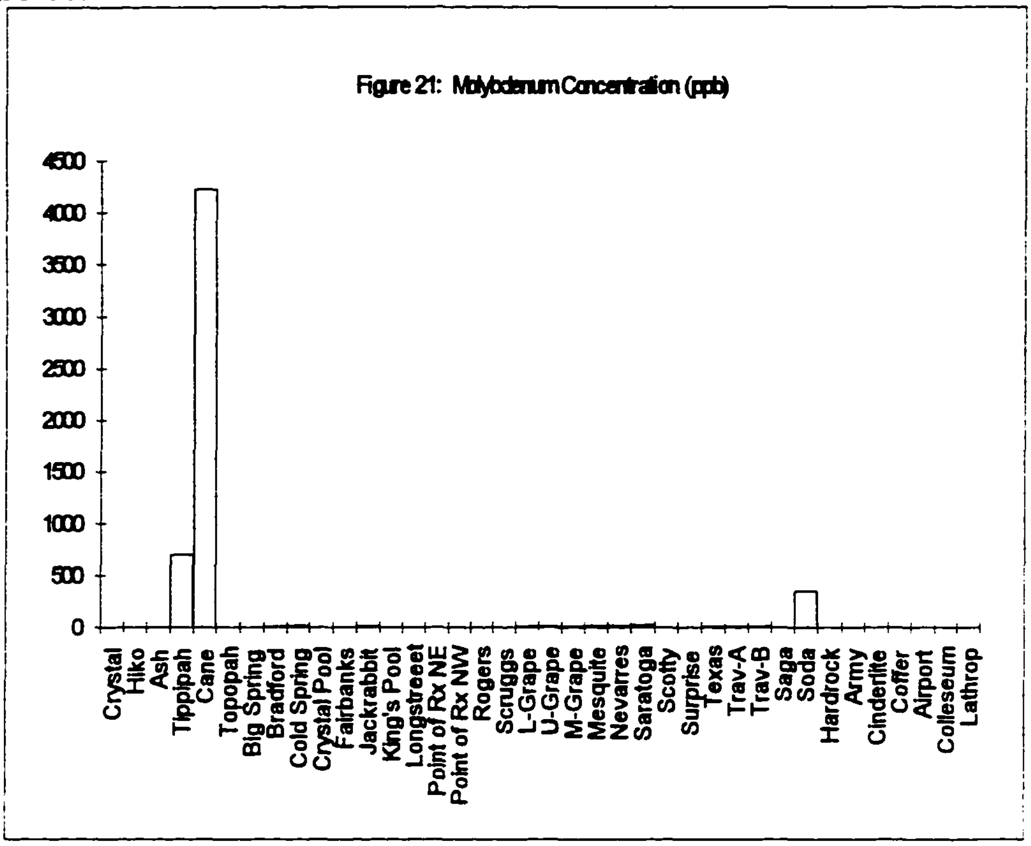


Figure 12:

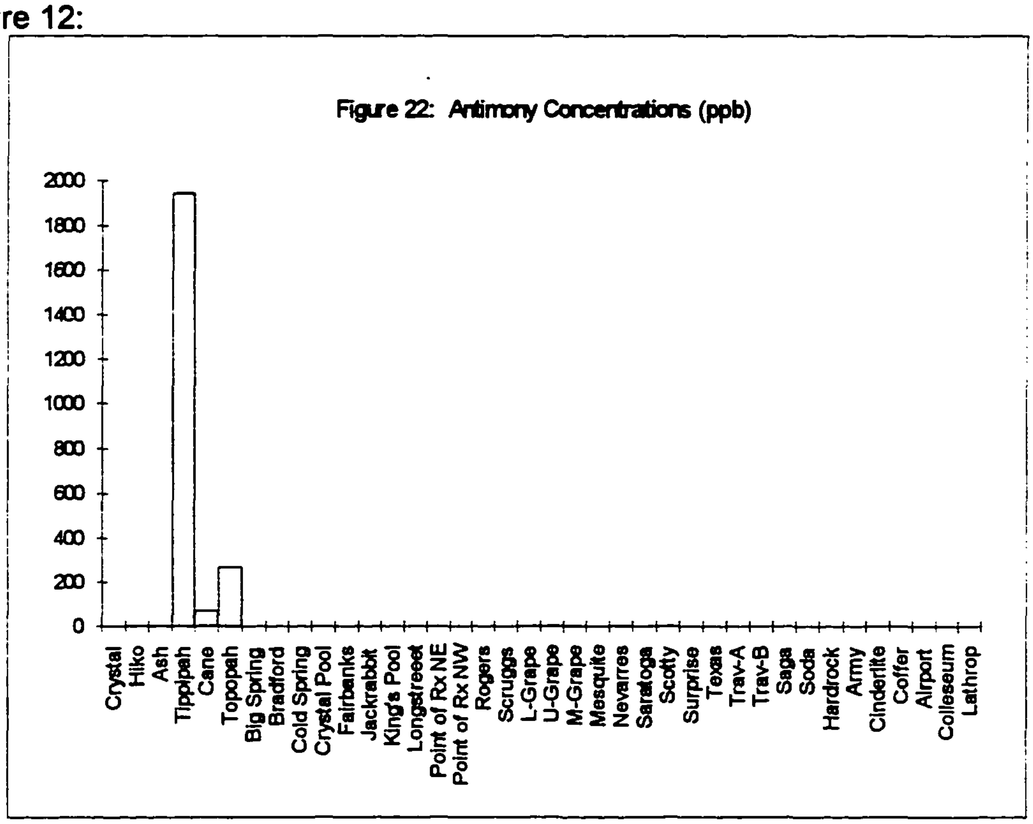
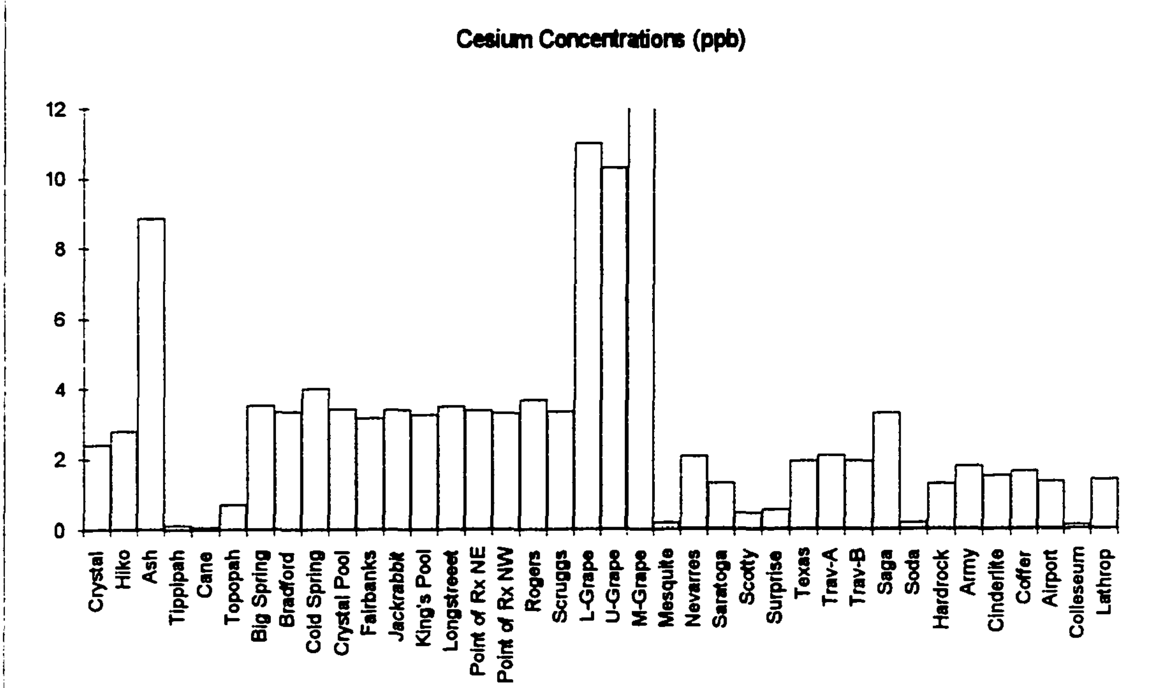
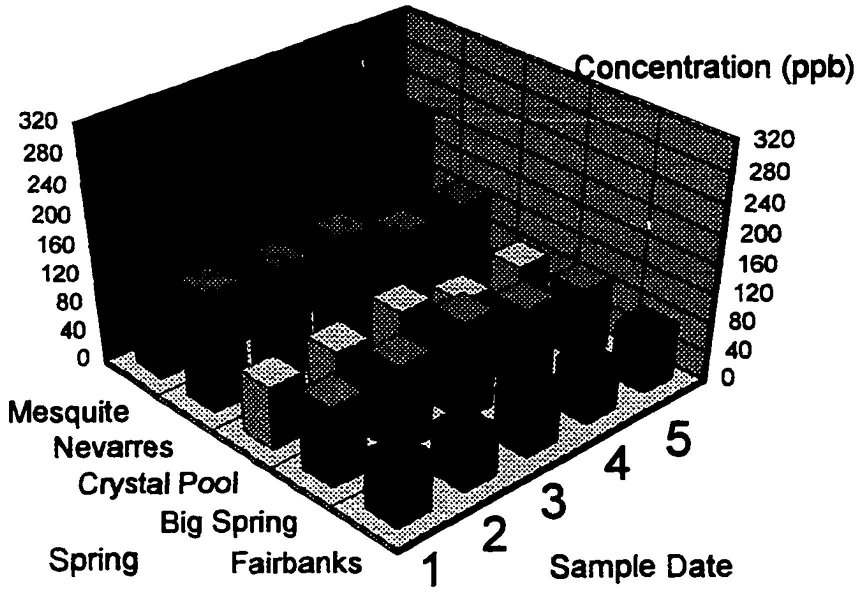


Figure 13:



As mentioned in Chapter 3 and Chapter 4, the springs of Death Valley and Ash Meadows were sampled six times by the Harry Reid Center (HRC). During the study attempts were made to identify any marked changes over time in chemical concentrations. Figure 24 was included on page 44 in this section for illustration of lithium concentrations in select Ash Meadow springs. Although there are some differences, these differences are more likely to represent improved techniques in sampling and analysis, than changes that occur over time (K. J. Stetzenbach, 1996 pers comm, V. F. Hodge, 1995 pers comm). For springs that were sampled multiple times, trace element concentration values were taken from the fifth sampling date, unless the spring was not sampled on that date. In the case of missing values in the fifth sampling date of springs sampled multiple times, the fourth sampling date was used.

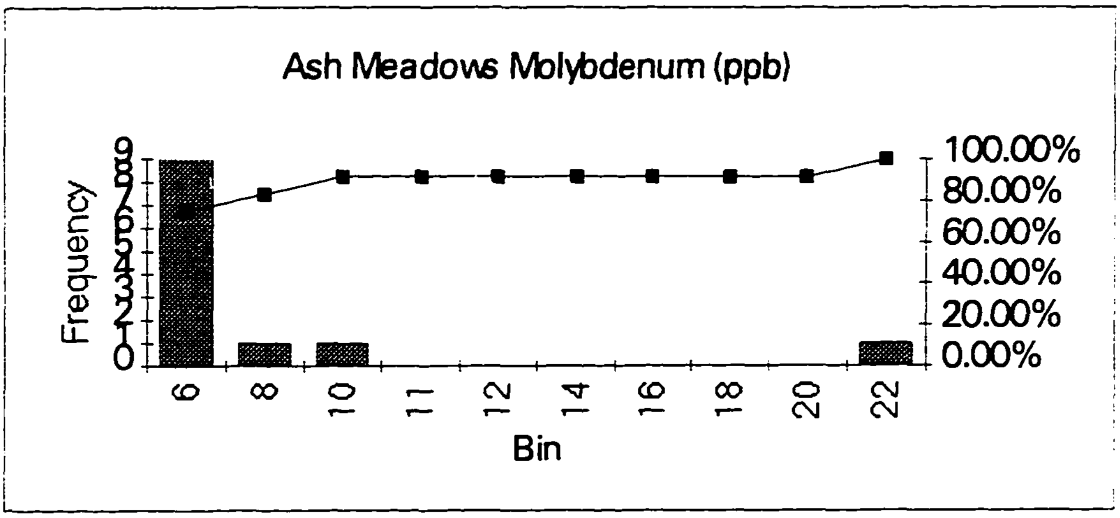
Figure 14: Lithium Concentrations in Ash Meadows and Death Valley (ppb)

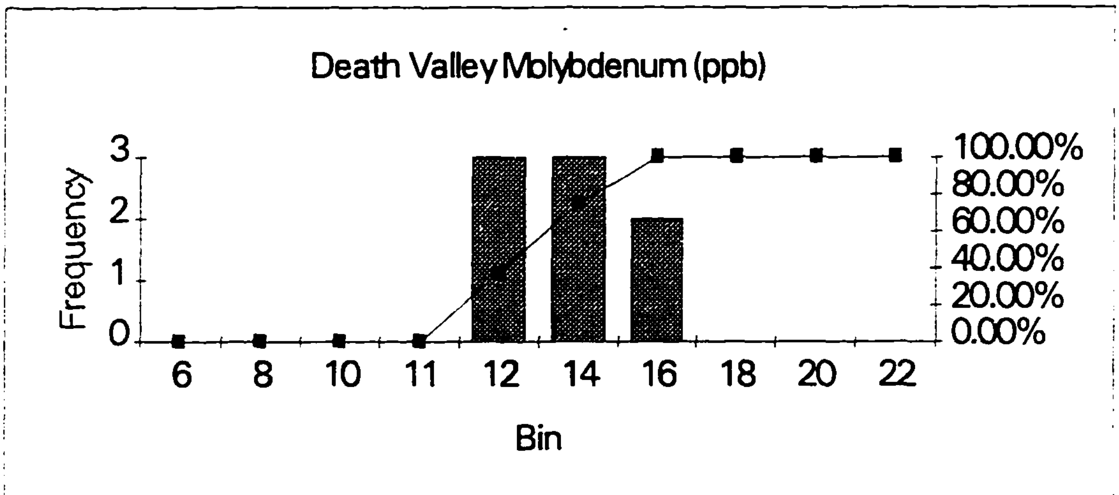


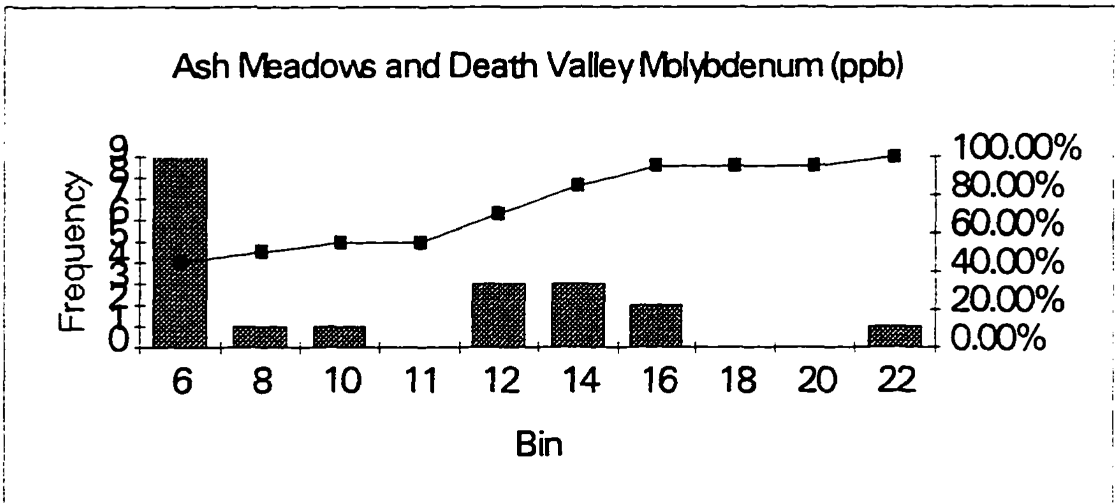
HISTOGRAMS

It is interesting to note how the histograms of some elements differ between subbasins. Figure 15 on page 38 shows the distribution of molybdenum in carbonate waters from Ash Meadows springs (in ppb) versus the distribution of molybdenum in carbonate waters from Death Valley springs (in ppb). This means that although there may be normal distributions when one examines the entire data set and when one examines an individual subbasin, there may also be a great enough difference between the mean of each chemical element in each different subbasin to create distributions with more than one mode. The histograms of Figure 15 make use of all of the first five sampling dates' data.

Figure 15:


Ash Meadows Molybdenum (ppb)
Frequency
0
1
2
3
4
5
6
7
8
9
100.00%
80.00%
60.00%
40.00%
20.00%
0.00%
6
8
10
11
12
14
16
18
20
22
Bin


Death Valley Molybdenum (ppb)
Frequency
3
2
1
0
100.00%
80.00%
60.00%
40.00%
20.00%
0.00%
6
8
10
11
12
14
16
18
20
22
Bin


Ash Meadows and Death Valley Molybdenum (ppb)
Frequency
0
1
2
3
4
5
6
7
8
9
100.00%
80.00%
60.00%
40.00%
20.00%
0.00%
6
8
10
11
12
14
16
18
20
22
Bin

From an analysis of the entire data set simple histograms were created. Medians, maximums, and minimums were also included with stem and leaf plots in Appendix A. The histograms were used to determine contour intervals in Chapter 6 where contour maps of different element concentrations were made. The histograms are also useful for visual reference to gain a simple understanding of the abundance of elements in the ground water throughout the study area. Additional histograms are in Appendix A.

Figure 16: Histogram of Selenium

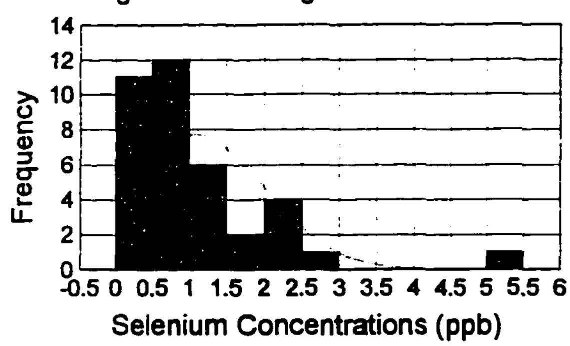


Figure 17: Histogram of Vanadium

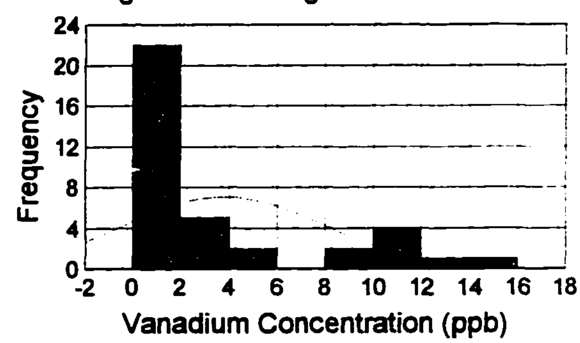


Figure 18; Histogram of Arsenic

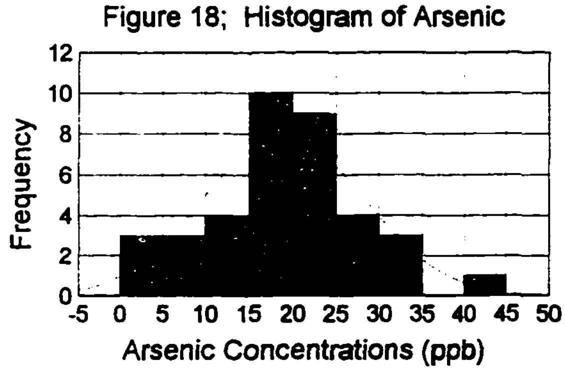


Figure 19: Histogram of Uranium

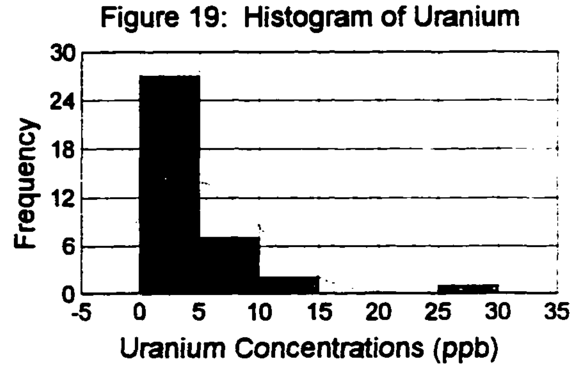


Figure 20: Histogram of Tungsten

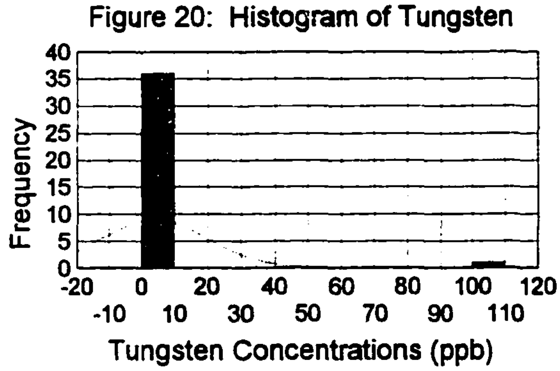
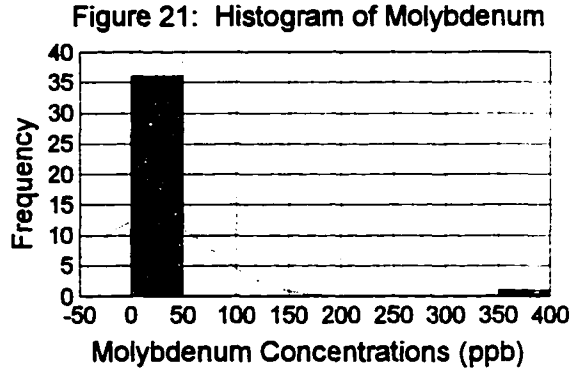


Figure 21: Histogram of Molybdenum



PRINCIPAL COMPONENT ANALYSIS

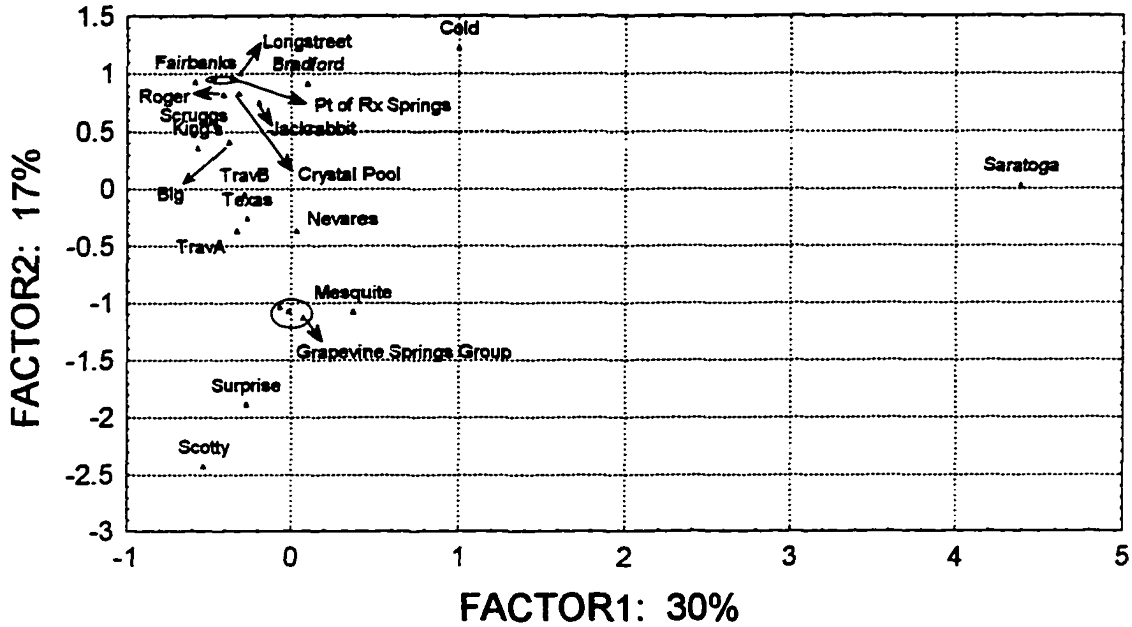
In science the output of a model or program is dependent on input. It is also true in science that specific parameters are measured, not neccessarily every possible one. Sometimes items are measured and upon analysis it is obvious that there was some error in the measurement process, as is often the case with certain trace metals. In any case one must always be aware of what information an analysis is based on, and understand as well as possible the effect of each piece of data on the result. This section is included to illustrate that although there are differences resulting from certain changes in the variables of the data set analyzed, certain relationships are almost always found in this study area.

Effects of Different Variable Sets on Analysis: Entire Data Set vs Major Elements and Anions vs Trace Elements (no REEs)

The first principal component analysis is based on trace element data from springs and wells in addition to majors and anions to create Figure 22. Although it might be hypothesized that standard deviations of element concentrations measured at part per trillion levels might be higher and in effect weight the results of principal component analysis, this is not necessarily the case. If one examines water sample collected in Ash Meadows and Death Valley this is evident. The variables included in this analysis are indicated in materials within Appendix D. This analysis will then be compared with other variable sets in this section to get an idea of what effect major elements and anions, and the trace elements had in the PCA of Ash Meadows and Death Valley data. The graphical results of using different variable sets follow in Figures 22-24 on the following pages. Each graph is followed by discussion. For each scatterplot of waters as described by principal components, the author has included a variable list, eigenvalues, and factor loading matrix in Appendix

D. These materials are not needed to visualize or discuss results but do allow for inspection of information in the analysis.

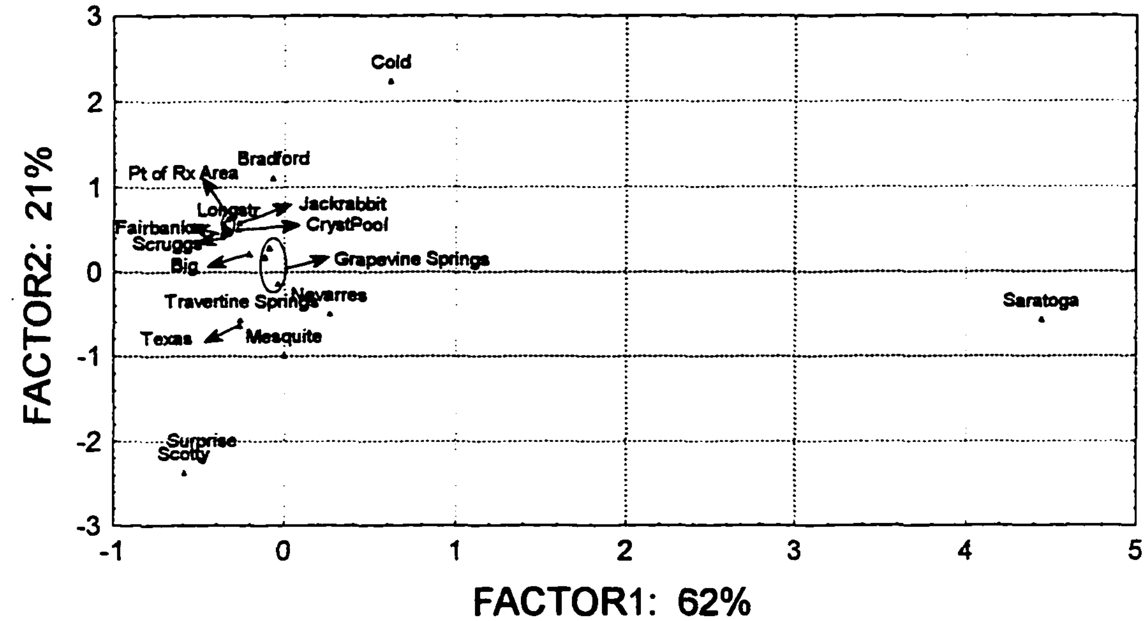
Figure 22: Scatterplot of Ash Meadows & Death Valley (entire variable set)



In Figure 22 outliers include Cold, Saratoga, Surprise, and Scotty's Castle. The Furnace Creek springs cluster togetherand the majority of Ash Meadows cluster closely together and near the Furnace Creek or middle Death Valley springs. The Grapevine springs and Mesquite Spring plot near each other.

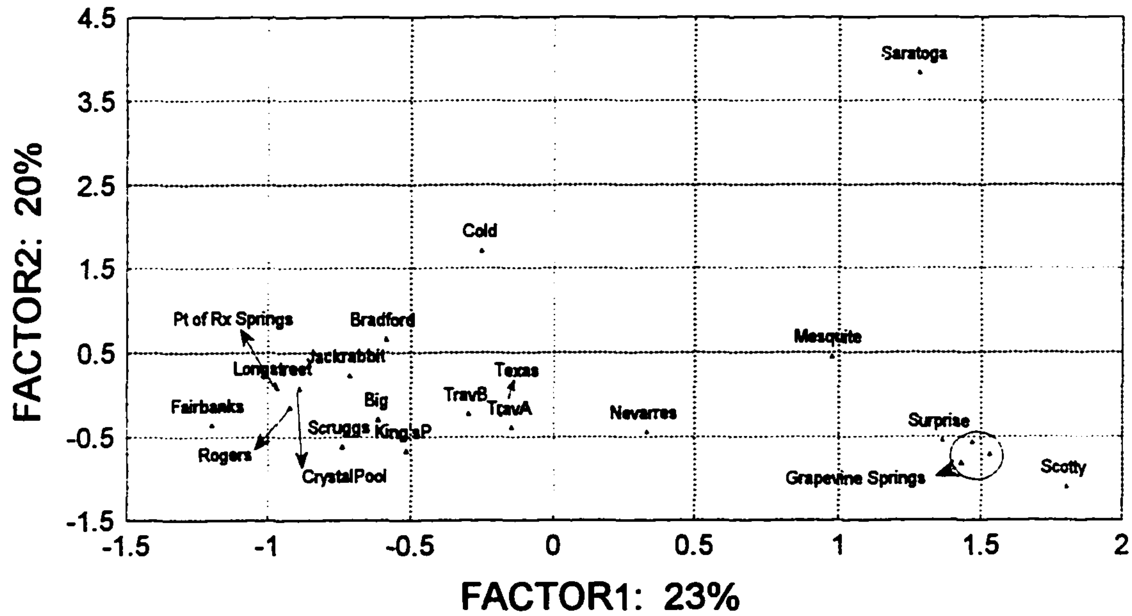
It is interesting to note that in the second plot in this section, Figure 23 (p43), generated using only major elements and anions, there is the greatest amount of clustering. In other words, the outliers, Cold, Saratoga, Scotty's, and Surprise are more isolated from the remaining springs (Ash Meadows and middle Death Valley) which cluster together more closely. Note that there are still two separate "centers of mass" one for Ash Meadows and one for the carbonate springs of upper and middle Death Valley (Furnace Creek Region). The only difference in relationships seems to be that the Grapevine Springs do not plot as close to Mesquite Spring and actually plot between Ash Meadows and the Furnace Creek springs.

Figure 23: Scatterplot of Ash Meadows & Death Valley (major elements and ions only)



If the analysis includes the trace elements of the data set a slightly different picture emerges (Figure 24, page 43). Once again, Saratoga, Surprise and Scotty plot away from the clustered group. The "clustered group" in this instance is not quite as clustered as in Figure 23 though, and Cold Spring is as near the "clustered group" as the Mesquite and Grapevine Springs are. This plot is important for several reasons. The difficulty of finding accurate values of concentrations on the part per trillion level might cause some speculation of results. Specifically, one might guess that the problem might exaggerate PCA plot results. From the following figure one may now see that this problem is not likely.

Figure 24: Scatterplot: Ash Meadows and Death Valley (trace elements)



<u>Substitution of Missing Values: mean, zero, detection limit</u>

Many of the elements examined have at least some values of "not measured" or "not detected" in at least one case. Only two dimensional scatterplots of spring classifications based on first and second principal components are shown here. The data, eigenvalues, and factor loadings are including in Appendix D.

From the graphs on page 44 and 45 one can see that although there may be slight differences in exact position with respect to certain springs, the groupings are essentially very similar. Saratoga plots alone, the upper Death Valley springs (indicated as Death Valley I on page 7) group together, Cold is separate from Ash Meadows and the Furnace Creek springs (middle Death Valley- indicated as Death Valley II on page 7) plot together near the Ash Meadows springs, in each analysis. These results would suggest that substituting means for empty cells in the data set is not an unreasonable method.

Figure 25:

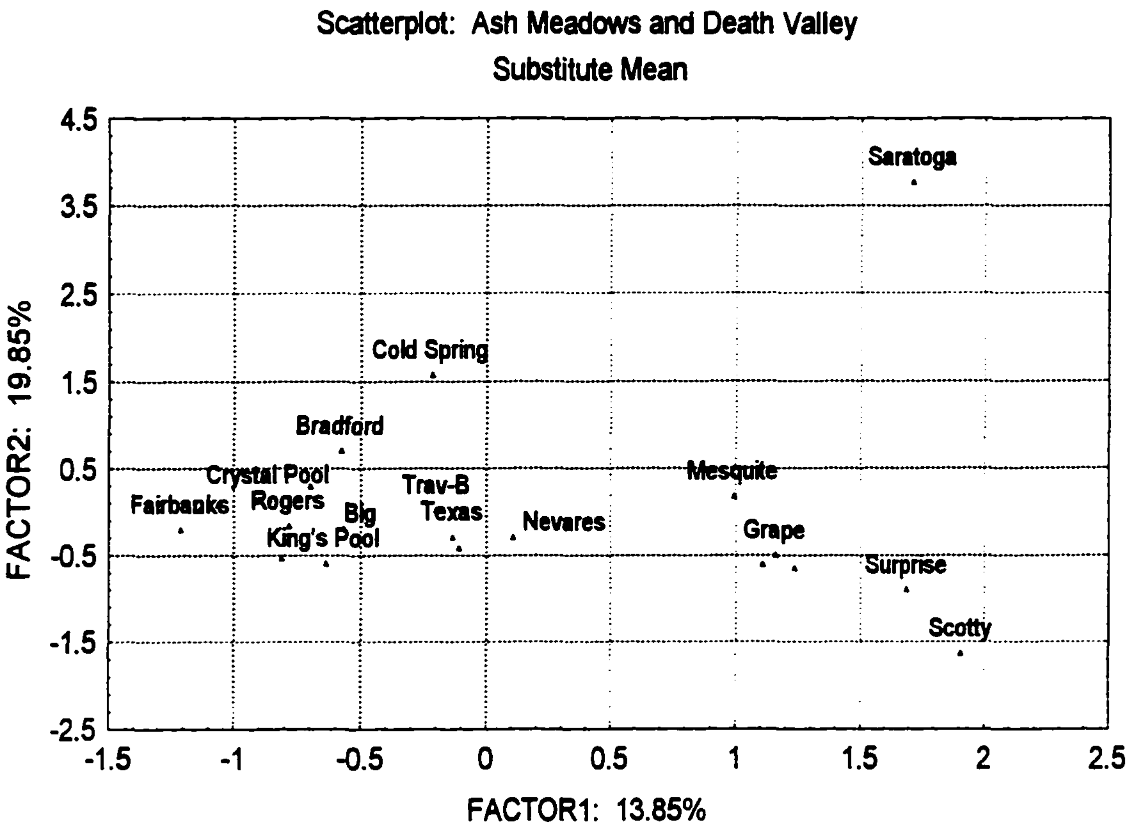


Figure 26:

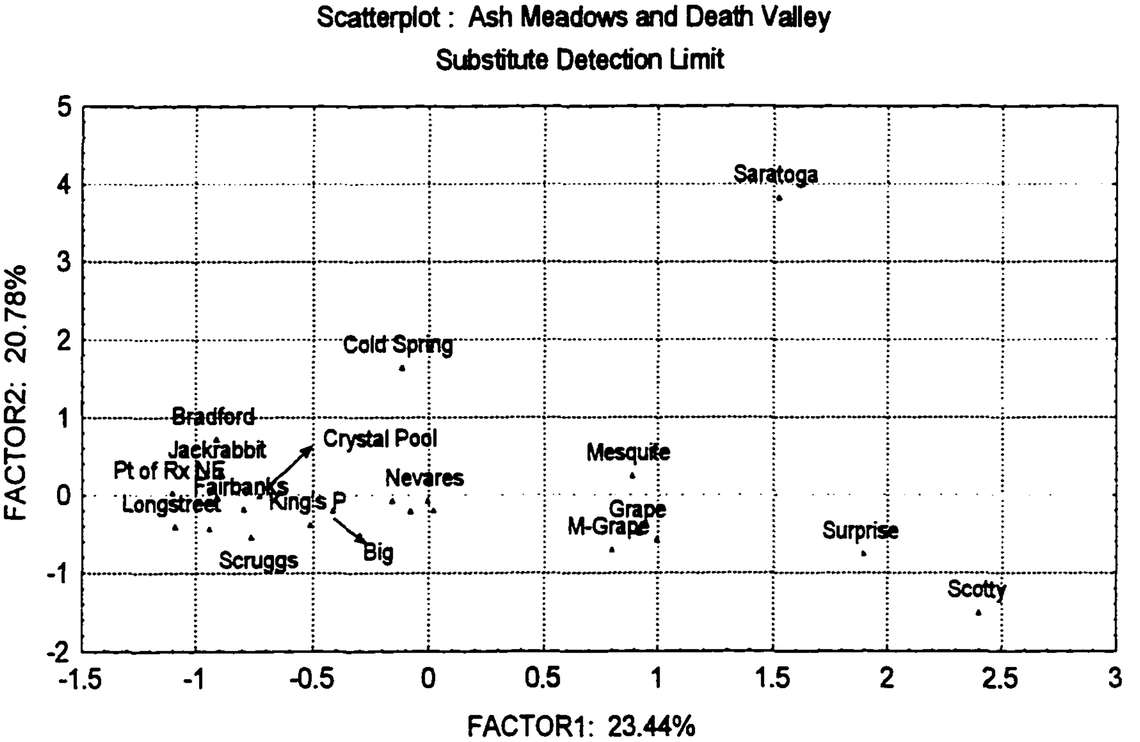
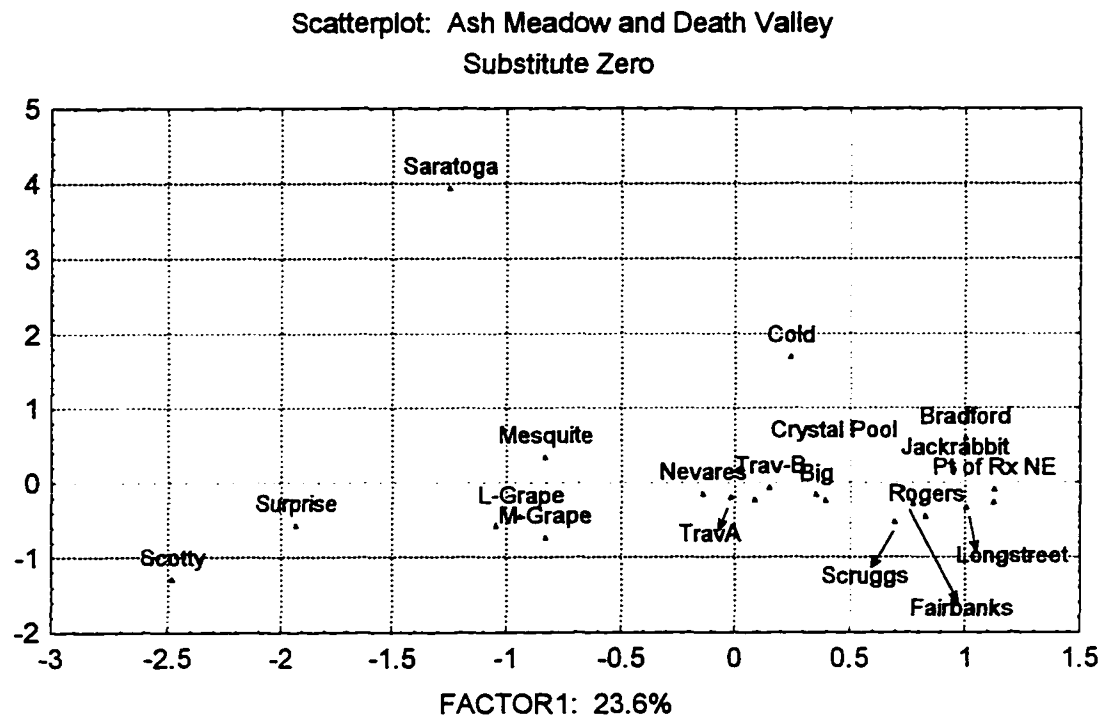


Figure 27:

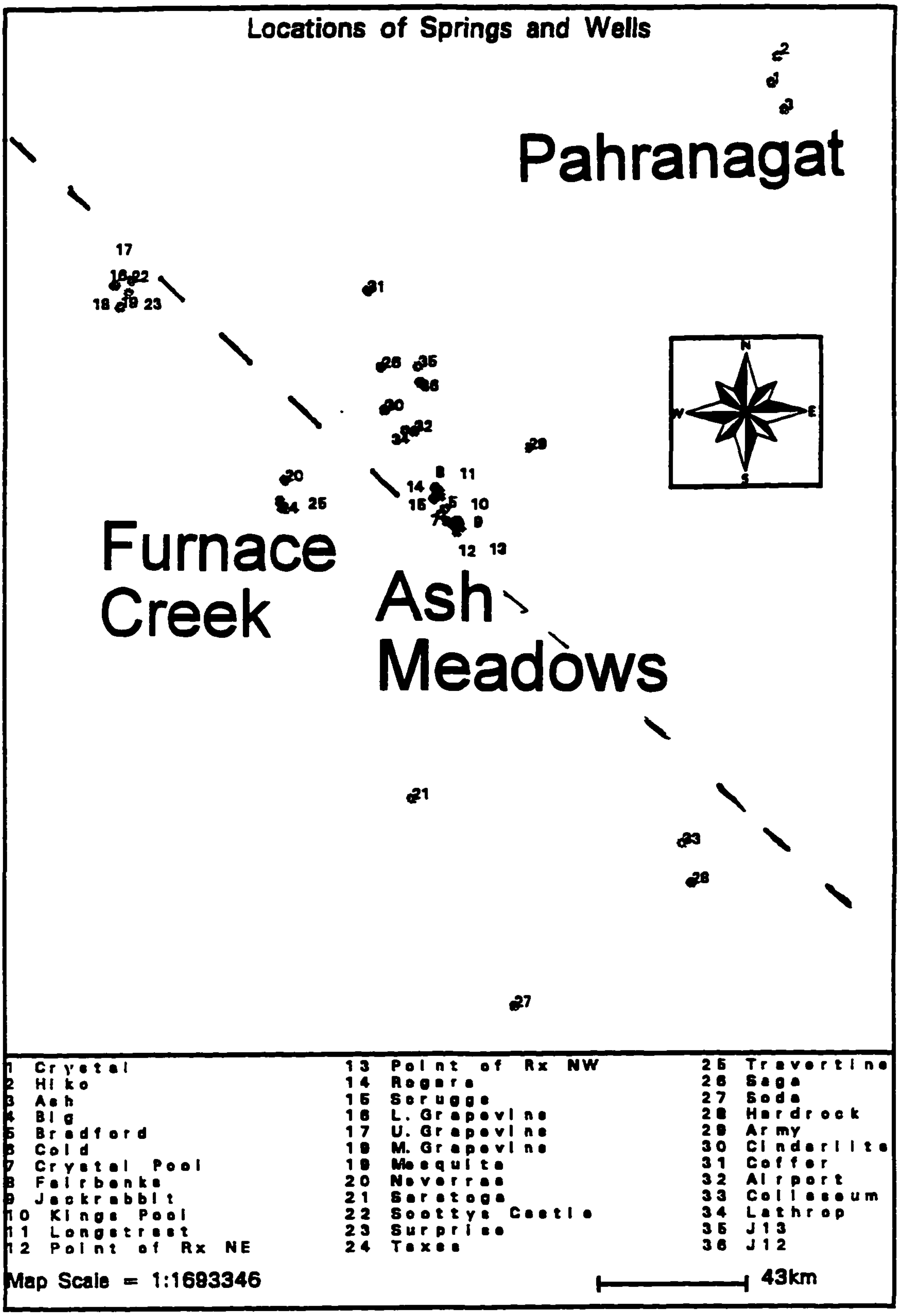


Geographic Information Systems

Map

As explained in Chapter 4, the first graphical product generated was a location map. The location map is included as Figure 28 on page 47. Springs and wells are labeled to correlate with a listing at the bottom of the map. For the Ash Meadows and the Grapevine springs locale the spring symbols used to identify each spring overprinted one another due to their proximity. While the proximity actually does make it difficult, coordinates for each data point are included in Chapter 2 to assist in identification. All spring and well locations are projected in the Nevada State Plane Coordinate System. The Fipszone 2702, the spheroid is GRS80, the datum is NAD83, and the units are in meters.

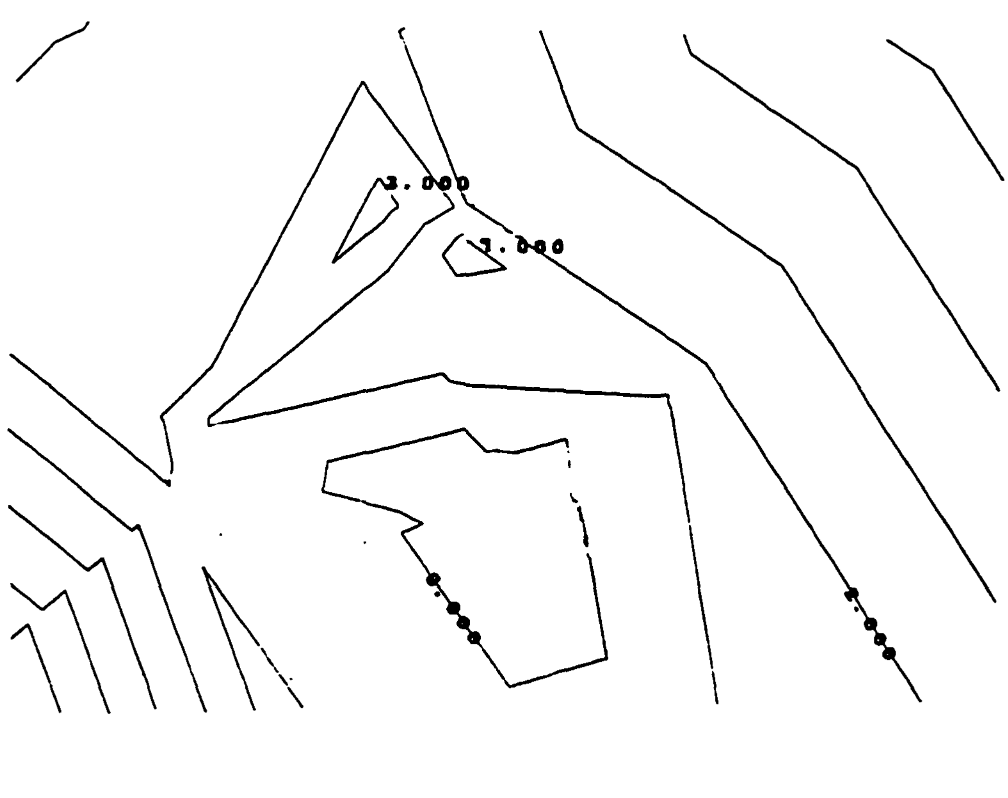
Figure 28:


Locations of Springs and Wells
Pahranagat
Furnace Creek
Ash Meadows
N
E
S
W
1 Crystal
2 Hiko
3 Ash
4 Big
5 Bradford
6 Cold
7 Crystal Pool
8 Fairbanks
9 Jackrabbit
10 Kings Pool
11 Longstreet
12 Point of Rx NE
13 Point of Rx NW
14 Rogers
15 Scruggs
16 L. Grapevine
17 U. Grapevine
18 M. Grapevine
19 Mesquite
20 Navarres
21 Saratoga
22 Scottys Castle
23 Surprise
24 Texas
25 Travertine
26 Saga
27 Soda
28 Hardrock
29 Army
30 Cinderlite
31 Coffer
32 Airport
33 Colliseum
34 Lathrop
35 J13
36 J12
Map Scale = 1:1693346
43km

TINs

According to Clarke's Analytical and Computer Cartography, TINS are best suited for modeling overland flow, stream hydrology, and erosion. From the TIN contour map in Figure 29 one might guess that this is not an appropriate method to create contours for chemical concentrations. The corners and straight lines, while mathematically exact and a true representation of raw data, are not necessarily repeated in nature. Please note that one major difference between TIN modeling and kriging is that TIN modeling does not incorporate the influence of neighbors into the analysis. Because of this the TIN results (although created using all point locations) is cropped to show only Ash Meadows, some of the Nevada Test Site, and the Furnace Creek region of Death Valley. As a result these maps are represented at a different scale in hard copy than those created by kriging.

Figure 29: Uranium Concentrations (TIN)



Chapter 6:

RESULTS AND DISCUSSION

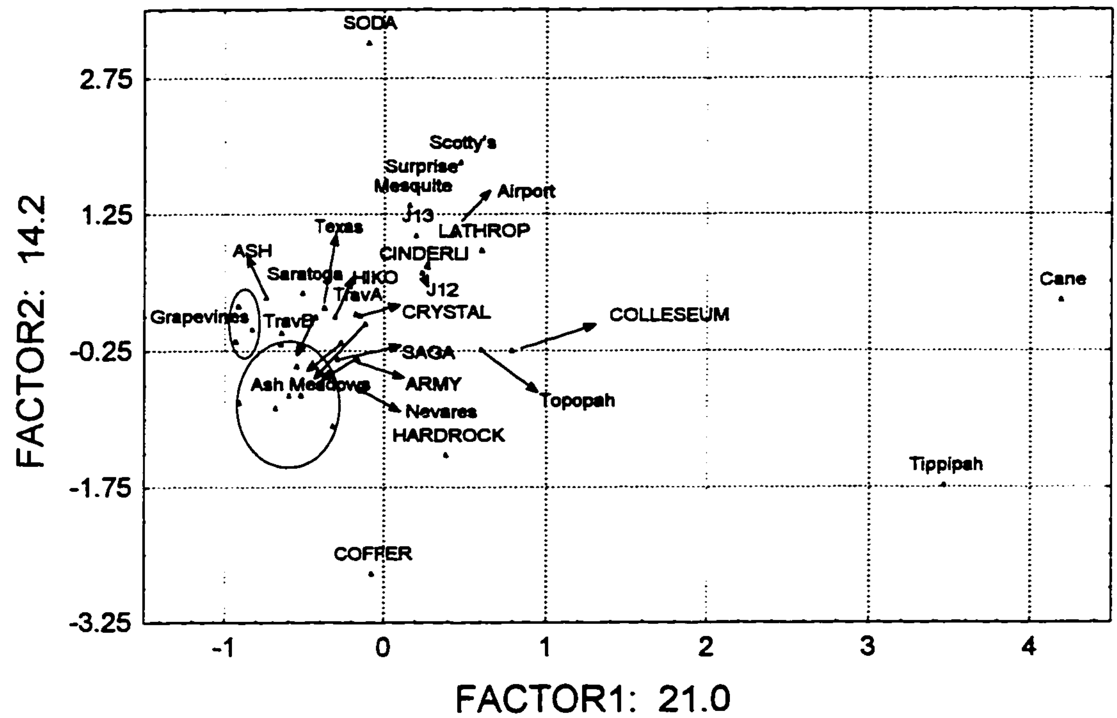
Results From PCA and Agglomerative Cluster Analysis

Only the two dimensional Principal Component Analysis results are illustrated here. Supporting parts of the analysis are presented in Appendix D. In this section, the mean values have been substituted in for empty cells. The analyses in this section are performed in different ways based on inclusion. The first considers all cases (water sampling locations) and is called All Springs and Wells. The second eliminates perched waters and waters flowing out of volcanics and is called Carbonate System Only. Lastly, only Ash Meadows and Death Valley are examined in Ash Meadows and Death Valley Only. The variables included in all of these analyses are trace elements (excluding REEs) and are listed in Appendix D.

