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Uranium and other element geochemical covariation in a granitic host rock and in the derived sediment, Deep Creek Range, Juab County, Utah

By

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This report is preliminary and has not
been reviewed for conformity with U.S.
Geological Survey editorial standards
and nomenclature

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Abstract

Correlation and factor analysis of geochemical data from a Tertiary biotite quartz monzonite, the Ibapah stock, and from derived sediment shows on comparison a major shift in element covariation among uranium and 24 other elements. Samples used were collected for a 1978 study in the central part of the Deep Creek Range, Juab County, Utah.

Computed correlations among elements in granitic igneous rock samples suggest a high degree of covariation among elements that compose the rock. Uranium, however, shows significant correlation with only 12 elements and almost zero correlation with thorium. Computed correlations among elements in the derived sediment suggest that major decreases have occurred in covariation of the elements in the derived sands. Uranium in the sands, however, shows 15 significant correlations compared to 12 in the igneous rock samples, and shows an extremely high correlation with thorium. Factor analysis shows three geochemical petrogenic factors and the regional Be-U mineralization factor in the igneous rocks, and two mechanical segregation and one chemical precipitation factors in the sediments.

Introduction

During a recent (1978) economic resource study of a proposed wilderness withdrawal area in part of the Deep Creek Range in Juab County, Utah, many of the samples collected were from a granitic intrusive, the Ibapah stock. A few samples were also collected from alluvial-lacustrine sands adjacent to and apparently derived from the stock. Analytical data from these and other samples were published along with a resource evaluation of the area (Cadigan and others, 1979). The report was prepared for the U.S. Bureau of Land Management.