Results All Springs and Wells

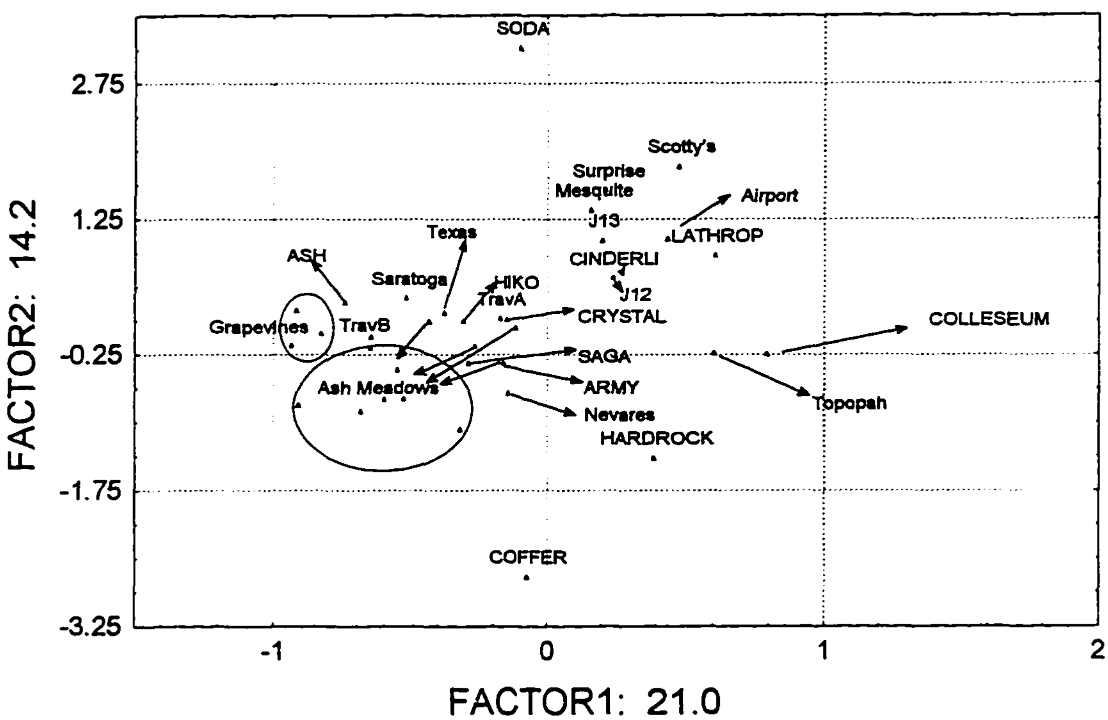
Before looking at the results of the first analysis, (Figure 30 and 31 on pages 50 and 52) one should know that since the rock through which the water flows is important to determine water chemistry (Claassen, 1983), the signature of rock type might be as well represented on the graph as the signature due to groundwater flow paths; however, one may still gain a broader understanding of southern Nevada aquifer systems by studying this graph if one considers waters discharging from similar rocks.

Figure 30: Scatterplot: All Springs and Wells



The first relationship to notice is that the three springs which issue from volcanic tuffs on the test site, Cane, Tippipah, and Topopah plot uniquely. These springs are outliers , plotting not only separate from the other groups of springs, but from each other as well (especially Cane and Tippipah springs). There are several possible reasons why these springs are different in addition to their spatial distance from one another. As mentioned previously, these springs issue from volcanic tuff. Perhaps the spring water flowing through this part of the aquifer system is not related to the groundwater of the other hydrologic subdivisions within southern Nevada such as the Amargosa Desert or Death Valley. Since this water is perched (Thordarson, 1965) so this explanation seems adequate to account for differences between the rest of the samples and differences between Tippipah, Topapah, and Cane Springs. If the water is perched then the water chemistry of these three springs is likely more dependent on the effect of water movement through local rock or possibly an ancient water table which is no longer continuous and is behaving as closed system with respect to horizontal flow. In other words the perched waters are not hydraulically connected to the rest of the regional groundwater flow system. Since this is true, trace element geochemical concentrations of perched waters might prove less useful in understanding regional horizontal flow relationships.

Figure 31: Scatterplot: All Springs and Wells (changed scale-Cane and Tippipah cropped out by cutting off the graph for Factor 1 values greater than 2 and less than -1.5)



There are similarities of the Ash Meadows group to the Pahranagat group when one examines Figure 31 in terms of first and second principal component values. First principal component values overlap and second principal component values are quite similar for Pahranagat and Ash Meadows waters. Since 60% of the water in Ash Meadows is hypothesized to come from the Pahranagat Valley, it is understandable that the waters would seem similar in principal component analysis (Winograd & Thordarson, 1975). There is a third group which plots along with Pahranagat Valley and Ash Meadows waters. This is the middle Death Valley group which contains Texas, Nevares, and two of the Travertine springs. All of these springs issue from carbonate rock or alluvium composed of principally carbonate rock debris and consequently are thought to be from the lower Paleozoic carbonate aquifer. This group is slightly different from the Ash Meadows and Pahranagat group in terms of average first and second principal component values, but still has principal component one and two values which overlap those of Ash Meadows and Pahranagat Valley. Saga and Army wells are located on the Nevada Test Site and are clustered by PCA of trace element concentrations closely around three of the Ash Meadows springs and the Pahranagat Valley springs.

The upper Death Valley springs, Scotty's Castle, Surprise, and Mesquite. Scotty's and Surprise flow from volcanic rock are clustered together by PCA of trace element concentrations. Mesquite spring flows from alluvial material (Johannesson et al., 1995). At least two of the springs in this cluster are quite similar in chemistry to a cluster of wells which includes Cinderlite, Airport, and Lathrop. The other upper Death Valley springs plot together with factor two values similar to those of the group just described, but the factor one values are quite different. This is likely because the waters of the Grapevine springs have a carbonate aquifer source in comparison to volcanic rock. Both Soda and Coffer well waters plot apart from all other groups. Topopah Spring plots with Coliseum well waters.

In this particular analysis molybdenum, tungsten, titanium, zirconium, and germanium seem to be most important to Factor 1. This means that most of the 21% of the variance in this particular data set is caused by different amounts of these elements. Nickel, arsenic, and vanadium are most important to Factor 2 (refer to Factor Loadings Matrix in Appendix D). Factor 3 is commposed primarily of selenium, cobalt, and tin. Molybdenum and tungsten are in Group VIA and germanium is from IVB (Greenwood & Earnshaw, 1984). These elements have ionic radii ranging from 59 to 147 pm (Greenwood & Earnshaw, 1984) which is fairly similar in size to the range of ionic radii involved in substitution within the crystal lattices of clay minerals (Hurlbut & Klein, 1977). In Factor 2, arsenic, nickel and vanadium are important. In the periodic table of elements arsenic is in group VB. Vanadium is in group V. Nickel is in VIII.

Figure 32 on page 53 illustrates the hierarchical classification of all springs and wells (these figures use the same data sets that the Principal Component Analyses did in the previous section). One can see that Cane and Tippipah are by far the most different waters in comparison to the rest. Saratoga seems to be like Coffer Well. These two groups are both very different from the remainder of the waters. Again these waters are classified as being different based on trace element concentrations.

With the exception of the four outliers (Cane, Tippipah, Saratoga, and Coffer), construction of dendograms reveals that the bulk of the waters divides itself into two groups: 1)Ash Meadows, and the carbonate springs of Death Valley 2)Army, Lathrop, Cinderlite, Airport, Colleseum, Hardrock wells, Pahranagat Valley, and waters from volcanic rocks. In addition:

a) The bulk of Ash Meadows springs are together.

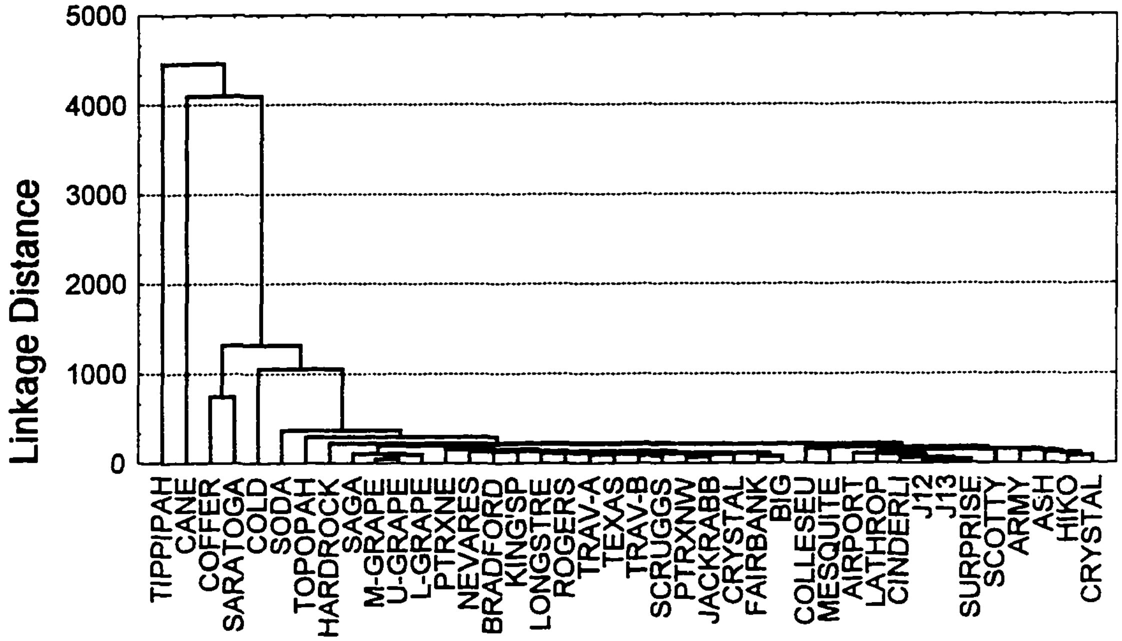
b) Saga well and the carbonate springs of upper Death Valley are grouped together.

c) Mesquite is different from the neighboring springs in volcanics and carbonates (the Grapevine Springs, Scotty's Castle, and Surprise Spring).

The Pahranagat waters are clustered with the remaining wells .With the exception of Cold Spring, Nevarres Spring, and Mesquite Spring, most of the clustering agrees with what a common geology and proximate locations would demand. In other words, waters near each other, which flow from similar surficial geology, are chemically similar with respect to trace element concentrations.

Figure 32: Hierarchical Cluster Analysis (Dendogram): All Springs and Well

Single Linkage-Euclidean distances



<u>Discussion: All Springs and Wells</u>

Vertical Movement of Groundwater on the Nevada Test Site:

Other studies have previously indicated that in this local area water leaks downward from the shallow aquifer into the regional groundwater system (Winograd & Thordarson, 1975, Peterman and Stuckless, 1993). The results in Figure 30 support the hypothesis that ground water is moving vertically . The carbonate waters of Ash Meadows, the waters from springs in volcanics, and the waters from wells in volcanics on the Nevada Test Site, each have different trace element chemical characters. Some of the NTS wells plot between the carbonate waters and the waters flowing from volcanic rock. The intermediate composition of waters like J12 and J13 may indicate that there is an upward component of flow from the carbonate aquifer which mixes with waters more typical of the tuff aquifers in some portions of the Nevada Test Site. Perhaps the chemistry differences are also related to changes in solubility which might occur in vertical movement of ground water from one rock type to another.

There are other reasons to believe that vertical flow is important in this area. Most likely the influence of glass dissolution and the replacement of divalent ions with monovalent ions changes the waters' chemistry as the waters move down through the subsurface (White, Claassen, & Benson, 1980), which might then change once again if these waters mixed with carbonate waters. This is supported by high loading of lithium, rubidium, and cesium (monovalent in ion form) in the factors of some principal component analyses (Appendix D) which is important in defining the differences between the Nevada Test Site cluster and the Ash Meadows & middle Death Valley clusters. In other words, since these elements are appropriated high loadings in the factors, most likely it is differences in these concentrations which account for a large part of the difference in both the "X & Y Direction" on the plots. Generally elements in the same family behave similarly. Since the wells are cased at different depths and the springs are obviously from a far different datum, these difference may be due to how much the waters of the tuff aquifer waters are mixing with the carbonate aquifer at certain locations and depths. Since the waters of Topopah spring appear to be much more similar to the well waters of the Nevada Test Site, but are assumed to be perched in this study, one might conclude that there is some reason other than the fact that the waters are perched which makes Tippipah and Cane springs plot so uniquely.

Perched Water on the Nevada Test Site:

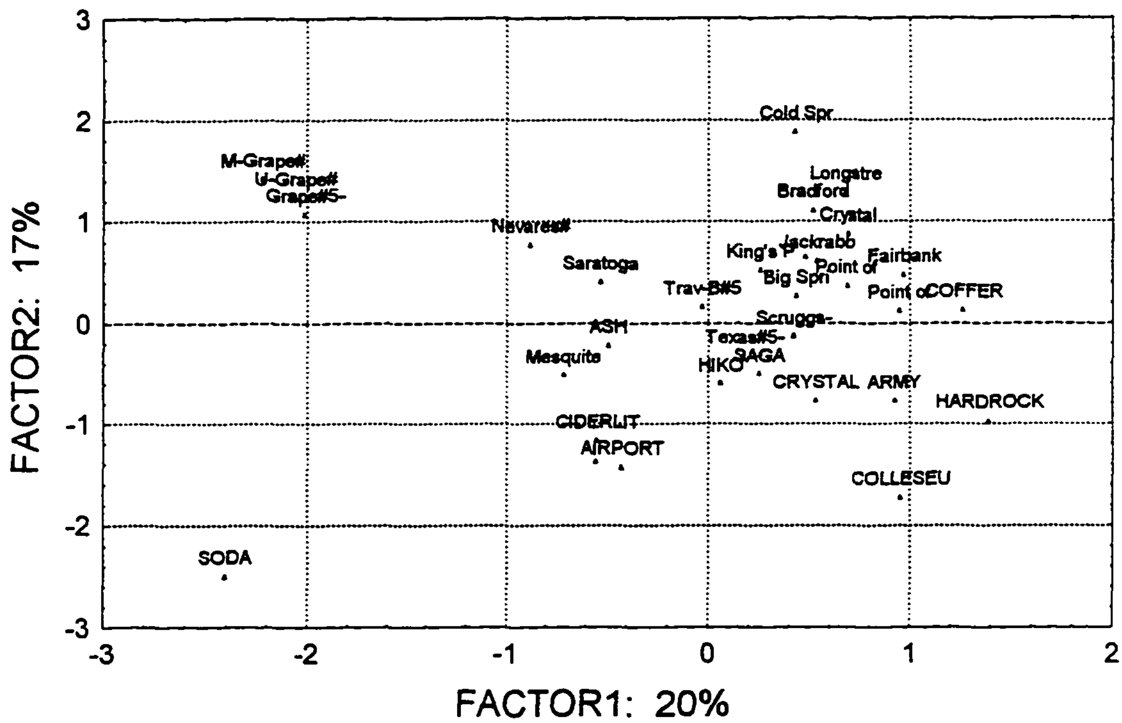
The most dramatic observation to be made of the PCA : All Springs and Wells, is the distance of outliers, Tippipah and Cane springs (of the Nevada Test Site, from the other clusters. According to Thordarson, 1965, all springs in Yucca Flat are perched waters retarded by tuffs. From Winograd and Thordarson (1975), it is known that ground water tables of Frenchman Flat, Yucca Flat, and Jackass Flat differ by only 9 feet in elevation. It is because of these two studies that the springs of the Nevada Test Site are assumed to perched waters (in addition to chemical characteristics of the springs). The very different chemistry of Tippipah and Cane springs supports this classification but Topopah appears to be slightly different. Topopah plots closer to some of the Nevada Test Site wells and so it is not so obviously different from the rest of the clusters. This might be explained simply by the likelihood that perched waters which are not hydrologically related might have different chemistries dependent on local conditions. The springs are located in flats so perhaps there are constituents of the playa deposits (dried lake beds) which determine the positions of these outliers.

According to principal component analysis of trace element data (Figures 30 and 31), the waters from wells of the NTS loosely gather themselves into a staggered, widespread cluster, while Cane and Tippipah springs (also on the Nevada Test Site plot some distance from them. Perhaps the reason for the existing range in Factor 1 and Factor 2 for these waters is influenced by chemical changes that occur or do not occur over certain flow paths. In other words chemical heterogeneities between different tuffs may be strong enough to influence ground water chemistry and possibley cause noticeable dispersion of the clusters of waters. For the perched waters, which are less important to regional flow of groundwater, local conditions are most likely more important in determining the trace element chemistry of the waters.

Results: Carbonate System Only

This analysis includes only those springs which are thought to be the result of springs flowing from the lower carbonate aquifer through alluvial deposits or directly to the surface and all wells. Supplementary information is included in Appendix D for the following Figure 43.

Figure 33: Scatterplot: Carbonate Waters Only



Again the Ash Meadows group and the mid death valley group plot together. Pahranagat appears just as different from these two groups as Mesquite does (Mesquite plotted nearer Scotty's and Surprise in first analysis: All Springs and Wells). Groups of wells plot together, one with the Ash Meadows and middle Death Valley springs while others are more isolated.

In this analysis Factor 1 accounts for approximately 20% of the variance in this study is most substantially composed of tungsten rubidium, lithium, arsenic, antimony, and germanium. Factor 2 explains about 17% of the variance and is most heavily influenced by the variables rhenium, and cobalt. Lithium, chromium, uranium, and antimony are important to Factor 3 (15% of the variance) Tungsten chromium, uranium, and rhenium are thought to form conservative oxyanion species in this system. Perhaps it is best to focus on the these elements that occur in this conservative oxyanion species when looking at regional flow patterns; if the entire groundwater system of southern Nevada were well mixed, and oxidized the concentrations of these oxyanions would be relatively uniform and not so important to the first three principal components which explain ≅50% of the variance within this analysis. Since these factors seem to be important perhaps this supports mixing.

This analysis is useful because it may illuminate which waters would yield the most reliable result when put into a model. This is not to say that certain data points should be ignored and cut from the study, but there may be a need to eliminate some data from a spatial analysis in order to better understand regional flow. This anomalous waters may be due to problems with sampling and analysis, or simply a small scale heterogeneity not representative of the locale. An example of one of this might be the exclusion of Bradford data from a set of data points chosen to represent Ash Meadows.

Discussion: Carbonate System Only

Groundwater Flow Between Sub-basins

Many studies have indicated that water from the Pahranagat Valley is a large component of the flow at Ash Meadows by using isotope and other kinds of data(Winograd & Thordarson, 1975). The small distance between the centers of mass of clusters from my study would intuitively support this, but now some attempts at modeling mixing of conservative oxyanions should be made. Modification of the mixing model PHREEQE is suggested. This would require making changes in both the program and the database to make use of trace element data (particularly those elements who are thought to behave conservatively in southern Nevadan and southeastern California groundwaters).

From Peterman and Stuckless (1993)one can see the trend of increasing δ87 Sr from the Nevada Test Site to Ash Meadows to the middle Death Valley springs. This can possibly be correlated to the trend of the centers of mass of the corresponding clusters with respect to Factor 2 of several principal component analyses. Important variables for this factor from different analyses are below, many of which behave conservatively:

Analysis of entire data set: lithium, vanadium, uranium

Analysis of Carbonate System Only (+wells): cobalt, rhenium

Analysis of Ash Meadows and Death Valley only: chromium, uranium, rhenium, and strontium, lithium, molybdenum

Czarnecki & Waddell (1984), modeled groundwater in southern Nevada through the use of finite element simulation. The results of this study indicate that there is a component of middle Death Valley flow which is from the Nevada Test Site and a component of the more northern reaches of Death Valley which is from the Oasis Valley. Both of these observations are supported by PCA of trace elements by the fact that the center of mass of the Nevada Test Site cluster lies between the Ash Meadows and middle Death Valley clusters with respect to Factor 1(not just simple trend in Factor 1 from Nevada Test Site to Ash Meadows to middle Death Valley).

This support is not specifically for an additional source from the Oasis Valley, but is indicative of some additional source (other than Ash Meadows and the Nevada Test Site). This support is based on the idea that without another source one would think that middle Death Valley waters would plot between Ash Meadows and the Nevada Test Site. It is certainly possible that this observation could be due to the effects of source rock on groundwater geochemistry signatures, but the springs in both Ash Meadows and the Furnace Creek region (middle Death Valley) are all assumed to flow from the same carbonate aquifer and issue from carbonate rocks or carbonate rich sediments.

Principal component analysis also reveals a cluster of northern Death Valley waters (with considerably large differences in Factor 1-in most analyses) that is further removed from the other clusters. If the Oasis Valley does contribute to Death Valley perhaps the percentage of Oasis Valley water is greater in the upper reaches of Death Valley which could statistically detach this group from other waters. Possibly the upper Death Valley springs are not only chemically unique because of source rock, but also due to mixing of waters. If one notes, only Scotty's and Surprise springs have volcanic source rock. Perhaps source rock does still play a key role and mixing is occurring between the waters of the volcanic rock springs and the Grapevine and Mesquite springs. The variables of higest loading in Factor 1 may provide some clues as to which effects are more dominant. Again there seem to be some chemical elements which consistently are combined into Factor 1. These are explained below:

Analysis of entire data set: Tungsten, molybdenum, thallium, germanium, zirconium

Analysis of Carbonate System Only (+wells): Lithium, arsenic, tungsten, rubidium, antimony, germanium

Analysis of Ash Meadows and Death Valley only: Lithium, selenium, vanadium, tungsten, uranium, rubidium, barium

Using this knowledge of what variables are important in defining the waters of southern Nevada (based on trace element geochemistry) should prove useful in future efforts to model mixing between hydrologic sub-basins.

This analysis is very similar to the one performed using the entire data set and is located in Appendix D. In the first run it can be seen that basically there is an Ash Meadows/Death Valley group and a second Well Data and Pahranagat group (ignoring outliers- Cold, Saratoga, and Coffer). After deleting Cold, Saratoga, and Coffer, the carbonate waters generally divide themselves into a Mid Death Valley group, an Ash Meadows group, an Upper Death Valley group, and several groups made up of wells, and Pahranagat waters. Mesquite clusters uncharacteristically for an Upper Death Valley water and Bradford (AM), and Ash (PAH) also seem to stray from the expected clustering trends of their geographic groups.

Sub-basin Classification:

In this study sub-basins are classified different ways, a technique used in Mifflin, 1968 which defines studies as being "regional," "local," and "small local". In this study analyses were conducted on the regional scale with waters from all source rocks considered, on the regional scale with only waters obtained from carbonate sources and wells, and on the local scale. Waters that are thought to be perched (Tippipah, Topopah, and Cane Springs) are omitted from classification. Principal component analysis classifies waters on the regional scale as follows: Amargosa Desert- all Ash Meadows springs and all of the middle Death Valley springs from the Furnace Creek region, and some Nevada Test Site wells including Saga, Army, and usually Coffer (depending on list of elements in analysis); lower Death Valley- Soda Well and Saratoga Spring; Volcanics and Nevada Test Site-Cinderlite, Mesquite, Scotty's, Surprise, Colleseum, Lathrop, and Airport; Pahranagat-Hiko, Crystal, and Ash springs; Upper Death Valley Nonvolcanics-Upper, Middle, and Lower Grapevine springs. Hardrock plots near Topopah when a study of this scale is considered.

On the same physical scale but considering waters only thought to be carbonate and wells, the following classifications were made: Amargosa Desert- all Ash Meadows springs and all of the middle Death Valley springs from the

Furnace Creek region, and some Nevada Test Site wells including Saga, Army, Cinderlite, Lathrop, and Airport; lower Death Valley- Soda Well and Saratoga Spring; IS-Colleseum, Coffer, and Hardrock; Pahranagat-Hiko, Crystal, and Ash springs; Upper Death Valley Nonvolcanics-Upper, Middle, and Lower Grapevine springs.

Due to the time restraints, the author did not study the structural geology in detail; however, efforts were made to understand the general regional and local geology of study areas, and in doing so a general correlation was noted and compares well to the results of this study. If one refers to Figure 4: Structure in the South-Central Great Basin (Stevens, Stone, & Belasky) on page 10 and is familiar with the location of the springs and wells in the study one might observe that most waters which clustered in this study were located within boundaries. Most of these areas are bounded by shear zones and mountain ranges, although one should note that in this study data points are not distributed in homogeneous grid, but rather as nature dictated (for springs) and man chose for purposes other than this study (wells).

The Pahranagat waters are north of the Las Vegas Valley Shear Zone and west of the the Sheep Range. The Nevada Test Site waters are northeast of the Furnace Creek Fault Zone and north of the Las Vegas Valley Fault Zone. It might be interesting to note that if the entire fault lengths are not represented in this map, the faults might dissect the Nevada Test Site. If this is the case, this possibility might also explain some of the differences in waters in this area. The Ash Meadows springs are all west of the Spring Mountains and near the Stewart Valley Fault.

The middle Death Valley springs are just west of the Furnace Creek Fault Zone, east of the Panamint Range, and southwest of the Funeral Mountains.

The upper Death Valley springs are also located on the Furnace Creek Fault Zone but are just east of the upper reaches of the Panamint Range.

As mentioned in Chapter One, there has already been work done to define hydrologic sub-basins in southern Nevada. The Perfect thesis from the Colorado School of Mines (1991) defines sub-basins using cluster analysis of major elements and ions. The groupings were defined in SAS and other tools and then defined by the spatially correlated surficial geology. These identified clusters were then used to delineate spatial boundaries. Each bounded area was labeled with most common cluster definitions. Included were comments pertaining to relationships between nearby clusters which would include a signature not due solely to the source rock, but also flow parameters such as mixing and chemical evolution of water over time.

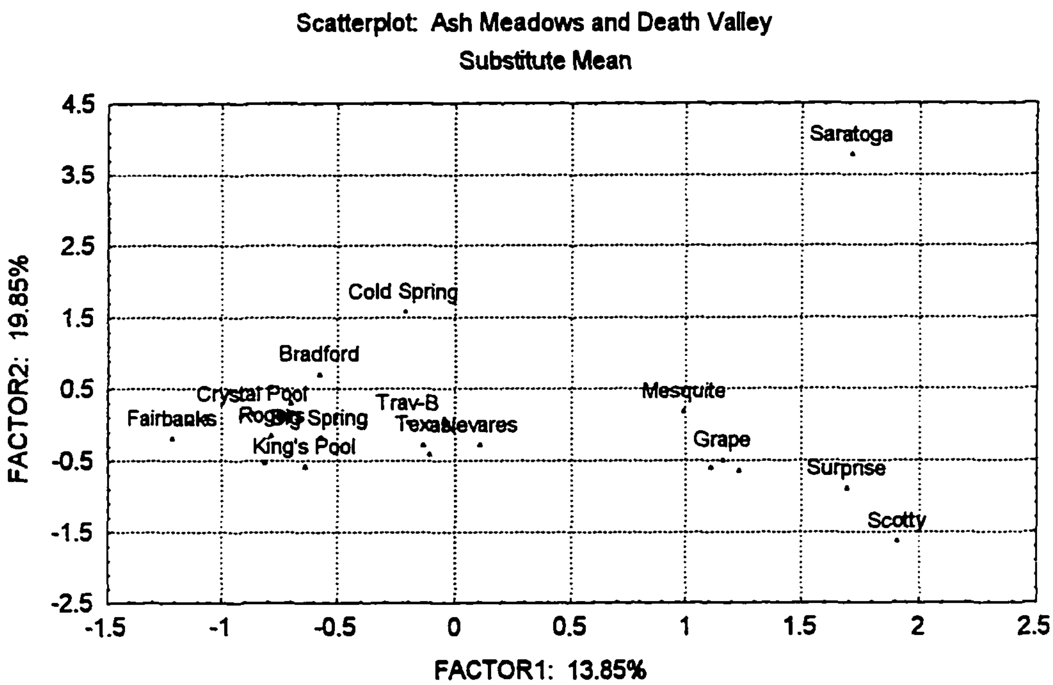
Comparisons may be made for sub-basins common to both Perfect's major ion and element data and the Harry Reid Center trace element data, but only on check basins. If spatial boundaries were drawn for subbasins based on this study most boundaries would rely on inference for their placement. Where locations are common to both studies this study suports that of Perfect. In general source rock seems to be dominant when statistically clustering data by trace element chemistry, as Perfect indicated by major ion chemistry. When considering waters of similar source rock however, one might possibly be able to interpret certain relationships between subbasins. Conservative chemical species have the potential to be a powerful tool in these kinds of studies.

Principal component analysis generally clusters waters into the same groups whether one uses a balanced variable set (each column of the periodic table is fairly equally represented) or a weighted variable set (more elements from certain columns on periodic table included). It is true that outliers are further distanced from the "clusters" by a weighted column analysis. Both analyses may be useful and neither should be ignored as a tool in statistical analysis of groundwater samples.

Results: Ash Meadows and Death Valley Only:

Since there are only two springs of these two areas flowing from volcanics it seems logical that these two, Surprise and Scotty's, cluster together and apart from the rest. Saratoga, with anomalous values for almost every variable

Figure 34:



concentration analyzed, obviously plots seperate from every other spring. In general however two groups of springs plot with each other. Once again these two groups are the mid and upper Death Valley grouping, and the Ash Meadows grouping. In addition to Scotty's, Surprise, and Saratoga, Cold Spring waters (from Ash Meadows) are characterized by anomalous concentrations so does not group with the rest of Ash Meadows. Nevares plots with most of the Ash Meadows springs and like Cold has a different temperature than nearby springs(Harry Reid Center). It may be interesting to note that with respect to Factor 2 both Cold and Nevarres Spring are about 1 unit more (in terms of values of principal components) than the "center of mass" of the group in which one might guess that they would cluster (Ash Meadows and middle Death Valley respectfully). The supporting information is in Appendix D and is the same for the Figure 25.

Tungsten, selenium, vanadium, uranium, rubidium, and barium are most important to Factor 1. Lithium, chromium, uranium, molbdenum, rhenium, and strontium heavily influence Factor 2. Some of these same variables have proven to be important in preceding analyses and are probably important in defining relationships between Ash Meadows and Mid and Upper Death Valley carbonate springs.

On the local scale examined, Ash Meadows and Death Valley, three main groups may be defined: Ash Meadows-13 springs previously identified as Ash Meadows; middle Death Valley-Texas, Travertine A&B, and Nevares springs; and upper Death Valley-Scotty's, Surprise, and the three Grapevine springs.

All of the waters in this analysis have been included in previous discussions, and there are no grand scale differences between these results and those of an agglomerative cluster analysis of a carbonate waters only section. Once again Cold and Saratoga Springs are outliers. Scotty's and Surprise group together. The remaining upper Death Valley waters cluster out neatly together, and until deletion of a case the remainder of Ash Meadows and Death Valley waters remain undivided. Upon deletion of Cold Spring and the volcanic waters, Mesquite separates from the Grapevines, and the MDV waters separate from the AM waters. Both Big and two thirds of the spring waters in the Point of Rocks region pull out from the Ash Meadows cluster.

Discussion: Ash Meadows and Death Valley

This analysis is useful because it may illuminate which waters would yield the most reliable result when put into a model. This is not to say that certain data points should be ignored and cut from the study, but there may be a need to eliminate some data from a spatial analysis in order to better understand regional flow. This anomalous waters may be due to problems with sampling and analysis, or simply a small scale heterogeneity not representative of the locale. An example of one of this might be the exclusion of Bradford data from a set of data points chosen to represent Ash Meadows.

Results from Spatial Analysis with Geographic Information Systems and Discussion

ARC/INFO makes analysis of spatial variance relatively simple in the kriging command. Kriging in this software creates a coverage of variance which can then also be contoured. This provides a map of variance. Areas of higher variance are areas where more data points are needed to improve the quality of the chemical concentration contour map. It is probably obvious that many more data points would be useful in this analysis just from looking at the location map. This topic will be further addressed in the Conclusions chapter.

With the definitions used in this study, contour maps had many interesting relationships. Contour maps seem to fall into four groups which display similar patterns. The patterns are more obvious in some contour maps than others but these differences could be minimized if contour intervals were adjusted. Almost every contour map fits into one of three classes. Groundwater movement can only be in one direction (downgradient) at any discrete point. If there is a way of analyzing flow with this data only one group of the three should be chosen to do it. Other groups should then represent the effects of other phenomenon. All conclusions are based on the major assumption that the data is sufficient to produce true concentrations throughout the study area when kriged. From variance maps one can see that this assumption is more valid in some areas than in others.The groupings and the trends are classified and describe below:

Group 1, thallium and nickel, exhibit similar features when contoured. These are included in Figures 35-36 on pages 68-69. Each has a zone higher concentrations. The zone trends roughly east northeast-west southwest through the central portion of the study area. The zone generally trends across Ash Meadows and the Furnace Creek or middle Death Valley areas. Spring or well locations are indicated on the map by an "O". Refer to the location map on page 48. The concentration maps (thallium and nickel) illustrate these observations.

Group 2, cesium and antimony, have a different contour pattern when kriged. Concentration contour maps for cesium and antimony are included as Figures 37 and 38 on pages 70 and 71. The two maps show areas of higher concentrations south of the Pahranagat Valley springs, south of the upper Death Valley springs, and in the area around Saratoga Spring. Concentrations are generally lower and more uniform throughout the study area with respect to Cesium and Antimony. Since there are several isolated highs that do not seem to correlate with geology, water table elevation, or topography perhaps they are more related to anthropogenic effects. Again, locations are indicated on the map by an "O".

Figure 35: Thallium Concentrations (ppb)

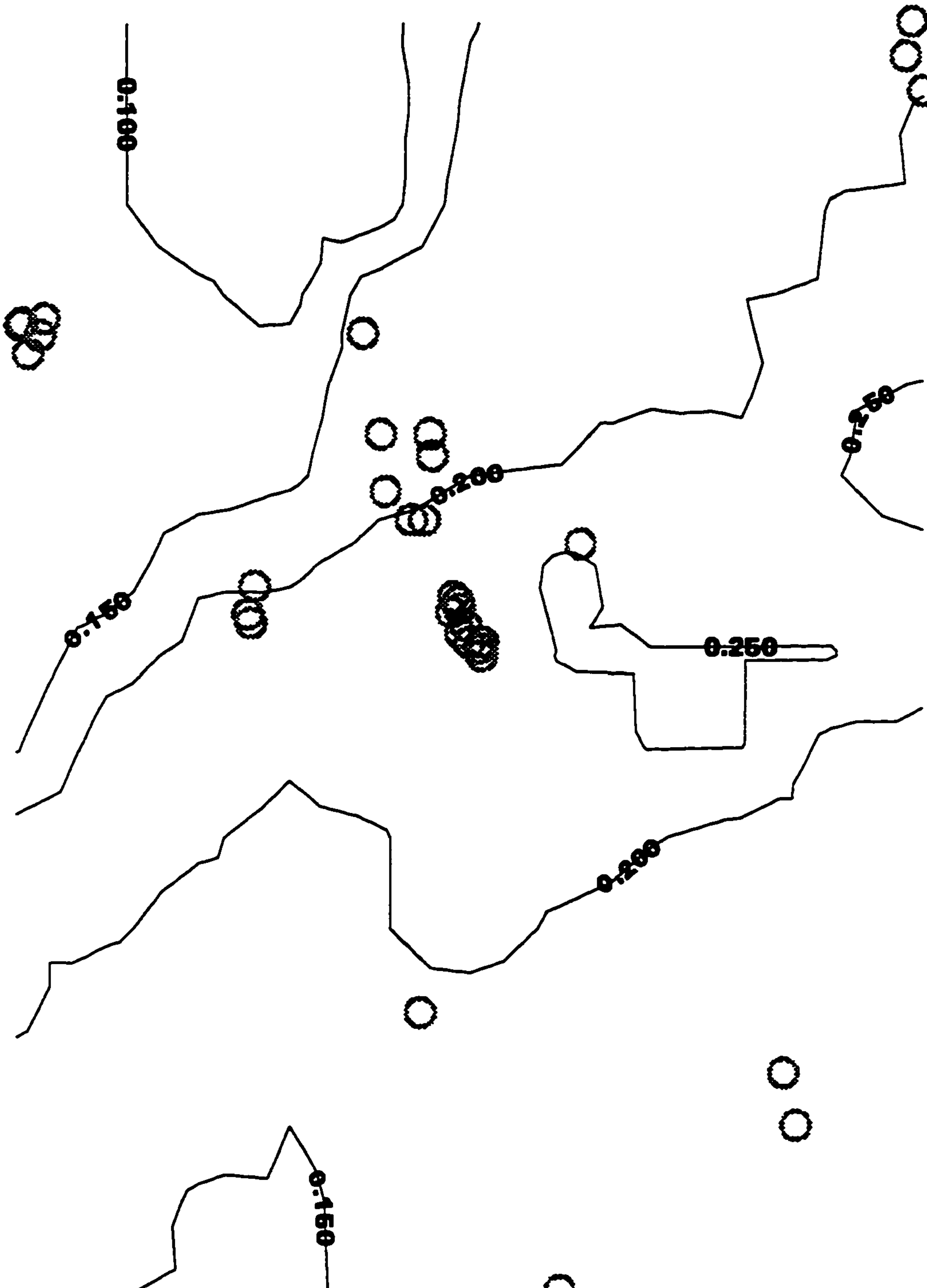


Figure 36: Nickel Concentrations (ppb)

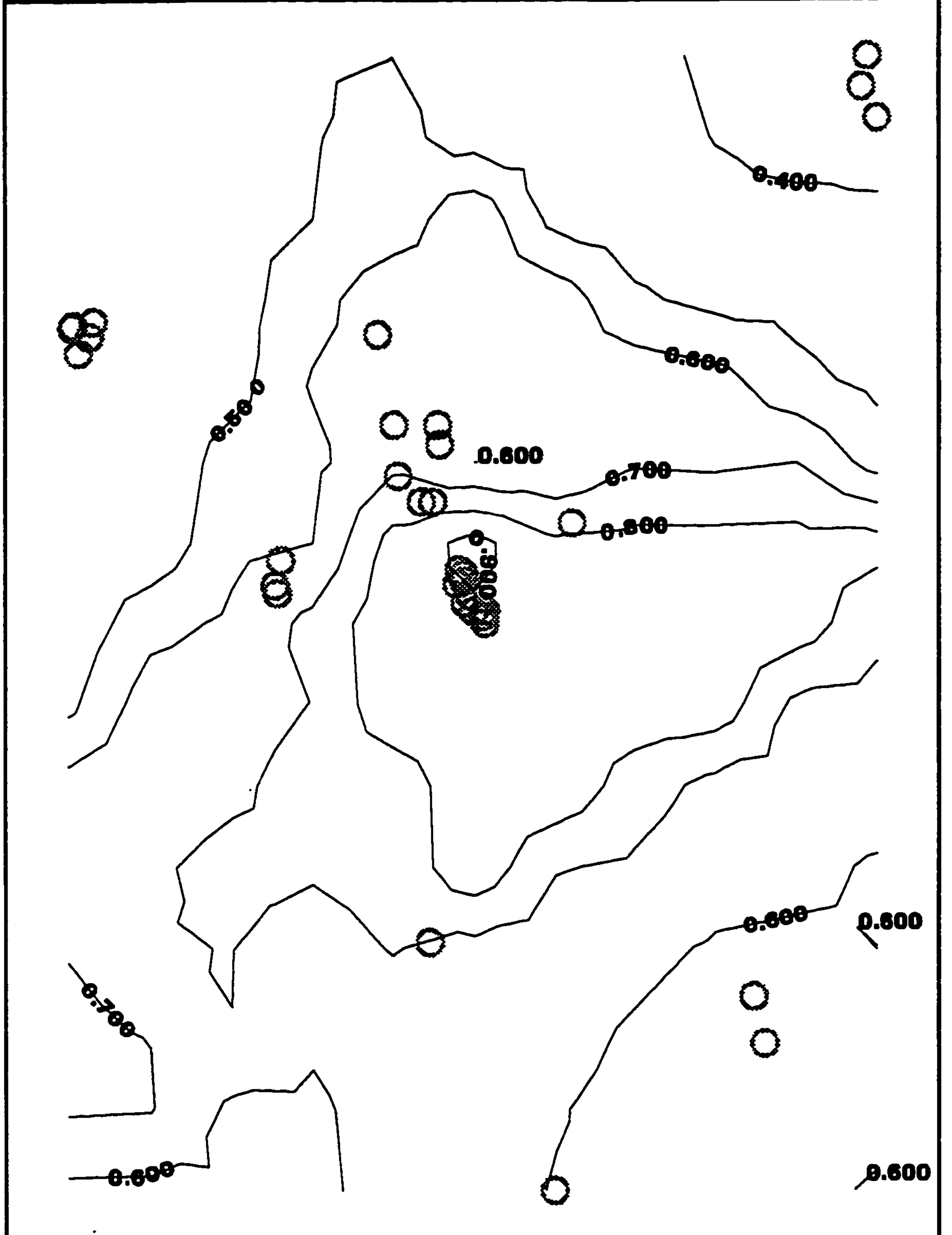


Figure 37: Cesium Concentrations (ppb)

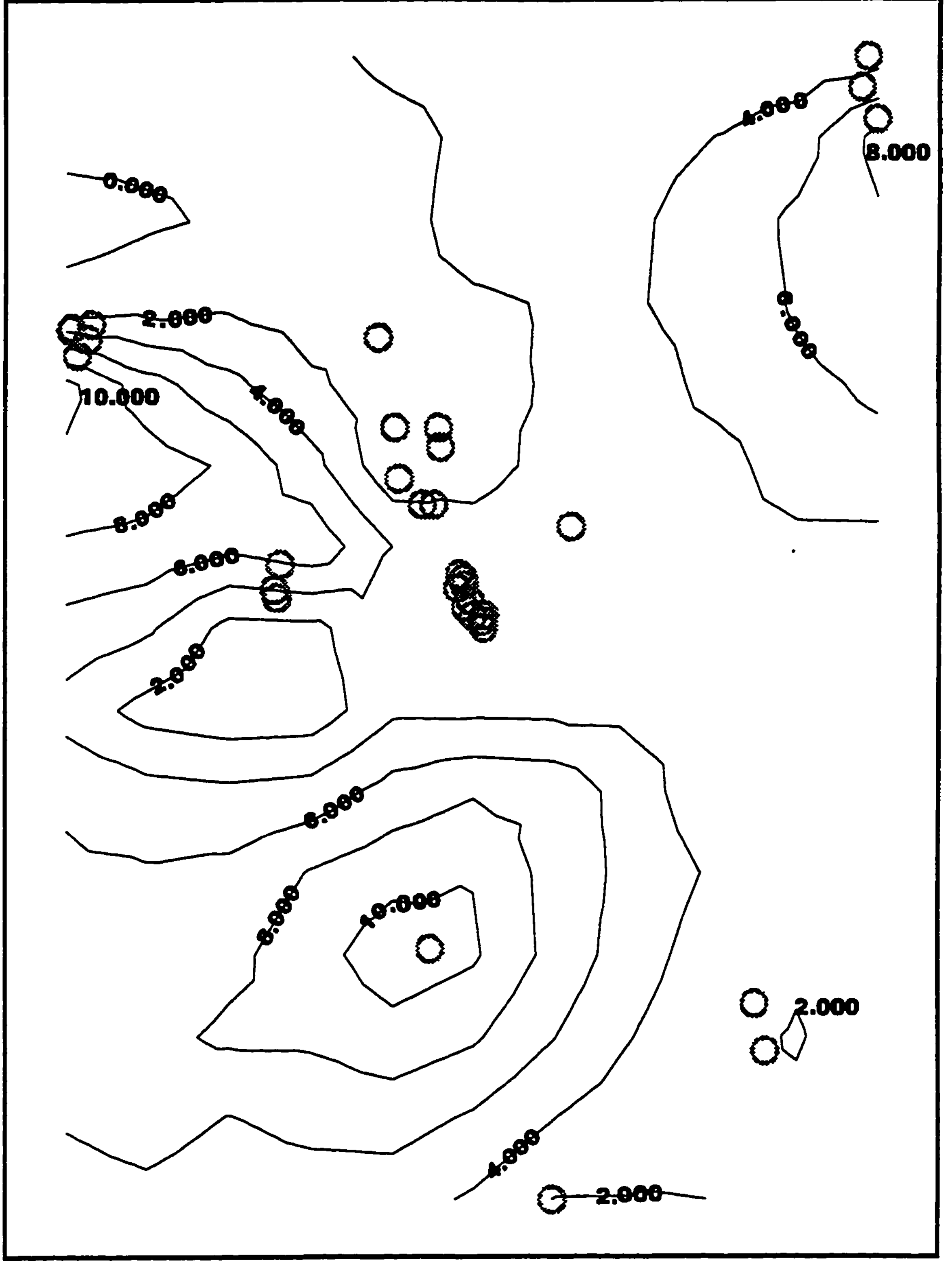
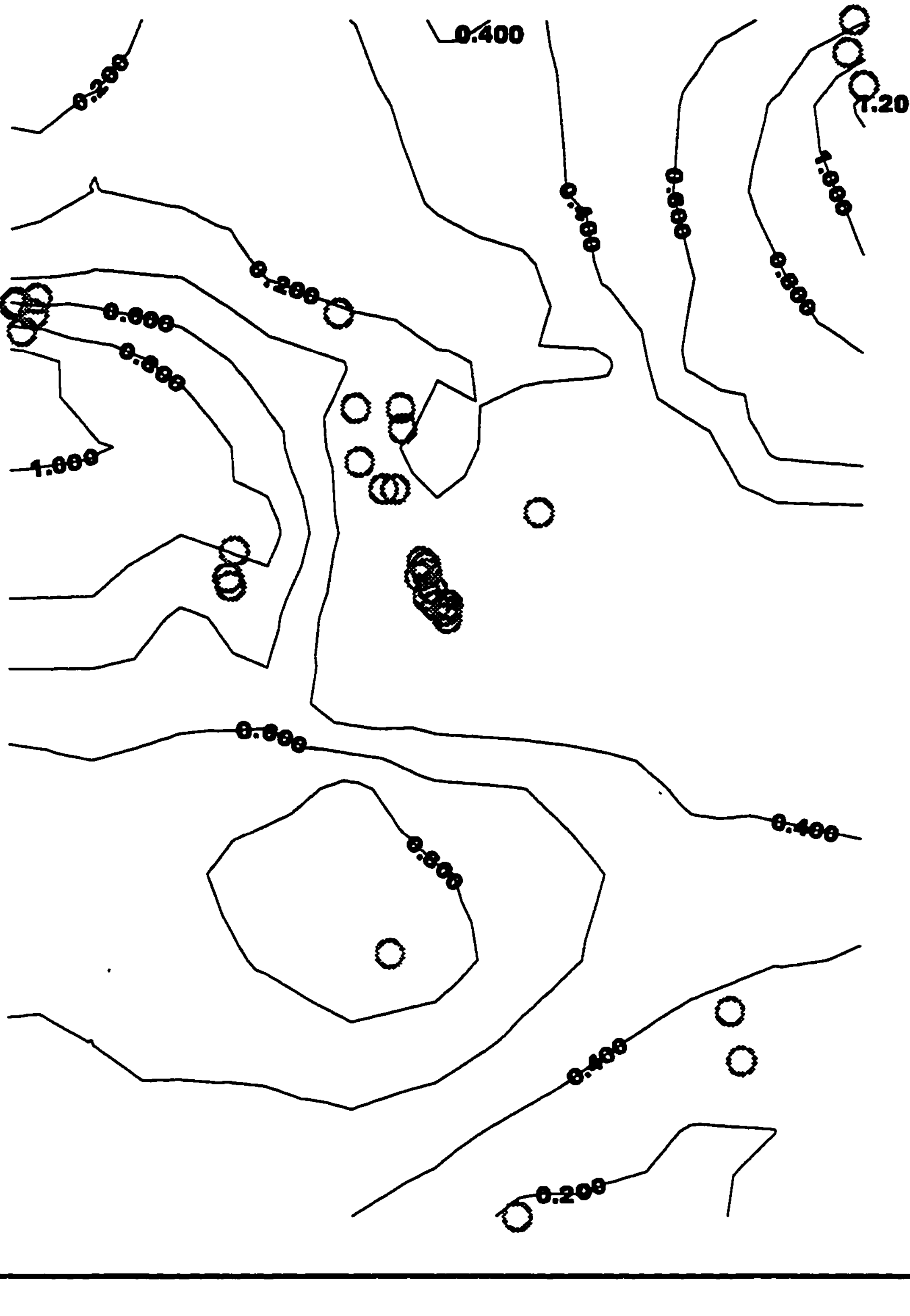


Figure 38: Antimony Concentrations (ppb)



Group 3, Uranium, Molybdenum, and Tungsten, also show corresponding concentration contour patterns. The trends of all three of thes elements are 1)highest concentrations in the vicinity of the Nevada Test Site and 2)a generally increasing trend of concentrations from the southeast portion of the study area toward the northwest. The steepest concentration gradients are in the vicinity of Saga, Cinderlite, Airport, Lathrop, J12, and J13 wells which are in or near the southern portions of the Nevada Test Site. Figures 40-42 on pages 74-76 are concentration contour maps for molybdenum, tungsten, and uranium. The chemical elements contoured in this group are thought to behave conservatively under certain conditions. Perhaps these maps show the conservative behavior in the "flat parts" and physical boundaries along the steep gradients. If these physical boundaries were fast pathways the contour maps might further support the ideas that mixing is occurring in different areas, for example between Ash Meadows and Death Valley.

Group 4, Germanium and Rubidium, share an interesting contour pattern. In general, there are higher concentrations in the southwestern portion of the study area. The region of higher concentrations stretches from the vicinity of the upper Death Valley to the southwestern corner of the map, west of the Furnace Creek-Death Valley Fault Zone. This area of higher concentrations is surrounded by an area of steeper concentration gradient. Figure 43 on page 77 is the concentration contour maps for rubidium. Rubidium and Germanium consistently have high loadings in Factor 1

Group 5 is made up of contour maps which do not fit into any pattern in particular. These include arsenic, selenium, titanium, cobalt, gallium, vanadium, and rhenium. These contour maps follow on pages 79-85 as Figures 44-50. Cobalt concentrations are fairly constant throughout the area. Gallium has concentration highs in the vicinity of the NTS, south of the Furnace Creek area, and north of Hardrock and Colleseum wells. The contour map of Vanadium concentrations has curvilinear zones of steep chemical concentration gradients approximately ninety degrees in orientation from the trend of the Furnace Creek Fault Zone as well as the steepest hydraulic flow gradients in the study area. A more detailed map of the potentiometric surface of the lower carbonate aquifer is included below as Figure 39 for comparison. Selenium concentrations are highest in the vicinity of the Nevada Test Site and generally decrease from the

Figure 39: Potentiometric Map of Lower Carbonate Aquifer (reformat from the Las Vegas Valley Water District of Thomas and Crabtree, 1986)

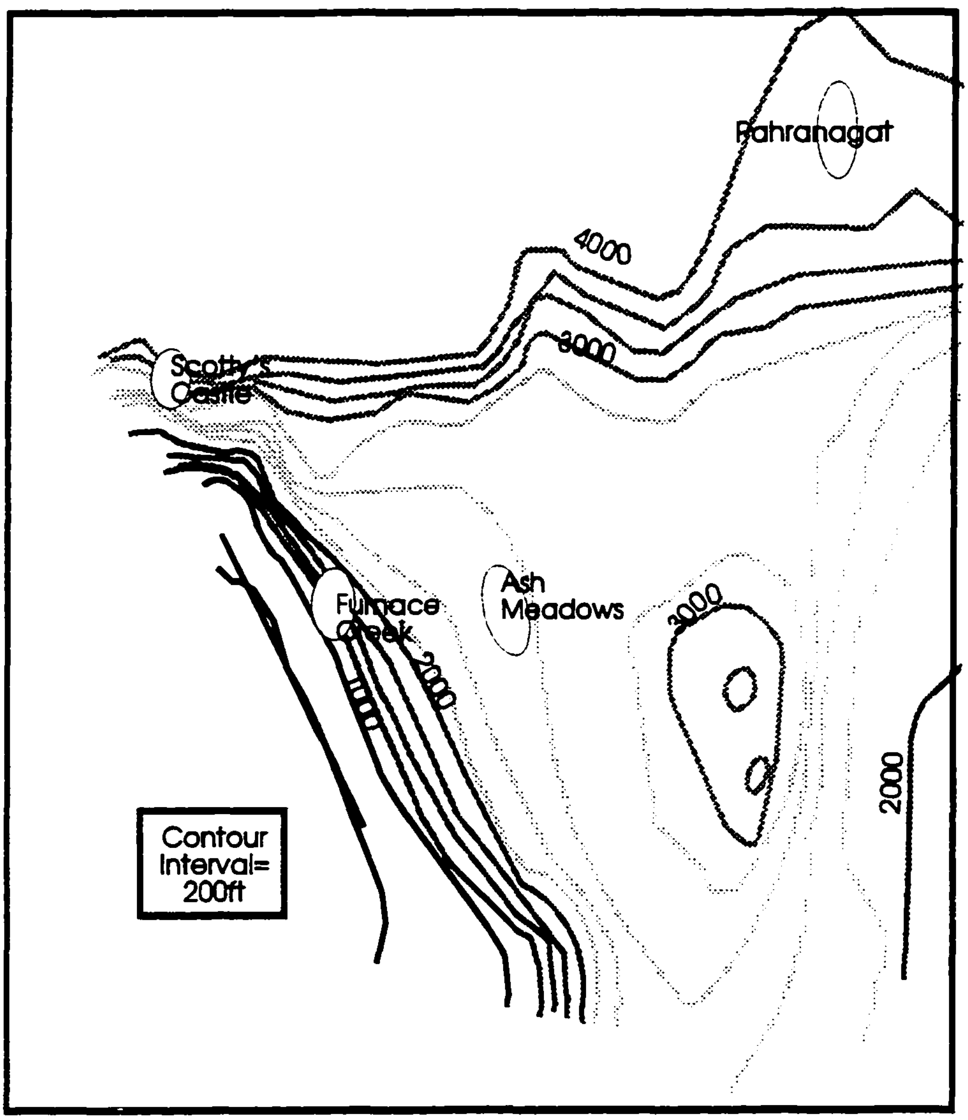


Figure 40: Molybdenum Concentrations (ppb)

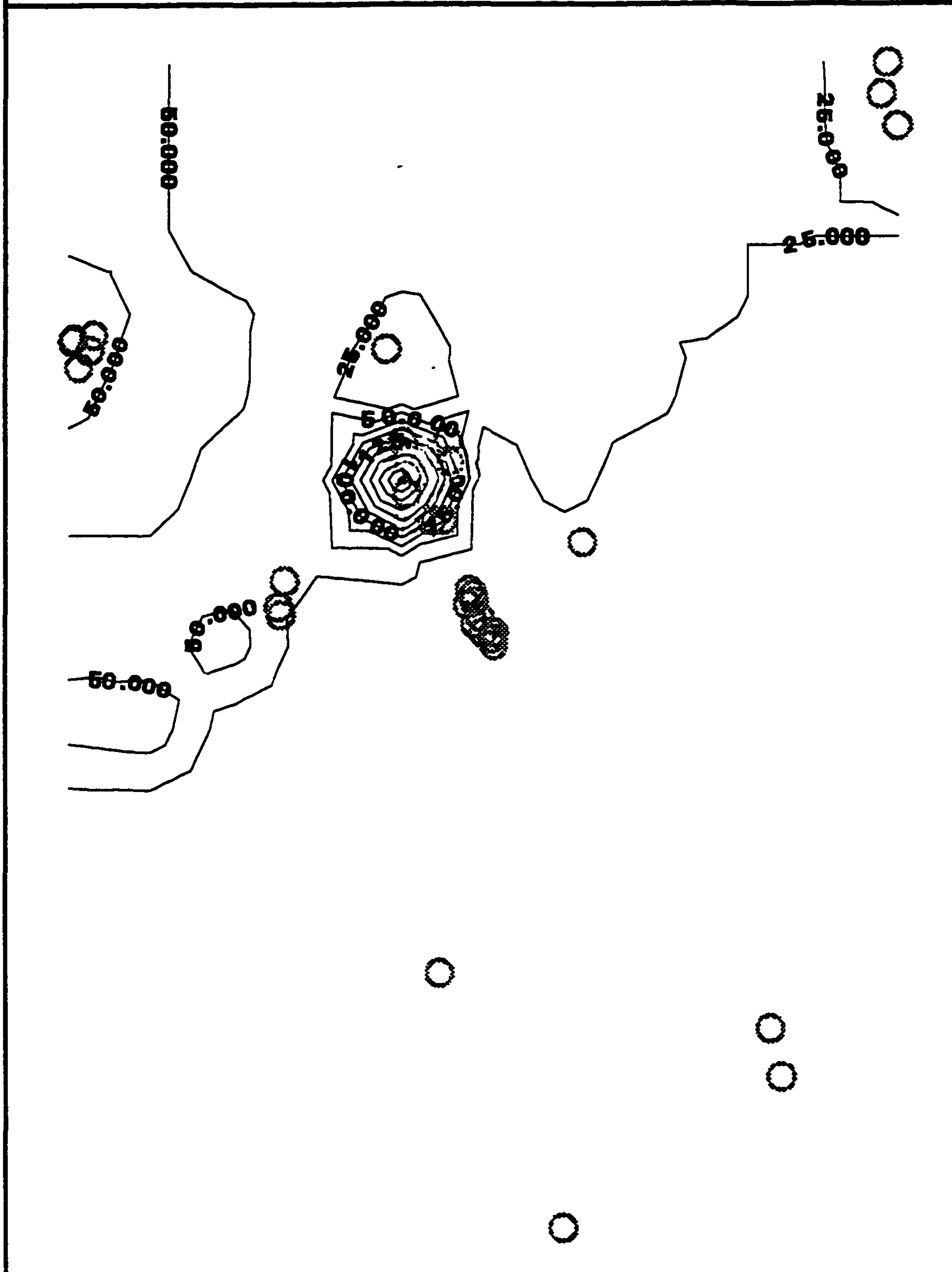


Figure 41: Tungsten Concentrations (ppb)

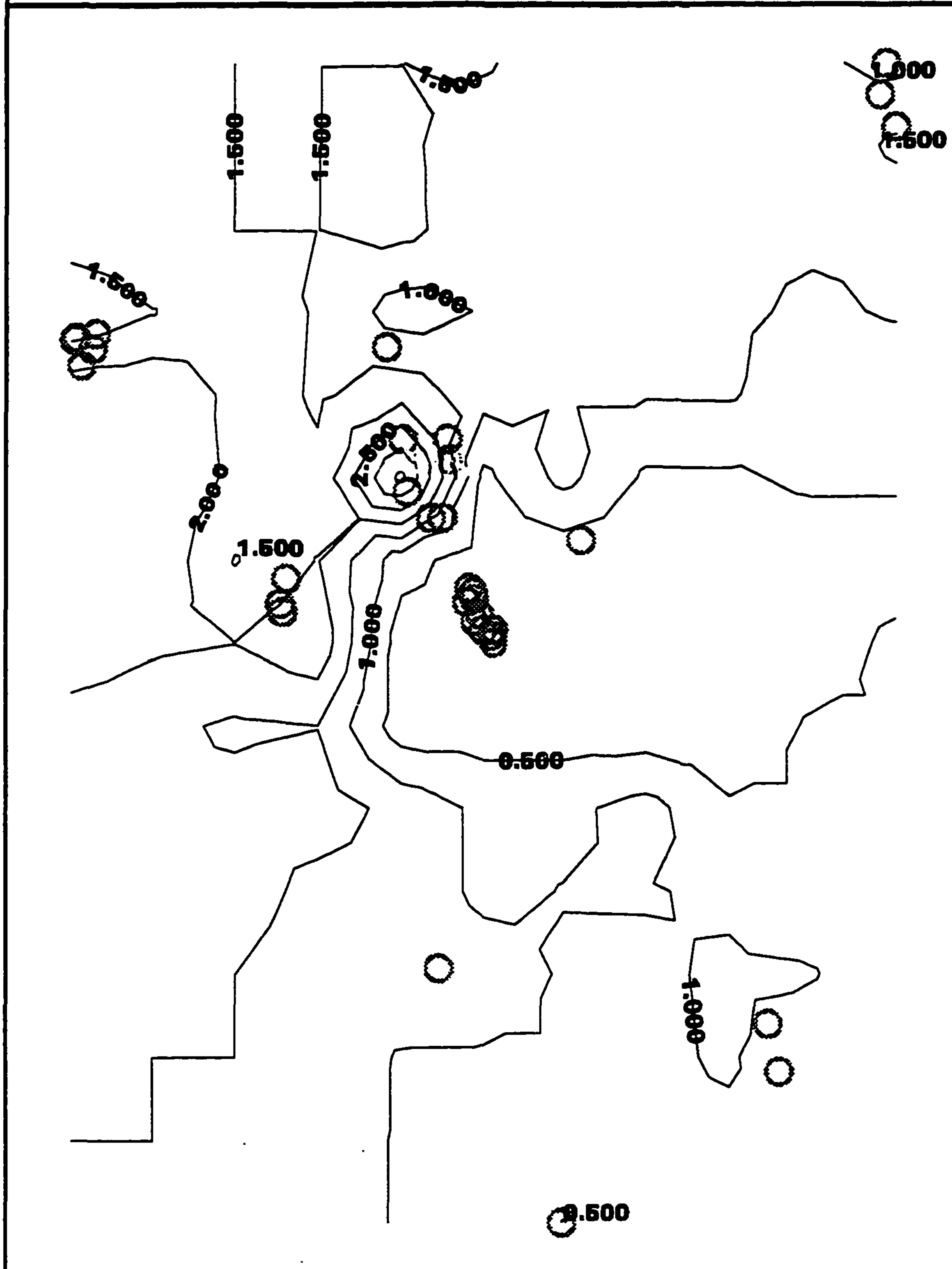
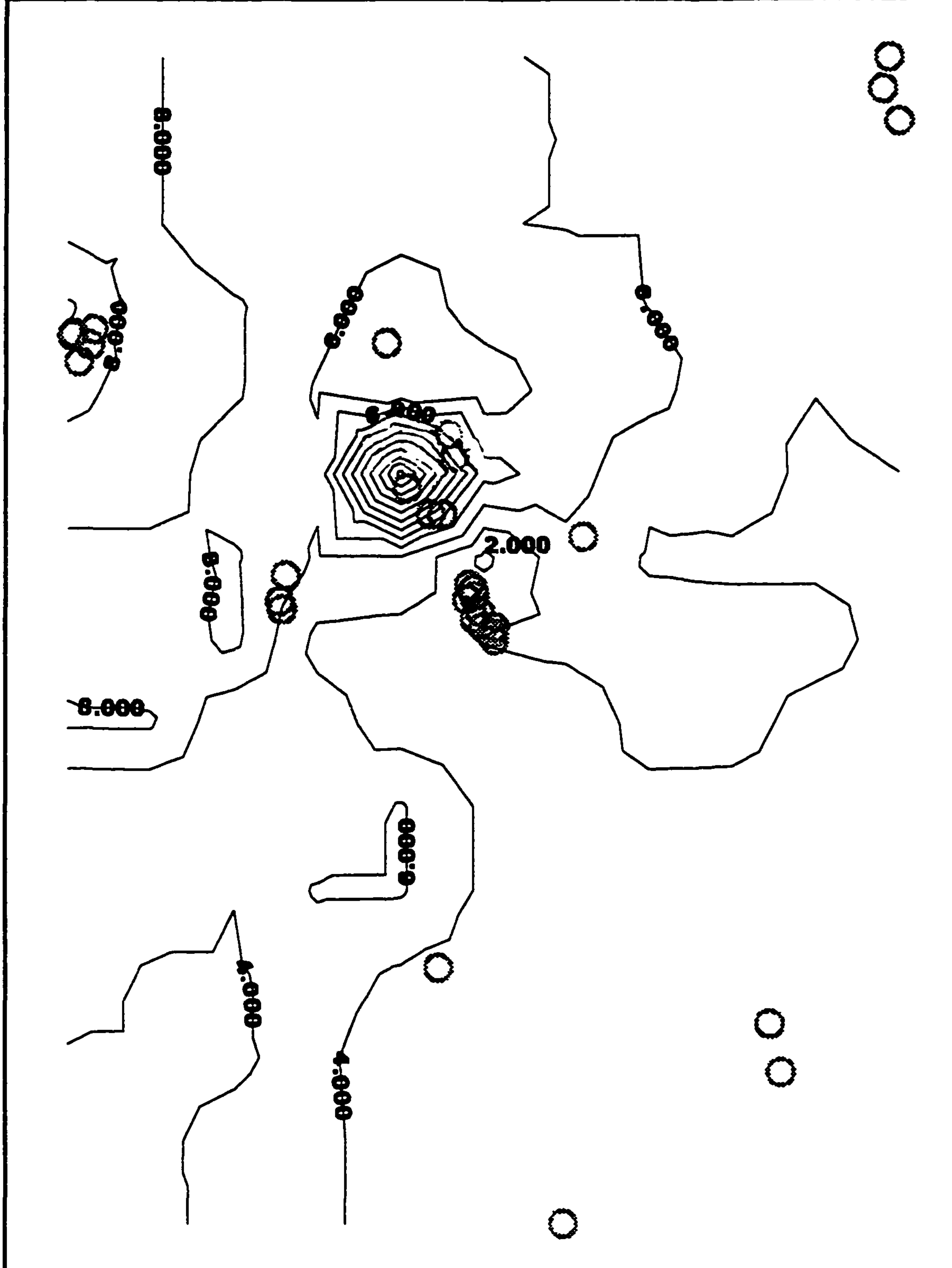


Figure 42: Uranium Concentrations (ppb)



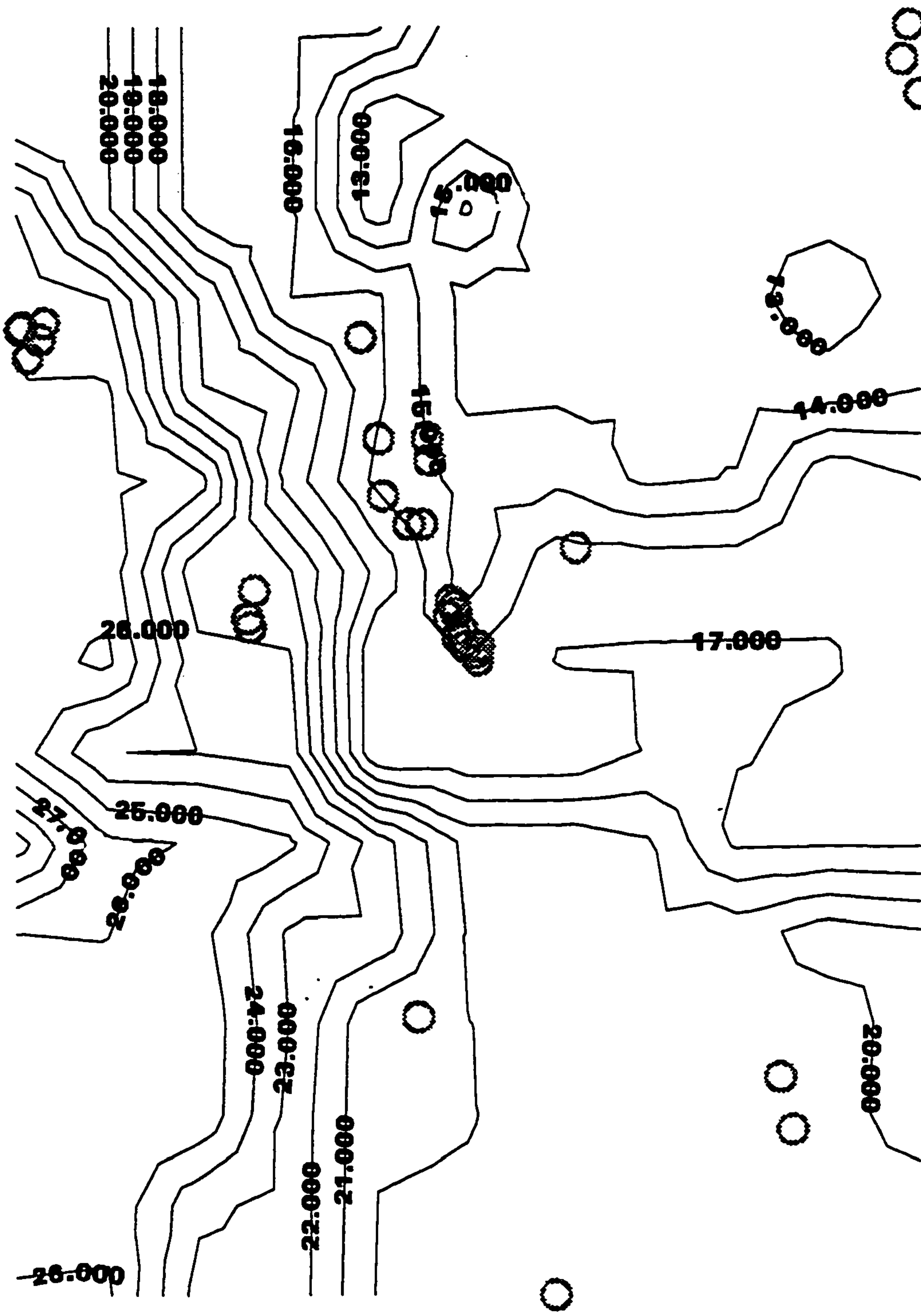


Figure 43: Rubidium Concentrations (ppb)

northwest to the southeast. There is a local high of arsenic concentrations in the vicinity of the Nevada Test Site and near the Pahranagat springs, with a general trend of decreasing concentrations from the northeast to the southwest. Rhenium concentrations also generally decreas from the northeast to the southwest. Titanium concentrations are generally greater in the southern half of the study area than in the northern half with concentrations in the northeast quadrant of the study area being more uniform.

Figure 44: Arsenic Concentrations (ppb)

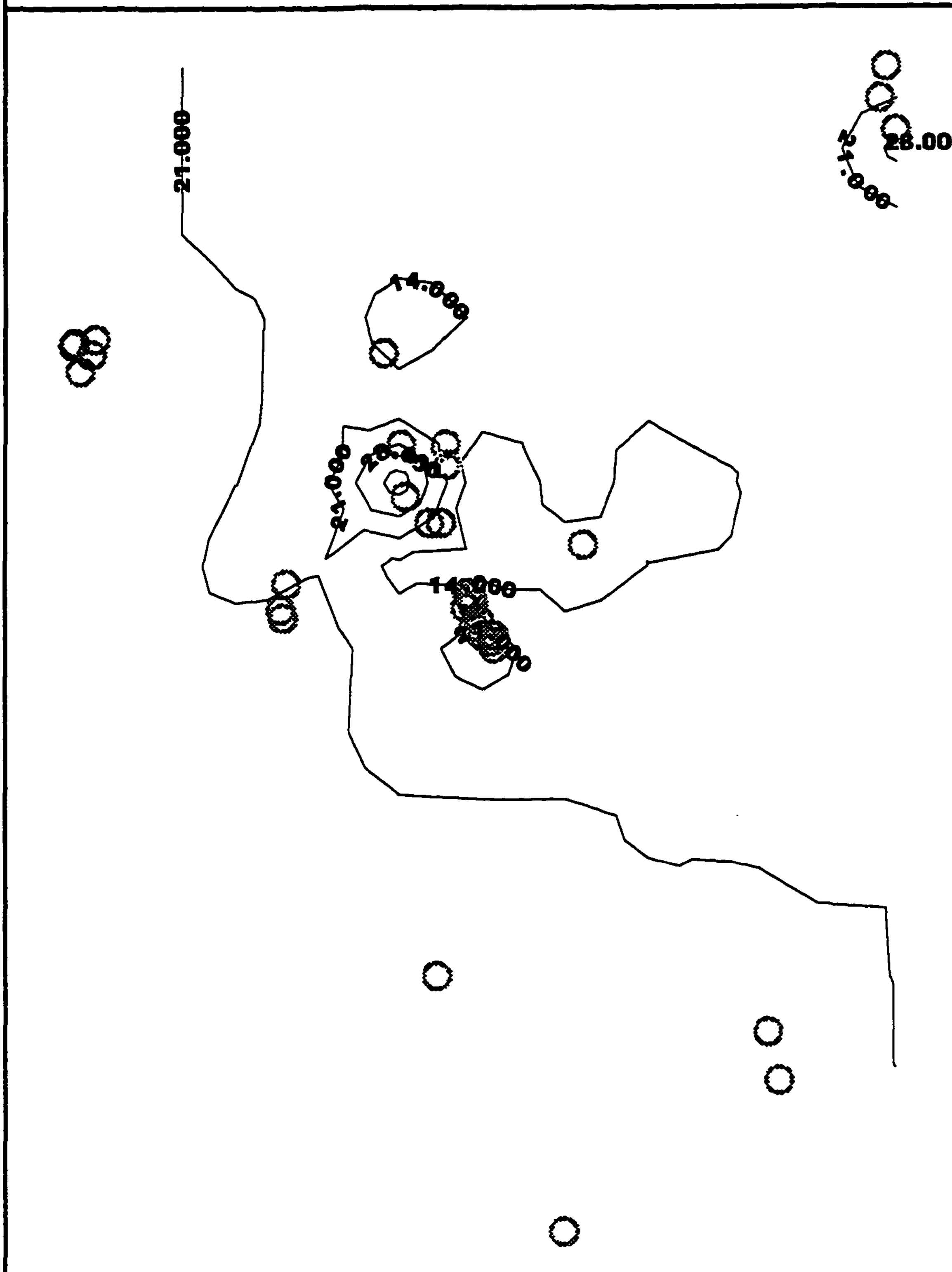


Figure 45: Rhenium Concentrations (ppt)

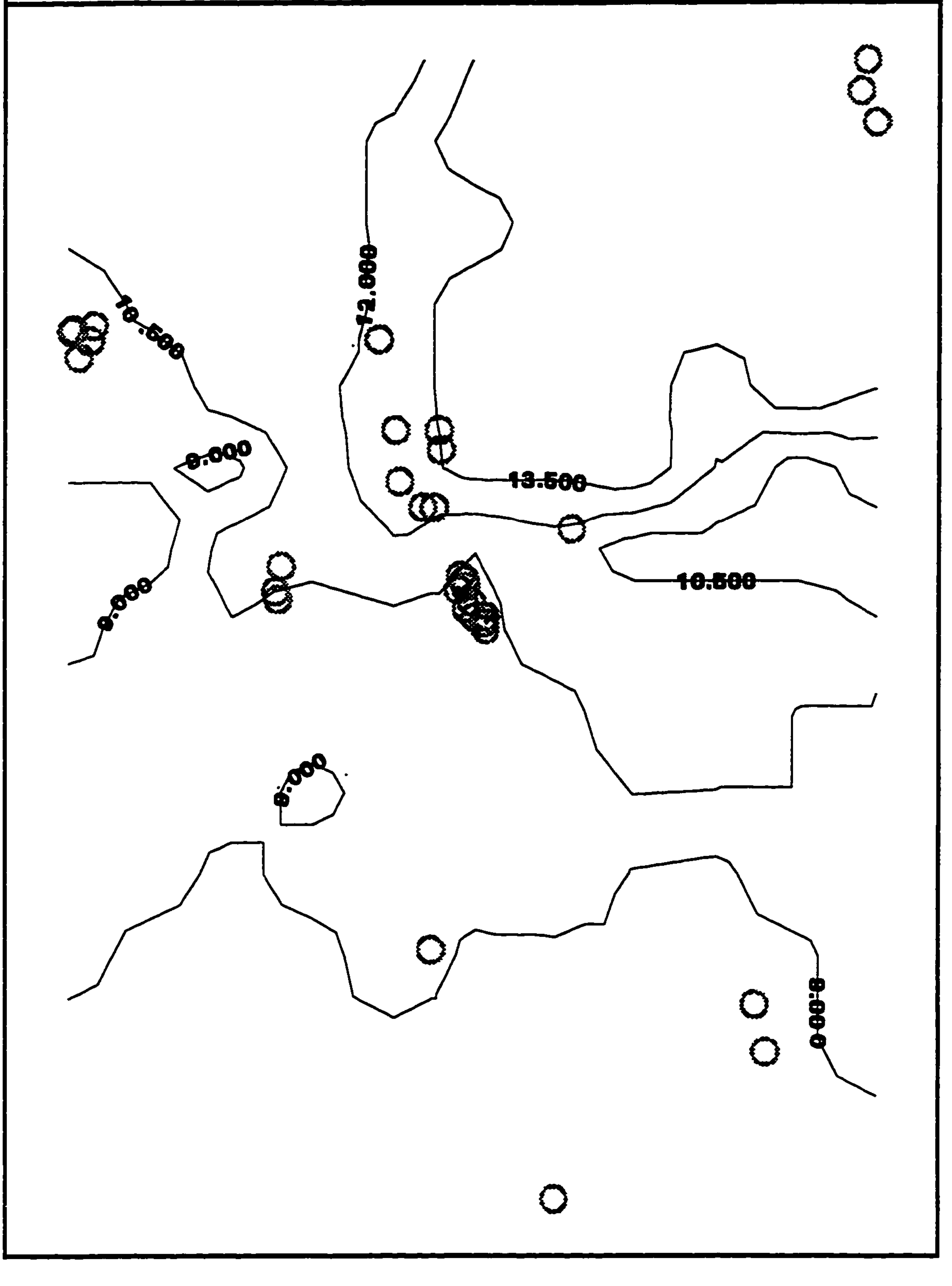


Figure 46: Cobalt Concentrations (ppt)

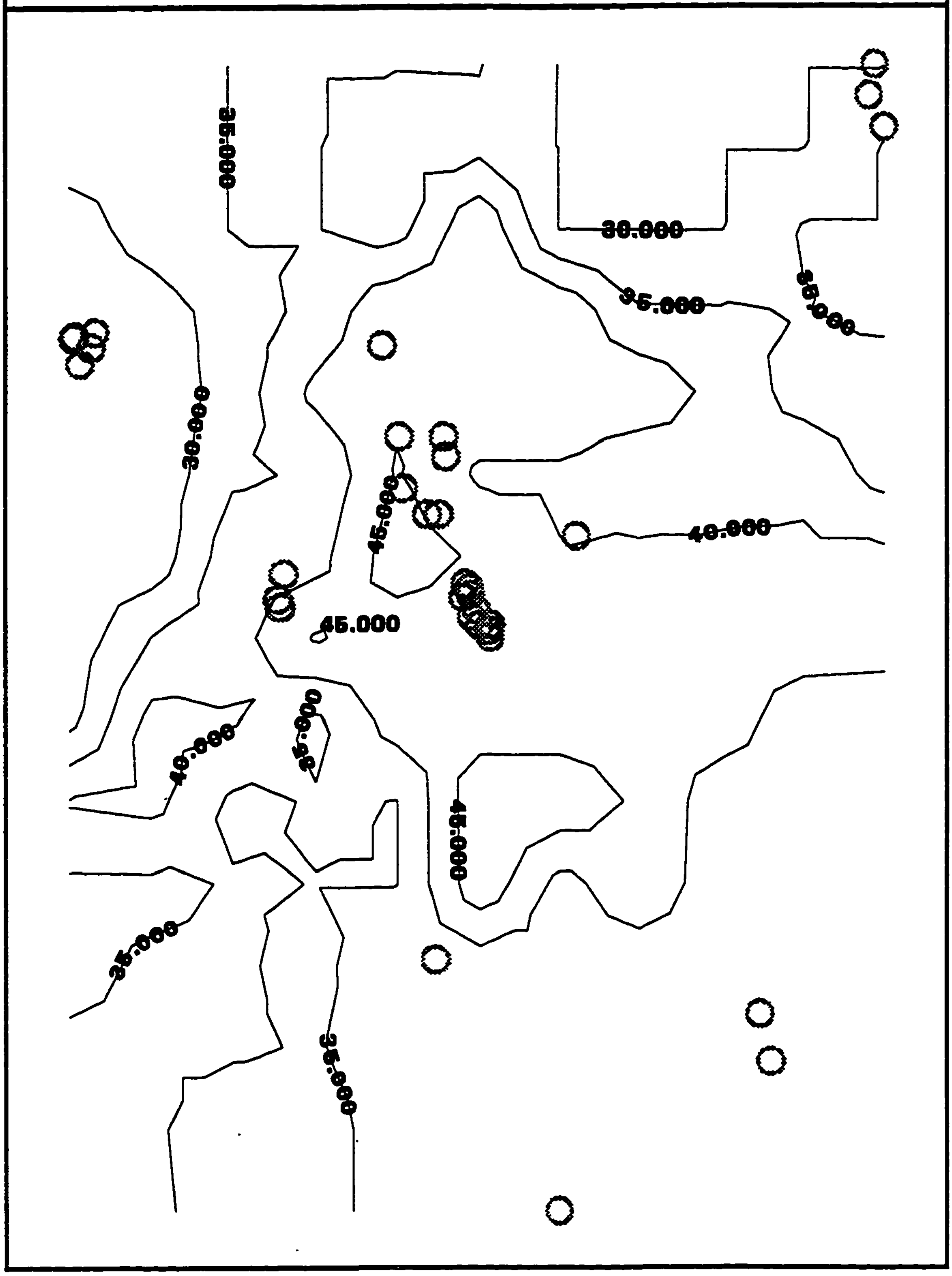


Figure 47: Gallium Concentrations (ppt)

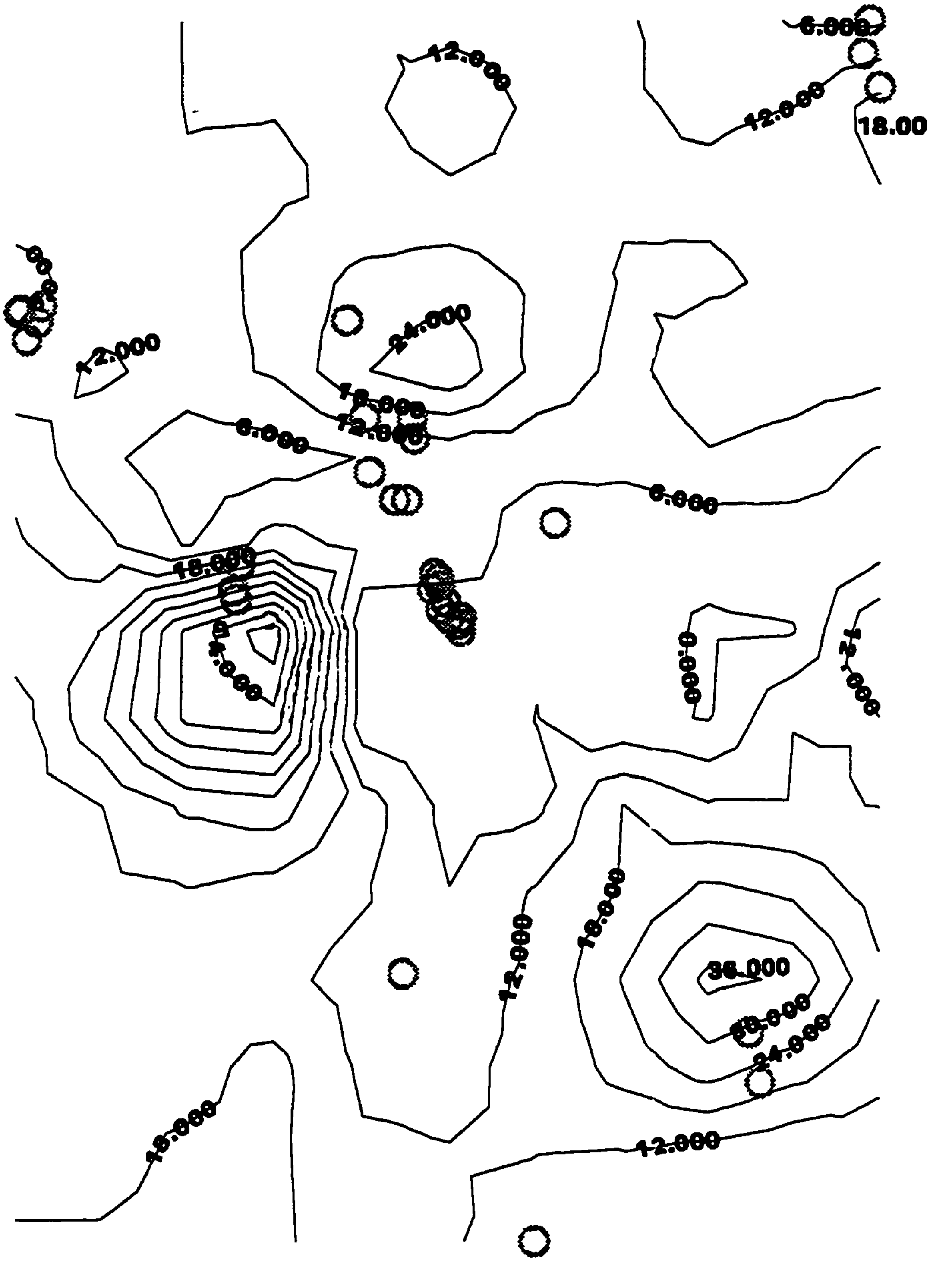


Figure 48: Vanadium Concentrations (ppb)

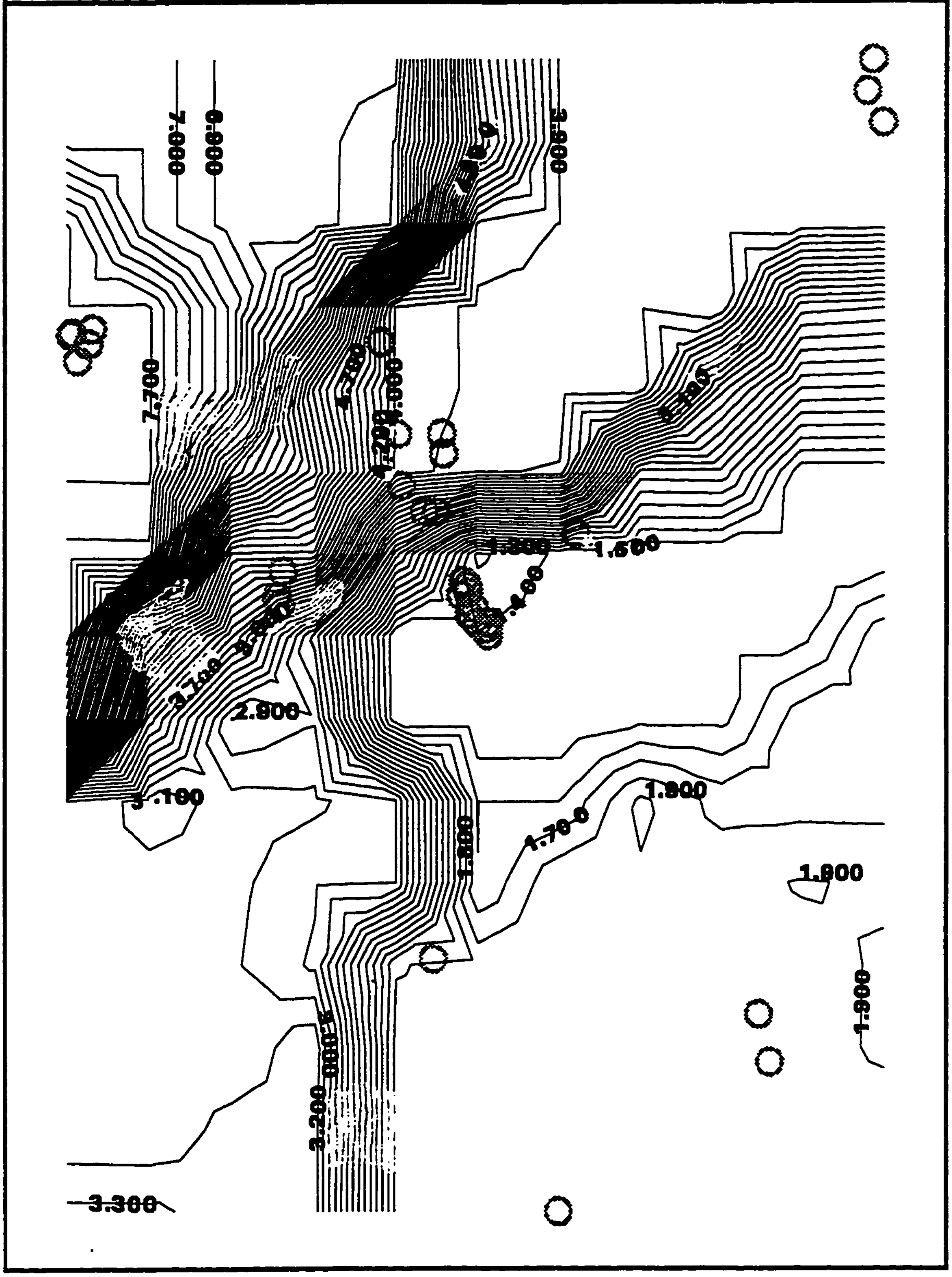


Figure 49: Selenium Concentrations (ppb)

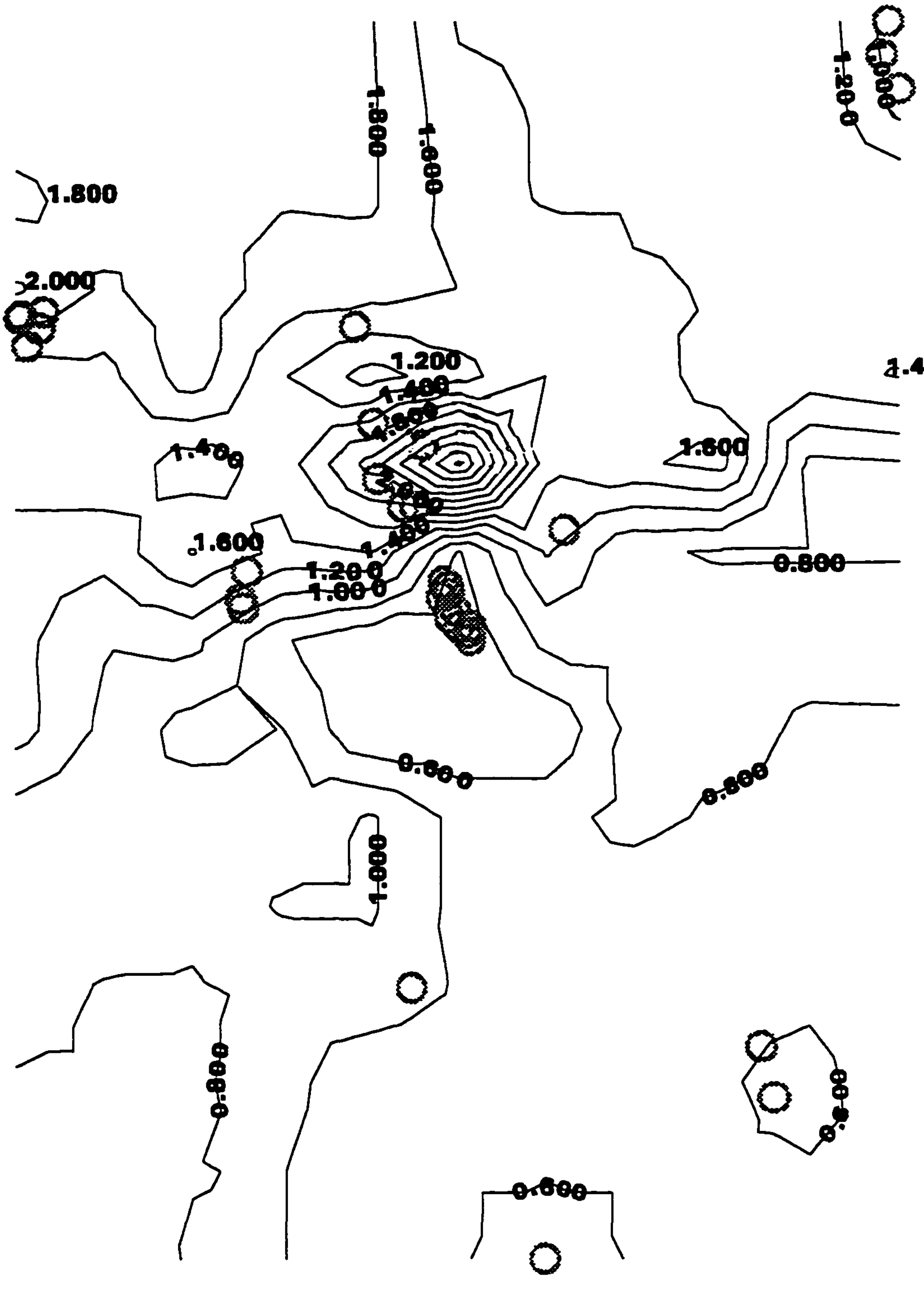
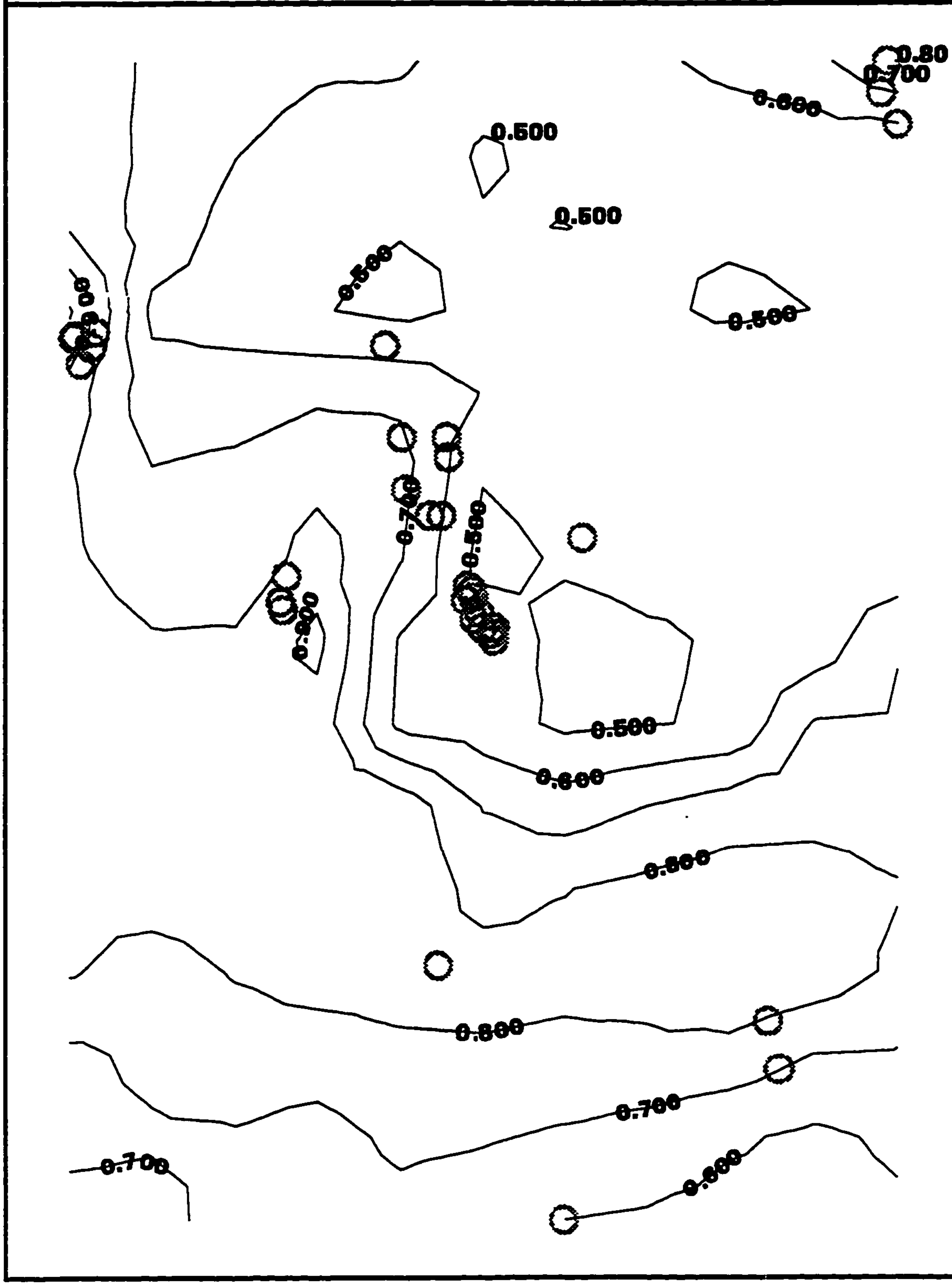


Figure 50: Titanium Concentrations (ppb)



Chapter 7:

CONCLUSIONS AND RECOMMENDATIONS FOR FURTHER STUDY

The strongest conclusion to be made is that more sampling is needed to accurately spatially analyze data on this scale. Using the variance maps and known locations of springs the following list of waters should be used in further analysis:

- Spring Mountains
- Black Mountains
  - Montgomery Spring
  - Salsberry Spring
  - Sheephead Spring
- Panamint Range
  - Fivemile Spring
  - Colter Spring
  - Emigrant Spring
- Montezuma Range
  - Railroad Spring
  - Indian Spring
  - McNamara Spring
- Death Valley and Funeral Mountains
  - Triangle Spring
  - Daylight Spring

It seems that trace elements support previous efforts to define hydrologic subbasins and the idea that mixing is occurring between Ash Meadows and the Furnace Creek area of Death Valley as well as between the Nevada Test Site and Furnace Creek. In addition, contouring of these trace elements indicates that there are several physical or physico-chemical parameters which are affecting distribution of trace elements concentrations throughout the study area. Possibly these are rock chemistry, flow paths, changes in pH or reduction/oxidation regimes. Because of relationships between components of principal component analysis and contouring patterns it is possible that a restricted list of elements could be analyzed for (within the study area) to gain an understanding of the hydrogeochemistry of the region.

When performing statistical analysis it is important to understand the techniques and methods the software package uses. Bin sizes should be selected carefully (or stem and leaf diagrams included). An appropriate method for substitution of missing values should be chosen for missing values. In this case either substitution of detection limit, mean, or zero are appropriate.

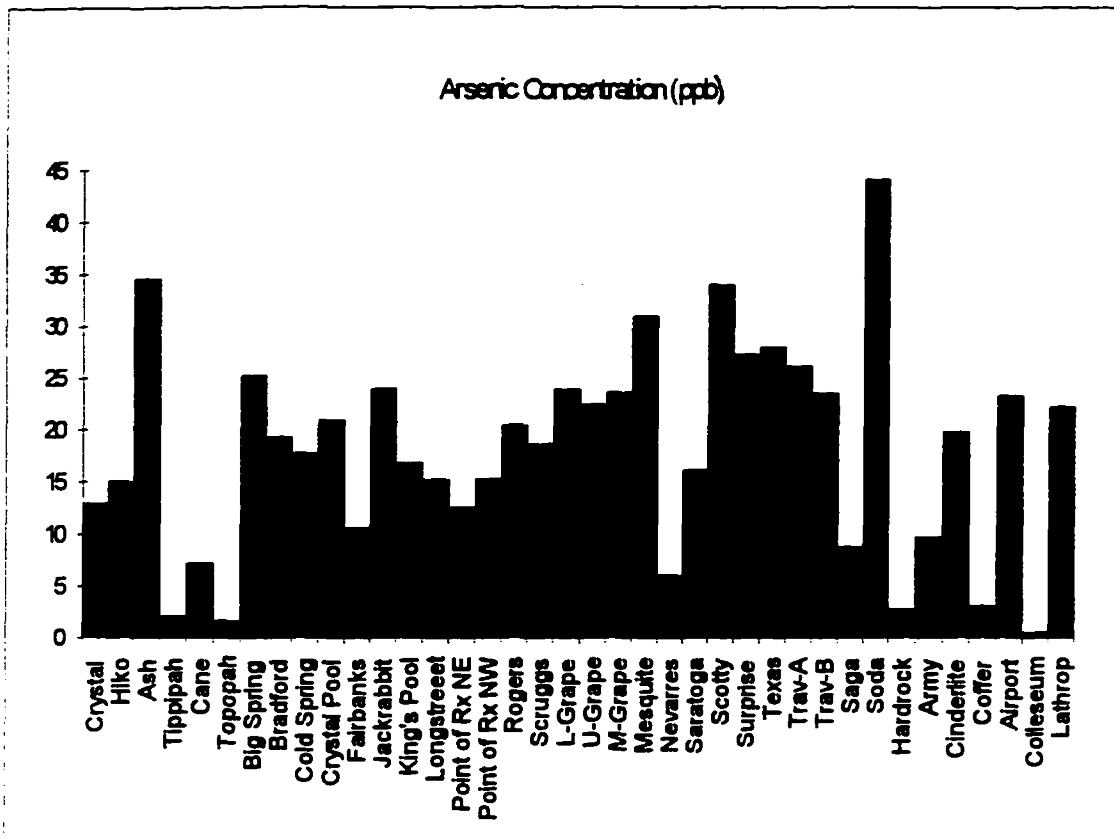
Other recommendations for additional study are numerous. Besides additional sampling at different locations throughout the study area, it would probably be beneficial to create or obtain additional ARC/INFO coverages; for example, surficial geology, geology at interval depths, and potentiometric maps for aquifers. If the user has enough disk space to manipulate these coverages within ARC/INFO then the contour maps should be draped or overlain over these different coverages. Then more accurate observations may be made or queries performed on the data set. There is certainly a wealth of borehole geology data on the Nevada Test Site. Much effort will be needed, if it is even possible, to gather enough information in other areas to have enough data density for valid interpretations.

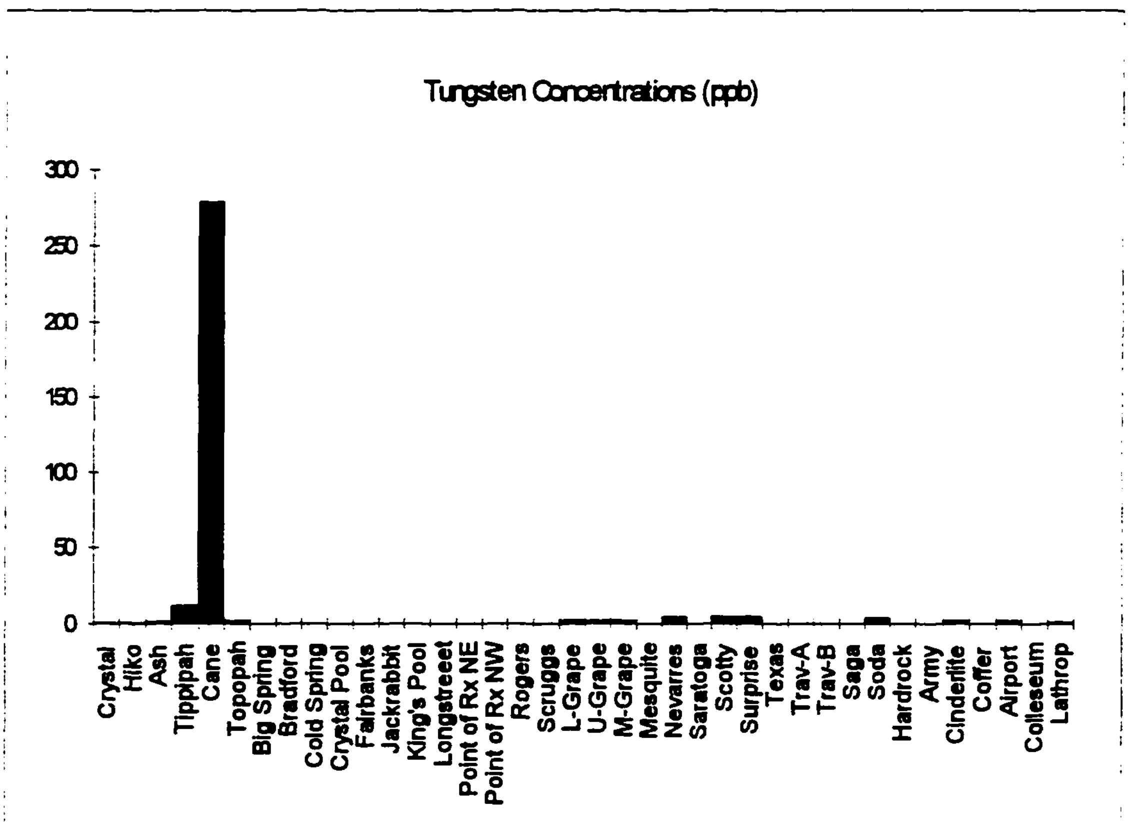
Appendix A:
Simple Plots

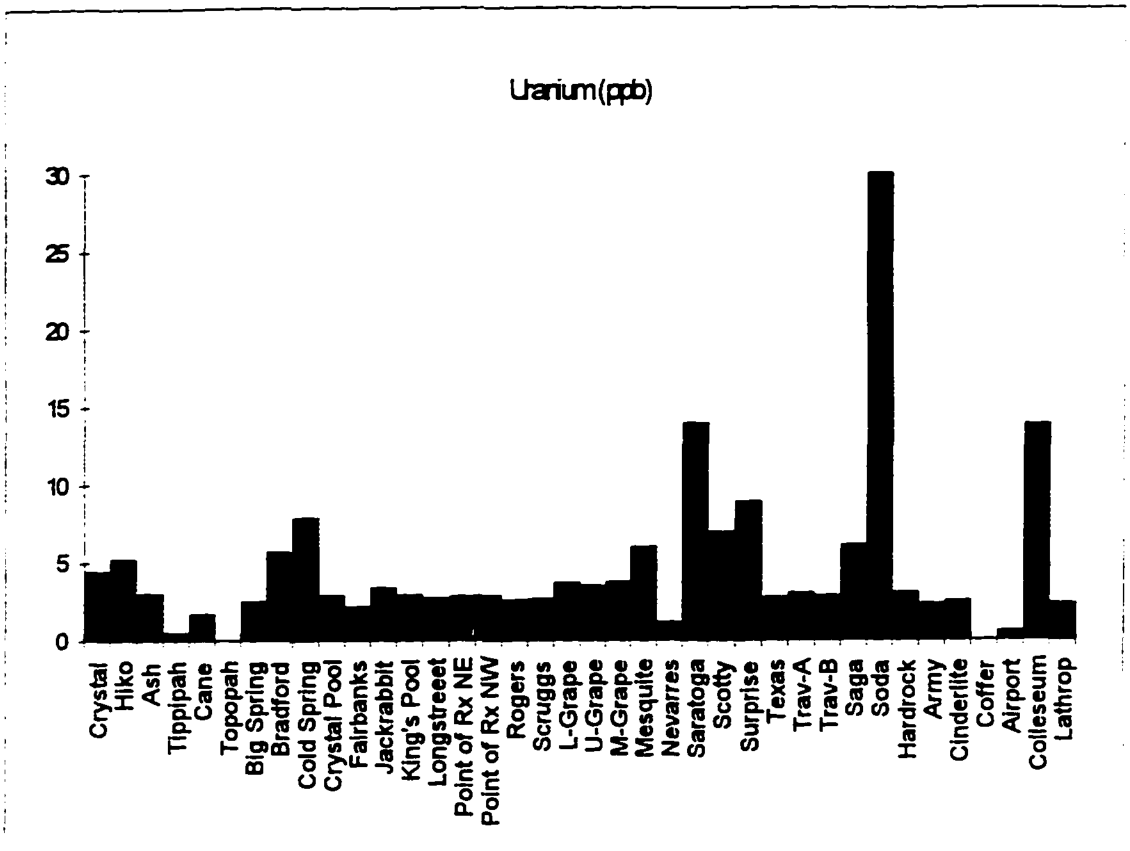
Data for Elemental Concentration Plots

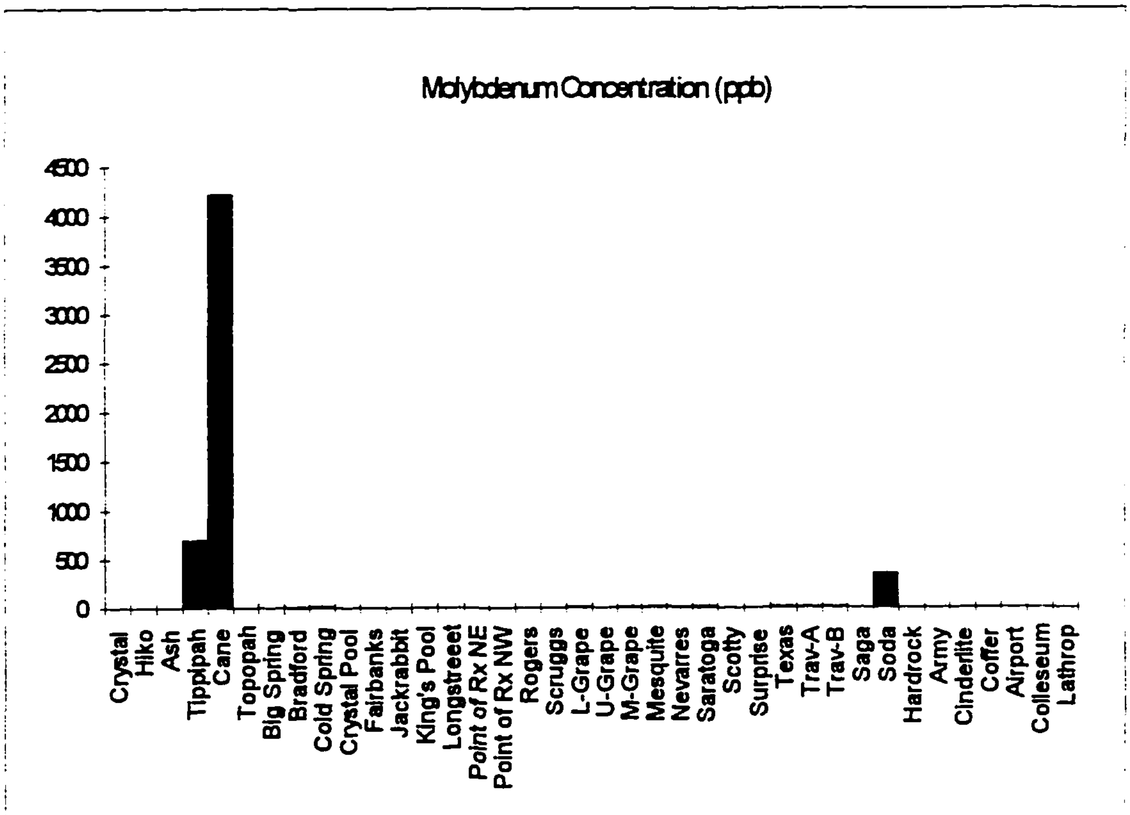
SPRING	SE_77	V_51	AS_75	W_182	U_238	MO_95	RE_187	MN55	NI_60	GA_71	RB_85	CO59
CRYSTAL	0.7857	0.964	12.9458	0.6104	4.4643	5.7653	17	ND	0.1627	3	10.0604	11
HIKO	0.779	2.0195	15.1142	0.8203	5.2417	6.021	17	ND	0.1376	4	13.809	14
ASH	0.6552	1.5373	34.6412	1.7554	3.0135	4.504	10	ND	0.1639	21	20.3163	13
Big	0.4	1.56	25.2	0.26	2.54	7.1	6	0.24	0.8	2	14.2	16
Bradford	0.43	2.16	19.3	0.27	5.7	14.3	13	0.195	1.42		17.4	74
Cold	0.84	1.37	17.7	0.2	7.9	22.5	26	0.017	0.78		19.9	34
CrysPool	0.33	1.3	20.9	0.224	2.9	7.85	9	0.193	1		19.8	44
Fairbank	0.33	0.79	10.6	0.21	2.2	6.57	7	0.061	0.5	11	14.6	16
Jackrabb	0.59	1.6	24	0.26	3.4	10.5	11	0.035	0.9	8	17.5	66
King's P	0.54	1.44	16.8	0.226	2.95	6.1	8	0.135	0.39	5	15.6	20
Longstre	0.49	1.31	15.2	0.214	2.74	6.26	8	0.061	0.89		16.7	91
PtRX NE	0.51	1.4	12.5	0.23	2.84	6.1	7.2		1.12	12	12	48
PtRX NW	0.64	1.71	15.2	0.232	2.9	6	9	0.048	1.25	9	13	Co 59
Rogers	0.42	1.08	20.4	0.164	2.61	6.3	8		1.01	1	17.1	81
Scruggs	0.36	1.13	18.6	0.3	2.7	6.2	7.2	0.1	0.42	1.6	14.4	18
L-Grape	1.2	3.4	23.9	2.33	3.7	12.7	7	0.244	0.53	4	55.4	54
U-Grape	1.1	2.74	22.4	2.1	3.53	11	7	0.481	0.9	8	50.2	38
M-Grape	1.2	3.02	23.6	2.1	3.8	12.3	6	0.57	0.74	7.7	53	91
Mesquite	1	13.6	31	0.31	6	16.7	7.4	0.091	0.31	4	17	60
Nevares	0.29	0.042	5.99	4.6	1.19	18	14	1.61	0.69	8	23.7	40
Saratoga	2.07	9	16.1	0.227	13.9	24	15	0.022	0.28	10	50	
Scotty's	0.96	10.1	34	4.42	6.98	8.5	2.2	0.06	0.06	81	17.8	8.4
Surprise	0.92	10.7	27.3	4.4	8.9	7.7	4.4	0.15	0.09	16	20.3	12
Texas	0.41	1.18	28	0.47	2.78	14.5	4.7		0.41	11	21.5	21
TravA	0.21	1	26.1	0.43	3.03	13.96	6.2		0.41	12.2	20.7	24
TravB	0.42	1.1	23.5	0.41	2.88	12.5	3.6	0.043	0.41	12	23	28
SAGA	1.56473	1.50923	8.71697	0.117798	6.0662	5.32403	25	0.817037	0.556236	ND	26.6635	19
SODA	2.17679	14.6467	44.1514	3.54389	29.994	352.095	11	1.5707	0.111639	4	27.1691	21
HARDROC	2.00739	1.81428	2.66804	ND	3.07779	1.08026	11	1.47762	1.10379	20	3.29346	73
ARMY	1.31195	1.5736	9.63807	0.169351	2.34425	5.63494	24	0.164564	0.978549	10	8.80307	29
CINDERLI	1.04805	4.7944	19.701	1.87081	2.53633	5.53656	16	0.186683	0.105727	48	12.7378	27
COFFER	0.607171	0.069264	3.00636	0.004665	0.0227	3.6379	ND	47.2715	1.37697	13	4.97967	75
AIRPORT	2.06565	10.1477	23.2049	1.81884	0.5958	1.99145	25	0.359618	0.051807	39	5.72541	23
COLLESE	5.39978	1.17976	0.515979	0.146274	13.7863	2.23018	22	0.652759	0.672417	ND	0.87824	52
LATHROP	2.50567	9.83047	22.1653	1.3249	2.34154	6.60461	31	0.216425	0.114182	4	10.9648	12
J13	1.584	11.43	17.315	1.1762	0.61747	8.1828	2	3.5303	0.3561	11	12.715	20
J12	0.688	5.39	10.2	0.493	0.58	7.36	3	0.104	0.323	0	13.7	0
Tippipah	0.56	1.396	2.04	11.9	0.52	701	11.3	1.39	0.087	76	7.07	28
Cane	2.22202	9.51455	7.20883	279	1.726	4227	21	1.11923	0.105777	1	9.69871	42
Topopah	0.17	1.34	1.64	2	0.076	3	0.2	5.16	0.2	93	9.98	46

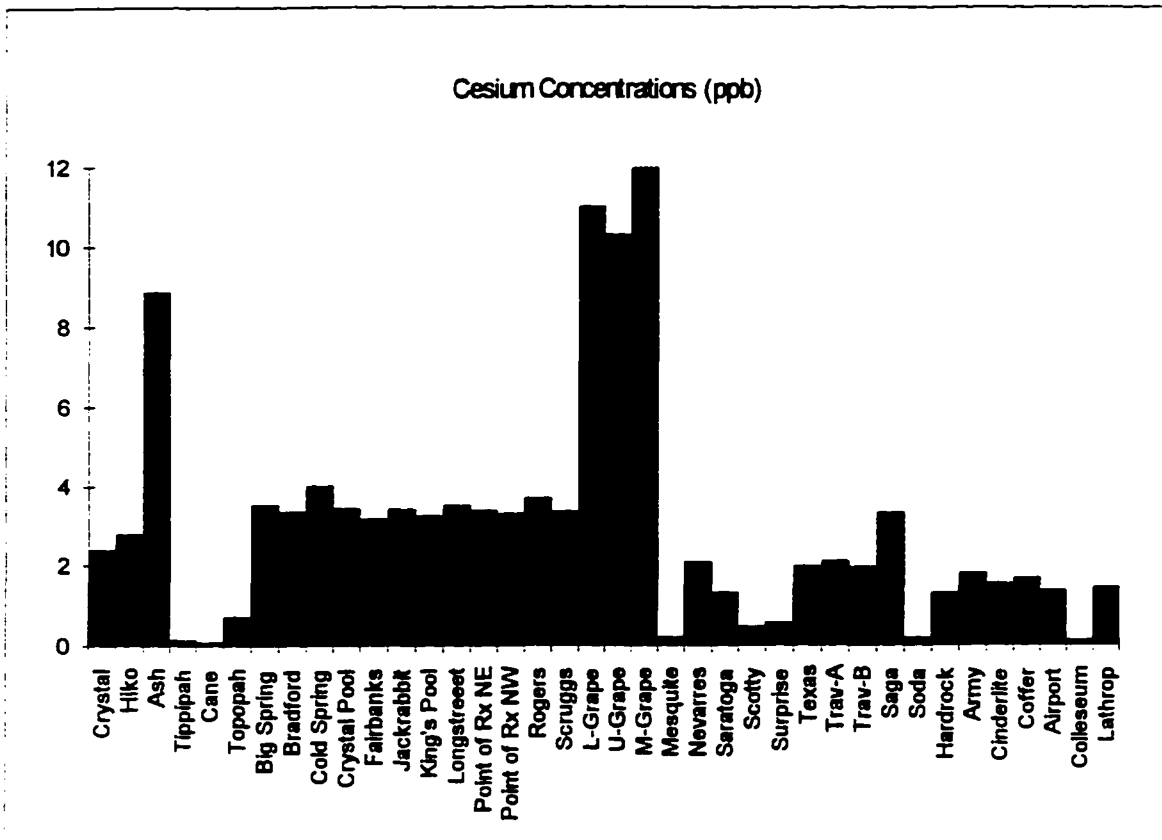
			Data for Elemental Concentration Plots (continued)							
SR_86	CD_114	CS_133	BA_135	TL_205	SN_117	SB_121	TI_47	GE73	TA_181	ZR_90
224.1034	ND	2.3973	77.0726	0.2972	ND	0.6324	0.5308	0.1317	2	10
307.5758	ND	2.789	107.463	0.4077	ND	0.7697	0.8378	0.2128	2	13
424.8716	ND	8.8624	145.914	0.2759	ND	1.301	0.5447	0.4595	3	5
860		3.53	40	0.173	0.037	0.29	0.56	0.6	8	42
1106	63	3.34	41	0.201	0.038	0.26	0.62	0.39	24	9
2168		4	18.2	0.41	0.063	0.247	0.7	0.45	15	
948		3.42	67	0.146	0.046	0.28	0.56	0.42	7	16
912		3.16	56	0.223	0.05	0.171	0.45	0.4	6	
976	113	3.4	54.2	0.2	0.028	0.175	0.48	0.42	15	11
767		3.25	66	0.165	0.14	0.347	0.69	0.36		73
970	43	3.5	57	0.299	0.041	0.327	0.61	0.39	7	
771	23	3.38	64	0.166	0.038	0.16	0.4	0.41	14	11
928	78	3.3	81	0.221	0.053	0.17	0.67	0.38	9	9
976	35	3.68	63.4	0.463	0.033	0.45	0.62	0.297	7	13
942	7	3.34	77	0.184	0.033	0.22	0.61	0.41	8	38
585	41	11	53	0.24	0.032	1.13	0.88	1.83	9	20
601	11	10.3	55	0.31	0.042	1.15	0.83	2.1		16
606	10	12	61	0.26	0.05	1.01	0.85	2.1		14
344	25	0.194	19.1	0.041	0.052	0.31	0.52	0.42		16
1130	15	2.08	43	0.2	0.11	0.96	0.74	0.88		33
3480	28	1.31	19	0.17	0.13	0.022	0.4	0.17	9	5
6.2		0.468	0.79	0.029		0.74	1	1.28		20
19.7	6	0.56	4.6	0.03	0.02	0.71	0.85	0.84	6	22
1067	12	1.95	35.6	0.062	0.02	0.16	0.6	0.5	9	13
1072	10	2.09	39	0.091		0.18	0.61	0.5	8	9
1021	14	1.94	40	0.67	0.02	0.15	0.73	0.46	7	21
608.251	30	3.30139	50.5515	0.385059	0.038799	0.277802	0.542626	0.548492	5	17
355.586	178	0.193634	6.39364	0.193866	0.102348	0.085539	0.697763	0.707353	ND	16
382.896	22	1.28896	213.402	0.058753	0.030573	0.039199	0.469918	0.025385	ND	ND
213.402	ND	1.78565	73.9171	0.095973	0.043499	0.19098	0.526806	0.300895	28	17
105.177	12	1.52311	1.33644	0.030468	0.034112	0.409871	0.928504	0.816321	25	14
4206.47	23	1.64772	39.735	0.051076	0.041193	0.022244	0.730641	0.231283	ND	ND
24.0881	ND	1.34594	1.7379	0.03132	0.027268	0.295055	0.724015	0.923708	12	62
433.511	19	0.124655	41.1697	0.049246	0.036503	0.068283	0.522129	0.056677	ND	ND
100.72	10	1.41486	8.82344	0.04902	0.032885	0.501128	0.718185	1.079	25	ND
54.766	13	1.935	1.578	0.059	0.231	0.516	1.346	0.404	0.00594	0.0425
44.5	0	0.815	1.81	0	0	0.219	0.864	0.355	0.00626	0.0165
6.24	3	0.139	0.34	0.0429	ND	1944	4068	41	16.5	294
107.8	4	0.079741	18.6461	0.059687	ND	69.5	1270	196	ND	ND
6.85	22	0.7	0.258	0.053	ND	269	2.8	4	12	5

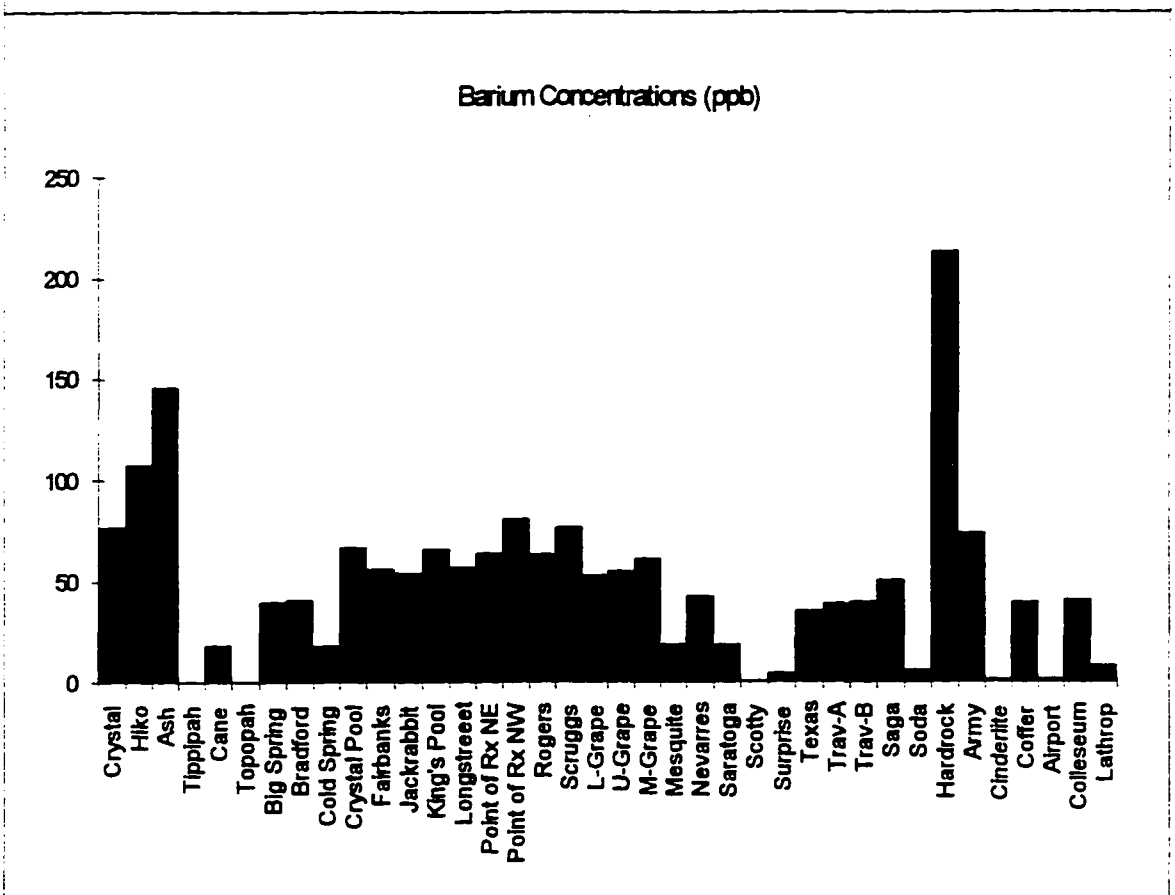

Arsenic Concentration (ppb)
0
5
10
15
20
25
30
35
40
45
Crystal
Hiko
Ash
Tippipah
Cane
Topopah
Big Spring
Bradford
Cold Spring
Crystal Pool
Fairbanks
Jackrabbit
King's Pool
Longstreeet
Point of Rx NE
Point of Rx NW
Rogers
Scruggs
L-Grape
U-Grape
M-Grape
Mesquite
Nevarres
Saratoga
Scotty
Surprise
Texas
Trav-A
Trav-B
Saga
Soda
Hardrock
Army
Cinderlite
Coffer
Airport
Colleseum
Lathrop

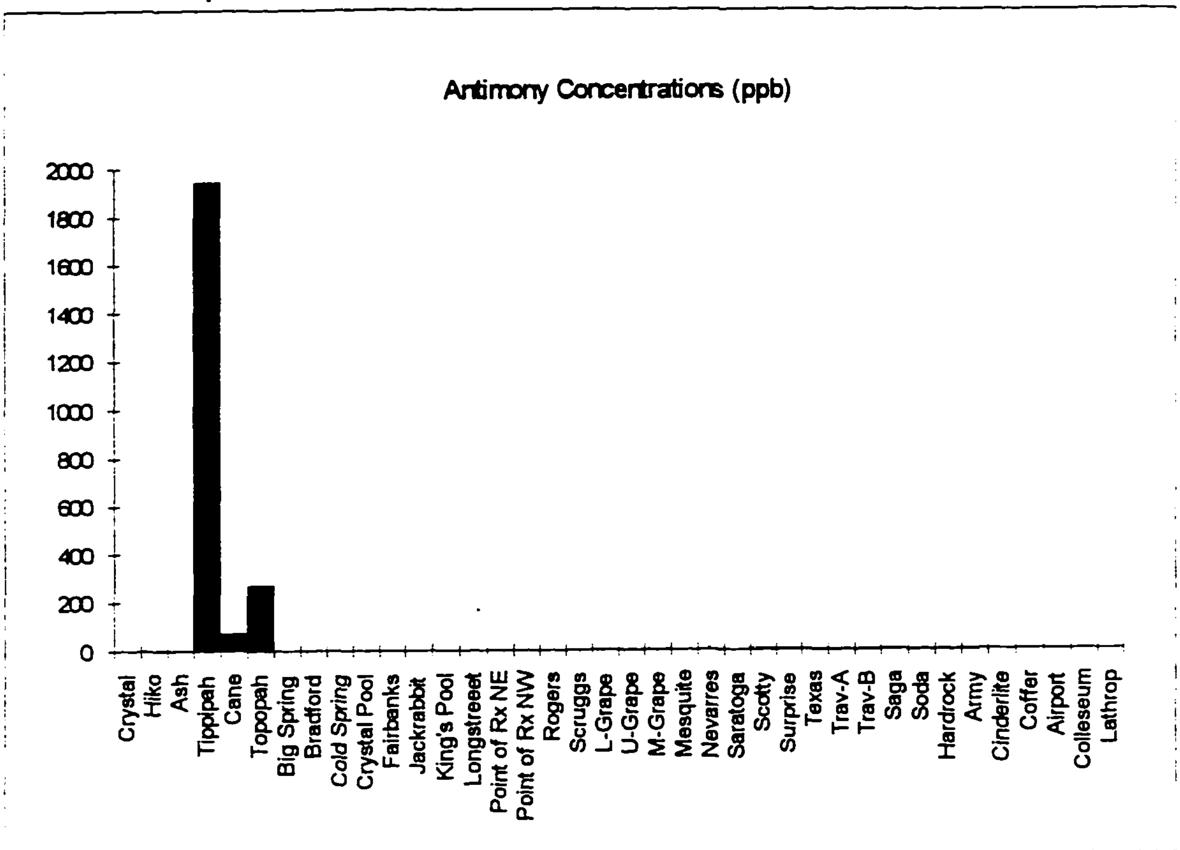

Tungsten Concentrations (ppb)
0
50
100
150
200
250
300
Crystal
Hiko
Ash
Tippipah
Cane
Topopah
Big Spring
Bradford
Cold Spring
Crystal Pool
Fairbanks
Jackrabbit
King's Pool
Longstreeet
Point of Rx NE
Point of Rx NW
Rogers
Scruggs
L-Grape
U-Grape
M-Grape
Mesquite
Nevarres
Saratoga
Scotty
Surprise
Texas
Trav-A
Trav-B
Saga
Soda
Hardrock
Army
Cinderlite
Coffer
Airport
Colleseum
Lathrop

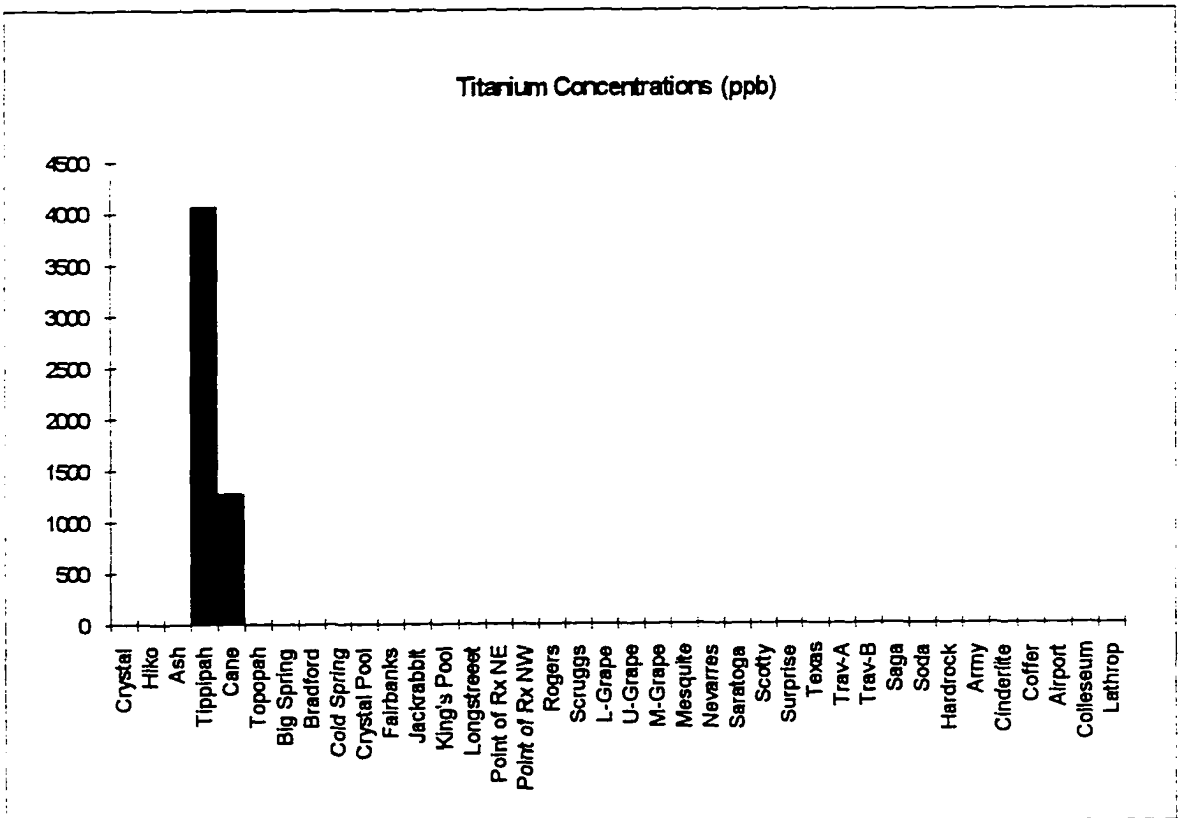

Uranium (ppb)
0
5
10
15
20
25
30
Crystal
Hiko
Ash
Tippipah
Cane
Topopah
Big Spring
Bradford
Cold Spring
Crystal Pool
Fairbanks
Jackrabbit
King's Pool
Longstreeet
Point of Rx NE
Point of Rx NW
Rogers
Scruggs
L-Grape
U-Grape
M-Grape
Mesquite
Nevarres
Saratoga
Scotty
Surprise
Texas
Trav-A
Trav-B
Saga
Soda
Hardrock
Army
Cinderlite
Coffer
Airport
Colleseum
Lathrop

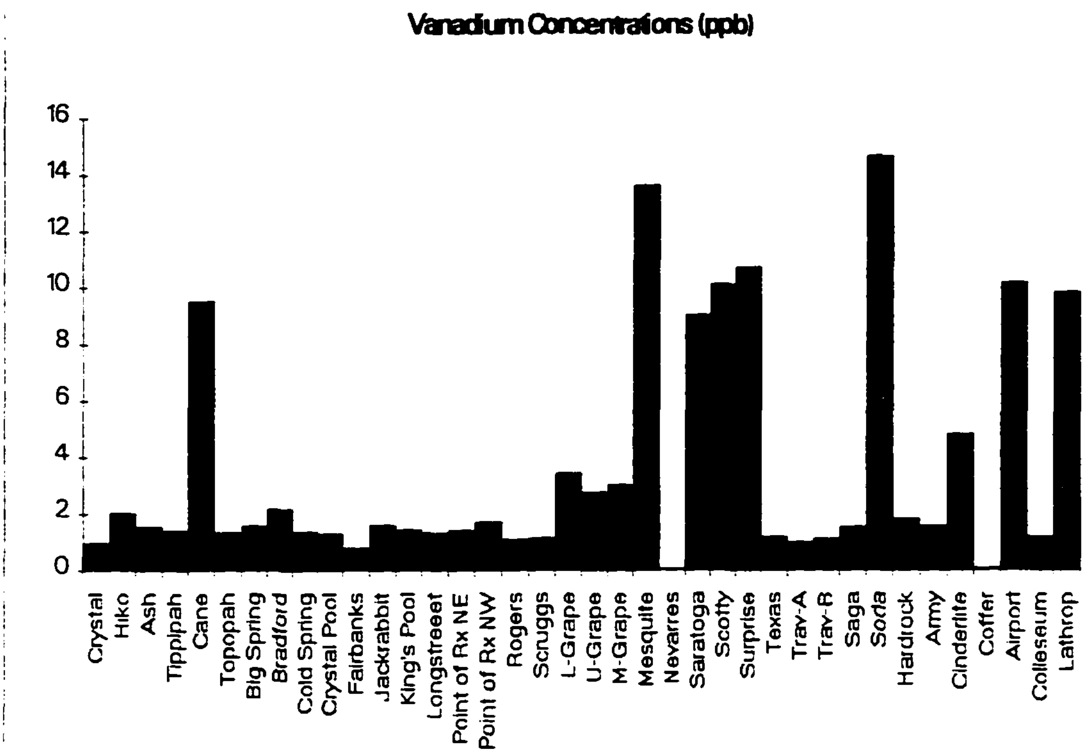

Molybdenum Concentration (ppb)
0
500
1000
1500
2000
2500
3000
3500
4000
4500
Crystal
Hiko
Ash
Tippipah
Cane
Topopah
Big Spring
Bradford
Cold Spring
Crystal Pool
Fairbanks
Jackrabbit
King's Pool
Longstreeet
Point of Rx NE
Point of Rx NW
Rogers
Scruggs
L-Grape
U-Grape
M-Grape
Mesquite
Nevarres
Saratoga
Scotty
Surprise
Texas
Trav-A
Trav-B
Saga
Soda
Hardrock
Army
Cinderlite
Coffer
Airport
Colleseum
Lathrop

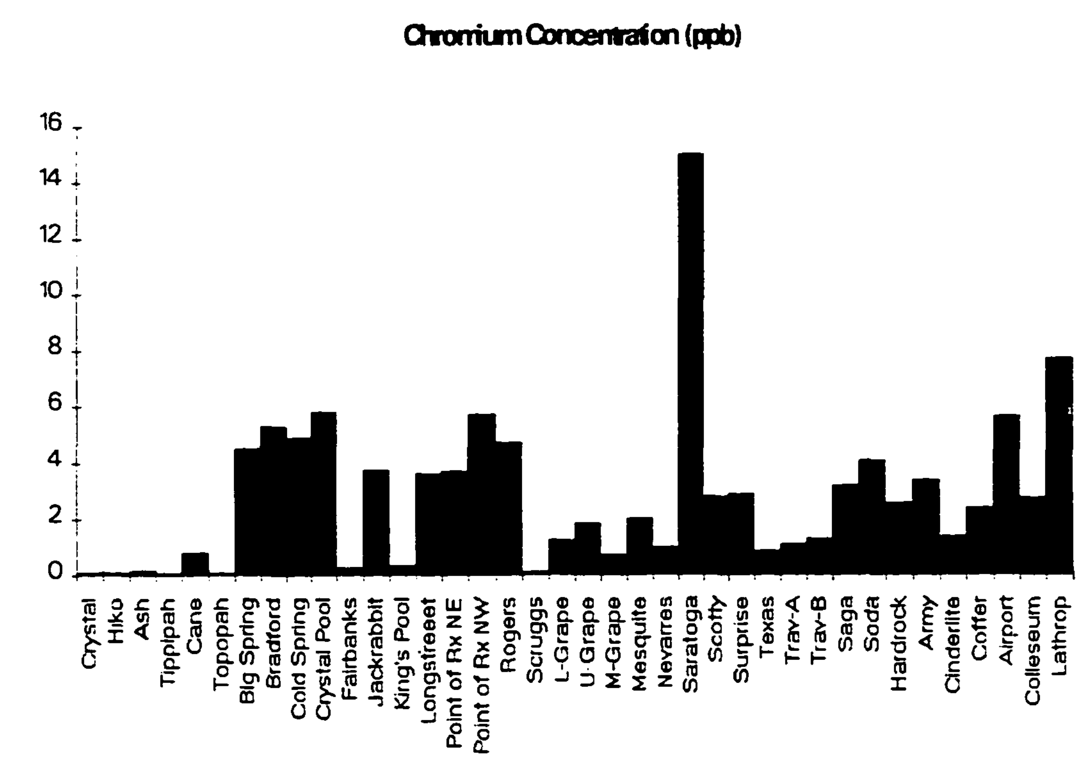

Cesium Concentrations (ppb)
0
2
4
6
8
10
12
Crystal
Hiko
Ash
Tippipah
Cane
Topopah
Big Spring
Bradford
Cold Spring
Crystal Pool
Fairbanks
Jackrabbit
King's Pool
Longstreeet
Point of Rx NE
Point of Rx NW
Rogers
Scruggs
L-Grape
U-Grape
M-Grape
Mesquite
Nevarres
Saratoga
Scotty
Surprise
Texas
Trav-A
Trav-B
Saga
Soda
Hardrock
Army
Cinderlite
Coffer
Airport
Colleseum
Lathrop

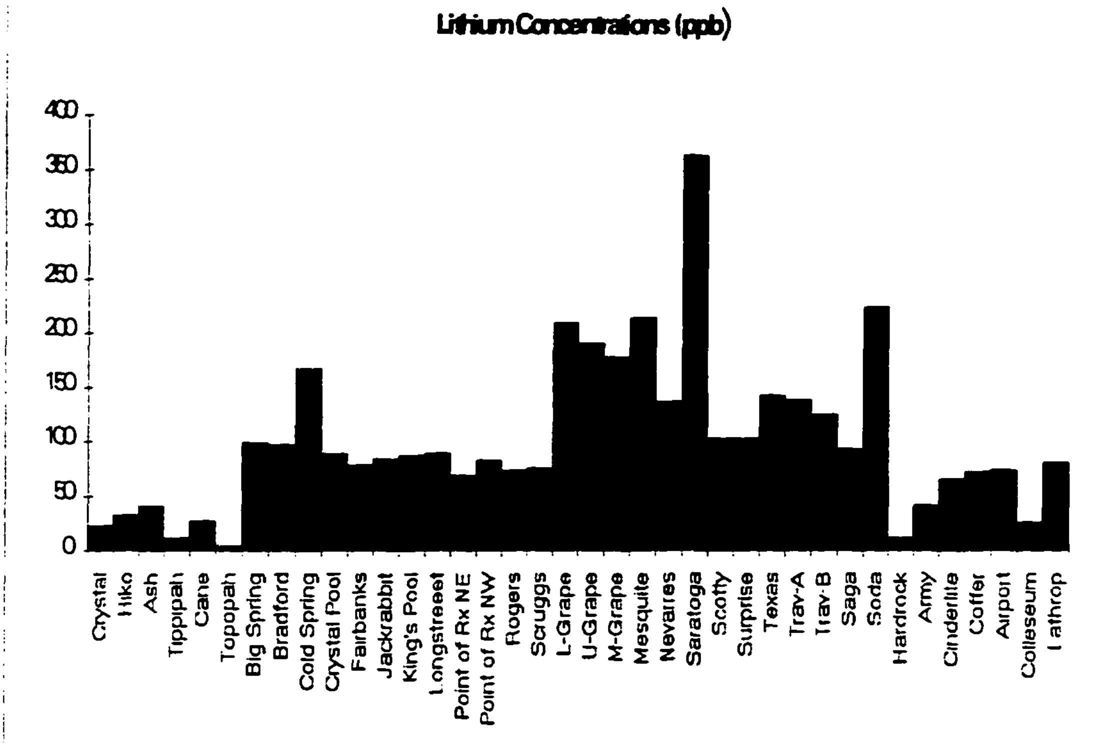

Barium Concentrations (ppb)
0
50
100
150
200
250
Crystal
Hiko
Ash
Tippipah
Cane
Topopah
Big Spring
Bradford
Cold Spring
Crystal Pool
Fairbanks
Jackrabbit
King's Pool
Longstreeet
Point of Rx NE
Point of Rx NW
Rogers
Scruggs
L-Grape
U-Grape
M-Grape
Mesquite
Nevarres
Saratoga
Scotty
Surprise
Texas
Trav-A
Trav-B
Saga
Soda
Hardrock
Army
Cinderlite
Coffer
Airport
Colleseum
Lathrop

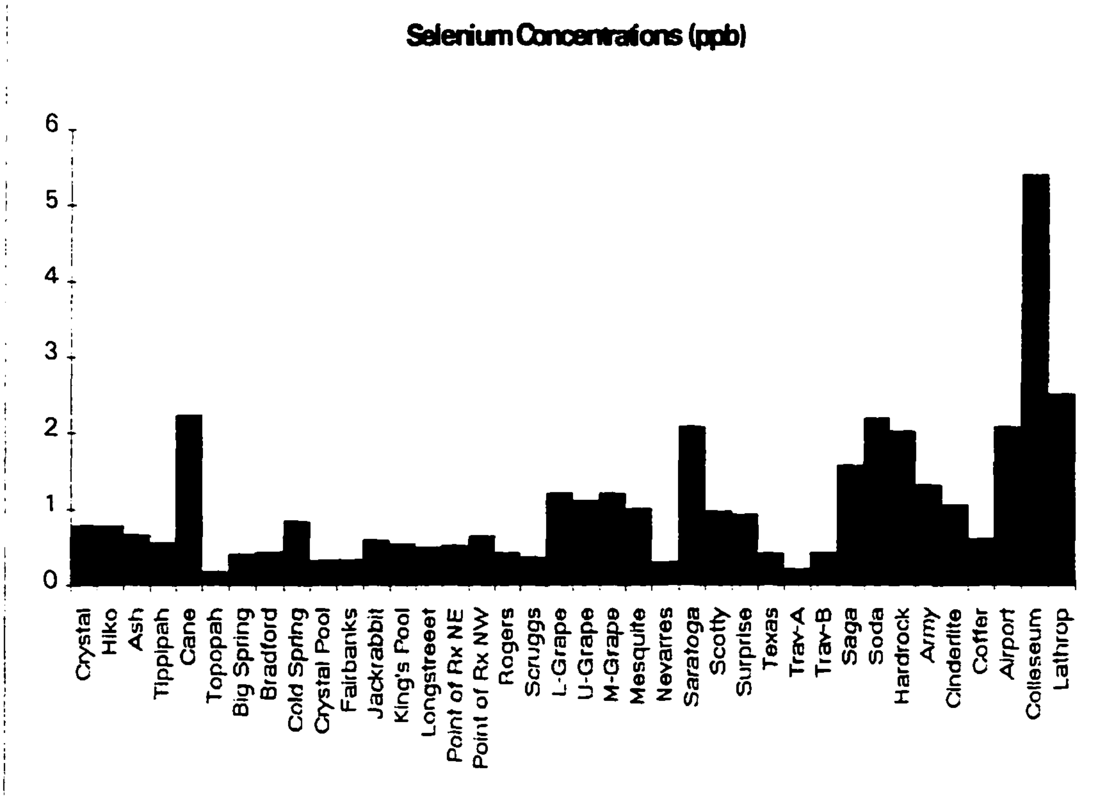

Antimony Concentrations (ppb)
2000
1800
1600
1400
1200
1000
800
600
400
200
0
Crystal
Hiko
Ash
Tippipah
Cane
Topopah
Big Spring
Bradford
Cold Spring
Crystal Pool
Fairbanks
Jackrabbit
King's Pool
Longstreet
Point of Rx NE
Point of Rx NW
Rogers
Scruggs
L-Grape
U-Grape
M-Grape
Mesquite
Nevarres
Saratoga
Scotty
Surprise
Texas
Trav-A
Trav-B
Saga
Soda
Hardrock
Army
Cinderlite
Coffer
Airport
Colleseum
Lathrop

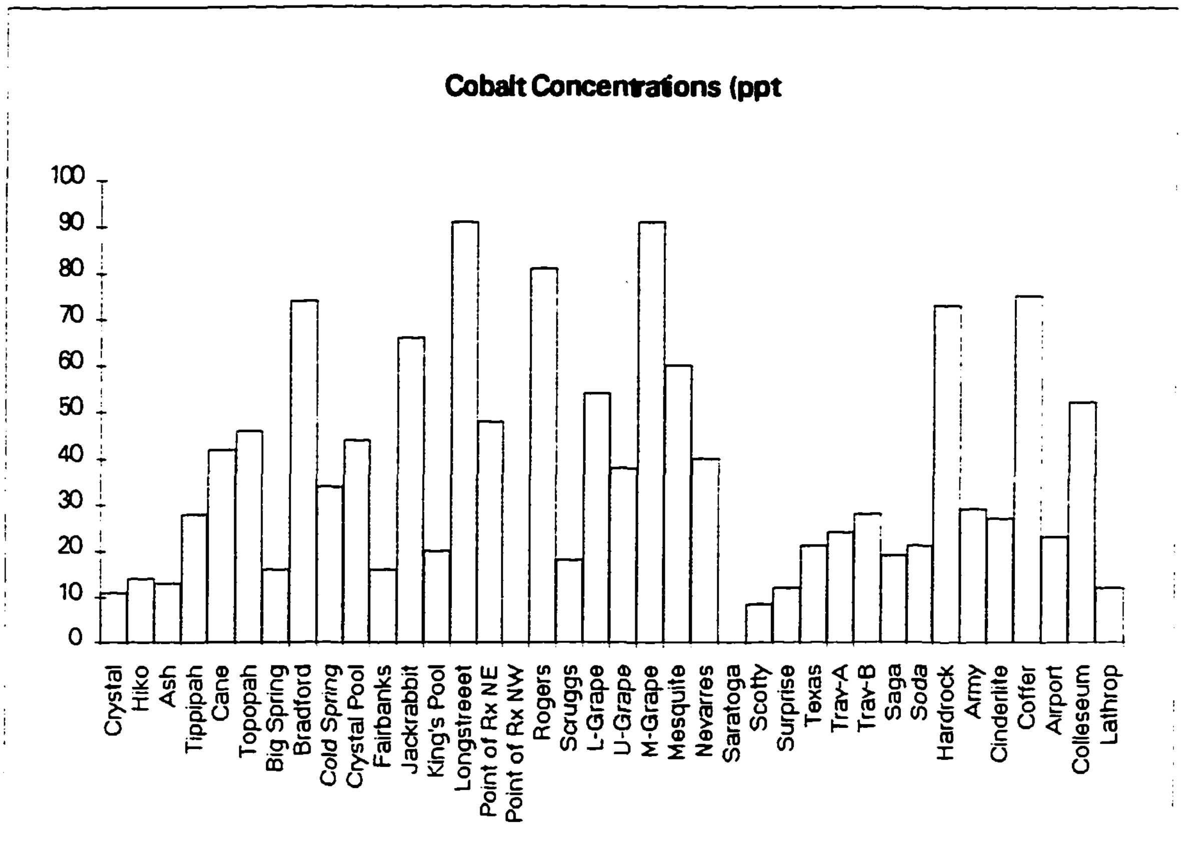

Titanium Concentrations (ppb)
4500
4000
3500
3000
2500
2000
1500
1000
500
0
Crystal
Hiko
Ash
Tippipah
Cane
Topopah
Big Spring
Bradford
Cold Spring
Crystal Pool
Fairbanks
Jackrabbit
King's Pool
Longstreet
Point of Rx NE
Point of Rx NW
Rogers
Scruggs
L-Grape
U-Grape
M-Grape
Mesquite
Nevarres
Saratoga
Scotty
Surprise
Texas
Trav-A
Trav-B
Saga
Soda
Hardrock
Army
Cinderlite
Coffer
Airport
Colleseum
Lathrop

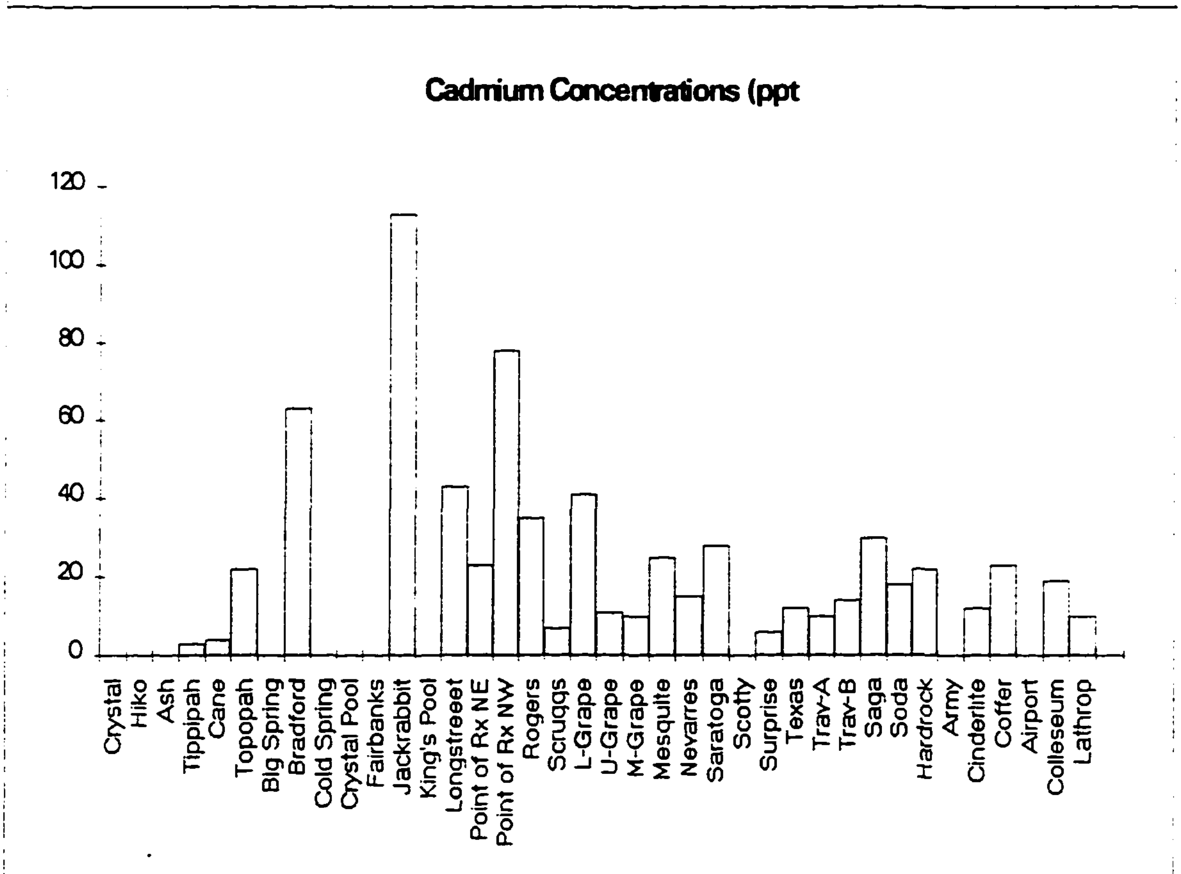

Vanadium Concentrations (ppb)
0
2
4
6
8
10
12
14
16
Crystal
Hiko
Ash
Tippipah
Cane
Topopah
Big Spring
Bradford
Cold Spring
Crystal Pool
Fairbanks
Jackrabbit
King's Pool
Longstreeet
Point of Rx NE
Point of Rx NW
Rogers
Scruggs
L-Grape
U-Grape
M-Grape
Mesquite
Nevarres
Saratoga
Scotty
Surprise
Texas
Trav-A
Trav-B
Saga
Soda
Hardrock
Army
Cinderlite
Coffer
Airport
Colleseum
Lathrop

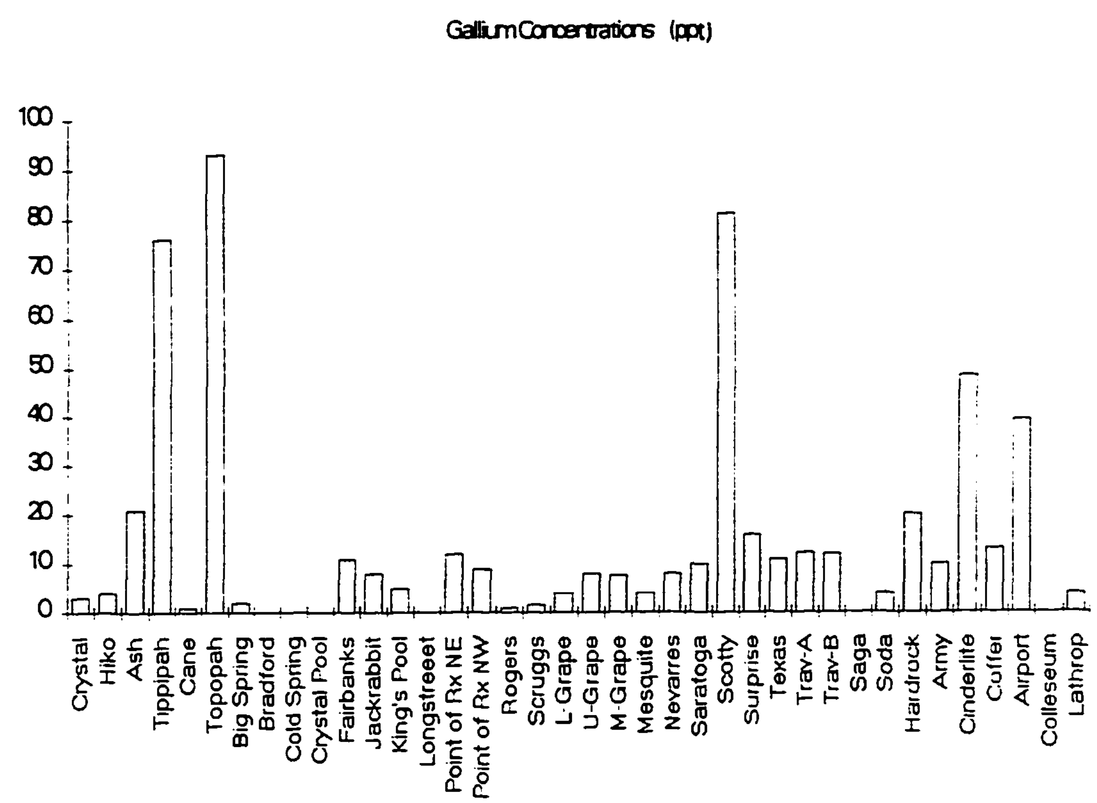

Chromium Concentration (ppb)
0
2
4
6
8
10
12
14
16
Crystal
Hiko
Ash
Tippipah
Cane
Topopah
Big Spring
Bradford
Cold Spring
Crystal Pool
Fairbanks
Jackrabbit
King's Pool
Longstreeet
Point of Rx NE
Point of Rx NW
Rogers
Scruggs
L-Grape
U Grape
M-Grape
Mesquite
Nevarres
Saratoga
Scotty
Surprise
Texas
Trav-A
Trav-B
Saga
Soda
Hardrock
Army
Cinderlite
Coffer
Airport
Colleseum
Lathrop

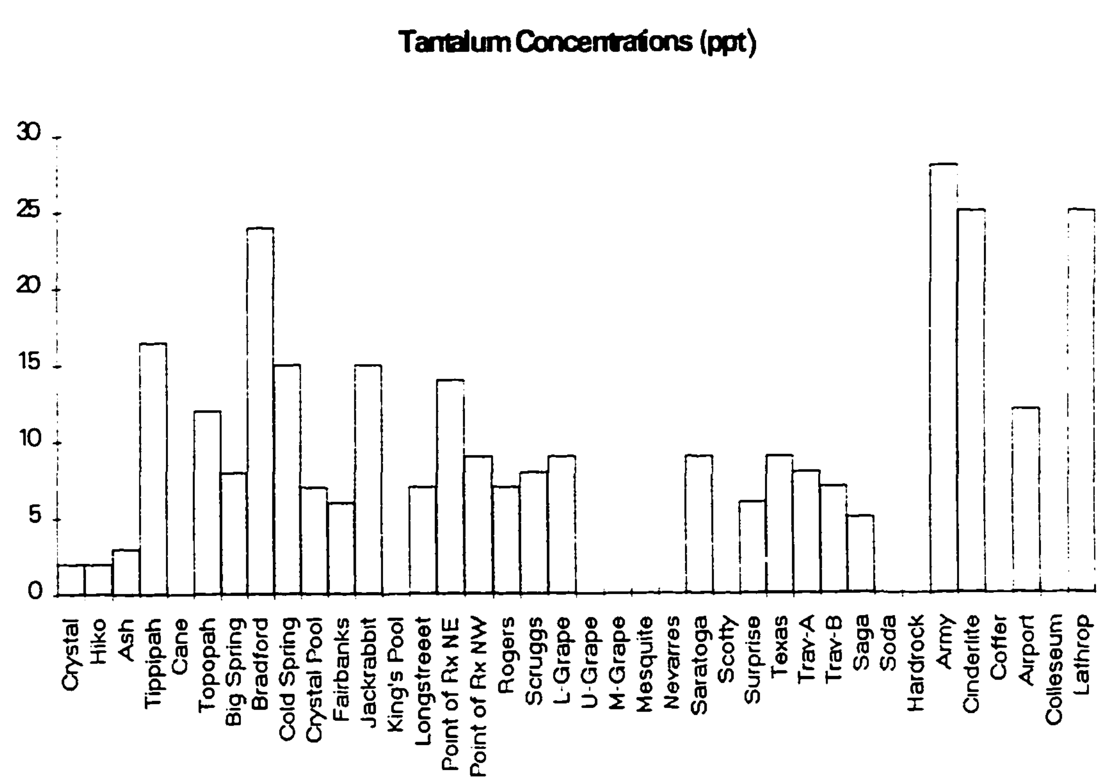

Lithium Concentrations (ppb)
0
50
100
150
200
250
300
350
400
Crystal
Hiko
Ash
Tippipah
Cane
Topopah
Big Spring
Bradford
Cold Spring
Crystal Pool
Fairbanks
Jackrabbit
King's Pool
Longstreeet
Point of Rx NE
Point of Rx NW
Rogers
Scruggs
L-Grape
U-Grape
M-Grape
Mesquite
Nevarres
Saratoga
Scotty
Surprise
Texas
Trav-A
Trav-B
Saga
Soda
Hardrock
Army
Cinderlite
Coffer
Airport
Colleseum
Lathrop

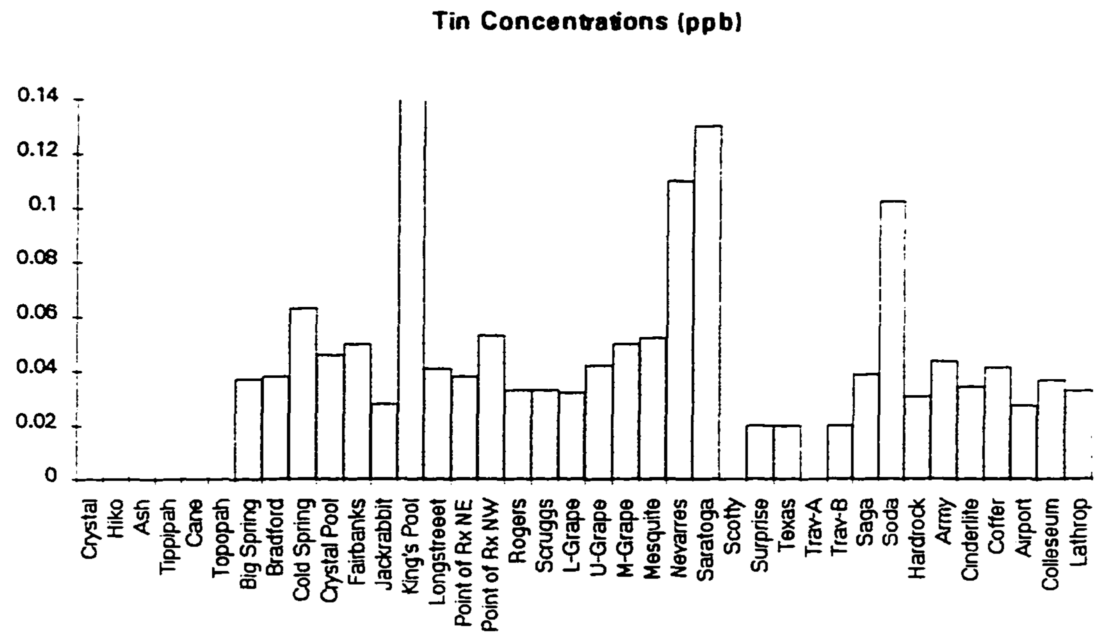

Selenium Concentrations (ppb)
0
1
2
3
4
5
6
Crystal
Hiko
Ash
Tippipah
Cane
Topopah
Big Spring
Bradford
Cold Spring
Crystal Pool
Fairbanks
Jackrabbit
King's Pool
Longstreeet
Point of Rx NE
Point of Rx NW
Rogers
Scruggs
L-Grape
U-Grape
M-Grape
Mesquite
Nevarres
Saratoga
Scotty
Surprise
Texas
Trav-A
Trav-B
Saga
Soda
Hardrock
Army
Cinderlite
Coffer
Airport
Colleseum
Lathrop

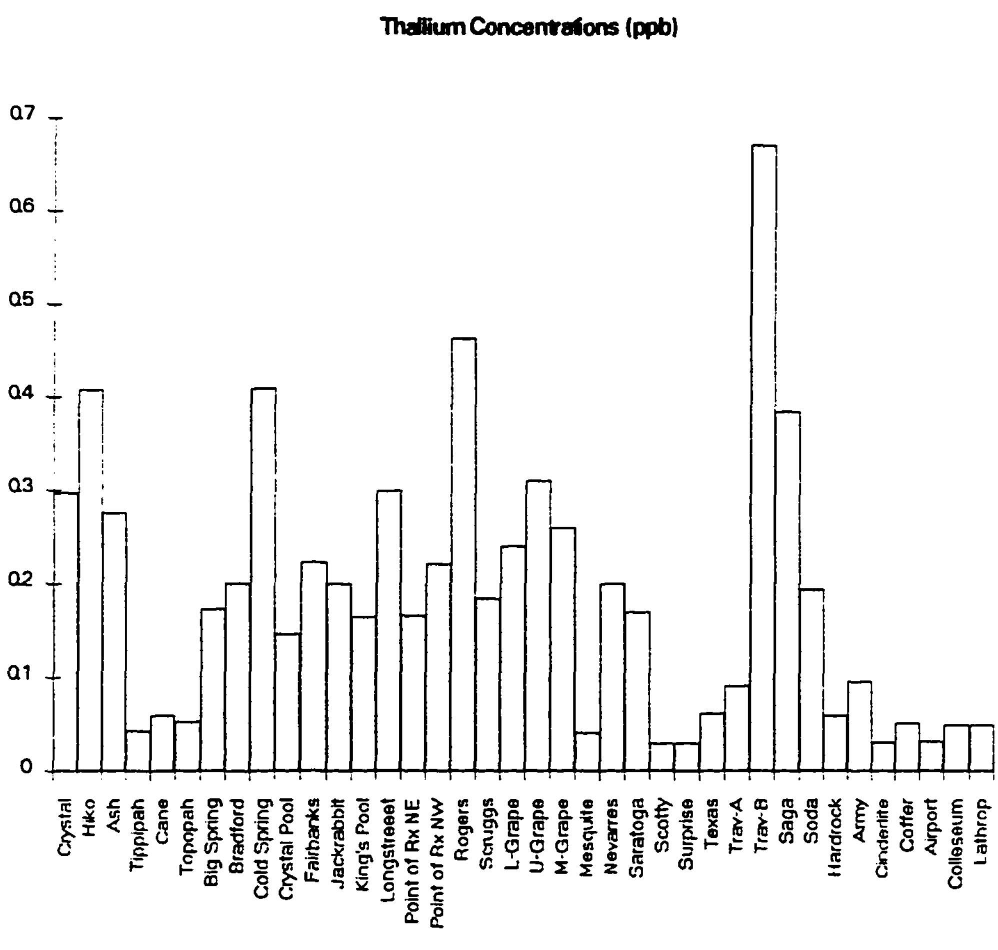

Cobalt Concentrations (ppt
100
90
80
70
60
50
40
30
20
10
0
Crystal
Hiko
Ash
Tippipah
Cane
Topopah
Big Spring
Bradford
Cold Spring
Crystal Pool
Fairbanks
Jackrabbit
King's Pool
Longstreeet
Point of Rx NE
Point of Rx NW
Rogers
Scruggs
L-Grape
U-Grape
M-Grape
Mesquite
Nevarres
Saratoga
Scotty
Surprise
Texas
Trav-A
Trav-B
Saga
Soda
Hardrock
Army
Cinderlite
Coffer
Airport
Colleseum
Lathrop

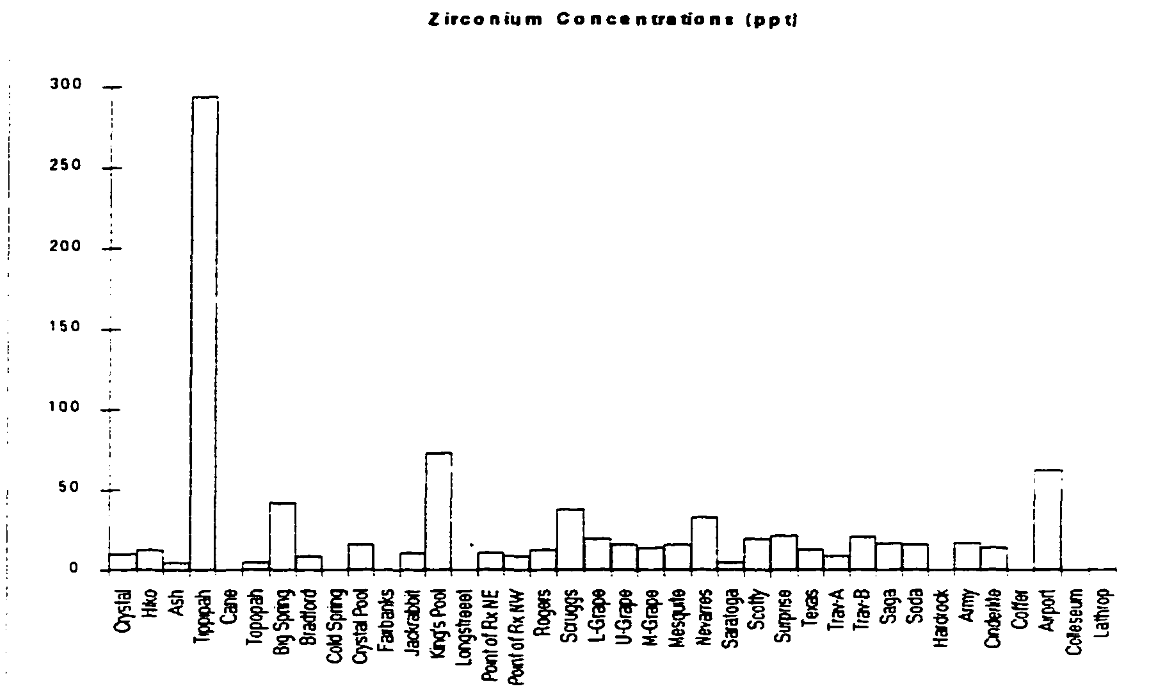

Cadmium Concentrations (ppt
120
100
80
60
40
20
0
Crystal
Hiko
Ash
Tippipah
Cane
Topopah
Big Spring
Bradford
Cold Spring
Crystal Pool
Fairbanks
Jackrabbit
King's Pool
Longstreeet
Point of Rx NE
Point of Rx NW
Rogers
Scruggs
L-Grape
U-Grape
M-Grape
Mesquite
Nevarres
Saratoga
Scotty
Surprise
Texas
Trav-A
Trav-B
Saga
Soda
Hardrock
Army
Cinderlite
Coffer
Airport
Colleseum
Lathrop

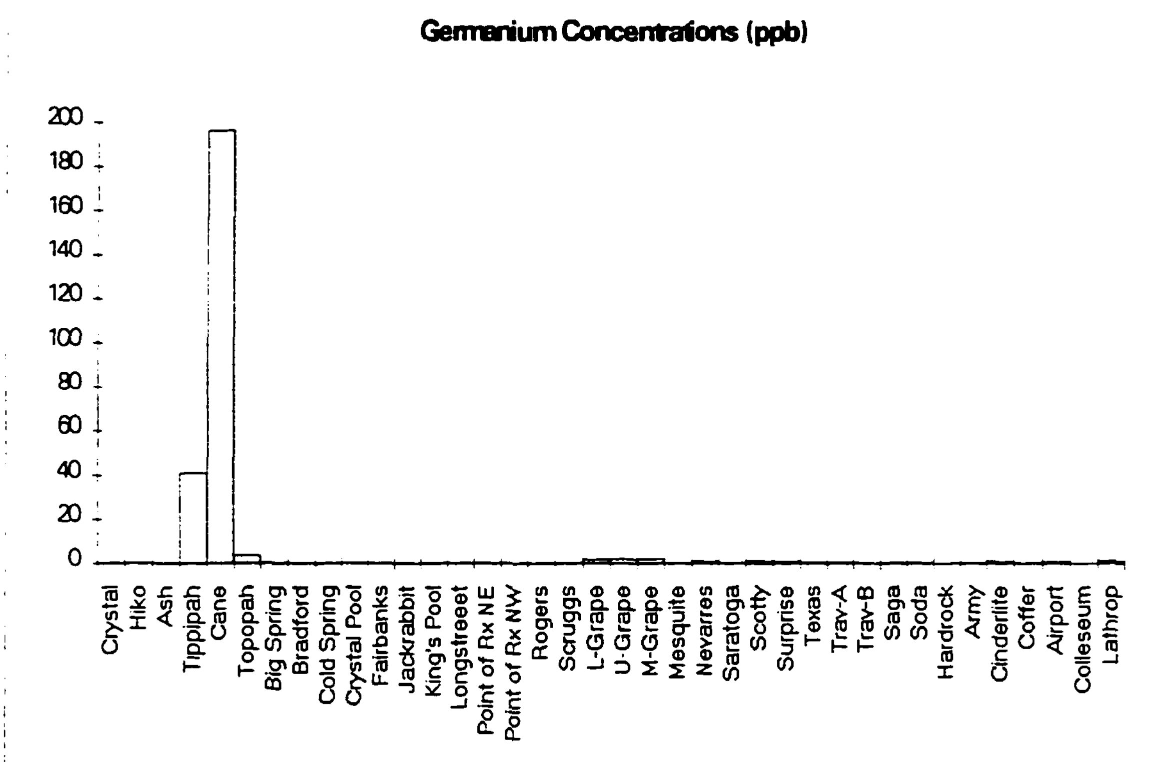

Gallium Concentrations (ppt)
0
10
20
30
40
50
60
70
80
90
100
Crystal
Hiko
Ash
Tippipah
Cane
Topopah
Big Spring
Bradford
Cold Spring
Crystal Pool
Fairbanks
Jackrabbit
King's Pool
Longstreeet
Point of Rx NE
Point of Rx NW
Rogers
Scruggs
L-Grape
U-Grape
M-Grape
Mesquite
Nevarres
Saratoga
Scotty
Surprise
Texas
Trav-A
Trav-B
Saga
Soda
Hardrock
Army
Cinderlite
Coffer
Airport
Colleseum
Lathrop

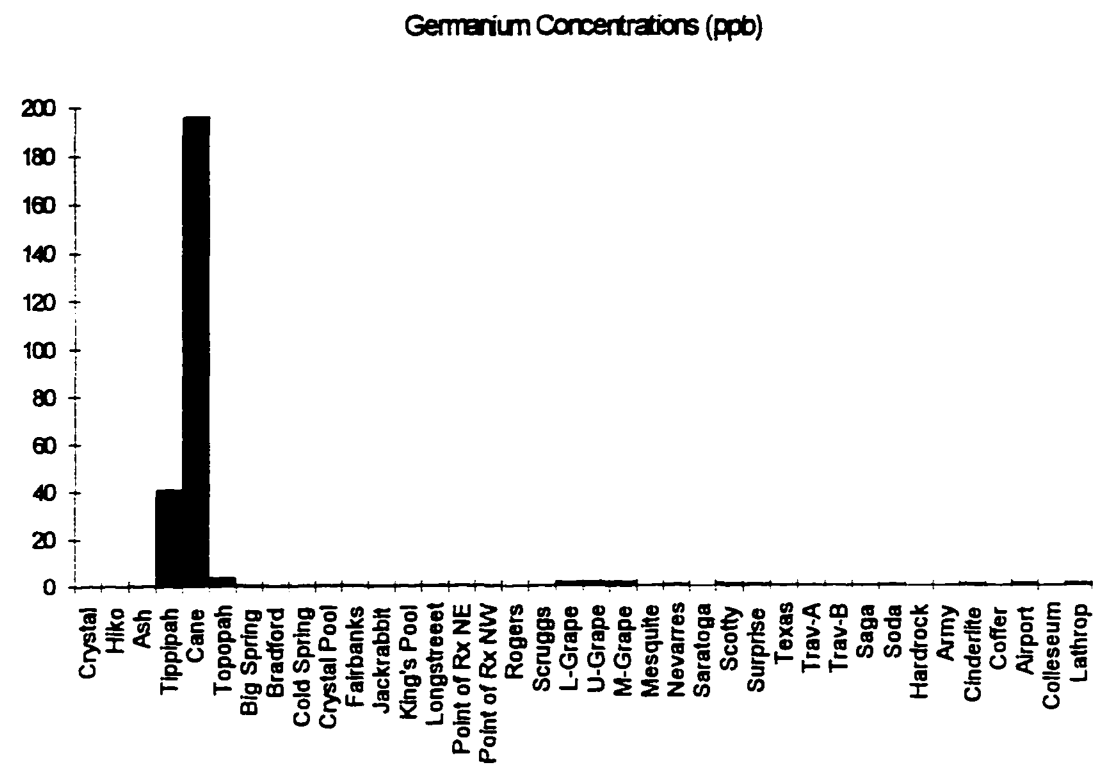

Tantalum Concentrations (ppt)
0
5
10
15
20
25
30
Crystal
Hiko
Ash
Tippipah
Cane
Topopah
Big Spring
Bradford
Cold Spring
Crystal Pool
Fairbanks
Jackrabbit
King's Pool
Longstreeet
Point of Rx NE
Point of Rx NW
Rogers
Scruggs
L-Grape
U-Grape
M-Grape
Mesquite
Nevarres
Saratoga
Scotty
Surprise
Texas
Trav-A
Trav-B
Saga
Soda
Hardrock
Army
Cinderlite
Coffer
Airport
Colleseum
Lathrop

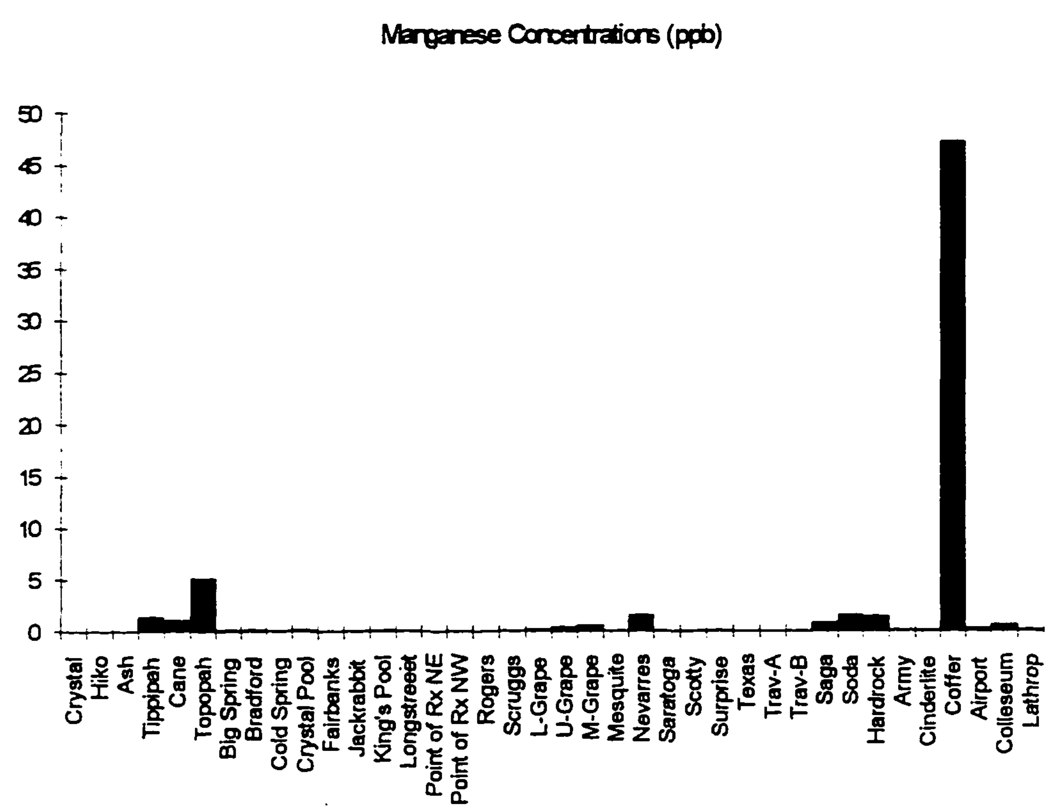

Tin Concentrations (ppb)
0.14
0.12
0.1
0.08
0.06
0.04
0.02
0
Crystal
Hiko
Ash
Tippipah
Cane
Topopah
Big Spring
Bradford
Cold Spring
Crystal Pool
Fairbanks
Jackrabbit
King's Pool
Longstreeet
Point of Rx NE
Point of Rx NW
Rogers
Scruggs
L-Grape
U-Grape
M-Grape
Mesquite
Nevarres
Saratoga
Scotty
Surprise
Texas
Trav-A
Trav-B
Saga
Soda
Hardrock
Army
Cinderlite
Coffer
Airport
Colleseum
Lathrop

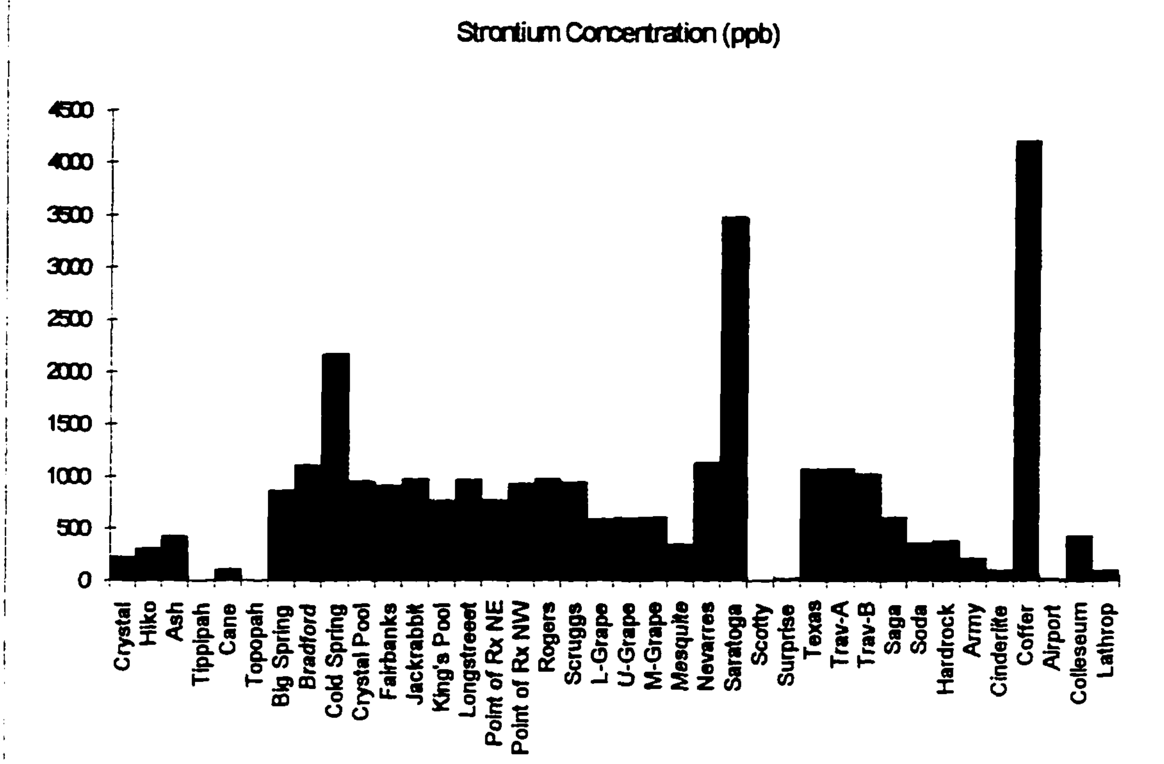

Thallium Concentrations (ppb)
0.7
0.6
0.5
0.4
0.3
0.2
0.1
0
Crystal
Hiko
Ash
Tippipah
Cane
Topopah
Big Spring
Bradford
Cold Spring
Crystal Pool
Fairbanks
Jackrabbit
King's Pool
Longstreeet
Point of Rx NE
Point of Rx NW
Rogers
Scruggs
L-Grape
U-Grape
M-Grape
Mesquite
Nevarres
Saratoga
Scotty
Surprise
Texas
Trav-A
Trav-B
Saga
Soda
Hardrock
Army
Cinderlite
Coffer
Airport
Colleseum
Lathrop

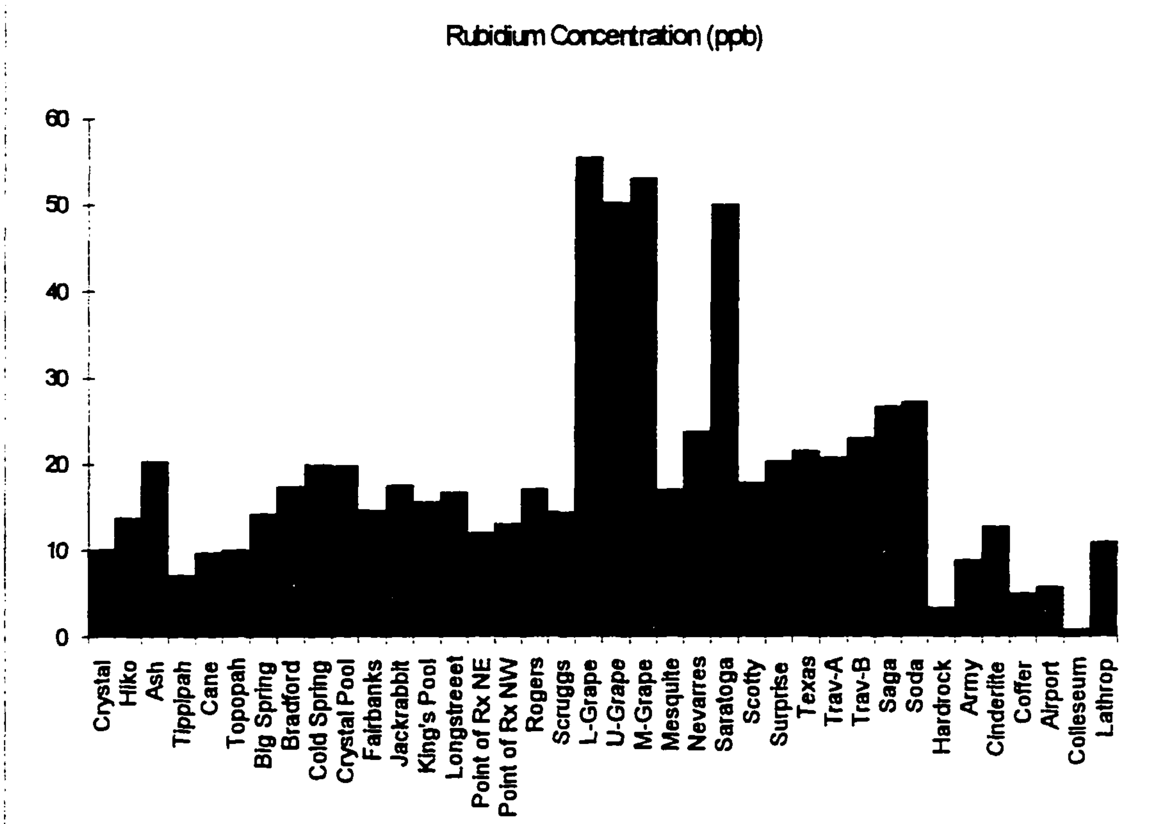

Zirconium Concentrations (ppt)
300
250
200
150
100
50
0
Crystal
Hiko
Ash
Tippipah
Cane
Topopah
Big Spring
Bradford
Cold Spring
Crystal Pool
Fairbanks
Jackrabbit
King's Pool
Longstreeel
Point of Rx NE
Point of Rx NW
Rogers
Scruggs
L-Grape
U-Grape
M-Grape
Mesquite
Nevarres
Saratoga
Scotty
Surprise
Texas
Trav-A
Trav-B
Saga
Soda
Hardrock
Army
Cinderlite
Coffer
Airport
Colleseum
Lathrop

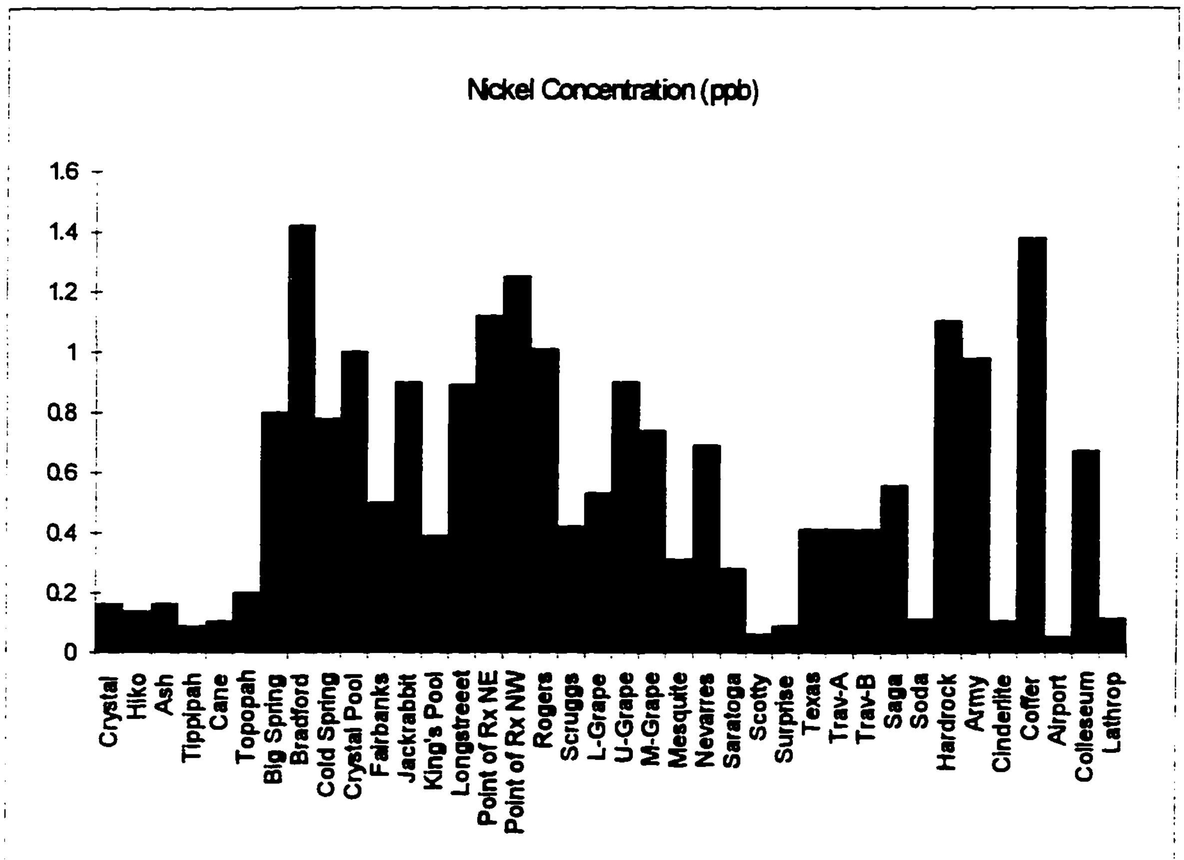

Germanium Concentrations (ppb)
200
180
160
140
120
100
80
60
40
20
0
Crystal
Hiko
Ash
Tippipah
Cane
Topopah
Big Spring
Bradford
Cold Spring
Crystal Pool
Fairbanks
Jackrabbit
King's Pool
Longstreeet
Point of Rx NE
Point of Rx NW
Rogers
Scruggs
L-Grape
U-Grape
M-Grape
Mesquite
Nevarres
Saratoga
Scotty
Surprise
Texas
Trav-A
Trav-B
Saga
Soda
Hardrock
Army
Cinderlite
Coffer
Airport
Colleseum
Lathrop


Germanium Concentrations (ppb)
0
20
40
60
80
100
120
140
160
180
200
Crystal
Hiko
Ash
Tippipah
Cane
Topopah
Big Spring
Bradford
Cold Spring
Crystal Pool
Fairbanks
Jackrabbit
King's Pool
Longstreeet
Point of Rx NE
Point of Rx NW
Rogers
Scruggs
L-Grape
U-Grape
M-Grape
Mesquite
Nevarres
Saratoga
Scotty
Surprise
Texas
Trav-A
Trav-B
Saga
Soda
Hardrock
Army
Cinderlite
Coffer
Airport
Colleseum
Lathrop

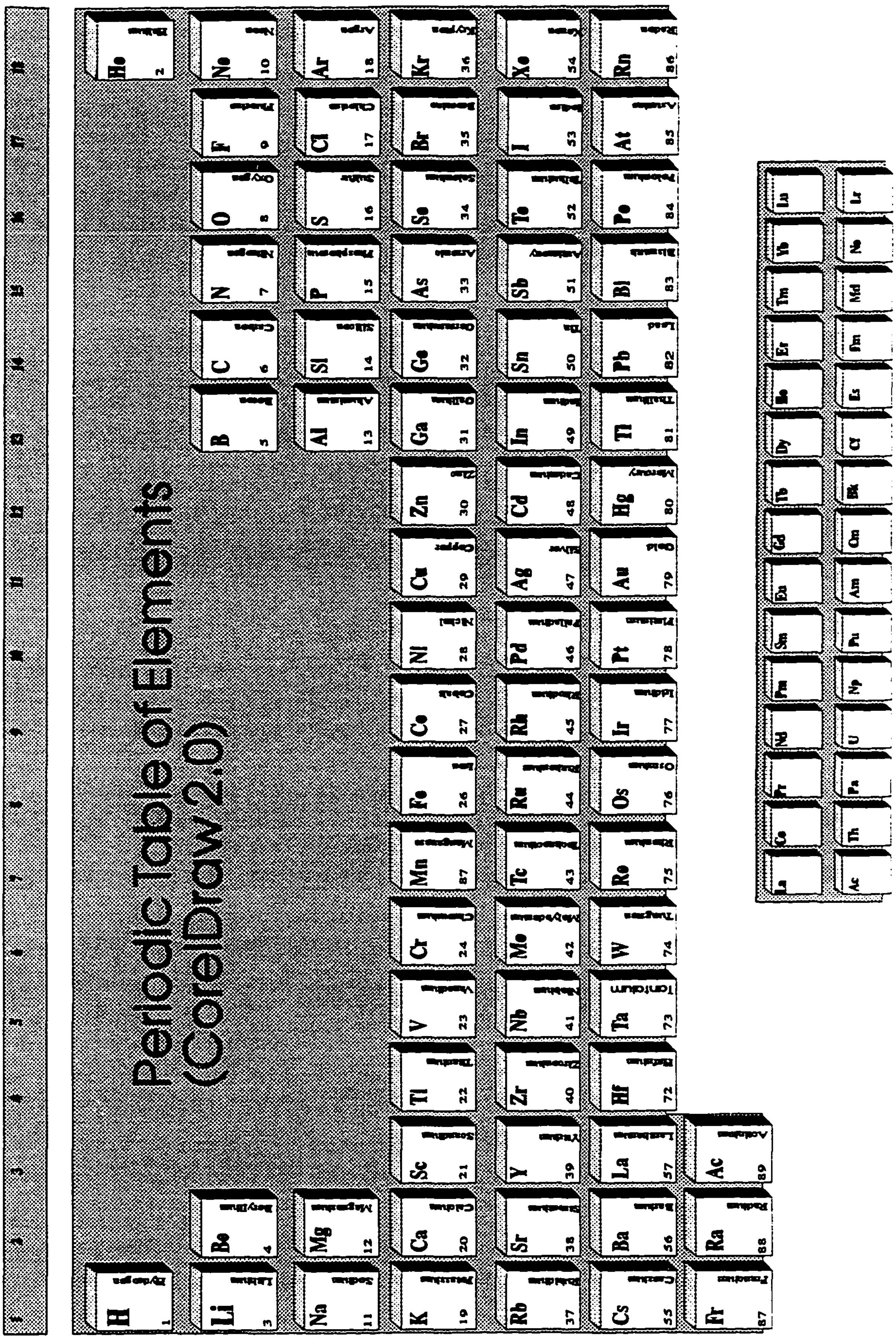

Manganese Concentrations (ppb)
0
5
10
15
20
25
30
35
40
45
50
Crystal
Hiko
Ash
Tippipah
Cane
Topopah
Big Spring
Bradford
Cold Spring
Crystal Pool
Fairbanks
Jackrabbit
King's Pool
Longstreeet
Point of Rx NE
Point of Rx NW
Rogers
Scruggs
L-Grape
U-Grape
M-Grape
Mesquite
Nevarres
Saratoga
Scotty
Surprise
Texas
Trav-A
Trav-B
Saga
Soda
Hardrock
Army
Cinderlite
Coffer
Airport
Colleseum
Lathrop


Strontium Concentration (ppb)
4500
4000
3500
3000
2500
2000
1500
1000
500
0
Crystal
Hiko
Ash
Tippipah
Cane
Topopah
Big Spring
Bradford
Cold Spring
Crystal Pool
Fairbanks
Jackrabbit
King's Pool
Longstreeet
Point of Rx NE
Point of Rx NW
Rogers
Scruggs
L-Grape
U-Grape
M-Grape
Mesquite
Nevarres
Saratoga
Scotty
Surprise
Texas
Trav-A
Trav-B
Saga
Soda
Hardrock
Army
Cinderlite
Coffer
Airport
Colleseum
Lathrop

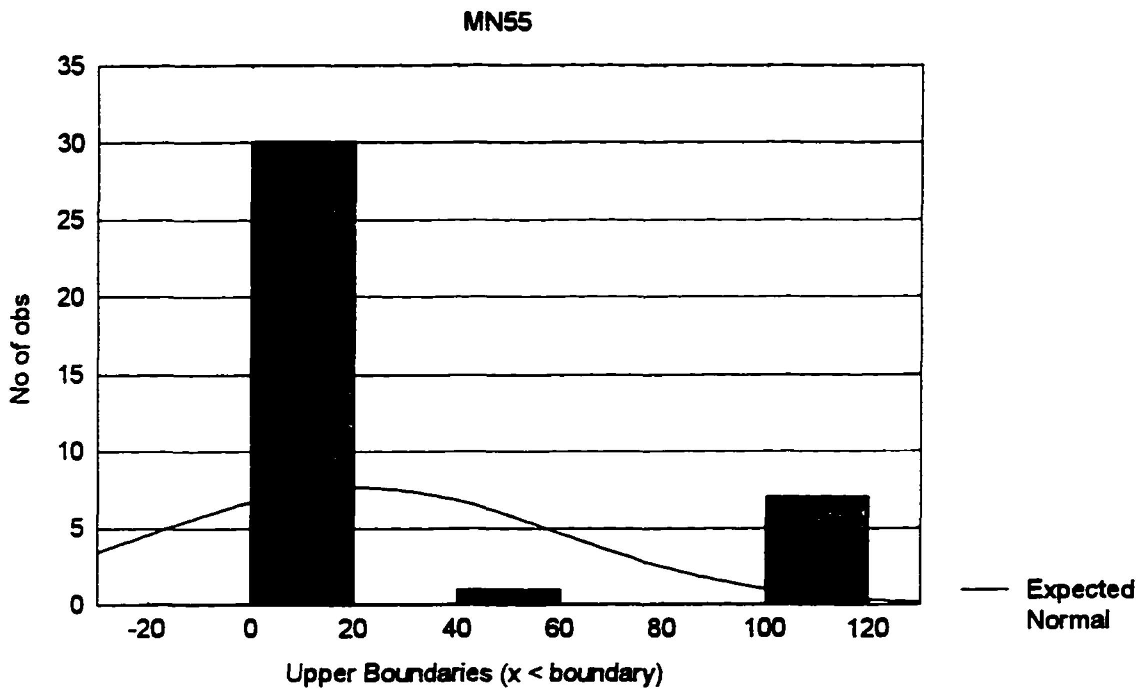

Rubidium Concentration (ppb)
60
50
40
30
20
10
0
Crystal
Hiko
Ash
Tippipah
Cane
Topopah
Big Spring
Bradford
Cold Spring
Crystal Pool
Fairbanks
Jackrabbit
King's Pool
Longstreeet
Point of Rx NE
Point of Rx NW
Rogers
Scruggs
L-Grape
U-Grape
M-Grape
Mesquite
Nevarres
Saratoga
Scotty
Surprise
Texas
Trav-A
Trav-B
Saga
Soda
Hardrock
Army
Cinderlite
Coffer
Airport
Colleseum
Lathrop

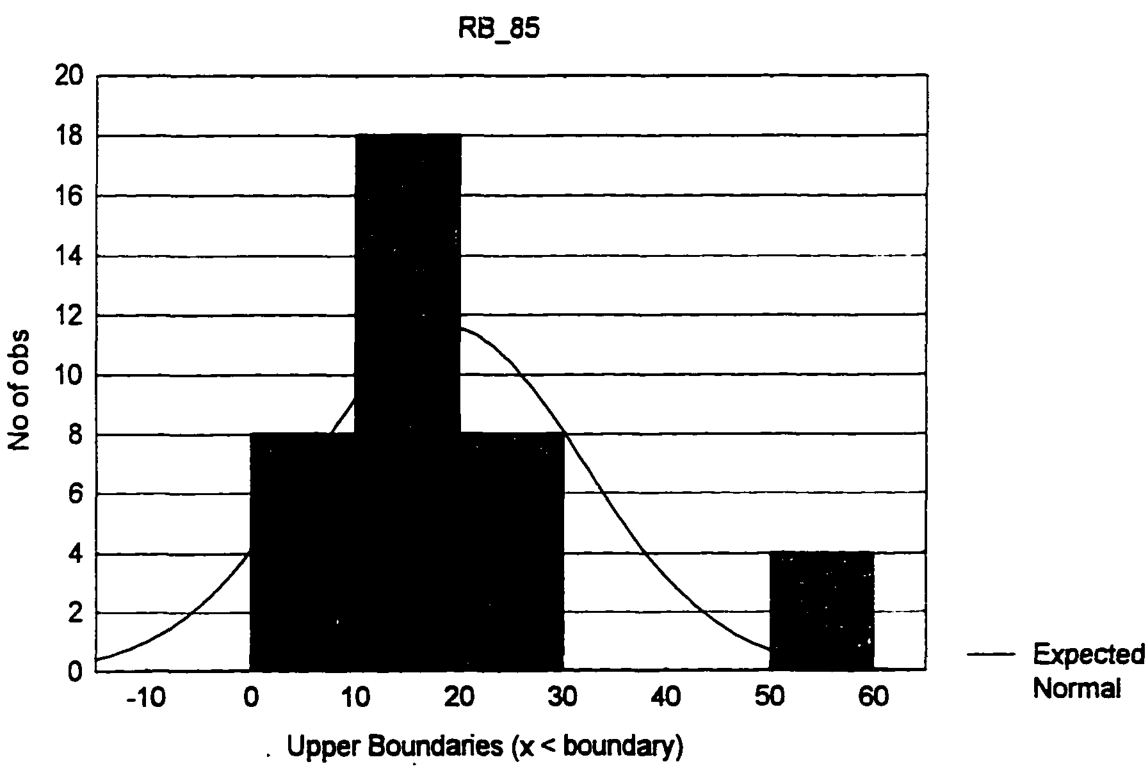

Nickel Concentration (ppb)
1.6
1.4
1.2
1
0.8
0.6
0.4
0.2
0
Crystal
Hiko
Ash
Tippipah
Cane
Topopah
Big Spring
Bradford
Cold Spring
Crystal Pool
Fairbanks
Jackrabbit
King's Pool
Longstreeet
Point of Rx NE
Point of Rx NW
Rogers
Scruggs
L-Grape
U-Grape
M-Grape
Mesquite
Nevarres
Saratoga
Scotty
Surprise
Texas
Trav-A
Trav-B
Saga
Soda
Hardrock
Army
Cinderlite
Coffer
Airport
Colleseum
Lathrop

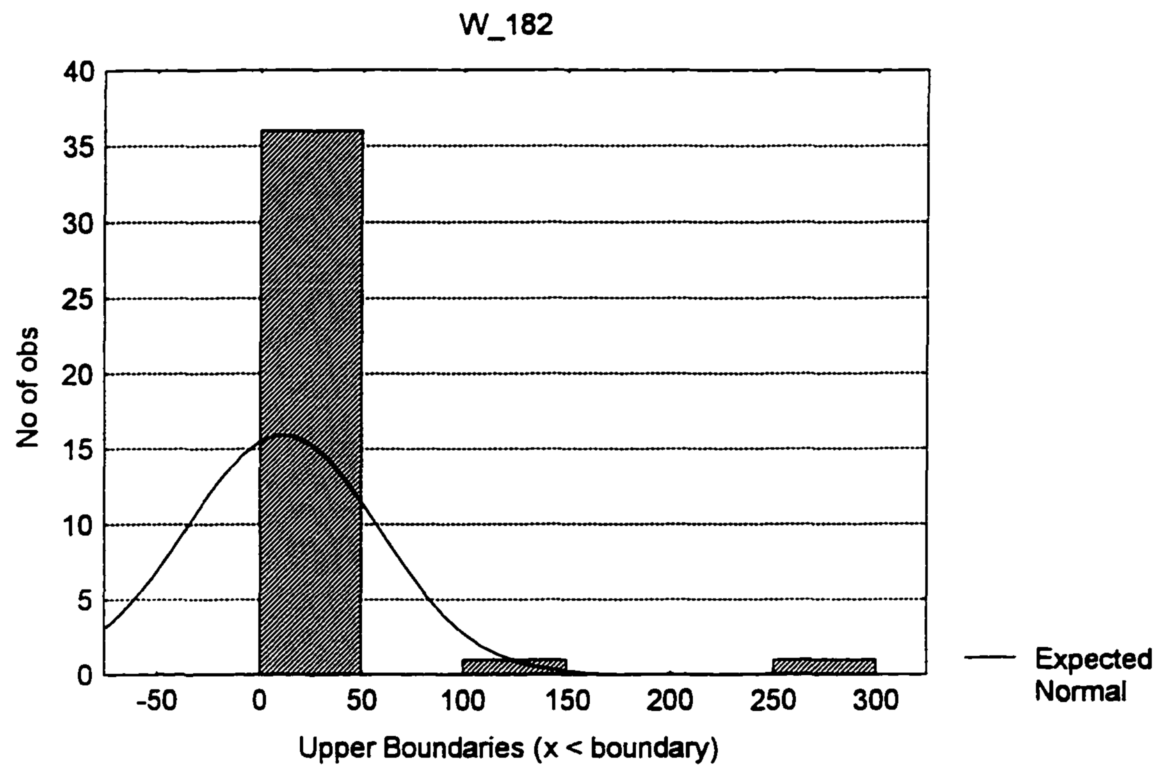
Appendix B: Periodic Table of Elements

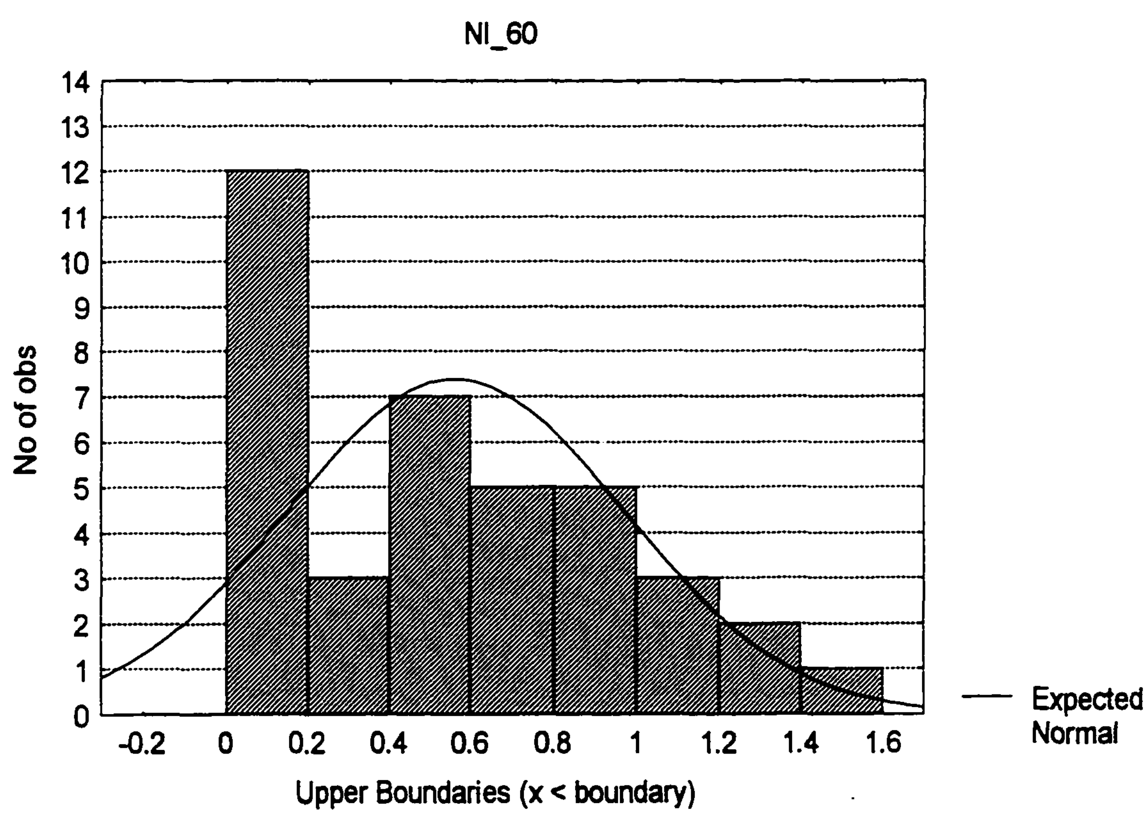

Periodic Table of Elements
(CorelDraw 2.0)

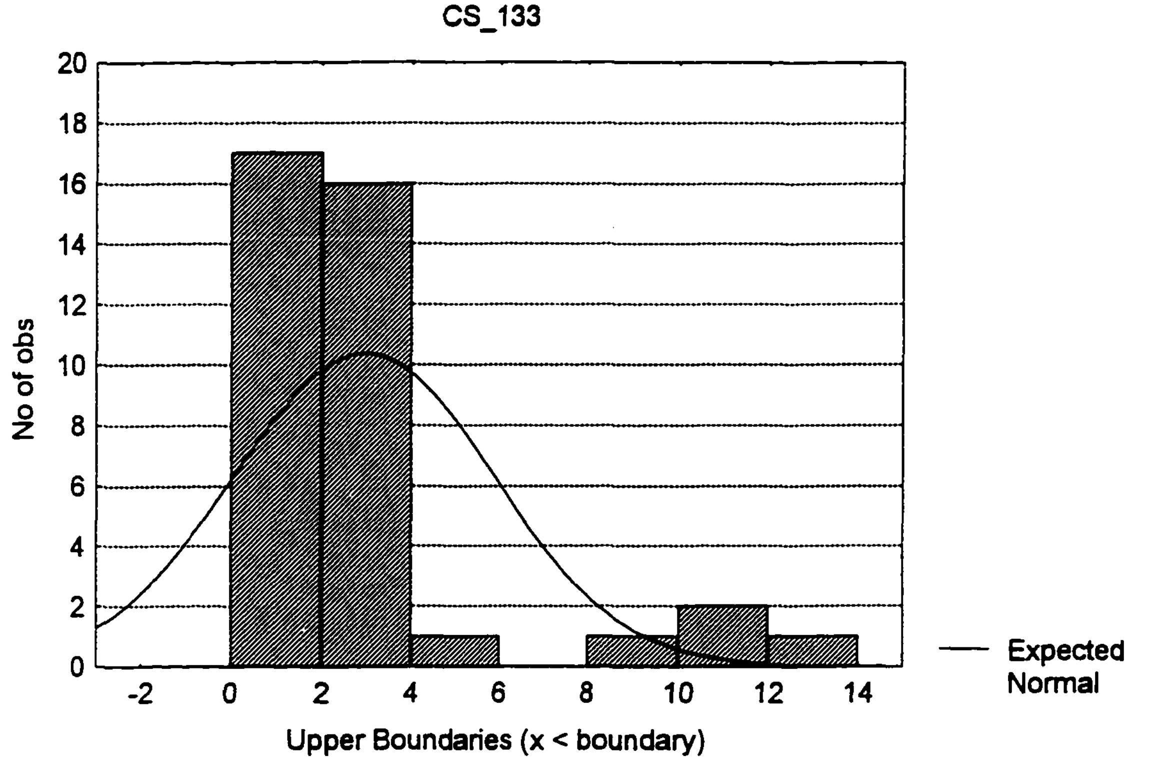
Appendix C: Histograms and Stem and Leaf Plots

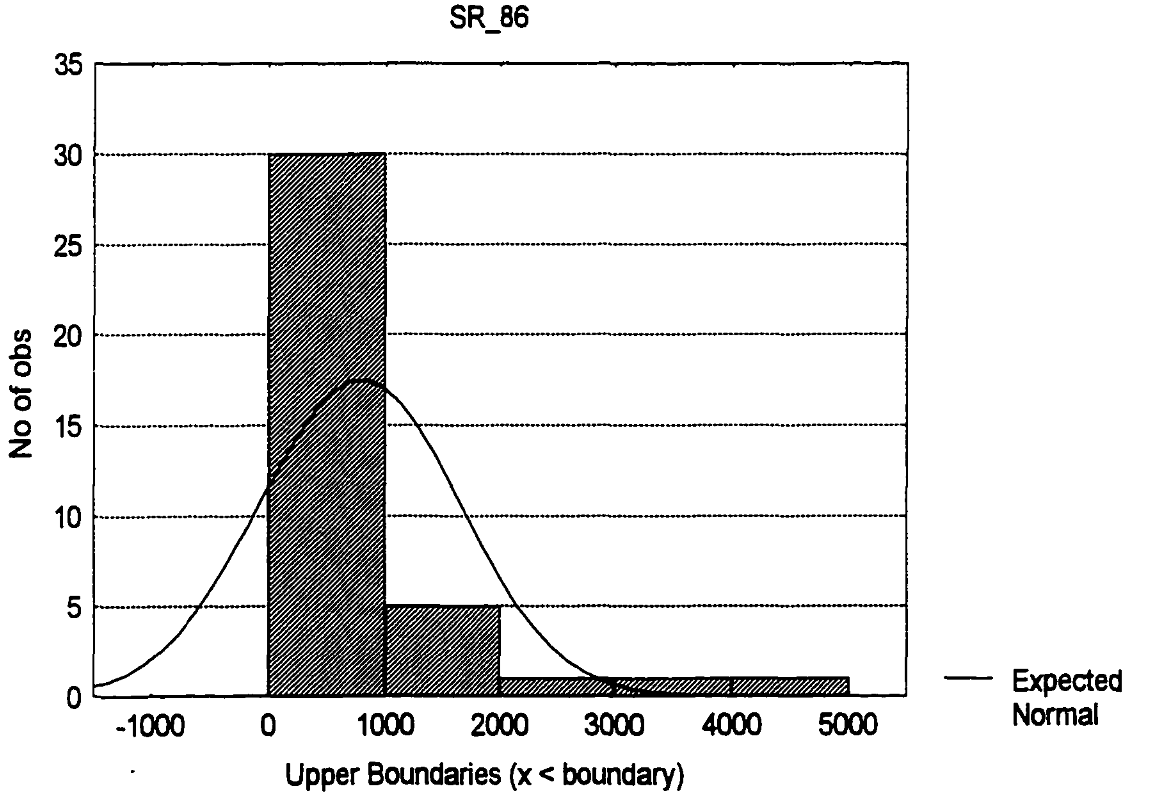

MN55
35
30
25
20
15
10
5
0
No of obs
-20
0
20
40
60
80
100
120
Upper Boundaries (x < boundary)
Expected Normal

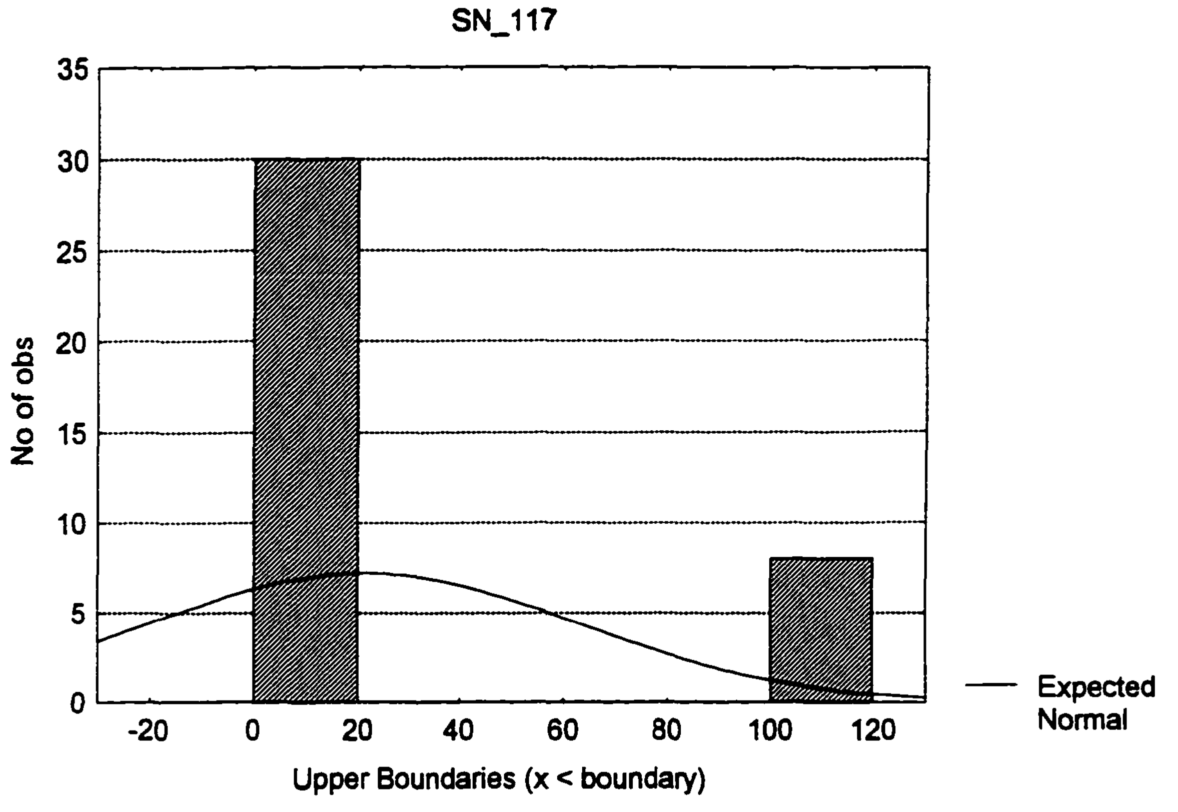

RB_85
20
18
16
14
12
10
8
6
4
2
0
No of obs
-10
0
10
20
30
40
50
60
Upper Boundaries (x < boundary)
Expected Normal

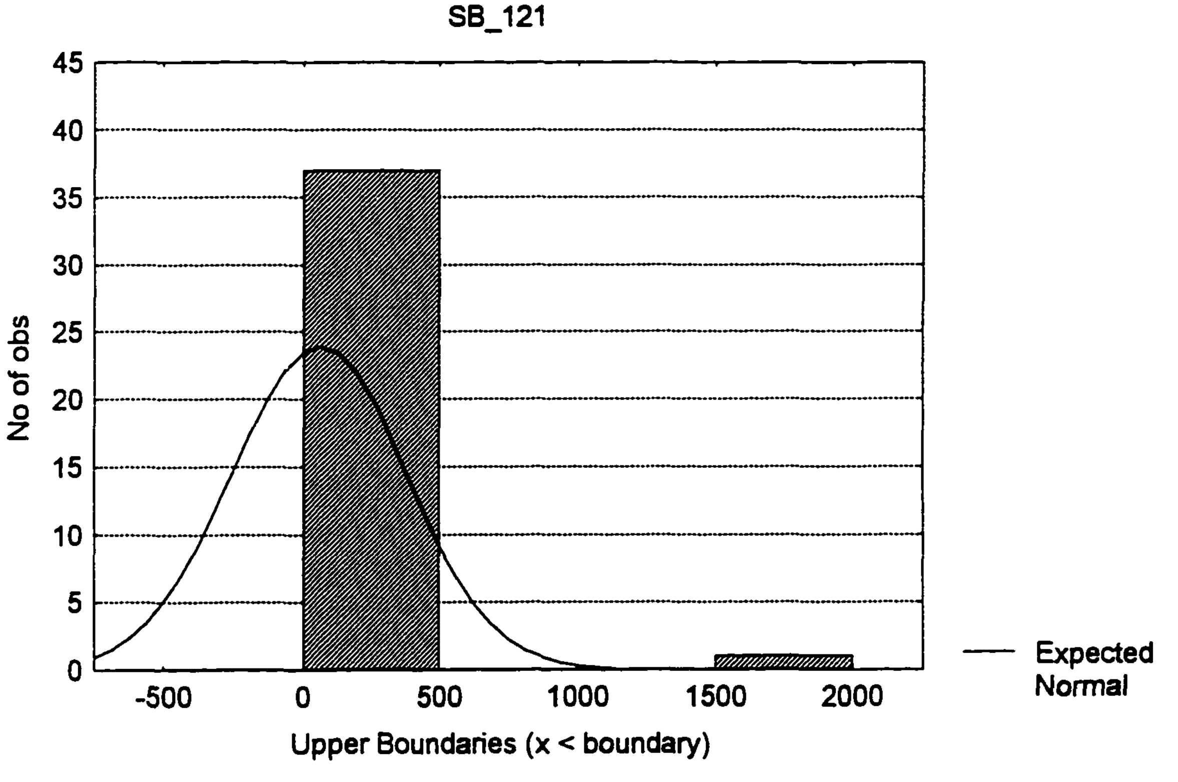

W_182
No of obs
40
35
30
25
20
15
10
5
0
-50
0
50
100
150
200
250
300
Upper Boundaries (x < boundary)
Expected Normal

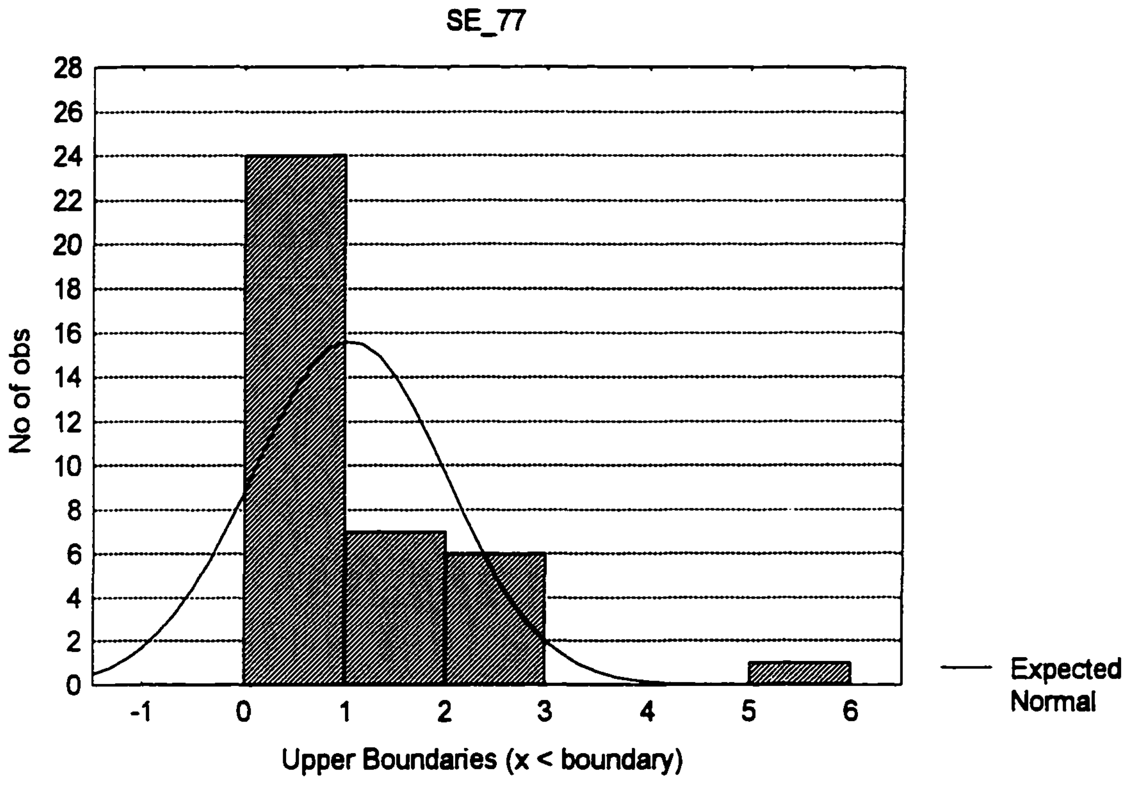

NI_60
No of obs
14
13
12
11
10
9
8
7
6
5
4
3
2
1
0
-0.2
0
0.2
0.4
0.6
0.8
1
1.2
1.4
1.6
Upper Boundaries (x < boundary)
Expected Normal

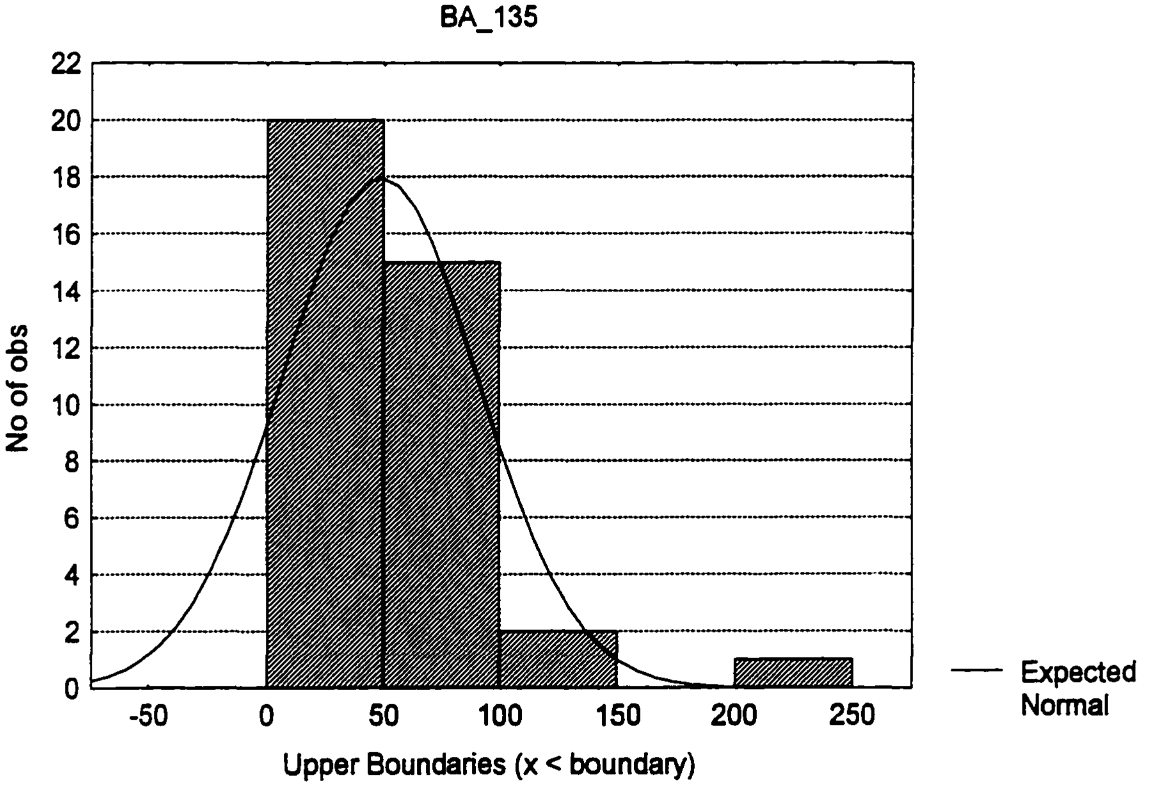

CS_133
No of obs
20
18
16
14
12
10
8
6
4
2
0
-2
0
2
4
6
8
10
12
14
Upper Boundaries (x < boundary)
— Expected Normal

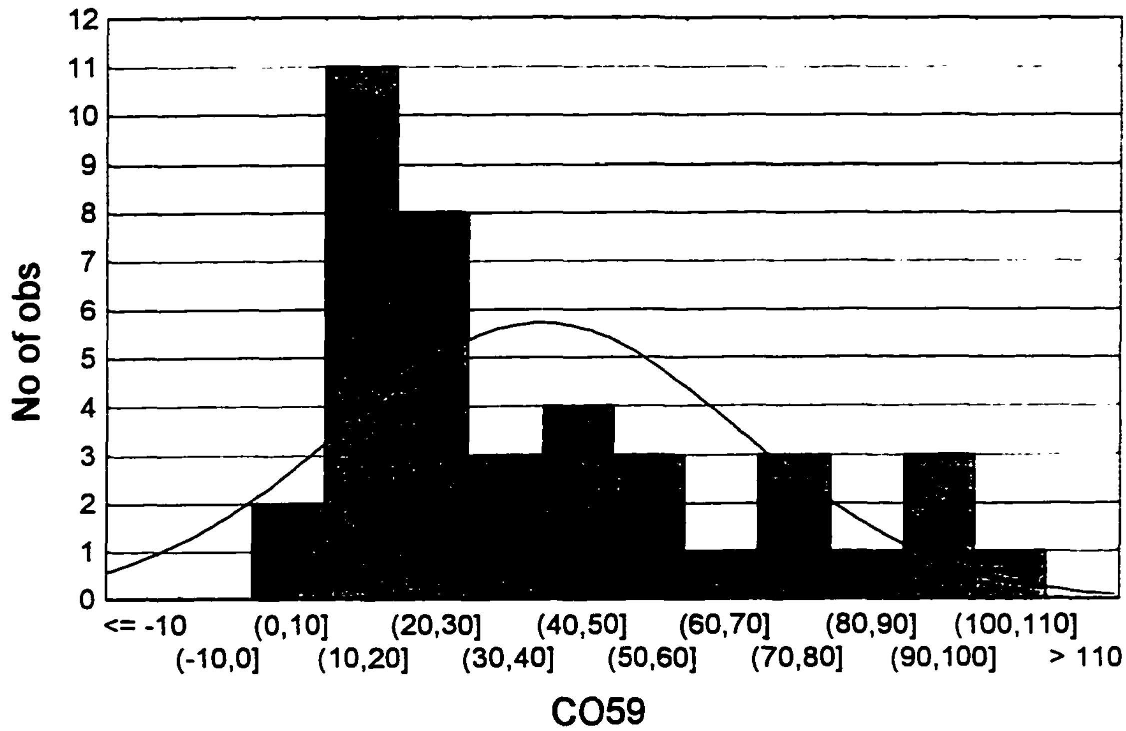

SR_86
No of obs
35
30
25
20
15
10
5
0
-1000
0
1000
2000
3000
4000
5000
Upper Boundaries (x < boundary)
— Expected Normal

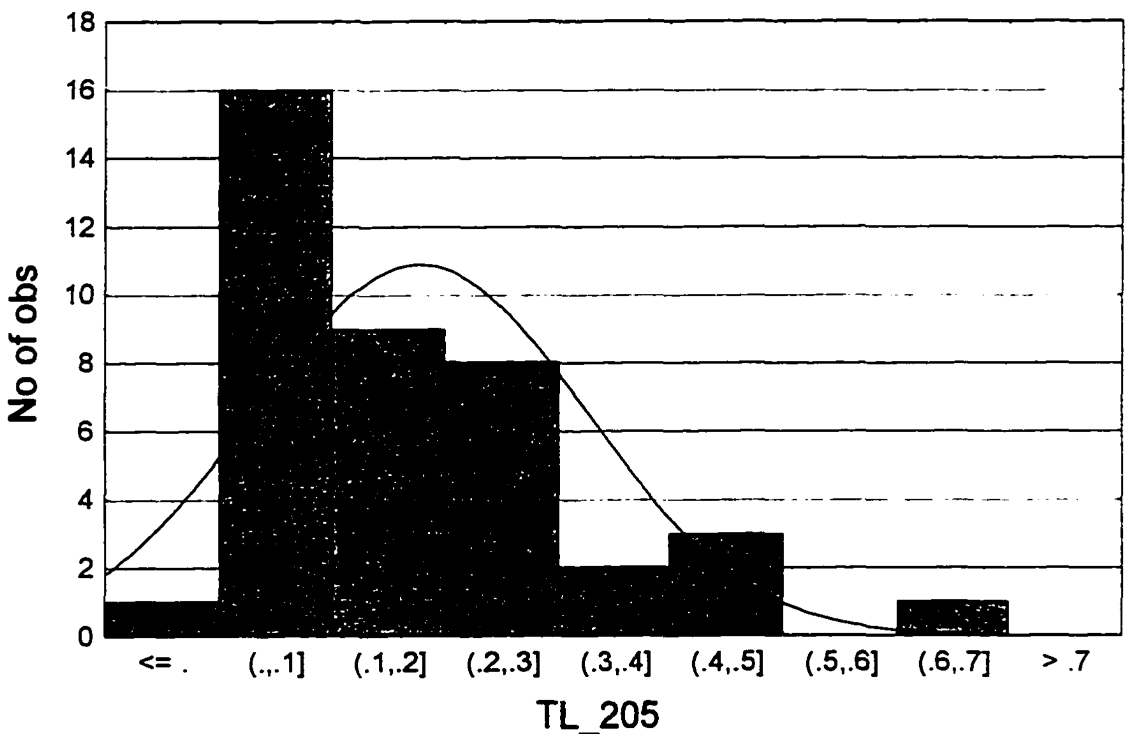

SN_117
No of obs
35
30
25
20
15
10
5
0
-20
0
20
40
60
80
100
120
Upper Boundaries (x < boundary)
Expected Normal

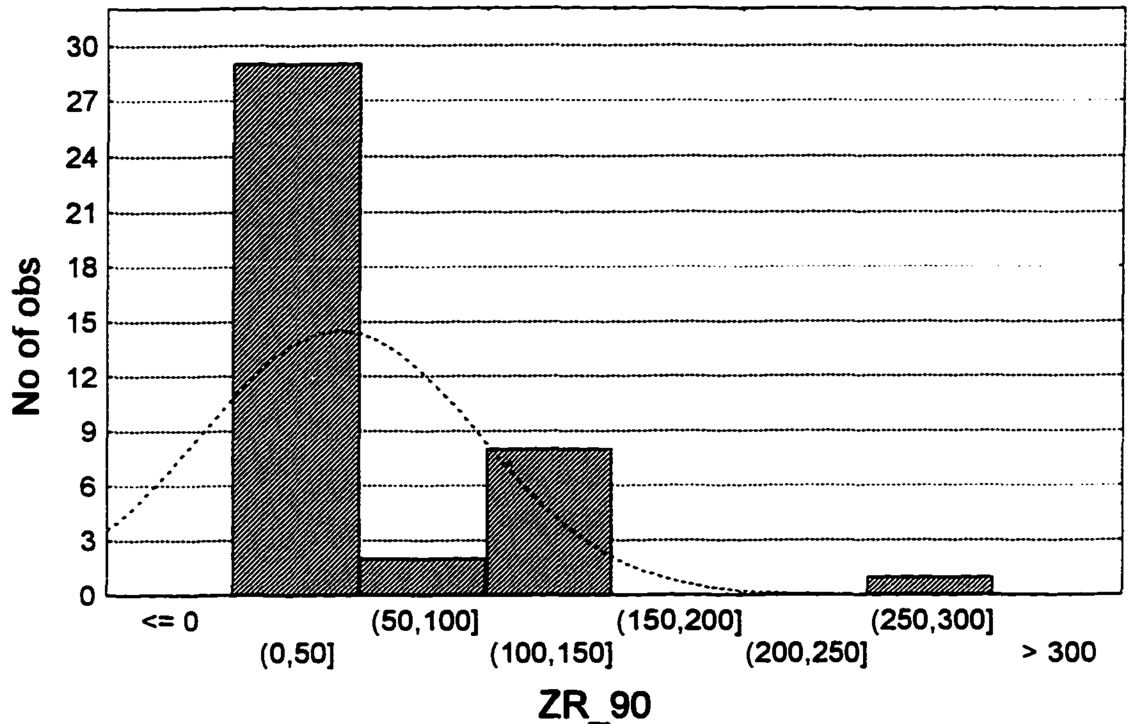

SB_121
No of obs
45
40
35
30
25
20
15
10
5
0
-500
0
500
1000
1500
2000
Upper Boundaries (x < boundary)
Expected Normal

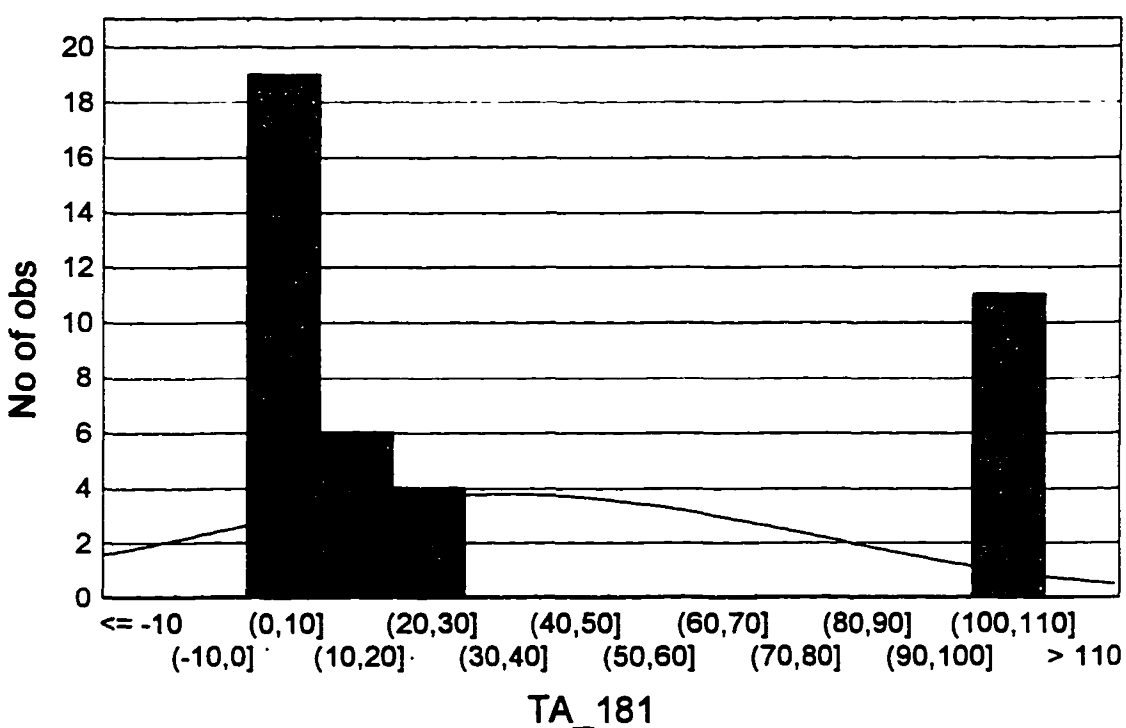

SE_77
28
26
24
22
20
18
16
14
12
10
8
6
4
2
0
No of obs
-1
0
1
2
3
4
5
6
Upper Boundaries (x < boundary)
Expected Normal

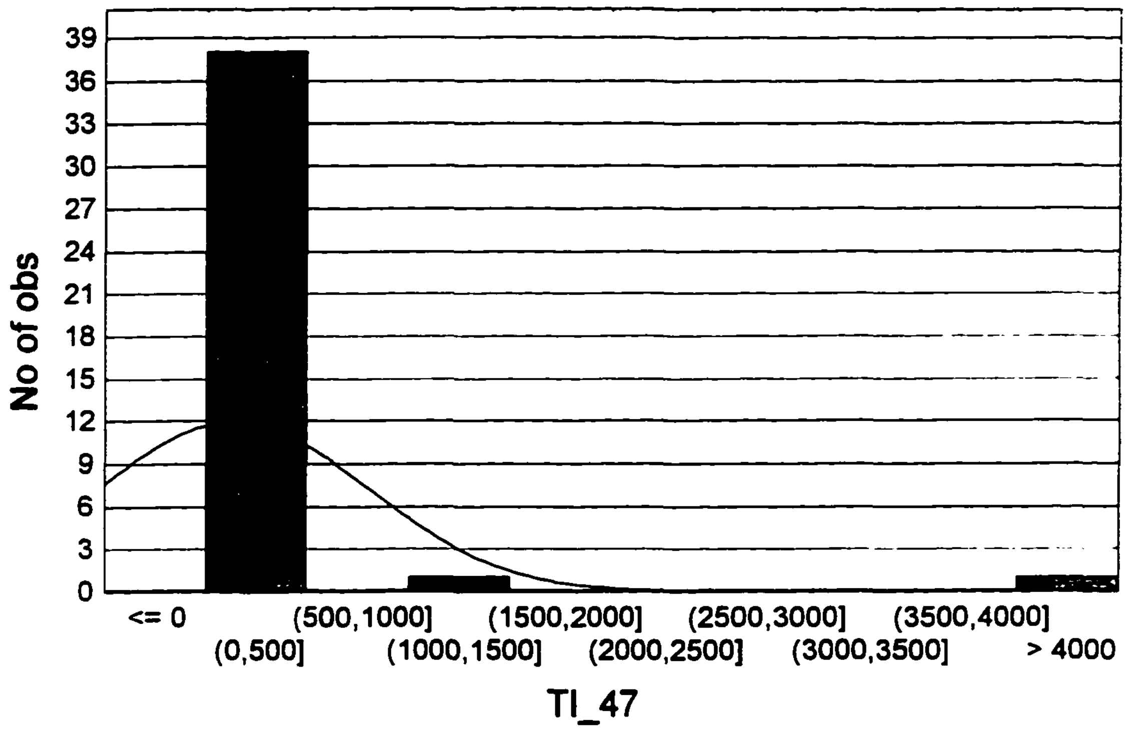

BA_135
22
20
18
16
14
12
10
8
6
4
2
0
No of obs
-50
0
50
100
150
200
250
Upper Boundaries (x < boundary)
Expected Normal

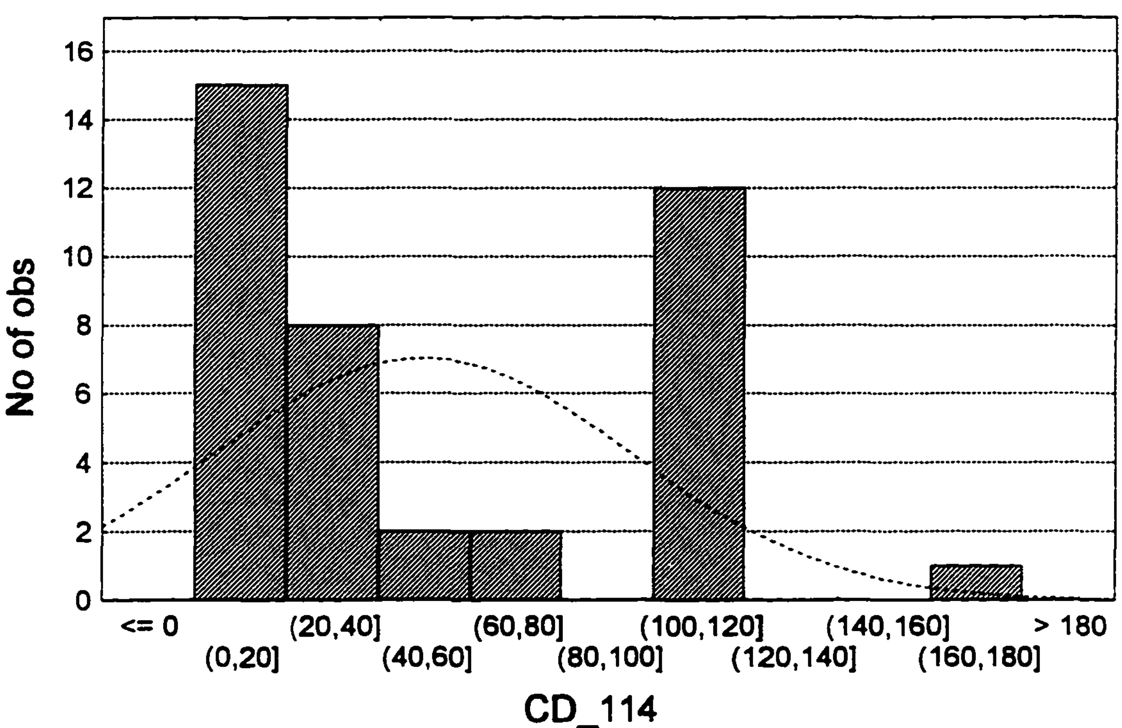

No of obs
12
11
10
9
8
7
6
5
4
3
2
1
0
<= -10
(-10,0]
(0,10]
(10,20]
(20,30]
(30,40]
(40,50]
(50,60]
(60,70]
(70,80]
(80,90]
(90,100]
(100,110]
> 110
CO59

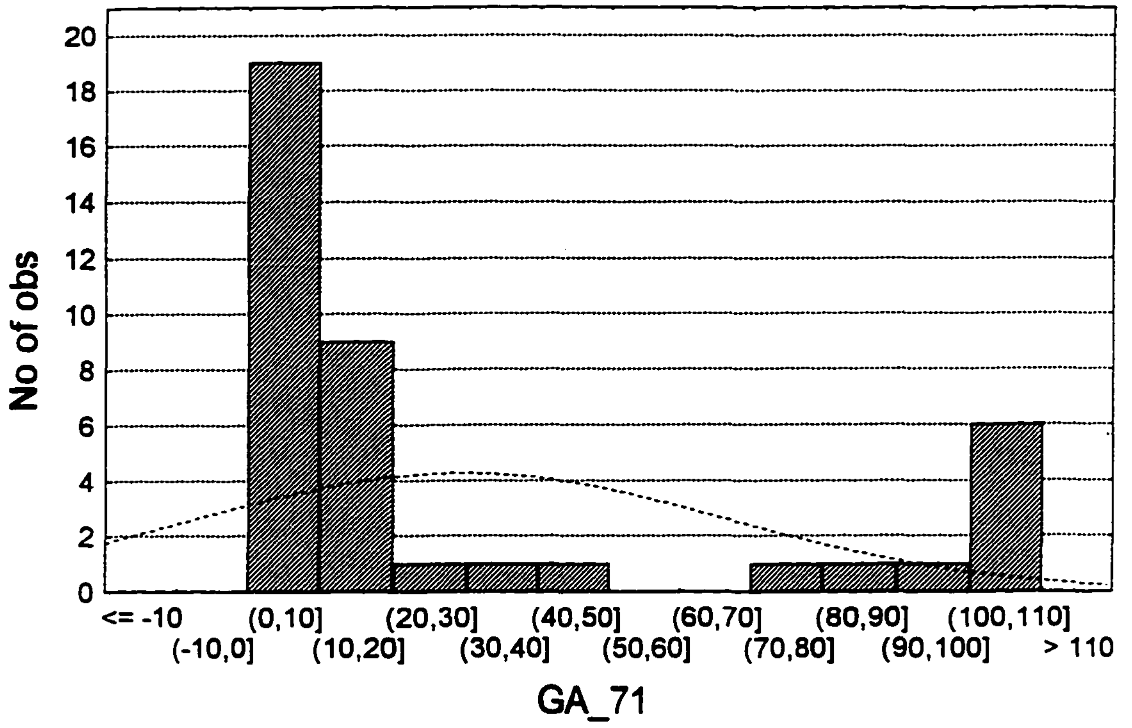

No of obs
18
16
14
12
10
8
6
4
2
0
<= .
(.,.1]
(.1,.2]
(.2,.3]
(.3,.4]
(.4,.5]
(.5,.6]
(.6,.7]
> .7
TL_205


No of obs
30
27
24
21
18
15
12
9
6
3
0
<= 0
(0,50]
(50,100]
(100,150]
(150,200]
(200,250]
(250,300]
> 300
ZR_90

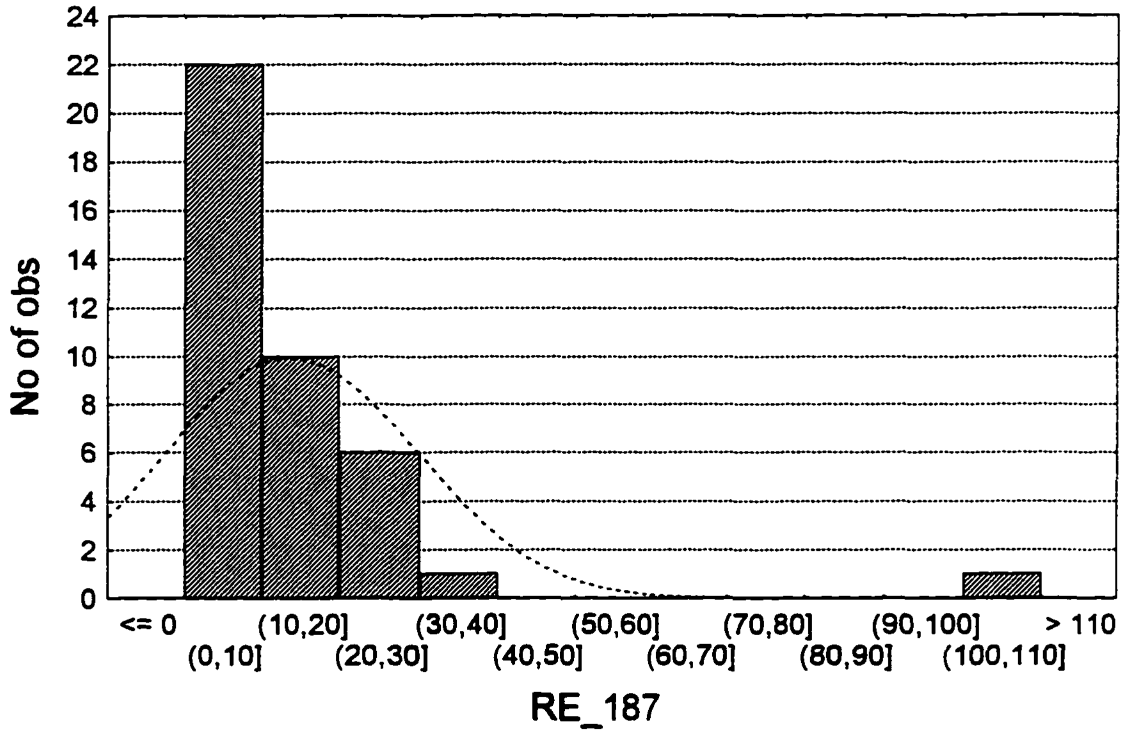

No of obs
20
18
16
14
12
10
8
6
4
2
0
<= -10
(-10,0]
(0,10]
(10,20]
(20,30]
(30,40]
(40,50]
(50,60]
(60,70]
(70,80]
(80,90]
(90,100]
(100,110]
> 110
TA_181


No of obs
39
36
33
30
27
24
21
18
15
12
9
6
3
0
<= 0
(0,500]
(500,1000]
(1000,1500]
(1500,2000]
(2000,2500]
(2500,3000]
(3000,3500]
(3500,4000]
> 4000
TI_47

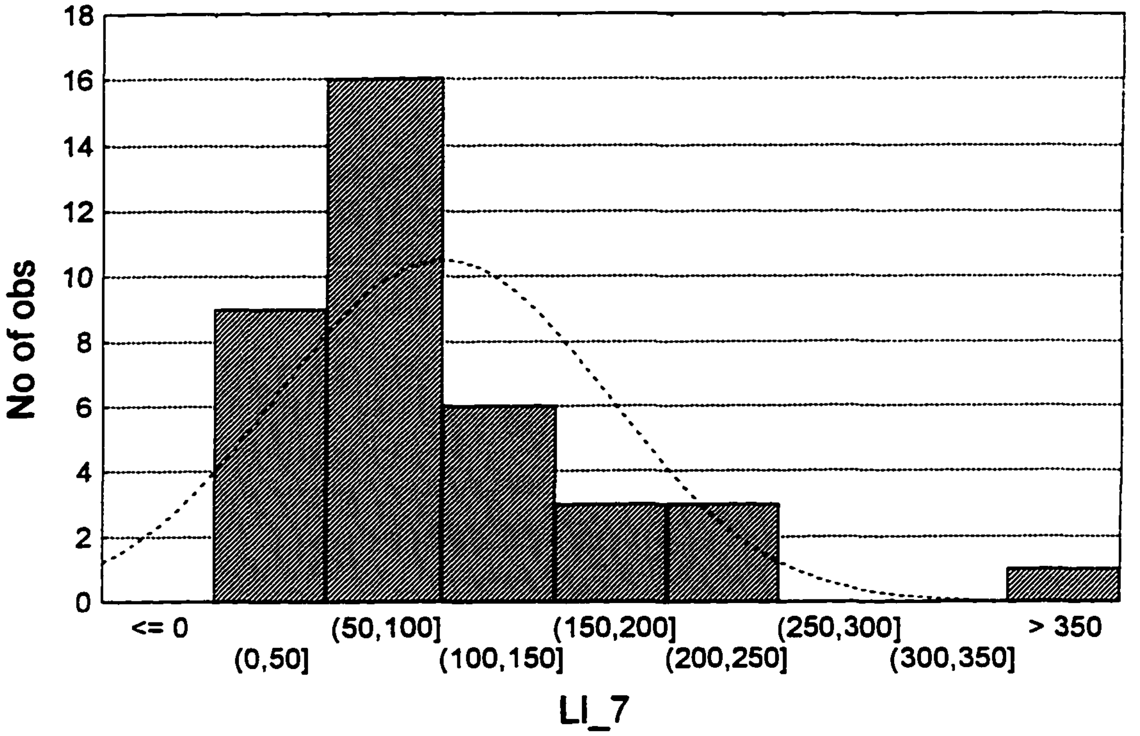

No of obs
16
14
12
10
8
6
4
2
0
<= 0
(0,20]
(20,40]
(40,60]
(60,80]
(80,100]
(100,120]
(120,140]
(140,160]
(160,180]
> 180
CD_114

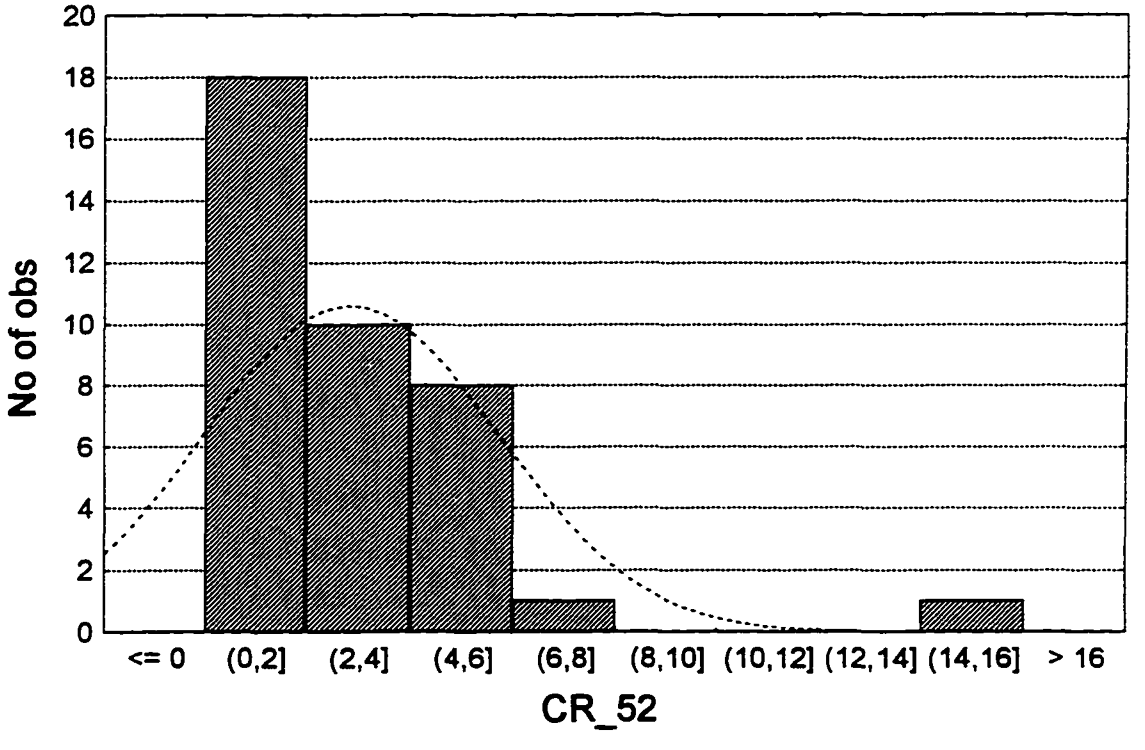


No of obs
20
18
16
14
12
10
8
6
4
2
0
<= -10
(-10,0]
(0,10]
(10,20]
(20,30]
(30,40]
(40,50]
(50,60]
(60,70]
(70,80]
(80,90]
(90,100]
(100,110]
> 110
GA_71



No of obs
24
22
20
18
16
14
12
10
8
6
4
2
0
<= 0
(0,10]
(10,20]
(20,30]
(30,40]
(40,50]
(50,60]
(60,70]
(70,80]
(80,90]
(90,100]
(100,110]
> 110
RE_187


18
16
14
12
10
8
6
4
2
0
No of obs
<= 0
(0,50]
(50,100]
(100,150]
(150,200]
(200,250]
(250,300]
(300,350]
> 350
LI_7


20
18
16
14
12
10
8
6
4
2
0
No of obs
<= 0
(0,2]
(2,4]
(4,6]
(6,8]
(8,10]
(10,12]
(12,14]
(14,16]
> 16
CR_52

GE73_1 SMEAN(GE73)

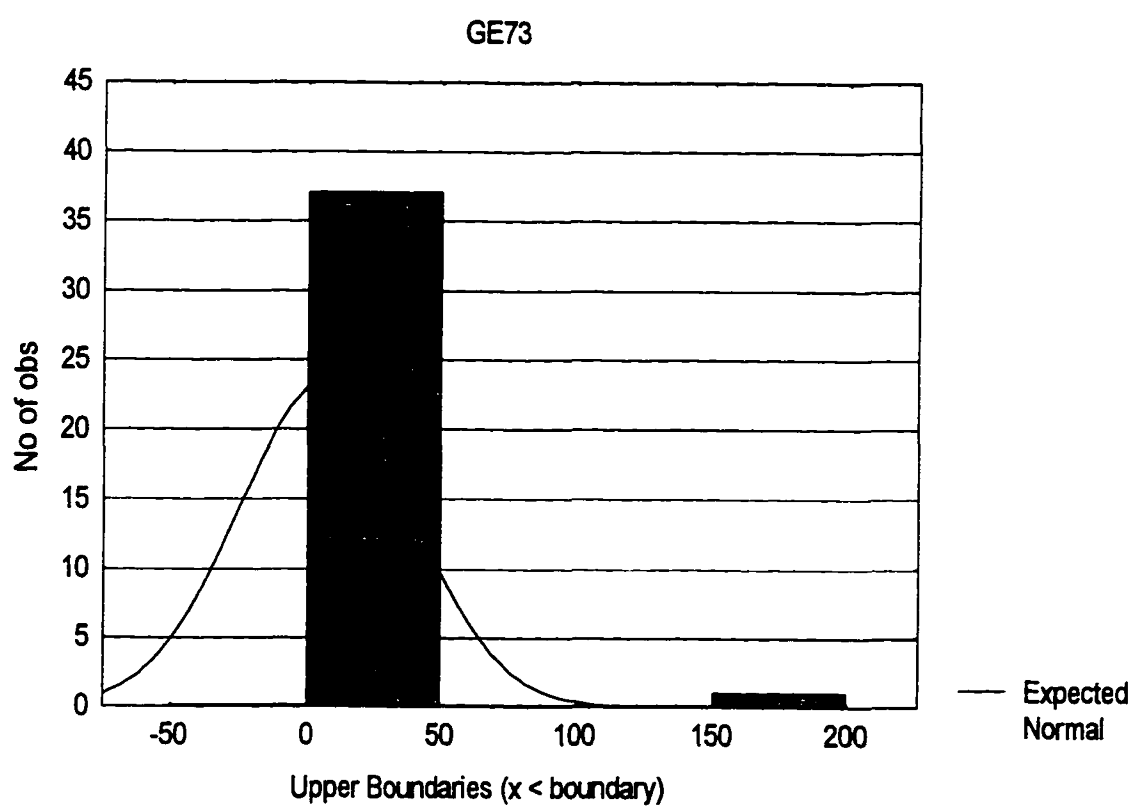
Valid cases: 39.0 Missing cases: .0 Percent missing: .0
Mean 6.9079 Std Err 5.0851 Min .0254 Skewness 5.8827
Median .4595 Variance 1008.470 Max 196.0000 S E Skew .3782
5% Trim .9795 Std Dev 31.7564 Range 195.9746 Kurtosis 35.5344
95% CI for Mean (-3.3863, 17.2021) IQR .5437 S E Kurt .7410

Frequency	Stem & Leaf
4.00	0 * 0011
8.00	0 t 22233333
12.00	0 f 444444444555
2.00	0 s 67
4.00	0 . 8889
1.00	1 * 0
1.00	1 t 2
7.00 Extremes	(1.8), (2.1), (4.0), (6.9), (41.0), (196.0)

Stem width: 1.00
Each leaf: 1 case(s)

5 Highest	SPRING	5 Lowest	SPRING
196.00	Cane	.03	HARDROCK
41.00	Tippipah	.06	COLLESEUM
6.91	mean	.13	CRYSTAL
4.00	Topopah	.17	Saratoga
2.10	M-Grape#	.21	HIKO

Note: Only a partial list of cases with the value 2.10 are shown in the table of upper extremes.



SE77_1 SMEAN(SE77)

Valid cases: 39.0 Missing cases: .0 Percent missing: .0
Mean 1.0405 Std Err .1530 Min .1700 Skewness 2.7853
Median .7800 Variance .9131 Max 5.4000 S E Skew .3782
5% Trim .9238 Std Dev .9556 Range 5.2300 Kurtosis 10.6453
95% CI for Mean (.7308, 1.3503) IQR .7800 S E Kurt .7410

```
Frequency    Stem &  Leaf
  12.00        0 * 122333444444
  12.00        0 . 555566677899
   7.00        1 * 0001223
   1.00        1 . 5
   5.00        2 * 00012
   2.00 Extremes    (2.5), (5.4)
Stem width:      1.00
Each leaf:       1 case(s)
```

5 Highest	SPRING	5 Lowest	SPRING
5.40	COLLESEUM	.17	Topopah
2.51	LATHROP	.21	Trav-A#5
2.22	Cane	.29	Nevares#
2.18	SODA	.33	Crystal
2.07	Saratoga	.33	Fairbanks

Note: Only a partial list of cases with the value 2.07 are shown in the table of upper extremes.

V51_1 SMEAN(V51)

Valid cases: 39.0 Missing cases: .0 Percent missing: .0
Mean 3.5516 Std Err .6393 Min .0400 Skewness 1.5564
Median 1.5600 Variance 15.9376 Max 14.6000 S E Skew .3782
5% Trim 3.1591 Std Dev 3.9922 Range 14.5600 Kurtosis 1.1120
95% CI for Mean (2.2575, 4.8457) IQR 2.3716 S E Kurt .7410

```
Frequency    Stem &  Leaf
   2.00        0 * 00
   2.00        0 . 79
  13.00        1 * 0011113333444
   7.00        1 . 5555678
   2.00        2 * 01
   1.00        2 . 7
   2.00        3 * 04
   1.00        3 . 5
    .00        4 *
   1.00        4 . 7
   8.00 Extremes    (9.0), (9.5), (9.8), (10.1), (10.7), (13.6), (14.6)
Stem width:      1.00
Each leaf:       1 case(s)
```

5 Highest	SPRING	5 Lowest	SPRING
14.60	SODA	.04	Nevares#
13.60	Mesquite	.07	COFFER
10.70	Surprise	.79	Fairbanks
10.10	AIRPORT	.96	CRYSTAL
10.10	Scotty#5	1.00	Trav-A#5

AS75_1 SMEAN(AS75)

```
Valid cases:      39.0  Missing cases:      .0  Percent missing:    .0
Mean       18.0432  Std Err    1.5909  Min        .5200  Skewness    .1775
Median     18.6000  Variance  98.7103  Max      44.2000  S E Skew    .3782
5% Trim    17.7930  Std Dev    9.9353  Range    43.6800  Kurtosis    .0930
95% CI for Mean (14.8225, 21.2638)     IQR      13.3000  S E Kurt    .7410

Frequency   Stem &  Leaf
   5.00       0 *  01223
   4.00       0 .  5789
   3.00       1 *  022
  10.00       1 .  5556678899
   9.00       2 *  002233334
   4.00       2 .  5678
   3.00       3 *  144
   1.00 Extremes   (44)
Stem width:    10.0
Each leaf:     1 case(s)

  5  Highest   SPRING             5  Lowest   SPRING

      44.2     SODA                   .5    COLLESEUM
      34.6     ASH                   1.6    Topopah
      34.0     Scotty#5              2.0    Tippipah
      31.0     Mesquite              2.7    HARDROCK
      28.0     Texas#5-              3.0    COFFER
```

W182_1 SMEAN(W182)

```
Valid cases:      39.0  Missing cases:      .0  Percent missing:    .0
Mean        8.9097  Std Err    7.1210  Min        .0000  Skewness   6.2085
Median       .4300  Variance 1977.642  Max     279.0000  S E Skew    .3782
5% Trim     1.6257  Std Dev   44.4707  Range   279.0000  Kurtosis  38.6840
95% CI for Mean (-5.5060, 23.3255)     IQR       1.8700  S E Kurt    .7410

Frequency   Stem &  Leaf
  21.00       0 *  011112222222222233444
   2.00       0 .  68
   1.00       1 *  3
   3.00       1 .  788
   4.00       2 *  0113
    .00       2 .
    .00       3 *
   1.00       3 .  5
   2.00       4 *  44
   1.00       4 .  6
   4.00 Extremes   (8.9), (11.9), (279.0)
Stem width:    1.00
Each leaf:     1 case(s)

  4  Highest   SPRING             5  Lowest   SPRING

    279.00     Cane                  .00    COFFER
     11.90     Tippipah              .12    SAGA
      8.91     HARDROCK              .15    COLLESEUM
                                     .16    Rogers
      4.60     Nevares#              .17    ARMY
```

U238_1 SMEAN(U238)

```
Valid cases:      39.0  Missing cases:     .0  Percent missing:   .0
Mean      4.5763  Std Err    .8279  Min      .0200  Skewness   3.5475
Median    2.9500  Variance 26.7288  Max    30.0000  S E Skew    .3782
5% Trim   3.8511  Std Dev   5.1700  Range  29.9800  Kurtosis  15.5085
95% CI for Mean (2.9004, 6.2522)    IQR     2.7000  S E Kurt    .7410

Frequency   Stem &  Leaf

  4.00       0 . 0056
  2.00       1 . 17
 14.00       2 . 23355677788999
  7.00       3 . 0004578
  2.00       4 . 45
  2.00       5 . 27
  3.00       6 . 009
  1.00       7 . 9
  4.00 Extremes    (8.9), (13.8), (13.9), (30.0)
Stem width:    1.00
Each leaf:     1 case(s)
```

5 Highest	SPRING	5 Lowest	SPRING
30.00	SODA	.02	COFFER
13.90	Saratoga	.08	Topopah
13.80	COLLESEUM	.52	Tippipah
8.90	Surprise	.60	AIRPORT
7.90	Cold Spring	1.19	Nevares#

MO95_1 SMEAN(MO95)

```
Valid cases:      39.0  Missing cases:     .0  Percent missing:   .0
Mean    147.0789  Std Err  109.1761  Min      1.0800  Skewness   5.9512
Median    7.1000  Variance 464857.3  Max    4227.000  S E Skew    .3782
5% Trim  23.9361  Std Dev  681.8044  Range  4225.920  Kurtosis  36.2821
95% CI for Mean (-73.9365, 368.0944)  IQR     8.5300  S E Kurt    .7410

Frequency   Stem &  Leaf
  6.00       0 * 112334
 17.00       0 . 55556666666667778
  8.00       1 * 01222444
  2.00       1 . 68
  2.00       2 * 24
  4.00 Extremes    (147), (352), (701), (4227)
Stem width:    10.00
Each leaf:     1 case(s)
```

5 Highest	SPRING	5 Lowest	SPRING
4227.00	Cane	1.08	HARDROCK
701.00	Tippipah	1.99	AIRPORT
352.00	SODA	2.23	COLLESEUM
147.08	mean	3.00	Topopah
24.00	Saratoga	3.64	COFFER

CS133_1 SMEAN(CS133)

```
Valid cases:     39.0  Missing cases:      .0  Percent missing:    .0
Mean      2.9680  Std Err   .4609  Min       .0797  Skewness   1.9479
Median    2.3973  Variance  8.2843  Max     12.0000  S E Skew   .3782
5% Trim   2.6526  Std Dev   2.8782  Range   11.9203  Kurtosis  3.6515
95% CI for Mean (2.0350, 3.9011)    IQR      2.0900  S E Kurt   .7410

Frequency    Stem &  Leaf
   6.00        0 * 011114
   2.00        0 . 57
   4.00        1 * 2334
   5.00        1 . 56799
   3.00        2 * 003
   2.00        2 . 79
   9.00        3 * 123333344
   3.00        3 . 556
   1.00        4 * 0
   4.00 Extremes    (8.9), (10.3), (11.0), (12.0)
Stem width:    1.000
Each leaf:     1 case(s)

  5  Highest   SPRING            5  Lowest   SPRING
      12.000    M-Grape#               .080    Cane
      11.000    L-Grape-               .125    COLLESEUM
      10.300    U-Grape#               .139    Tippipah
       8.862    ASH                    .194    SODA
       4.000    Cold Spring            .194    Mesquite
```

BA135_1 SMEAN(BA135)

```
Valid cases:     39.0  Missing cases:      .0  Percent missing:    .0
Mean     48.4645  Std Err   6.6610  Min       .2580  Skewness   1.8756
Median   43.0000  Variance 1730.392  Max    213.4020  S E Skew   .3782
5% Trim  43.8038  Std Dev  41.5980  Range   213.1440  Kurtosis  5.8441
95% CI for Mean (34.9800, 61.9490)    IQR    45.3539  S E Kurt   .7410

Frequency    Stem &  Leaf
   8.00        0 . 00011468
   4.00        1 . 8899
    .00        2 .
   3.00        3 . 599
   6.00        4 . 001138
   6.00        5 . 034567
   5.00        6 . 13467
   3.00        7 . 377
   1.00        8 . 1
    .00        9 .
   1.00       10 . 7
   2.00 Extremes    (146), (213)
Stem width:    10.00
Each leaf:     1 case(s)
  5  Highest   SPRING            5  Lowest   SPRING
      213.40    HARDROCK               .26    Topopah
      145.91    ASH                    .34    Tippipah
      107.46    HIKO                   .79    Scotty#5
       81.00    Point of Rx NE        1.34    CINDERLITE
       77.07    CRYSTAL               1.74    AIRPORT
```

TL205_1 SMEAN(TL205)

```
Valid cases:      39.0  Missing cases:     .0  Percent missing:    .0
Mean       .1851  Std Err    .0231  Min      .0290  Skewness   1.2419
Median     .1730  Variance   .0208  Max      .6700  S E Skew    .3782
5% Trim    .1724  Std Dev    .1442  Range    .6410  Kurtosis   2.0190
95% CI for Mean (.1384, .2319)      IQR      .2070  S E Kurt    .7410

Frequency   Stem & Leaf
   8.00      0 * 23334444
   7.00      0 . 5555699
   1.00      1 * 4
   7.00      1 . 6677889
   6.00      2 * 000224
   4.00      2 . 6799
   1.00      3 * 1
   1.00      3 . 8
   2.00      4 * 01
   1.00      4 . 6
   1.00 Extremes    (.67)
Stem width:      .10
Each leaf:       1 case(s)

  5  Highest   SPRING              5  Lowest   SPRING
       .67     Trav-B#5                 .03    Scotty#5
       .46     Rogers                   .03    Surprise
       .41     Cold Spring              .03    CINDERLITE
       .41     HIKO                     .03    AIRPORT
       .39     SAGA                     .04    Mesquite
```

SN117_1 SMEAN(SN117)

```
Valid cases:      39.0  Missing cases:     .0  Percent missing:    .0
Mean       .0488  Std Err    .0043  Min      .0200  Skewness   2.2126
Median     .0435  Variance   .0007  Max      .1400  S E Skew    .3782
5% Trim    .0456  Std Dev    .0269  Range    .1200  Kurtosis   4.8462
95% CI for Mean (.0400, .0575)      IQR      .0158  S E Kurt    .7410

Frequency   Stem & Leaf
   3.00      2 * 000
   2.00      2 . 78
   6.00      3 * 022334
   5.00      3 . 67888
   4.00      4 * 1123
  10.00      4 . 6888888888
   4.00      5 * 0023
    .00      5 .
   1.00      6 * 3
   4.00 Extremes    (.102), (.110), (.130), (.140)
Stem width:      .01
Each leaf:       1 case(s)

  5  Highest   SPRING              5  Lowest   SPRING
       .14     King's Pool              .02    Trav-B#5
       .13     Saratoga                 .02    Texas#5-
       .11     Nevares#                 .02    Surprise
       .10     SODA                     .03    AIRPORT
       .06     Cold Spring              .03    Jackrabbit
```

SB121_1 SMEAN(SB121)

```
Valid cases:       39.0  Missing cases:      .0  Percent missing:     .0
Mean      60.4398  Std Err   50.0844  Min       .0220  Skewness   6.0591
Median      .2951  Variance 97829.59  Max    1944.000  S E Skew    .3782
5% Trim    4.4889  Std Dev  312.7772  Range  1943.978  Kurtosis  37.2888
95% CI for Mean (-40.9509, 161.8304)  IQR       .5987  S E Kurt    .7410

Frequency    Stem &  Leaf
  13.00        0 *  0000011111111
  10.00        0 t  2222222333
   3.00        0 f  445
   4.00        0 s  6777
   1.00        0 .  9
   3.00        1 *  011
   1.00        1 t  3
   4.00 Extremes    (60.4), (69.5), (269.0), (1944.0)
Stem width:     1.00
Each leaf:      1 case(s)

  5  Highest   SPRING            5  Lowest    SPRING
     1944.00   Tippipah               .02     Saratoga
      269.00   Topopah                .02     COFFER
       69.50   Cane                   .04     HARDROCK
       60.44   mean                   .07     COLLESEUM
        1.30   ASH                    .09     SODA
```

TI47_1 SMEAN(TI47)

```
Valid cases:       39.0  Missing cases:      .0  Percent missing:     .0
Mean     141.1462  Std Err  108.3694  Min       .4000  Skewness   5.5385
Median      .6700  Variance 458013.2  Max    4068.000  S E Skew    .3782
5% Trim    6.5362  Std Dev  676.7667  Range  4067.600  Kurtosis  31.9233
95% CI for Mean (-78.2362, 360.5286)  IQR       .2952  S E Kurt    .7410

Frequency    Stem &  Leaf
   5.00        4 .  00568
   8.00        5 .  22234466
   9.00        6 .  011122799
   6.00        7 .  012334
   5.00        8 .  33558
   1.00        9 .  2
   1.00       10 .  0
   4.00 Extremes    (2.80), (141.15), (1270.00), (4068.00)
Stem width:     .10

  5  Highest   SPRING            5  Lowest    SPRING

     4068.00   Tippipah               .40     Saratoga
     1270.00   Cane                   .40     Point of
      141.15   mean                   .45     Fairbanks
        2.80   Topopah                .47     HARDROCK
        1.00   Scotty#5               .48     Jackrabbit
```

NI60_1 SMEAN(NI60)

```
Valid cases:     39.0  Missing cases:    .0  Percent missing:   .0
Mean      .5589  Std Err   .0648  Min      .0500  Skewness   .4744
Median    .5000  Variance  .1638  Max     1.4200  S E Skew   .3782
5% Trim   .5402  Std Dev   .4047  Range   1.3700  Kurtosis  -.8697
95% CI for Mean (.4278, .6901)    IQR      .7400  S E Kurt   .7410

Frequency   Stem & Leaf
  11.00      0 * 00001111111
   4.00      0 t 2233
   8.00      0 f 44445555
   4.00      0 s 6677
   5.00      0 . 88999
   4.00      1 * 0011
   2.00      1 t 23
   1.00      1 f 4
Stem width:    1.00
Each leaf:     1 case(s)

 5  Highest   SPRING            5  Lowest   SPRING
    1.42      Bradford                .05   AIRPORT
    1.38      COFFER                  .06   Scotty#5
    1.25      Point of Rx NE          .09   Surprise
    1.12      Point of Rx NW          .09   Tippipah
    1.10      HARDROCK                .11   Cane
Note: Only a partial list of cases with the value .11 are shown in the table of lower extremes.
```

MN55_1 SMEAN(MN55)

```
Valid cases:     39.0  Missing cases:    .0  Percent missing:   .0
Mean     2.0897  Std Err   1.2020  Min      .0200  Skewness   6.0514
Median    .3600  Variance 56.3458  Max    47.3000  S E Skew    .3782
5% Trim   .8335  Std Dev   7.5064  Range  47.2800  Kurtosis  37.3086
95% CI for Mean (-.3436, 4.5230)   IQR     1.9897  S E Kurt    .7410

Frequency   Stem & Leaf
  21.00      0 * 000000000111111222234
   3.00      0 . 568
   3.00      1 * 134
   2.00      1 . 56
   8.00      2 * 00000000
   2.00 Extremes    (5.2), (47.3)
Stem width:    1.00
Each leaf:     1 case(s)

 5  Highest   SPRING            5  Lowest   SPRING

   47.30      COFFER                  .02   Cold Spring
    5.16      Topopah                 .02   Saratoga
    2.09      CRYSTAL                 .04   Trav-B#5
    2.09      HIKO                    .04   Jackrabbit
    2.09      ASH                     .05   Point of Rx NE

Note: Only a partial list of cases with the value 2.09 are shown in the table of upper extremes.
```

RB85_1 SMEAN(RB85)

```
Valid cases:    39.0  Missing cases:     .0  Percent missing:    .0
Mean      18.8692  Std Err    2.0691  Min        .8800  Skewness    1.6668
Median    17.0000  Variance 166.9620  Max      55.4000  S E Skew     .3782
5% Trim   17.8389  Std Dev   12.9214  Range    54.5200  Kurtosis    2.6522
95% CI for Mean (14.6806, 23.0578)    IQR       9.7000  S E Kurt     .7410

Frequency    Stem &  Leaf
   3.00        0 *  034
   5.00        0 .  57899
   9.00        1 *  012233444
  10.00        1 .  5677777899
   6.00        2 *  000133
   2.00        2 .  67
   4.00 Extremes    (50), (53), (55)
Stem width:    10.00
Each leaf:      1 case(s)

  5  Highest   SPRING           5  Lowest    SPRING

      55.40    L-Grape-             .88    COLLESEUM
      53.00    M-Grape#            3.29    HARDROCK
      50.20    U-Grape#            4.98    COFFER
      50.00    Saratoga            5.73    AIRPORT
      27.20    SODA                7.07    Tippipah
```

SR86_1 SMEAN(SR86)

```
Valid cases:    39.0  Missing cases:     .0  Percent missing:    .0
Mean     783.2485  Std Err  136.7031  Min      6.2000  Skewness    2.6088
Median   608.2510  Variance 728821.7  Max    4206.470  S E Skew     .3782
5% Trim  655.9001  Std Dev  853.7105  Range  4200.270  Kurtosis    8.1621
95% CI for Mean (506.5075, 1059.989)  IQR    751.8966  S E Kurt     .7410

Frequency    Stem &  Leaf
   5.00        0 .  00012
   3.00        1 .  000
   2.00        2 .  12
   4.00        3 .  0458
   2.00        4 .  23
   1.00        5 .  8
   3.00        6 .  000
   3.00        7 .  678
   1.00        8 .  6
   7.00        9 .  1244777
   3.00       10 .  267
   2.00       11 .  03
   3.00 Extremes    (2168), (3480), (4206)
Stem width:   100.00
Each leaf:      1 case(s)
  5  Highest   SPRING           5  Lowest    SPRING
    4206.47    COFFER              6.20    Scotty#5
    3480.00    Saratoga            6.24    Tippipah
    2168.00    Cold Spring         6.85    Topopah
    1130.00    Nevares#           19.70    Surprise
```

Appendix D: Information for Factor Graphs from PCA

					Raw Data for Figures 22-24									
SPRING	LI_7	SE_77	V_51	CR_52	AS_75	W_182	U_238	MO_95	RE_187	MN55	NI_60	GA_71	RB_85	CO59
Big	98	0.4	1.56	4.5	25.2	0.26	2.54	7.1	6	0.24	0.8	2	14.2	16
Bradford	96	0.43	2.16	5.3	19.3	0.27	5.7	14.3	13	0.195	1.42		17.4	74
Cold	167	0.84	1.37	4.89	17.7	0.2	7.9	22.5	26	0.017	0.78		19.9	34
CrystalP	88	0.33	1.3	5.8	20.9	0.224	2.9	7.85	9	0.193	1		19.8	44
Fairbank	78	0.33	0.79	0.27	10.6	0.21	2.2	6.57	7	0.061	0.5	11	14.6	16
Jackrabb	83	0.59	1.6	3.74	24	0.26	3.4	10.5	11	0.035	0.9	8	17.5	66
King's P	86	0.54	1.44	0.34	16.8	0.226	2.95	6.1	8	0.135	0.39	5	15.6	20
Longstr	88.2	0.49	1.31	3.6	15.2	0.214	2.74	6.26	8	0.061	0.89		16.7	91
Pt RX NE	68	0.51	1.4	3.7	12.5	0.23	2.84	6.1	7.2		1.12	12	12	48
Pt RX NW	82	0.64	1.71	5.7	15.2	0.232	2.9	6	9	0.048	1.25	9	13	Co 59
Rogers	73	0.42	1.08	4.71	20.4	0.164	2.61	6.3	8		1.01	1	17.1	81
Scruggs	75	0.36	1.13	0.11	18.6	0.3	2.7	6.2	7.2	0.1	0.42	1.6	14.4	18
L.Grape	209	1.2	3.4	1.23	23.9	2.33	3.7	12.7	7	0.244	0.53	4	55.4	54
U.Grape	190	1.1	2.74	1.83	22.4	2.1	3.53	11	7	0.481	0.9	8	50.2	38
M.Grape	177	1.2	3.02	0.72	23.6	2.1	3.8	12.3	6	0.57	0.74	7.7	53	91
Mesquite	214	1	13.6	2	31	0.31	6	16.7	7.4	0.091	0.31	4	17	60
Nevarres	136	0.29	0.042	0.98	5.99	4.6	1.19	18	14	1.61	0.69	8	23.7	40
Saratoga	363	2.07	9	15	16.1	0.227	13.9	24	15	0.022	0.28	10	50	
Scotty	102	0.96	10.1	2.77	34	4.42	6.98	8.5	2.2	0.06	0.06	81	17.8	8.4
Surprise	102	0.92	10.7	2.88	27.3	4.4	8.9	7.7	4.4	0.15	0.09	16	20.3	12
Texas	142	0.41	1.18	0.87	28	0.47	2.78	14.5	4.7		0.41	11	21.5	21
TravA	138	0.21	1	1.09	26.1	0.43	3.03	13.96	6.2		0.41	12.2	20.7	24
TravB	124	0.42	1.1	1.27	23.5	0.41	2.88	12.5	3.6	0.043	0.41	12	23	28

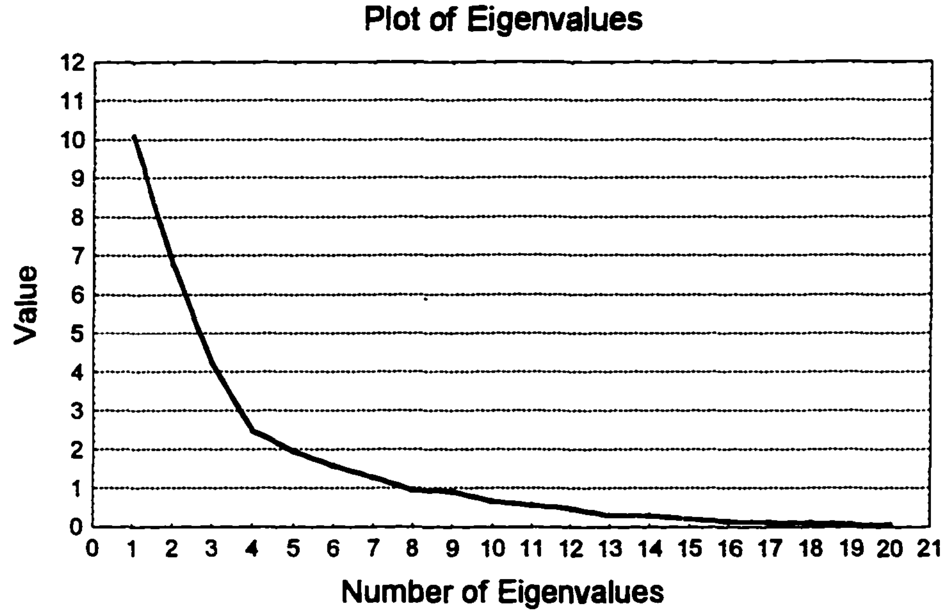
					Raw Data for Figures 22-24							
SR_86	CD_114	CS_133	BA_135	TL_205	SN_117	SB_121	TI_47	GE73	TA_181	ZR_90	BROMIDE	CHLORIDE
860		3.53	40	0.173	0.037	0.29	0.56	0.6	8	42	0.18	23.6
1106	63	3.34	41	0.201	0.038	0.26	0.62	0.39	24	9	0.19	33
2168		4	18.2	0.41	0.063	0.247	0.7	0.45	15		0.34	60.1
948		3.42	67	0.146	0.046	0.28	0.56	0.42	7	16	0.18	23
912		3.16	56	0.223	0.05	0.171	0.45	0.4	6		0.15	20
976	113	3.4	54.2	0.2	0.028	0.175	0.48	0.42	15	11	0.16	23.4
767		3.25	66	0.165	0.14	0.347	0.69	0.36		73	0.18	20.8
970	43	3.5	57	0.299	0.041	0.327	0.61	0.39	7		0.15	17.4
771	23	3.38	64	0.166	0.038	0.16	0.4	0.41	14	11	0.13	19.5
928	78	3.3	81	0.221	0.053	0.17	0.67	0.38	9	9	0.16	19.8
976	35	3.68	63.4	0.463	0.033	0.45	0.62	0.297	7	13	0.17	16.7
942	7	3.34	77	0.184	0.033	0.22	0.61	0.41	8	38	0.14	19.4
585	41	11	53	0.24	0.032	1.13	0.88	1.83	9	20	0.18	57
601	11	10.3	55	0.31	0.042	1.15	0.83	2.1		16	0.18	43.7
606	10	12	61	0.26	0.05	1.01	0.85	2.1		14	0.19	47
344	25	0.194	19.1	0.041	0.052	0.31	0.52	0.42		16	0.26	83
1130	15	2.08	43	0.2	0.11	0.96	0.74	0.88		33	0.15	69.3
3480	28	1.31	19	0.17	0.13	0.022	0.4	0.17	9	5	1.31	1284
6.2		0.468	0.79	0.029		0.74	1	1.28		20	0.15	42
19.7	6	0.56	4.6	0.03	0.02	0.71	0.85	0.84	6	22	0.16	45.9
1067	12	1.95	35.6	0.062	0.02	0.16	0.6	0.5	9	13	0.15	67
1072	10	2.09	39	0.091		0.18	0.61	0.5	8	9	0.15	69
1021	14	1.94	40	0.67	0.02	0.15	0.73	0.46	7	21	0.16	68

	Raw Data for Figures 22-24					
FLUORIDE	NITRATE	SULFATE	CALCIUM	MG	K	NA
1.29	0.61	100.1	44.6	19.3	8.7	
1.72	0.29	143	56.3	28.9	10.5	112
1.72	0.39	294.8	76.1	37.5	18.6	198
1.66	0.36	90.1	48.7	22.1	9.23	81
1.6	0.14	79.7	48.7	21.3	7.9	73
1.38	0.88	97	48	23.2	8.4	89
1.26	0.65	78.4	48.1	20.9	7.8	69
1.42	0.47	88	48.6	21.5	7.8	74
1.26	0.47	77	49	21.6	7.7	70.6
1.29	0.75	77	50.9	21.7	7.7	72
1.5	0.31	86.8	48.5	21.5	7.8	72
1.52	0.45	75.8	48.6	20.3	8.4	71
2.86	0.41	128.6	41.5	19.4	15.8	183
2.7	0.57	120	54.1	18.5	15.1	170
2.57	0.59	117.2	52	17.7	14	169
3.08	1.32	180.3	28.3	14.6	13.2	242
3.09		168.7	43.2	19.8	11	146
0.34		990	32.2	34.2	32.2	1010
1.96	3.49	86.2	4.51	0.4	5.12	153
1.6	3.78	91.8	6.48	0.36	7.38	149
3.56	0.68	153.1	33.9	18	11	148
3.56	0.68	150.7	35.1	18.3	11	147
3.55	0.7	151	35	17.6	11.1	148

Information to Accompany Figure 22

Eigenvalues and Scree Plots (amanddv.sta)-Extraction: Principal components

	Eigenval	% total Variance	Cumul. Eigenval	Cumul. %
1	10.10185	29.71133	10.10185	29.71133
2	6.78529	19.95674	16.88715	49.66808
3	4.23941	12.46886	21.12656	62.13693
4	2.47794	7.28807	23.60450	69.42500
5	1.94680	5.72590	25.55131	75.15090



Factor Loadings (Unrotated) (amanddv.sta)-Extraction: Principal components

	Factor 1	Factor 2	Factor 3	Factor 4	Factor 5
LI_7	.84096	-.337452	-.220592	.115143	-.105739
SE_77	.74952	-.430149	-.211104	-.100524	.307872
V_51	.36646	-.653011	.377409	-.149625	.268092
CR_52	.78433	.252106	.187829	-.075603	.353757
AS_75	-.12247	-.619558	.277474	.059497	.141093
W_182	-.09897	-.762019	-.116570	-.252790	-.096706
U_238	.78671	-.280815	.272309	-.252253	.135259
MO_95	.73212	-.124182	-.119326	-.045576	-.520278
RE_187	.50472	.474034	-.182419	-.426555	-.327242
MN55	-.16734	.127883	.200314	.667592	-.178025
NI_60	-.16472	.650177	-.388325	-.023244	.282680
GA_71	.00987	.201944	.120989	-.661201	-.051784
RB_85	.47656	-.433001	-.672382	.123056	.081052
CO59	.42512	.288272	-.346074	.118349	.454501
SR_86	.81801	.449202	-.012687	.041541	-.213790
CD_114	-.11211	.359422	.210139	-.638603	.191328
CS_133	-.08533	-.097616	-.895148	.021004	.194367
BA_135	-.37220	.557935	-.439710	.287737	.292457
TL_205	-.00002	.366135	-.442241	.026898	-.194502
SN_117	-.13023	-.422136	.378019	-.016498	-.190584
SB_121	-.16544	-.638533	-.634192	-.174329	.027803
TI_47	-.27086	-.677606	-.340283	-.331708	-.067109
GE73	-.12614	-.641235	-.678011	-.084831	.093038

TA_181	-.06482	-.520069	-.284767	-.232498	-.086214
ZR_90	-.12881	.356567	-.000846	-.564864	-.315271
BROMIDE	.95545	.021308	.094590	.039808	.089355
CHLORIDE	.92886	-.036020	.119600	.142078	.088490
FLUORIDE	-.28841	-.436638	-.214122	.347877	-.591484
NITRATE	.66657	-.073369	-.035682	.053420	-.237726
SULFATE	.96450	.004781	.079938	.068312	-.052813
CALCIUM	-.01227	.738661	-.557620	-.133496	-.124714
MG	.49239	.744553	-.289457	-.037965	-.175273
K	.91333	-.050108	-.254500	.068481	-.132011
NA	.94540	-.149778	.079530	.100241	.043115

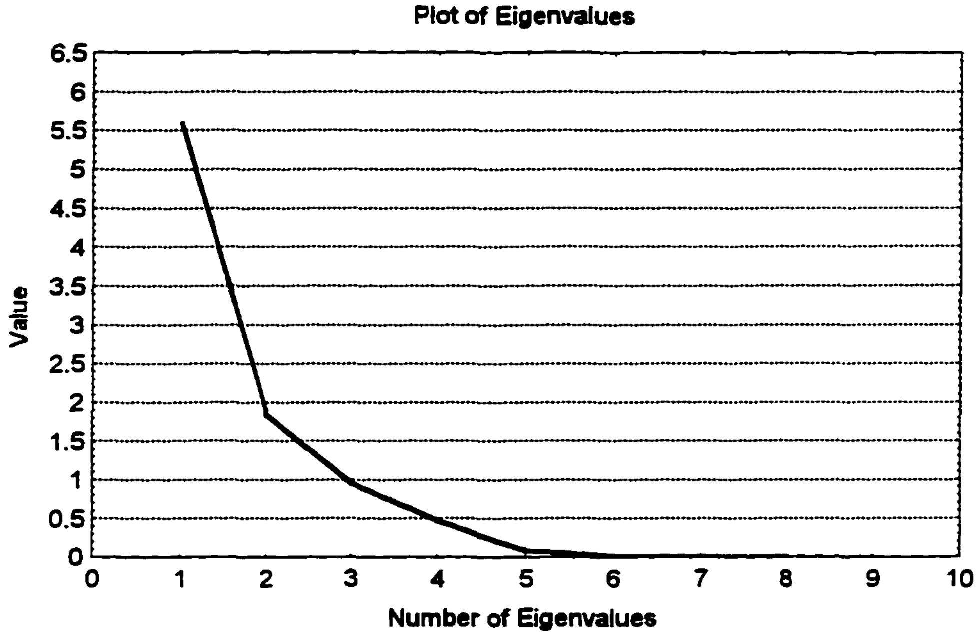
Factor Scores (amanddv.sta)-Rotation: Unrotated-Extraction: Principal components

	Factor 1	Factor 2	Factor 3	Factor 4	Factor 5
Big Spri	-.380002	.40986	.54011	-.21775	.54607
Bradford	.099784	.91390	-.06776	-.81056	.30919
Cold Spr	.997414	1.22574	-.44430	-2.42291	-2.11091
Crystal	-.318649	.83188	.24761	-.63271	.77573
Fairbank	-.587491	.92713	.41213	-.50942	-.42756
Jackrabb	-.193958	.74961	.26330	-.12391	.81694
King's P	-.574856	.35713	.14751	-.76245	.00075
Longstre	-.356901	.96321	-.05377	-.91879	.39498
Point of Rx NE	-.469655	.95897	.32484	1.28087	.67459
Point of Rx NW	-.308769	1.00520	-.15104	.14779	1.63131
Rogers-M	-.413019	.81846	-.13807	1.20458	.64269
Scruggs-	-.597968	.47494	.21299	.57160	-.04829
Grape#5-	.075197	-1.12787	-1.90047	.16512	.32605
U-Grape#	-.067541	-1.03300	-2.21987	.07725	.23288
M-Grape#	-.012266	-1.07579	-2.35905	.23996	.77237
Mesquite	.373943	-1.07880	.97361	.30268	-.01762
Nevares#	.034165	-.36632	-.92528	-.20919	-2.23817
Saratoga	4.391232	.03111	.59178	.61288	.66247
Scotty#5	-.532038	-2.42611	1.55800	-1.77653	.38961
Surprise	-.272547	-1.88496	1.34240	-.50772	.74070
Texas#5-	-.268436	-.26188	.68944	1.70019	-1.21855
Trav-A#5	-.334174	-.36398	.92976	1.67029	-1.62584
Trav-B#5	-.283466	-.04840	.02613	.91874	-1.22937

Information to Accompany Figure 23

Eigenvalues and Scree Plot(amanddv2.sta)-Extraction: Principal components

	Eigenval	% total Variance	Cumul. Eigenval	Cumul. %
1	5.599226	62.21362	5.599226	62.21362
2	1.851475	20.57195	7.450701	82.78557



Factor Loadings (Unrotated) (amanddv2.sta)-Extraction: Principal components

	Factor 1	Factor 2
BROMIDE	.986655	-.053214
CHLORIDE	.974937	-.157019
FLUORIDE	-.332555	-.308299
NITRATE	.738549	-.194311
SULFATE	.991257	-.062331
CALCIUM	-.001903	.978164
MG	.518434	.825118
K	.910234	.088604
NA	.969173	-.204507

Factor Scores (amanddv2.sta)-Rotation: Unrotated-Extraction: Principal components

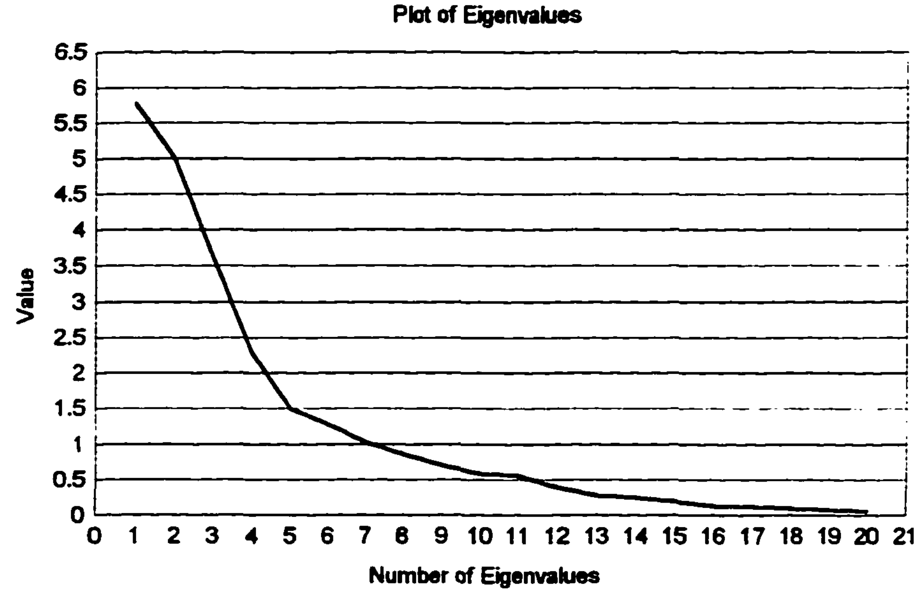
	Factor 1	Factor 2
Big Spri	-.206627	.21511
Bradford	-.069306	1.10538
Cold Spr	.612927	2.22915
Crystal	-.271559	.49937
Fairbank	-.357348	.46682
Jackrabb	-.262759	.57511
King's P	-.322406	.48292
Longstre	-.337590	.50444
Point of Rx NE	-.355465	.55816
Point of Rx NW	-.331622	.61827
Rogers-M	-.332367	.48598
Scruggs-	-.360832	.42936
Grape#5-	-.039317	-.14160
U-Grape#	-.087710	.28051
M-Grape#	-.114061	.17720
Mesquite	-.001617	-.99024
Nevares#	.260958	-.49618
Saratoga	4.441460	-.57374
Scotty#5	-.591587	-2.37066
Surprise	-.489934	-2.22112

Texas#5-	-.263293	-.63667
Trav-A#5	-.261706	-.57830
Trav-B#5	-.258238	-.61926

Information to Accompany Figure 24

Eigenvalues & Scree Plot(amanddv.sta)-Extraction: Principal components

	Eigenvalue	% Total Variance	Cumul. Eigenvalue	Cumul. % Variance
1	5.763194	23.05278	5.76319	23.05278
2	5.001040	20.00416	10.76423	43.05694
3	3.633903	14.53561	14.39814	57.59255
4	2.289652	9.15861	16.68779	66.75115
5	1.499255	5.99702	18.18704	72.74817



Factor Loadings (Unrotated) (amanddv.sta)-Extraction: Principal components

	Factor 1	Factor 2	Factor 3	Factor 4	Factor 5
LI_7	.644675	.623271	-.164664	-.174519	.183793
SE_77	.728969	.518433	-.169052	-.054386	-.159552
V_51	.668577	.216546	.485729	-.041510	-.265372
CR_52	.026620	.841549	.011041	-.055062	-.366156
AS_75	.482117	-.219791	.454942	-.186180	-.273796
W_182	.677111	-.379040	.086427	.230150	.068434
U_238	.518307	.705411	.283235	.086774	-.116928
MO_95	.409868	.661030	-.044315	.062324	.381625
RE_187	-.145538	.659482	-.241025	.455857	.189635
MN55	-.270605	-.104260	.162190	-.636591	.174089
NI_60	-.532057	.058422	-.547298	.042238	-.435311
GA_71	-.128491	.189954	.126076	.645400	-.314180
RB_85	.698089	.168976	-.577722	-.152723	.062708
CO59	-.025514	.477184	-.509025	-.193601	-.461809
SR_86	-.121408	.878440	-.164354	-.019027	.260746
CD_114	-.339519	.073217	.153767	.606677	-.353956
CS_133	.273444	-.248288	-.825252	-.002403	-.079460
BA_135-	.571002	-.277461	-.598283	-.204782	-.143665
TL_205	-.246326	.080425	-.518164	.100161	.256844
SN_117	.250464	-.224486	.523696	-.009746	-.027885

SB_121	.668894	-.467974	-.428206	.172223	.001013
TI_47	.618687	-.502433	-.106289	.326987	-.015615
GE73	.698268	-.436787	-.466101	.065873	-.052777
TA_181	.528837	-.292960	-.090971	.220663	.017836
ZR_90	-.327536	.007847	-.015960	.670932	.366841

Factor Scores (amanddv.sta)-Rotation: Unrotated-Extraction: Principal components

	Factor 1	Factor 2	Factor 3	Factor 4	Factor 5
Big Spri	-.61531	-.28899	.43049	.14868	-.36605
Bradford	-.58611	.66504	-.19421	.68219	-1.40735
Cold Spr	-.25692	1.71239	-.19666	2.58118	1.40187
Crystal	-.88954	.07963	.00885	.60481	-1.52248
Fairbank	-1.19963	-.35562	.20340	.83853	1.07102
Jackrabb	-.71403	.23486	.01531	-.05208	-.97847
King's P	-.51583	-.66512	.16905	.86623	.52914
Longstre	-.96865	.09253	-.41387	1.06051	-.49831
Point of	-1.15959	-.14548	-.06739	-1.39290	-.28322
Point of	-.97409	.13324	-.64506	-.31678	-1.73087
Rogers-M	-.92359	-.14657	-.53284	-1.24837	-.33891
Scruggs-	-.73924	-.61157	.12019	-.47491	.82047
Grape#5-	1.46816	-.56134	-1.56268	-.16701	.02401
U-Grape#	1.42844	-.81202	-1.78853	-.06549	.03338
M-Grape#	1.53198	-.70957	-2.02959	-.34429	-.47074
Mesquite	.97557	.45949	1.31528	-.62916	-.34104
Nevares#	.33253	-.43927	-.70523	.83157	1.89030
Saratoga	1.27691	3.83641	.03627	-1.01597	.10689
Scotty#5	1.80070	-1.09735	2.21413	1.38490	-1.22685
Surprise	1.36318	-.54098	1.57681	.07009	-.16010
Texas#5-	-.18600	-.22829	.83341	-1.49228	1.06098
Trav-A#5	-.14851	-.38528	1.22593	-1.44999	1.04559
Trav-B#5	-.30042	-.22615	-.01306	-.41948	1.34073

SPRING	Y89	LA_139	CE_140	LI_7	SE_77	V_51	CR_52	AS_75	W_182	U_238
Big Spring	11.1	4.42	2.19	98	0.4	1.56	4.5	25.2	0.26	2.54
Bradford	10.6	2.21	0.55	96	0.43	2.16	5.3	19.3	0.27	5.7
Cold Sprin	10.19	3.1	1.79	167	0.84	1.37	4.89	17.7	0.2	7.9
Crystal Po	8.7	3.7	1.85	88	0.33	1.3	5.8	20.9	0.224	2.9
Fairbanks	7.37	2.18	1.35	78	0.33	0.79	0.27	10.6	0.21	2.2
Jackrabbit	9.2	2.65	1.84	83	0.59	1.6	3.74	24	0.26	3.4
King's Pool	5.5	2.8	2.5	86	0.54	1.44	0.34	16.8	0.226	2.95
Longstreet	1.82	4	0.58	88.2	0.49	1.31	3.6	15.2	0.214	2.74
NEPoint of	8.2	2.3	1.22	68	0.51	1.4	3.7	12.5	0.23	2.84
NWPoint o	4.9	10.5	2.07	82	0.64	1.71	5.7	15.2	0.232	2.9
Rogers	6.1	11.9	5.83	73	0.42	1.08	4.71	20.4	0.164	2.61
Scruggs	4	5.81	0.95	75	0.36	1.13	0.11	18.6	0.3	2.7
L-Grape	10.6	5.93	4.4	209	1.2	3.4	1.23	23.9	2.33	3.7
U-Grape	17	7.7	7.7	190	1.1	2.74	1.83	22.4	2.1	3.53
M-Grape	9.1	4.52	2.93	177	1.2	3.02	0.72	23.6	2.1	3.8
Mesquite	9.6	5.74	6.92	214	1	13.6	2	31	0.31	6
Nevares	10.4	2.05	1.61	136	0.29	0.042	0.98	5.99	4.6	1.19
Saratoga	36.7	5.39	1.07	363	2.07	9	15	16.1	0.227	13.9
Scotty	8	5.9	25.9	102	0.96	10.1	2.77	34	4.42	6.98
Surprise	16.8	7.12	26.6	102	0.92	10.7	2.88	27.3	4.4	8.9
Texas	7.7	7	4.6	142	0.41	1.18	0.87	28	0.47	2.78
Trav-A	9	4.9	4.3	138	0.21	1	1.09	26.1	0.43	3.03
Trav-B	18.6	6.2	1.09	124	0.42	1.1	1.27	23.5	0.41	2.88

MO_95	RE_187	MN55	NI_60	GA_71	RB_85	CO59	SR_86	CD_114	CS_133	BA_135
7.1	6	0.24	0.8	2	14.2	16	860		3.53	40
14.3	13	0.195	1.42		17.4	74	1106	63	3.34	41
22.5	26	0.017	0.78		19.9	34	2168		4	18.2
7.85	9	0.193	1		19.8	44	948		3.42	67
6.57	7	0.061	0.5	11	14.6	16	912		3.16	56
10.5	11	0.035	0.9	8	17.5	66	976	113	3.4	54.2
6.1	8	0.135	0.39	5	15.6	20	767		3.25	66
6.26	8	0.061	0.89		16.7	91	970	43	3.5	57
6.1	7.2		1.12	12	12	48	771	23	3.38	64
6	9	0.048	1.25	9	13	Co 59	928	78	3.3	81
6.3	8		1.01	1	17.1	81	976	35	3.68	63.4
6.2	7.2	0.1	0.42	1.6	14.4	18	942	7	3.34	77
12.7	7	0.244	0.53	4	55.4	54	585	41	11	53
11	7	0.481	0.9	8	50.2	38	601	11	10.3	55
12.3	6	0.57	0.74	7.7	53	91	606	10	12	61
16.7	7.4	0.091	0.31	4	17	60	344	25	0.194	19.1
18	14	1.61	0.69	8	23.7	40	1130	15	2.08	43
24	15	0.022	0.28	10	50		3480	28	1.31	19
8.5	2.2	0.06	0.06	81	17.8	8.4	6.2		0.468	0.79
7.7	4.4	0.15	0.09	16	20.3	12	19.7	6	0.56	4.6
14.5	4.7		0.41	11	21.5	21	1067	12	1.95	35.6
13.96	6.2		0.41	12.2	20.7	24	1072	10	2.09	39
12.5	3.6	0.043	0.41	12	23	28	1021	14	1.94	40

TL_205	SN_117	SB_121	TI_47	GE73	TA_181	ZR_90
0.173	0.037	0.29	0.56	0.6	8	42
0.201	0.038	0.26	0.62	0.39	24	9
0.41	0.063	0.247	0.7	0.45	15	
0.146	0.046	0.28	0.56	0.42	7	16
0.223	0.05	0.171	0.45	0.4	6	
0.2	0.028	0.175	0.48	0.42	15	11
0.165	0.14	0.347	0.69	0.36		73
0.299	0.041	0.327	0.61	0.39	7	
0.166	0.038	0.16	0.4	0.41	14	11
0.221	0.053	0.17	0.67	0.38	9	9
0.463	0.033	0.45	0.62	0.297	7	13
0.184	0.033	0.22	0.61	0.41	8	38
0.24	0.032	1.13	0.88	1.83	9	20
0.31	0.042	1.15	0.83	2.1		16
0.26	0.05	1.01	0.85	2.1		14
0.041	0.052	0.31	0.52	0.42		16
0.2	0.11	0.96	0.74	0.88		33
0.17	0.13	0.022	0.4	0.17	9	5
0.029		0.74	1	1.28		20
0.03	0.02	0.71	0.85	0.84	6	22
0.062	0.02	0.16	0.6	0.5	9	13
0.091		0.18	0.61	0.5	8	9
0.67	0.02	0.15	0.73	0.46	7	21

Information to Accompany Figure 25				
Eigenvalues (amdv.sta)				
Extraction: Principal components				
		% total	Cumul.	Cumul.
	Eigenval	Variance	Eigenval	%
1	6.4415312	23.005469	6.4415312	23.005469
2	5.55667	19.84525	11.998201	42.850719
3	3.8786995	13.852498	15.876901	56.703217
Factor Scores (amdv.sta)				
Rotation: Unrotated				
Extraction: Principal components				
	Factor	Factor	Factor	
	1	2	3	
Big Spring	-0.569884	-0.187354	-0.438062	
Bradford	-0.577852	0.7018146	-0.025716	
Cold Spring	-0.215907	1.5748459	-0.156463	
Crystal Poo	-0.860183	0.1422064	-0.187409	
Fairbanks	-1.209408	-0.199868	-0.340088	
Jackrabbit	-0.697939	0.2993638	-0.159777	
King's Pool	-0.638492	-0.588686	-0.142948	
Longstreet	-1.062268	0.0866037	0.1974959	
NEPoint of	-1.134112	0.0181383	-0.073417	
NWPoint of	-0.912395	0.1238356	0.456576	
Rogers	-0.783118	-0.15509	0.3886796	
Scruggs	-0.811657	-0.534045	-0.067988	
L-Grape	1.1595098	-0.496119	1.8193244	
U-Grape	1.2340595	-0.645487	2.0178874	
M-Grape	1.108826	-0.59517	2.3044155	
Mesquite	0.9947218	0.1781173	-1.088677	
Nevares	0.107265	-0.284758	0.7977733	
Saratoga	1.7130325	3.7704743	-0.272425	
Scotty	1.9089641	-1.63105	-1.920328	
Surprise	1.6914044	-0.897157	-1.475635	
Texas	-0.135486	-0.2836	-0.690532	
A-Trav-A	-0.10993	-0.416149	-1.027995	
B-Trav-B	-0.199151	0.0191329	0.0853092	

Data for Figure 26

SPRING	Y89	LA_139	CE_140	LI_7	SE_77	V_51	CR_52	AS_75	W_182	U_238
Big Spri	11.1	4.42	2.19	98	0.4	1.56	4.5	25.2	0.26	2.54
Bradford	10.6	2.21	0.55	96	0.43	2.16	5.3	19.3	0.27	5.7
Cold Spr	10.19	3.1	1.79	167	0.84	1.37	4.89	17.7	0.2	7.9
Crystal	8.7	3.7	1.85	88	0.33	1.3	5.8	20.9	0.224	2.9
Fairbank	7.37	2.18	1.35	78	0.33	0.79	0.27	10.6	0.21	2.2
Jackrabb	9.2	2.65	1.84	83	0.59	1.6	3.74	24	0.26	3.4
King's P	5.5	2.8	2.5	86	0.54	1.44	0.34	16.8	0.226	2.95
Longstre	1.82	4	0.58	88.2	0.49	1.31	3.6	15.2	0.214	2.74
Point of	8.2	2.3	1.22	68	0.51	1.4	3.7	12.5	0.23	2.84
Point of	4.9	10.5	2.07	82	0.64	1.71	5.7	15.2	0.232	2.9
Rogers-M	6.1	11.9	5.83	73	0.42	1.08	4.71	20.4	0.164	2.61
Scruggs-	4	5.81	0.95	75	0.36	1.13	0.11	18.6	0.3	2.7
Grape#5-	10.6	5.93	4.4	209	1.2	3.4	1.23	23.9	2.33	3.7
U-Grape#	17	7.7	7.7	190	1.1	2.74	1.83	22.4	2.1	3.53
M-Grape#	9.1	4.52	2.93	177	1.2	3.02	0.72	23.6	2.1	3.8
Mesquite	9.6	5.74	6.92	214	1	13.6	2	31	0.31	6
Nevares#	10.4	2.05	1.61	136	0.29	0.042	0.98	5.99	4.6	1.19
Saratoga	36.7	5.39	1.07	363	2.07	9	15	16.1	0.227	13.9
Scotty#5	8	5.9	25.9	102	0.96	10.1	2.77	34	4.42	6.98
Surprise	16.8	7.12	26.6	102	0.92	10.7	2.88	27.3	4.4	8.9
Texas#5-	7.7	7	4.6	142	0.41	1.18	0.87	28	0.47	2.78
Trav-A#5	9	4.9	4.3	138	0.21	1	1.09	26.1	0.43	3.03
Trav-B#5	18.6	6.2	1.09	124	0.42	1.1	1.27	23.5	0.41	2.88

MO_95	RE_187	MN55	NI_60	GA_71	RB_85	CO59	SR_86	CD_114	CS_133	BA_135
7.1	6	0.24	0.8	2	14.2	16	860	5	3.53	40
14.3	13	0.195	1.42	0.8	17.4	74	1106	63	3.34	41
22.5	26	0.017	0.78	0.8	19.9	34	2168	5	4	18.2
7.85	9	0.193	1	0.8	19.8	44	948	5	3.42	67
6.57	7	0.061	0.5	11	14.6	16	912	5	3.16	56
10.5	11	0.035	0.9	8	17.5	66	976	113	3.4	54.2
6.1	8	0.135	0.39	5	15.6	20	767	5	3.25	66
6.26	8	0.061	0.89	0.8	16.7	91	970	43	3.5	57
6.1	7.2	0.005	1.12	12	12	48	771	23	3.38	64
6	9	0.048	1.25	9	13	1	928	78	3.3	81
6.3	8		1.01	1	17.1	81	976	35	3.68	63.4
6.2	7.2	0.1	0.42	1.6	14.4	18	942	7	3.34	77
12.7	7	0.244	0.53	4	55.4	54	585	41	11	53
11	7	0.481	0.9	8	50.2	38	601	11	10.3	55
12.3	6	0.57	0.74	7.7	53	91	606	10	12	61
16.7	7.4	0.091	0.31	4	17	60	344	25	0.194	19.1
18	14	1.61	0.69	8	23.7	40	1130	15	2.08	43
24	15	0.022	0.28	10	50	1	3480	28	1.31	19
8.5	2.2	0.06	0.06	81	17.8	8.4	6.2	5	0.468	0.79
7.7	4.4	0.15	0.09	16	20.3	12	19.7	6	0.56	4.6
14.5	4.7	0.005	0.41	11	21.5	21	1067	12	1.95	35.6
13.96	6.2	0.005	0.41	12.2	20.7	24	1072	10	2.09	39
12.5	3.6	0.043	0.41	12	23	28	1021	14	1.94	40

TL_205	SN_117	SB_121	TI_47	GE73	TA_181	ZR_90
0.173	0.037	0.29	0.56	0.6	8	42
0.201	0.038	0.26	0.62	0.39	24	9
0.41	0.063	0.247	0.7	0.45	15	0.6
0.146	0.046	0.28	0.56	0.42	7	16
0.223	0.05	0.171	0.45	0.4	6	0.6
0.2	0.028	0.175	0.48	0.42	15	11
0.165	0.14	0.347	0.69	0.36	0.03	73
0.299	0.041	0.327	0.61	0.39	7	103
0.166	0.038	0.16	0.4	0.41	14	11
0.221	0.053	0.17	0.67	0.38	9	9
0.463	0.033	0.45	0.62	0.297	7	13
0.184	0.033	0.22	0.61	0.41	8	38
0.24	0.032	1.13	0.88	1.83	9	20
0.31	0.042	1.15	0.83	2.1	0.03	16
0.26	0.05	1.01	0.85	2.1	0.03	14
0.041	0.052	0.31	0.52	0.42	0.03	16
0.2	0.11	0.96	0.74	0.88	0.03	33
0.17	0.13	0.022	0.4	0.17	9	5
0.029	0.004	0.74	1	1.28	0.03	20
0.03	0.02	0.71	0.85	0.84	6	22
0.062	0.02	0.16	0.6	0.5	9	13
0.091	0.004	0.18	0.61	0.5	8	9
0.67	0.02	0.15	0.73	0.46	7	21

	Information for Figure 26			
Eigenvalues (detlim.sta)				
Extraction: Principal components				
		% total	Cumul.	Cumul.
	Eigenval	Variance	Eigenval	%
1	6.5628867	23.438881	6.5628867	23.438881
2	5.8174146	20.776481	12.380301	44.215362
3	3.836282	13.701007	16.216583	57.916369
Factor Scores (detlim.sta)				
Rotation: Unrotated				
Extraction: Principal components				
	Factor	Factor	Factor	
	1	2	3	
Big Spri	-0.418541	-0.203799	-0.518387	
Bradford	-0.913928	0.7216213	0.0093721	
Cold Spr	-0.116526	1.6399941	0.2679769	
Crystal	-0.730599	-0.009058	-0.153049	
Fairbank	-0.795681	-0.175923	-0.534938	
Jackrabb	-0.895404	0.2921862	-0.207841	
King's P	-0.512474	-0.380799	-0.174366	
Longstre	-1.091333	-0.403841	0.2097682	
Point of	-1.100733	0.0242698	-0.392518	
Point of	-0.909767	-0.024164	-0.185285	
Rogers-M	-0.945147	-0.434212	0.3628378	
Scruggs-	-0.764741	-0.538563	-0.420597	
Grape#5-	0.9196892	-0.485437	2.0791733	
U-Grape#	0.9971061	-0.57942	2.0720264	
M-Grape#	0.7987016	-0.701623	2.4076057	
Mesquite	0.8887065	0.2526372	-0.961391	
Nevares#	-0.00643	-0.073501	0.8042809	
Saratoga	1.5224487	3.8299719	-0.051472	
Scotty#5	2.4006114	-1.514279	-1.616682	
Surprise	1.8940645	-0.756937	-1.314207	
Texas#5-	0.0213035	-0.199329	-0.788243	
Trav-A#5	-0.081737	-0.204564	-0.763329	
Trav-B#5	-0.159591	-0.075232	-0.130738	

				Data for Figure 27						
SPRING	Y89	LA_139	CE_140	LI_7	SE_77	V_51	CR_52	AS_75	W_182	U_238
Big Spri	11.1	4.42	2.19	98	0.4	1.56	4.5	25.2	0.26	2.54
Bradford	10.6	2.21	0.55	96	0.43	2.16	5.3	19.3	0.27	5.7
Cold Spr	10.19	3.1	1.79	167	0.84	1.37	4.89	17.7	0.2	7.9
Crystal	8.7	3.7	1.85	88	0.33	1.3	5.8	20.9	0.224	2.9
Fairbank	7.37	2.18	1.35	78	0.33	0.79	0.27	10.6	0.21	2.2
Jackrabb	9.2	2.65	1.84	83	0.59	1.6	3.74	24	0.26	3.4
King's P	5.5	2.8	2.5	86	0.54	1.44	0.34	16.8	0.226	2.95
Longstre	1.82	4	0.58	88.2	0.49	1.31	3.6	15.2	0.214	2.74
Point of	8.2	2.3	1.22	68	0.51	1.4	3.7	12.5	0.23	2.84
Point of	4.9	10.5	2.07	82	0.64	1.71	5.7	15.2	0.232	2.9
Rogers-M	6.1	11.9	5.83	73	0.42	1.08	4.71	20.4	0.164	2.61
Scruggs-	4	5.81	0.95	75	0.36	1.13	0.11	18.6	0.3	2.7
Grape#5-	10.6	5.93	4.4	209	1.2	3.4	1.23	23.9	2.33	3.7
U-Grape#	17	7.7	7.7	190	1.1	2.74	1.83	22.4	2.1	3.53
M-Grape#	9.1	4.52	2.93	177	1.2	3.02	0.72	23.6	2.1	3.8
Mesquite	9.6	5.74	6.92	214	1	13.6	2	31	0.31	6
Nevares#	10.4	2.05	1.61	136	0.29	0.042	0.98	5.99	4.6	1.19
Saratoga	36.7	5.39	1.07	363	2.07	9	15	16.1	0.227	13.9
Scotty#5	8	5.9	25.9	102	0.96	10.1	2.77	34	4.42	6.98
Surprise	16.8	7.12	26.6	102	0.92	10.7	2.88	27.3	4.4	8.9
Texas#5-	7.7	7	4.6	142	0.41	1.18	0.87	28	0.47	2.78
Trav-A#5	9	4.9	4.3	138	0.21	1	1.09	26.1	0.43	3.03
Trav-B#5	18.6	6.2	1.09	124	0.42	1.1	1.27	23.5	0.41	2.88

MO_95	RE_187	MN55	NI_60	GA_71	RB_85	CO59	SR_86	CD_114	CS_133	BA_135
7.1	6	0.24	0.8	2	14.2	16	860	0	3.53	40
14.3	13	0.195	1.42	0	17.4	74	1106	63	3.34	41
22.5	26	0.017	0.78	0	19.9	34	2168	0	4	18.2
7.85	9	0.193	1	0	19.8	44	948	0	3.42	67
6.57	7	0.061	0.5	11	14.6	16	912	0	3.16	56
10.5	11	0.035	0.9	8	17.5	66	976	113	3.4	54.2
6.1	8	0.135	0.39	5	15.6	20	767	0	3.25	66
6.26	8	0.061	0.89	0	16.7	91	970	43	3.5	57
6.1	7.2	0	1.12	12	12	48	771	23	3.38	64
6	9	0.048	1.25	9	13	Co 59	928	78	3.3	81
6.3	8	0	1.01	1	17.1	81	976	35	3.68	63.4
6.2	7.2	0.1	0.42	1.6	14.4	18	942	7	3.34	77
12.7	7	0.244	0.53	4	55.4	54	585	41	11	53
11	7	0.481	0.9	8	50.2	38	601	11	10.3	55
12.3	6	0.57	0.74	7.7	53	91	606	10	12	61
16.7	7.4	0.091	0.31	4	17	60	344	25	0.194	19.1
18	14	1.61	0.69	8	23.7	40	1130	15	2.08	43
24	15	0.022	0.28	10	50	0	3480	28	1.31	19
8.5	2.2	0.06	0.06	81	17.8	8.4	6.2	0	0.468	0.79
7.7	4.4	0.15	0.09	16	20.3	12	19.7	6	0.56	4.6
14.5	4.7	0	0.41	11	21.5	21	1067	12	1.95	35.6
13.96	6.2	0	0.41	12.2	20.7	24	1072	10	2.09	39
12.5	3.6	0.043	0.41	12	23	28	1021	14	1.94	40

TL_205	SN_117	SB_121	TI_47	GE73	TA_181	ZR_90
0.173	0.037	0.29	0.56	0.6	8	42
0.201	0.038	0.26	0.62	0.39	24	9
0.41	0.063	0.247	0.7	0.45	15	103
0.146	0.046	0.28	0.56	0.42	7	16
0.223	0.05	0.171	0.45	0.4	6	0
0.2	0.028	0.175	0.48	0.42	15	11
0.165	0.14	0.347	0.69	0.36	0	73
0.299	0.041	0.327	0.61	0.39	7	0
0.166	0.038	0.16	0.4	0.41	14	11
0.221	0.053	0.17	0.67	0.38	9	9
0.463	0.033	0.45	0.62	0.297	7	13
0.184	0.033	0.22	0.61	0.41	8	38
0.24	0.032	1.13	0.88	1.83	9	20
0.31	0.042	1.15	0.83	2.1	0	16
0.26	0.05	1.01	0.85	2.1	0	14
0.041	0.052	0.31	0.52	0.42	0	16
0.2	0.11	0.96	0.74	0.88	0	33
0.17	0.13	0.022	0.4	0.17	9	5
0.029	0	0.74	1	1.28	0	20
0.03	0.02	0.71	0.85	0.84	6	22
0.062	0.02	0.16	0.6	0.5	9	13
0.091	0	0.18	0.61	0.5	8	9
0.67	0.02	0.15	0.73	0.46	7	21

Information to Accompany Figure 27				
Eigenvalues (zero.sta)				
Extraction: Principal components				
		% total	Cumul.	Cumul.
	Eigenval	Variance	Eigenval	%
1	6.6084817	23.601721	6.6084817	23.601721
2	5.7776341	20.634407	12.386116	44.236128
3	4.0871249	14.596875	16.473241	58.833003
Factor Scores (zero.sta)				
Rotation: Unrotated				
Extraction: Principal components				
	Factor	Factor	Factor	
	1	2	3	
Big Spri	0.3529464	-0.167618	-0.468362	
Bradford	1.001764	0.5872973	-0.011533	
Cold Spr	0.2435241	1.6866337	0.3404161	
Crystal	0.7278829	-0.086262	-0.140149	
Fairbank	0.7742891	-0.28556	-0.496166	
Jackrabb	0.9518913	0.1753958	-0.315549	
King's P	0.3914799	-0.238213	-0.029474	
Longstre	1.0068858	-0.33583	0.0839388	
Point of	1.125258	-0.089861	-0.43876	
Point of	1.1238286	-0.26263	0.1032737	
Rogers-M	0.8277899	-0.449395	0.0353534	
Scruggs-	0.6949397	-0.529759	-0.418456	
Grape#5-	-0.936445	-0.464197	1.8326923	
U-Grape#	-1.04379	-0.57592	1.9531977	
M-Grape#	-0.828306	-0.734223	2.2650613	
Mesquite	-0.829789	0.339981	-1.001208	
Nevares#	-0.141791	-0.151978	1.5938362	
Saratoga	-1.250254	3.9394108	0.0080218	
Scotty#5	-2.482484	-1.296672	-1.64842	
Surprise	-1.930863	-0.566802	-1.288028	
Texas#5-	-0.017419	-0.19536	-0.864597	
Trav-A#5	0.0860957	-0.232069	-0.840938	
Trav-B#5	0.1525655	-0.06637	-0.254152	

Data for Figure 30 and 31

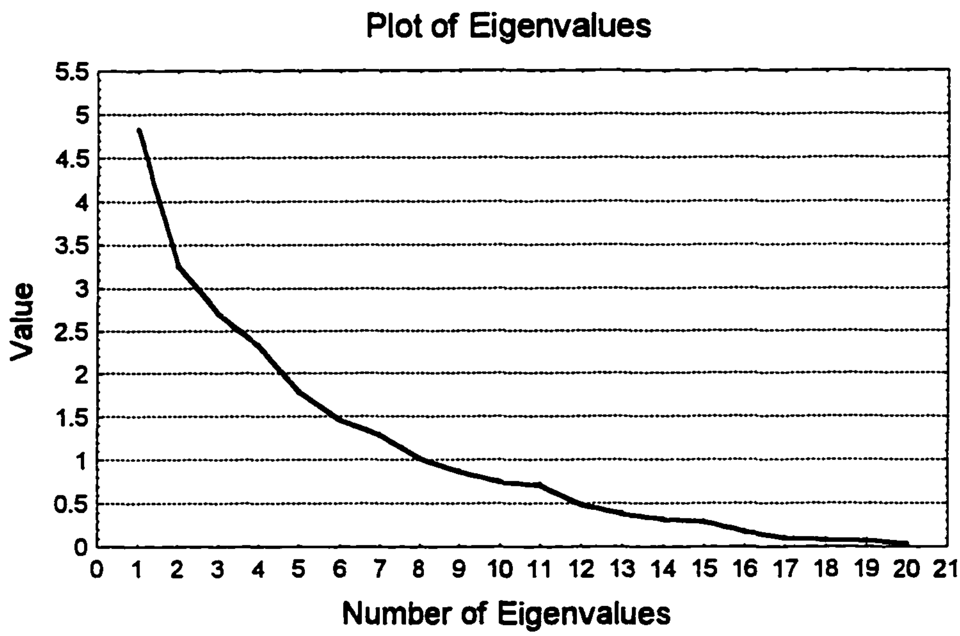
SPRING	SE_77	V_51	AS_75	W_182	U_238	MO_95	RE_187	MN55	NI_60	GA_71	RB_85	CO59
CRYSTAL	0.7857	0.964	12.9458	0.6104	4.4643	5.7653	17	ND	0.1627	3	10.0604	11
HIKO	0.779	2.0195	15.1142	0.8203	5.2417	6.021	17	ND	0.1376	4	13.809	14
ASH	0.6552	1.5373	34.6412	1.7554	3.0135	4.504	10	ND	0.1639	21	20.3163	13
Big	0.4	1.56	25.2	0.26	2.54	7.1	6	0.24	0.8	2	14.2	16
Bradford	0.43	2.16	19.3	0.27	5.7	14.3	13	0.195	1.42		17.4	74
Cold	0.84	1.37	17.7	0.2	7.9	22.5	26	0.017	0.78		19.9	34
CrysPool	0.33	1.3	20.9	0.224	2.9	7.85	9	0.193	1		19.8	44
Fairbank	0.33	0.79	10.6	0.21	2.2	6.57	7	0.061	0.5	11	14.6	16
Jackrabb	0.59	1.6	24	0.26	3.4	10.5	11	0.035	0.9	8	17.5	66
King's P	0.54	1.44	16.8	0.226	2.95	6.1	8	0.135	0.39	5	15.6	20
Longstre	0.49	1.31	15.2	0.214	2.74	6.26	8	0.061	0.89		16.7	91
PtRX NE	0.51	1.4	12.5	0.23	2.84	6.1	7.2		1.12	12	12	48
PtRX NW	0.64	1.71	15.2	0.232	2.9	6	9	0.048	1.25	9	13	Co 59
Rogers	0.42	1.08	20.4	0.164	2.61	6.3	8		1.01	1	17.1	81
Scruggs	0.36	1.13	18.6	0.3	2.7	6.2	7.2	0.1	0.42	1.6	14.4	18
L-Grape	1.2	3.4	23.9	2.33	3.7	12.7	7	0.244	0.53	4	55.4	54
U-Grape	1.1	2.74	22.4	2.1	3.53	11	7	0.481	0.9	8	50.2	38
M-Grape	1.2	3.02	23.6	2.1	3.8	12.3	6	0.57	0.74	7.7	53	91
Mesquite	1	13.6	31	0.31	6	16.7	7.4	0.091	0.31	4	17	60
Nevares	0.29	0.042	5.99	4.6	1.19	18	14	1.61	0.69	8	23.7	40
Saratoga	2.07	9	16.1	0.227	13.9	24	15	0.022	0.28	10	50	
Scotty's	0.96	10.1	34	4.42	6.98	8.5	2.2	0.06	0.06	81	17.8	8.4
Surprise	0.92	10.7	27.3	4.4	8.9	7.7	4.4	0.15	0.09	16	20.3	12
Texas	0.41	1.18	28	0.47	2.78	14.5	4.7		0.41	11	21.5	21
TravA	0.21	1	26.1	0.43	3.03	13.96	6.2		0.41	12.2	20.7	24
TravB	0.42	1.1	23.5	0.41	2.88	12.5	3.6	0.043	0.41	12	23	28
SAGA	1.56473	1.50923	8.71697	0.117798	6.0662	5.32403	25	0.817037	0.556236	ND	26.6635	19
SODA	2.17679	14.6467	44.1514	3.54389	29.994	352.095	11	1.5707	0.111639	4	27.1691	21
HARDROC	2.00739	1.81428	2.66804	ND	3.07779	1.08026	11	1.47762	1.10379	20	3.29346	73
ARMY	1.31195	1.5736	9.63807	0.169351	2.34425	5.63494	24	0.164564	0.978549	10	8.80307	29
CINDERLI	1.04805	4.7944	19.701	1.87081	2.53633	5.53656	16	0.186683	0.105727	48	12.7378	27
COFFER	0.607171	0.069264	3.00636	0.004665	0.0227	3.6379	ND	47.2715	1.37697	13	4.97967	75
AIRPORT	2.06565	10.1477	23.2049	1.81884	0.5958	1.99145	25	0.359618	0.051807	39	5.72541	23
COLLESE	5.39978	1.17976	0.515979	0.146274	13.7863	2.23018	22	0.652759	0.672417	ND	0.87824	52
LATHROP	2.50567	9.83047	22.1653	1.3249	2.34154	6.60461	31	0.216425	0.114182	4	10.9648	12
J13	1.584	11.43	17.315	1.1762	0.61747	8.1828	2	3.5303	0.3561	11	12.715	20
J12	0.688	5.39	10.2	0.493	0.58	7.36	3	0.104	0.323	0	13.7	0
Tippipah	0.56	1.396	2.04	11.9	0.52	701	11.3	1.39	0.087	76	7.07	28
Cane	2.22202	9.51455	7.20883	279	1.726	4227	21	1.11923	0.105777	1	9.69871	42
Topopah	0.17	1.34	1.64	2	0.076	3	0.2	5.16	0.2	93	9.98	46

			Data for Figure 30 and 31							
SR_86	CD_114	CS_133	BA_135	TL_205	SN_117	SB_121	TI_47	GE73	TA_181	ZR_90
224.1034	ND	2.3973	77.0726	0.2972	ND	0.6324	0.5308	0.1317	2	10
307.5758	ND	2.789	107.463	0.4077	ND	0.7697	0.8378	0.2128	2	13
424.8716	ND	8.8624	145.914	0.2759	ND	1.301	0.5447	0.4595	3	5
860		3.53	40	0.173	0.037	0.29	0.56	0.6	8	42
1106	63	3.34	41	0.201	0.038	0.26	0.62	0.39	24	9
2168		4	18.2	0.41	0.063	0.247	0.7	0.45	15	
948		3.42	67	0.146	0.046	0.28	0.56	0.42	7	16
912		3.16	56	0.223	0.05	0.171	0.45	0.4	6	
976	113	3.4	54.2	0.2	0.028	0.175	0.48	0.42	15	11
767		3.25	66	0.165	0.14	0.347	0.69	0.36		73
970	43	3.5	57	0.299	0.041	0.327	0.61	0.39	7	
771	23	3.38	64	0.166	0.038	0.16	0.4	0.41	14	11
928	78	3.3	81	0.221	0.053	0.17	0.67	0.38	9	9
976	35	3.68	63.4	0.463	0.033	0.45	0.62	0.297	7	13
942	7	3.34	77	0.184	0.033	0.22	0.61	0.41	8	38
585	41	11	53	0.24	0.032	1.13	0.88	1.83	9	20
601	11	10.3	55	0.31	0.042	1.15	0.83	2.1		16
606	10	12	61	0.26	0.05	1.01	0.85	2.1		14
344	25	0.194	19.1	0.041	0.052	0.31	0.52	0.42		16
1130	15	2.08	43	0.2	0.11	0.96	0.74	0.88		33
3480	28	1.31	19	0.17	0.13	0.022	0.4	0.17	9	5
6.2		0.468	0.79	0.029		0.74	1	1.28		20
19.7	6	0.56	4.6	0.03	0.02	0.71	0.85	0.84	6	22
1067	12	1.95	35.6	0.062	0.02	0.16	0.6	0.5	9	13
1072	10	2.09	39	0.091		0.18	0.61	0.5	8	9
1021	14	1.94	40	0.67	0.02	0.15	0.73	0.46	7	21
608.251	30	3.30139	50.5515	0.385059	0.038799	0.277802	0.542626	0.548492	5	17
355.586	178	0.193634	6.39364	0.193866	0.102348	0.085539	0.697763	0.707353	ND	16
382.896	22	1.28896	213.402	0.058753	0.030573	0.039199	0.469918	0.025385	ND	ND
213.402	ND	1.78565	73.9171	0.095973	0.043499	0.19098	0.526806	0.300895	28	17
105.177	12	1.52311	1.33644	0.030468	0.034112	0.409871	0.928504	0.816321	25	14
4206.47	23	1.64772	39.735	0.051076	0.041193	0.022244	0.730641	0.231283	ND	ND
24.0881	ND	1.34594	1.7379	0.03132	0.027268	0.295055	0.724015	0.923708	12	62
433.511	19	0.124655	41.1697	0.049246	0.036503	0.068283	0.522129	0.056677	ND	ND
100.72	10	1.41486	8.82344	0.04902	0.032885	0.501128	0.718185	1.079	25	ND
54.766	13	1.935	1.578	0.059	0.231	0.516	1.346	0.404	0.00594	0.0425
44.5	0	0.815	1.81	0	0	0.219	0.864	0.355	0.00626	0.0165
6.24	3	0.139	0.34	0.0429	ND	1944	4068	41	16.5	294
107.8	4	0.079741	18.6461	0.059687	ND	69.5	1270	196	ND	ND
6.85	22	0.7	0.258	0.053	ND	269	2.8	4	12	5

Information to Accompany Figure 30 and 31

Eigenvalues and Scree Plot-Extraction: Principal components

	Eigenvalue	% total Variance	Cumulative Eigenvalue	Cumulative %
1	4.826566	20.98507	4.82657	20.98507
2	3.261660	14.18113	8.08823	35.16620
3	2.702918	11.75182	10.79115	46.91802
4	2.322739	10.09887	13.11388	57.01689
5	1.789799	7.78173	14.90368	64.79862



Factor Loadings

	Factor 1	Factor 2	Factor 3	Factor 4	Factor 5
SE_77 .	299996	.249301	-.548296	-.219692	.077580
V_51	.279224	.792792	-.298606	-.118211	-.043455
AS_75	-.384144	.704981	.079957	.143105	-.165440
W_182	.689969	-.027291	-.342427	.570430	.111735
U_238	-.099638	.538659	-.375453	-.211014	-.120379
MO_95	.761320	.044751	-.253084	.522392	-.007254
RE_187	.098403	-.418091	-.411717	-.210540	.354151
MN55	-.207052	-.123815	.427376	.382259	.413354
NI_60	-.423573	-.669763	-.364153	.000847	.027296
GA_71	.128216	-.213623	.055859	-.490309	-.163250
RB_85	-.431058	.203183	-.183136	.311227	-.708656
CO59	-.195232	-.467612	-.537346	.069897	-.280199
SR_86	-.313710	-.468283	-.408534	-.092731	.011783
CD_114	-.269409	.271042	.073281	-.058728	.185249
CS_133	-.512921	-.147772	.018217	.455626	-.496291
BA_135	-.311478	-.401486	.014870	.423263	.227567
TL_205	-.470673	-.184790	.137338	.336781	-.244632
SN_117	.463789	.058457	.513071	.319635	.127303
SB_121	.595446	-.281684	.425079	-.273763	-.443960
TI_47	.743736	-.254405	.303521	-.097382	-.413498
GE73	.783451	-.005419	-.213668	.517801	-.026927
TA_181	.233929	.064676	-.632226	.060081	-.036035
ZR_90	.655101	-.418538	.034411	-.306709	-.210726

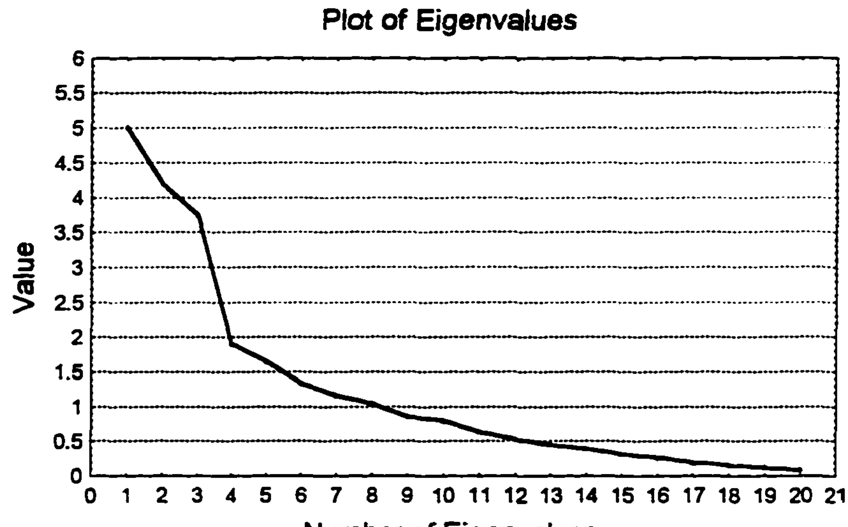
Factor Scores-Rotation: Unrotated

	Factor 1	Factor 2	Factor 3	Factor 4	Factor 5
CRYSTAL	-.148013	.13003	1.50684	.80814	1.49664
HIKO	-.310616	.11911	1.46203	1.09004	1.26827
ASH	-.739925	.32863	1.60214	1.75081	.45857
Big Spring	-.435805	.11497	.43685	-.00298	.17971
Bradford	-.598984	-.74260	-.49163	-.48881	-.39343
Cold Spring	-.415590	-.63477	-.28221	-.80613	-.52879
Crystal Pool	-.551762	-.42541	.14469	-.37507	-.14010
Fairbank	-.162592	-.34647	.56616	-.18390	.19564
Jackrabbit	-.648845	-.18140	-.13263	.12653	-.02531
King's Pool	-.116130	.04274	-.04412	-.01414	.19589
Longstreet	-.322487	-1.08030	-.14189	-.46473	-.76407
PtRxNE	-.527262	-.73769	.38370	.49218	.76991
PtRxNW	-.684725	-.87910	-.44337	.22005	-.00292
Rogers	-.908359	-.81212	.31698	.99008	.10649
Scruggs-	-.268768	-.16421	.46899	.17562	.13484
L-Grape	-.916651	.23083	-.18998	1.07587	-2.12589
U-Grape	-.827887	-.01931	-.64984	1.10803	-1.95094
M-Grape	-.933901	-.15144	-1.02609	1.28972	-2.46135
Mesquite	.161731	1.34475	-.80974	-.43776	-.08912
Nevares	-.145468	-.67883	-.40721	.06716	-.05274
Saratoga	-.515949	.37678	-1.68278	-.38199	-1.27744
Scotty's Castle	.476682	1.82199	.37774	-.58175	.16889
Surprise	.213536	1.55698	.19833	-.61123	-.06216
Texas	-.378525	.21613	.78622	.35798	.55055
Trav-A	-.173926	.14845	1.27987	.75073	.73273
Trav-B	-.645596	-.06136	.54408	.52089	-.67811
SAGA	-.292219	-.34227	.00406	-.47180	-.33147
SODA	-.099044	3.13704	-1.34108	-.71558	-.35427
HARDROCK	.389421	-1.39529	-1.24491	.49517	1.12997
ARMY	-.167802	-.36634	-.11907	-.32684	1.05141
CINDERLITE	.239720	.60010	.20247	-.73455	.26313
COFFER	-.076803	-2.71084	-2.02517	-.98605	1.80436
AIRPORT	.436848	1.02822	.04956	-1.10215	.76541
COLLESEUM	.793003	-.25212	-1.76616	-1.97925	.73814
LATHROP	.606686	.84635	-.25625	-.96122	.53326
J13	.203923	1.01353	.20685	-.48358	.26025
J12	.238788	.58742	.62972	-.46417	.55462
Tippipah	3.460918	-1.72578	2.53073	-1.74602	-2.79633
Cane	4.190417	.30117	-1.87521	3.59508	.46463
Topopah	.601962	-.23759	1.23133	-.59438	.21113

Information to Support Figure 33

Eigenvalues (a1.sta)-Extraction: Principal components

	Eigenval	% total Variance	Cumul. Eigenval	Cumul. %
1	5.013880	20.05552	5.01388	20.05552
2	4.194272	16.77709	9.20815	36.83261
3	3.747637	14.99055	12.95579	51.82316
4	1.910097	7.64039	14.86589	59.46354
5	1.654241	6.61696	16.52013	66.08051



Factor Loadings (Unrotated) (a1.sta)-Extraction: Principal components

	Factor 1	Factor 2	Factor 3	Factor 4	Factor 5
LI_7	-.627769	.259503	-.624796	-.187791	.128898
SE_77	-.109833	-.565313	-.199621	.384045	.431139
V_51	-.540492	-.487019	-.501404	.087341	-.020466
CR_52	.037112	.024280	-.760526	.053952	.283730
AS_75	-.605887	-.083788	-.173134	-.283823	-.557313
W_182	-.756010	-.145247	.198600	.124306	.036277
U_238	-.369346	-.401485	-.602283	.137679	-.149935
MO_95	-.463688	-.401814	-.430138	.028152	-.347320
RE_187	.050560	.766650	-.478372	.010220	-.034577
MN55	.227231	-.009079	.061382	-.833750	.029726
NI_60	.437036	.510881	-.040565	.045598	.334285
GA_71	.232178	.514345	-.346843	.232645	-.245082
RB_85	-.754087	.468574	-.110625	-.139687	.146996
CO59	-.187656	.686632	-.389646	-.134023	.154725
SR_86	.221188	.396609	-.494484	-.225701	.318170
CD_114	.299131	.499983	-.159553	.277987	-.474701
CS_133	-.498440	.585289	.445871	.003475	.046528
BA_135	.325941	.047863	.528927	.095336	.047788
TL_205	-.095667	.417728	.123999	.025745	-.393065
SN_117	.046339	-.065833	.036342	-.711527	-.121626
SB_121	-.608998	.290060	.601858	.066895	.002739
TI_47	-.581603	.098619	.349920	.075188	-.026799
GE73	-.804410	.280048	.276755	.029677	.176532
TA_181	-.443918	.299828	.085758	.158490	.284239
ZR_90	.252031	.470373	-.134011	.362967	-.288731

Factor Scores (a1.sta)-Rotation: Unrotated-Extraction: Principal components

	Factor 1	Factor 2	Factor 3	Factor 4	Factor 5
CRYSTAL	.53011	-.77729	.99674	-.00170	-.70864
HIKO	.06068	-.60088	1.32111	.10295	-.93671
ASH	-.48797	-.22465	1.73294	-.25937	-1.13244
Big Spri	.43683	.26876	-.12066	.27730	-.81673
Bradford	.51654	1.10608	-.86959	.36635	-.07476
Cold Spr	.42737	1.88338	-1.49038	1.04739	-1.41111
Crystal	.69105	.87662	-.55950	.50009	-.67856
Fairbank	.96909	.47858	.09653	.83665	-1.21744
Jackrabb	.53788	.60996	-.44573	.09377	-.54326
King's P	.25957	.52174	.35436	.89184	-.71433
Longstre	.67971	1.28214	-.49059	.84782	-.80102
Pt Rx NE	.94865	.12085	-.03340	-1.29605	.64872
Pt Rx NW	.68864	.37007	-.09932	.31143	.16543
Rogers-M	.47932	.65171	.05498	-1.46541	-.09852
Scruggs-	.42036	-.13011	.45677	-.02586	-.31465
Grape#5-	-2.01494	1.06621	.84658	.02641	.33220
U-Grape#	-2.06333	1.23267	1.03116	.21642	1.13291
M-Grape#	-2.22068	1.41688	.98314 .	06413	1.24569
Mesquite	-.70749	-.51295	-1.01409	-.03952 .	10201
Nevares#	-.87713	.76814	.68539	.52644	1.02265
Saratoga	-.52669	.40451	-3.40758	-.62173	1.98231
Texas#5-	.17487	-.32562	.00207	-1.78466	-.16673
Trav-A#5	.25657	-.31337	.07071	-3.95320	-.58393
Trav-B#5	-.03128	.15891	.20979	-.23463	-1.11664
SAGA	.25292	-.50498	.27041	.17586	.39708
SODA	-2.40625	-2.49517	-2.13516	.26972	-1.94207
HARDROCK	1.38931	-.97400	.90076	.89768	1.35153
ARMY	92481	-.77533	.45030	.37859	.54804
CIDERLIT	-.54780	-1.16742	.70879	.11155	.00381
COFFER	1.26150	.12453	-.12784	-.81120	1.96076
AIRPORT	-.42642	-1.43240	.00446	.44553	.08720
COLLESEU	.95477	-1.73154	-.27094	1.54929	1.72139
LATHROP	-.55059	-1.37605	-.11220	.55609	.55579

Appendix E:
ARC/INFO Macros

Macro for contouring using TIN: generates TIN contour maps for list of elements. Items within <> should be replaced with variable, value, or string of user's choice.

```
&do i &list <chemical elements, space delimited>
createtin %i%tin
cover location point %i%
end
tincontour %i%tin %i%contour <contour interval> <contour base line> %i%
ap
display 1040
%i%contour.gra
mape 460000 6150000 600000 6253000
pagesize 8 10
textfont universe
mapposition cen cen
textsize .14
arcs %i%contour
arctext %i%contour %i% # LINE # BLANK
points location
pointtext location %i%
quit
postscript %i%contour.gra %i%contour.ps
lpr -<printername> %i%contour.ps
kill %i%contour
kill %i%tin
&end
&do i &list <chemical elements>
createtin %i%tin
cover location point %i%
end
```

Macro for contouring variance: generates variance contour maps for specified element. Can be called from contouring macro. Items within <> should be replaced with variable, value, or string of user's choice.

```
ap
display 1040
%i%variance.gra
mape location
pagesize 8 11
maplimits 1.5 1 7.5 9
textfont universe
mapposition cen cen
textsize .14
arcs %i%variance
markerset water.mrk
markerpattern 411
markercolor 5
points location
arctext %i%variance %I% # LINE # BLANK
linesymbol 5
box 1.5 1 7.5 10
line 1.5,9 7.5,9
```

```
textsize .18
move 3 8.5
text %i% 'variance'
quit
postscript %i%variance.gra %i%variance.ps
lpr -<printername> %i%variance.ps
```

Macro for contouring using kriging: generates contour maps for specified elements. Items within <> should be replaced with variable, value, or string of user's choice.

```
&do i &list co re ti sn as sb ba cs ga ge tl ni w u mo se rb
&setvar int
&if %i% = re &then &s int 3
&if %i% = co &then &s int 10
&if %i% = sn &then &s int .01
&if %i% = ti &then &s int .01
&if %i% = as &then &s int 3
&if %i% = sb &then &s int .3
&if %i% = cs &then &s int .6
&if %i% = ba &then &s int 10
&if %i% = ga &then &s int .6
&if %i% = ge &then &s int .3
&if %i% = tl &then &s int .02
&if %i% = ni &then &s int .1
&if %i% = w &then &s int .3
&if %i% = v &then &s int .6
&if %i% = u &then &s int .6
&if %i% = mo &then &s int 5
&if %i% = se &then &s int .1
&if %i% = rb &then &s int 2.5
kriging location %i%lattice %i%var %i% # lattice
434904.062 6043319.500
630377.25 6317028.500
15
latticecontour %i%lattice %i%contour %int% 0 %i%
ap
display 1040
%i%contour.gra
mape location
pagesize 8 11
maplimits 1.5 1 7.5 9
textfont universe medium
textquality proportional
mapposition cen cen
textsize .14
arcs %i%contour
markerset water.mrk
markersymbol 412
markercolor 5
points location
linecolor 1
arctext %i%contour %i% # line # blank
linesymbol 5
box 1.5 1 7.5 10
```

```
line 1.5,9 7.5,9
textsize .18
move 3.5 9.5
text %i%
move 3.8 9.5
text 'Concentrations <concentration units>'
quit
postscript %i%contour.gra %i%contour.ps
lpr -<printername> %i%contour.ps
&end
```

Macro for location map: generates maps for specified sample sites in the location cover. Items within <> should be replaced with variable, value, or string of user's choice.

```
ap
display 1040
mymap.gra
mape location
pagesize 8 11
maplimits 1 2.7 8 9.7
mapposition cen cen
markerset water.mrk
markersymbol 412
markercolor 5
markersize .08
points location
textfont univers medium
textquality proportional
textsize .10
overpost .1 # .025
overpost on
overpost text moveable nodelete
pointtext location location-id
overpost off
textsize .18
textquality proportional
move 4.5 9.6
text 'Locations of Springs and Wells' cc
textquality constant
textsize .1
move 1.5 2.59
text '1 Crystal          13 Point of Rx NW      25 Travertine'
move 1.5 2.48
text '2 Hiko             14 Rogers              26 Saga'
move 1.5 2.37
text '3 Ash              15 Scruggs             27 Soda'
move 1.5 2.26
text '4 Big              16 L.Grapevine         28 Hardrock'
move 1.5 2.15
text '5 Bradford         17 U.Grapevine         29 Army'
move 1.5 2.04
text '6 Cold             18 M.Grapevine         30 Cinderlite'
move 1.5 1.93
text '7 Crystal Pool     19 Mesquite            31 Coffer'
```

```
move 1.5 1.82
text '8 Fairbanks        20 Nevarres         32 Airport'
move 1.5 1.71
text '9 Jackrabbit       21 Saratoga         33 Colleseum'
move 1.5 1.60
text '10 Kings Pool       22 Scottys Castle    34 Lathrop'
move 1.5 1.49
text '11 Longstreet      23 Surprise         35 J13'
move 1.5  1.38
text '12 Point of Rx NE    24 Texas            36 J12'
linesymbol 5
box  1.5 1 7.5 9.7
line 1.5,2.7 7.5,2.7
markerset scalebar.mrk
markerfont 15
markercolor 4
markersymbol 1
marker 6.5 7
box 6. 6.5 7. 7.5
move 1.5 1.15
textquality proportional
textsize .14
text 'Map Scale = 1:1693346'
line 5.5,1.15 6.5,1.15
line 5.5,1.1 5.5, 1.2
line 6.5,1.1 6.5,1.2
move 6.6 1.15
text '43km'
quit
postscript mymap.gra mymap.ps
lpr -<printername> mymap.ps
```

References:

Bedinger, M.S., Sargent, K.A., Langer, William H., "Studies of Geology and Hydrology in the Basin and Range Province, Southwestern United States, for Isolation of the Death Valley Region, Nevada and California," USGS Prof Paper 1370-F, 1989.

Broxton, David E., Warren, Richard G., Byers, Frank M., Scott, Robert B., "Chemical and Mineralogic Trends Within the Timber Mountain-Oasis Valley Caldera Complex, Nevada: Evidence for Multiple Cycles of Chemical Evolution in a Long-Lived Silicic Magma System," Journal of Geophysical Research, Vol. 94, No. B5, pp5961-8985, May 10, 1989.

Burbey, Thomas J., Prudic, David E., "Conceptual Evaluation of Regional Ground-Water Flow in the Carbonate-Rock Province of the Great Basin, Nevada, Utah, and Adjacent States, USGS Prof. Paper 1409-D, 1991.

Camera and Westenberg, "Selected Ground- Water Data for Yucca Mountain Region, Southern Nevada and Eastern California, Through December 1992, USGS OFR 94-54, 1994

Czarnecki, John B., Waddell, Richard K., "Finiete-Element Simulation of Ground-Water Flow in the Vicinity of Yucca Mountain, Nevada-California," USGS Water-Resources Investigations Report 84-4349, 1984.

Clarke, Keith C., Analytical and Computer Cartography, Prentice Hall, NJ, 1990.

Claassen, Hans C., Sources and Mechanisms of Recharge for Ground Water in the West-Central Amargosa Desert, Nevada-- A Geochemical Interpretation, USGS Open-file Report 83-542, pp1-57, 1983.

Dettinger, Michael D., "Distribution of Carbonate-Rock Aquifers in Southern Nevada and the Potential for their Development," Summary of Findings, 1985-1988, Summary Report No.1, 1989.

Dudley, W. W., Larson, J. D., Effect of Irrigation Pumping on Desert Pupfish Habitats in Ash Meadows, Nye County, Nevada, USGS professional Paper 927, pp1-55, 1976.

ESRI, Understanding GIS: The ARC/INFO Method, ESRI, 1990

Greenwood & Earnshaw, Chemistry of the Elements, Pergamon Press, Cambridge, 1984.

Hess, John W., "Hydrogeology of Regional Carbonate Aquifers in Eastern Nevada," International Contributions to Hydrogeology, Vol 13, 1992

Hodge, Vernon, Dept of Chemistry, University of Nevada, Las Vegas, personal communication 1995.

Hughes, Jerry L, Some Aspects of the Hydrogeology of the Spring Mountains and Pahrump Valley, Nevada, and Environs as Determined by Spring Evaluation, Mackay School of Mines, January 1966.

Hunt, C.B., Robinson, T.W., Bowles, W.A., and Washburn, A.L., "Hydrologic Basin, Death Valley, California," USGS Professional Paper 494-B, 1966.

Klein, Cornelis, and Hurlbut, Cornelius, Manual of Mineralogy, Wiley and Sons, 1977.

Johannesson, Kevin H., Stetzenbach, Klaus J., Kreamer, David K., Hodge, Vernon F., "Multivariate statistical analysis of arsenic and selenium concentrations in groundwater from south-central Nevada and Death Valley, Californnia," Journal of Hydrology, Vol, 1996.

Joreskog, K.G., Klovan, J. E., Reyment, R.A., Methods in Geomathematics 1: Geological Factor Analysis, Elsevier Scientific Publishing Company, NY, 1976.

Kreamer, David, Hodge, Vernon, Rabinowitz, Irving, Johannesson, Kevin, Stetzenbach, Klaus, "Trace Element Geochemistry in Water From Selected Springs in Death Valley National Monument, California," In press, 1996

La Camera, Richard J., Westenburg, Craig L., "Selected Groun-Water Data for Yucca Mountain Region, Southern Nevada and Eastern California, through December 1992, USGS OFR 94-54, 1994.

Linsley, Franzini, Freyberg, Tchobanoglous, Water Resources and Environmental Engineering, McGraw-Hill, USA, 1992.

Mack, C., Essentials of Statistics, Plenum Press, New York, 1967.

McKinley, P.W., Long, M.P., Benson L.V., "Chemical Analyses of Water from Selected Wells and Springs in the Yucca Mountain Area, Nevada and Southeastern California, USGS OFR 90-355, 1991.

MicroSoft Excel 4.0, MicroSoft Corporation, 1992-1993.

Mifflin, Martin D., Hess, John W., "Regional Carbonate Flow Systems in Nevada," Journal of Hydrology, 43, 1979, pp217-237.

Morrison, Donald F., Multivariate Statistical Methods, McGraw-Hill, 1967.

Norusis, Marija J., SPSS Professional Statistics 6.1, SPSS Incorporated, USA, 1994.

Okuda, Itaru, Okazaki, Masanori, & Hahitani, Takusei, "spatial and Temporal Variations in the Chemical Weathering of Basaltic Pyroclastic Materials," Soil Science Society of America Journal, 59:887-894 1995.

Nash, M.H, Daugherty, L.A., Whitford, W.G., "Cluster and Principal Commponent Analysis of Soil Sites Along a Transect," Soil Survey Horizons, Vol 34, no. 2, p39-60, summer 1993.

Perfect, Diana, Creation and Analysis of a Hydrochemical Data Base for the Death Valley Region, Nevada and California, thesis, Colorado School of Mines, March 29, 1994.

Perfect, Faunt, & Steinkampf, Hydrochemical Data Base for the Death Valley Region, U.S.G.S. OFR 94-XXXX, 1994 (data obtained on disk from Randy Lazniak-USGS (Water Resources Division, Las Vegas, NV).

Peterman, Z.E., Stuckless, J.S., Mahan, S.A., Marchall, B.D., Gutentag, E.D., and Downey, J.S., "Strontium isotope characterization of the Ash Meadows ground-water system, southern Nevada, USA," Water-Rock Interaction, 1992.

Peterman, Z.E., Stuckless, J.S., "Isotopic Evidence of Complex Ground-Water Flow at Yucca Mountain, Nevada, USA," High Level Radioactive Waste Management: Proceedings of 4th Annual International Conference, Vol 2, p. 1559-1566, 1993.

Runnells, Donald D, Shepherd, Thomas A., Angino, Ernest E., "Metals In Water," Environmental Science and Technology, Vol 26, no 12, 1992.

Salomons, W., Forstner, U., Metals in the Hydrocycle, Springer-Verlag, New York, 1984, pp138-209

Schoff, Stuart L., Moore, John E., "Chemistry and Movemnet of Ground Water, Nevada Test Site," USGS Report TEI-838, 1964.

SPSS 6.1, SPSS Inc., 1994.

Statistica 4.5, Statsoft, Inc. 1993.

Stetzenbach, Klaus, Harry Reid Center for Environmental Studies, personal communication, 1996.

Stetzenbach, Klaus, Amano, Megumi, Kreamer, David, Hodge, Vernon, "Testing the Limits of ICP-MS: Determination of Trace Elements in Ground Water at the Part-Per-Trillion Level," Ground Water, Vol 32, No. 6, Nov.-Dec. 1994.

Stevens, Calvin H., Stone, Paul, & Belasky, Paul, "Paleogeographic and structural significance of an Upper Mississippisan facies boundary in southern Nevada an deast-central California," Geological Society of America Bulletin, v. 103, p876-885, July 1991.

Stoodley, Keith, Applied and Computational Statistics, Ellis Horwood Limited, New York, 1984.

Thordarson, William, "Perched Ground Water in Zeolitized-Bedded Tuff, Rainier Mesa and Vicinity, Nevada Test Site," USGS Report TEI 862, 1965.

Veizer, Jan, "Trace Elements and Isotopes in Sedimentary Carbonates," Carbonates: Mineralogy and Chemistry, Reviews in Mineralogy, Vol 11, 1983

White, Art, Claassen, Hans, Benson, Larry, The Effect of Dissolution of Volcanic Glass on the Water Chemistry in a Tuffaceous Aquifer, Rainier Mesa, Nevada, USGS Water Supply Paper 1535-Q.

Windom, Herbert L, Byrd, James T., Smith, Ralph G, and Huan, Feng, "Inadequacy of NASQAN Data for Assessing Metal Trends in the Nation's Rivers," Environmental Science and Technology, vol 25, 1991, pp 1137-1142.

Winograd, Issac J., "Interbasin Movement of Ground Water at the Nevada Test Site," USGS, TEI 807, March 1962.

Winograd, Isaac, and Thordarson, William, Hydrogeologic and Hydrochemical Framework, South-Central Great Basin, Nevada-California, with Special Reference to the Nevada Test Site, USGS Professional Paper 712-C, 1-125 pp, 1975.

Winograd, Isaac, and Doty, Gene,Paleohydrology of the Southern Great Basin, With Special Reference to Water Table Fluctuations Beneath the Nevada Test Site During The Late (?) Pleistocene, USGS OFR 80-569, pp1-87, 1980.