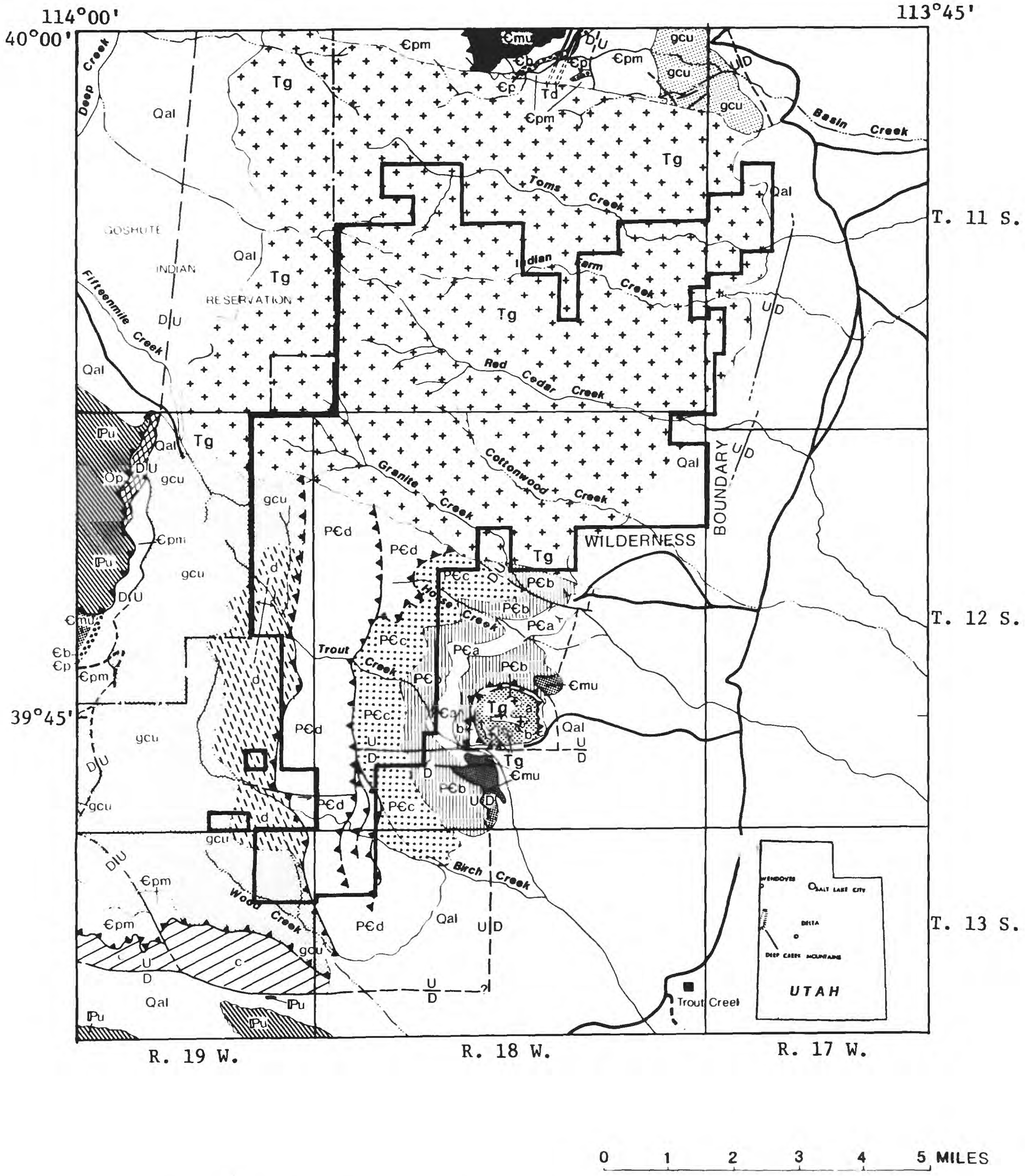

Figure 1.--Geology and location of the study area and Bureau of Land Management proposed wilderness area withdrawal boundaries. Explanation on following page. Prepared by R. S. Zech. Modified from Bick, 1966.

EXPLANATION FOR FIGURE 1

List of Map Units

(Modified from Bick, 1966)

Qal	Alluvium	Quaternary
Tg	Biotite quartz monzonites and granites of Ibapah stock	Tertiary
Td	Aplite dikes	
ℙu	Permian-Pennsylvanian rocks, undifferentiated	Permian and Pennsylvanian
Op	Pognip Group & Eureka Quartzite	Ordovician
Ꞓmu	Middle & Upper Cambrian rocks, undifferentiated	Cambrian
Ꞓb	Busby Quartzite	
Ꞓp	Pioche Shale	
Ꞓpm	Prospect Mountain Quartzite	
gcu	Goshute Canyon Formation, undivided	Cambrian or Precambrian
d	Formation d	
FAULT CONTACT		
pꞒd	Horse Canyon Formation, member D	Precambrian
pꞒc	" " " , " C	
pꞒb	" " " , " B	
pꞒa	" " " , " A	
FAULT CONTACT		
b	Formation b	Precambrian? (Relations unknown)
FAULT CONTACT		
a	Formation a	
FAULT CONTACT		
c	Formation c	

——— – – –	Contact, dashed where inferred	⇀ ——— – – –	Transverse fault
——— – – –	Normal fault, dashed where inferred	Y	Adit
—↕— – –	Anticlinal axis	━━━ - - -	Road
▲—▲—▲—	Thrust fault (sawteeth on upper plate)		

Climate and topography

The climate in the area studied varies from semiarid desert on the alluvial slopes (elevations, 1370-1670 m) to semiarid alpine in the mountains (2740-3680 m). Erosion on the eastern slope of the mountains has produced narrow steep-walled canyons. The mountainous terrain consists of bare rock in the lower elevations. Down-cutting streams dump their loads of detritus on the alluvial fans and coalescing fans of the bajada which rims the Snake Valley. In the late Pleistocene these land forms were modified by a lacustrine environment during the development and contraction of Lake Bonneville. The region, otherwise, is of typical Basin and Range province geologic structure and geomorphology.

Geochemical statistical study

One hundred and twenty-six samples of primarily quartz monzonite and granite were collected principally from surface outcrops and as representative of the exposed rocks. An occasional sample was taken near a fracture or fault in a potentially mineralized zone or area to detect possible incipient mineralization. Samples from recognizable mineralized or metamorphic zones are not included.

Eleven samples of alluvial sands were collected in areas where there tended to be radioactive concentrations of dark minerals. These were interpreted as possible placer concentrations of beach or stream origin. Analytical data are presented in table 1. Table 2 is a correlation chart for the elements in both igneous rocks and alluvium. Standardized *z* correlation coefficients are used to permit direct comparison of coefficients between the two populations because of the different numbers of sample pairs for each population. Coefficients in the upper right half of the matrix are those for

Table 1.--Analytical data from eleven samples of Tertiary to Holocene sediment derived principally from the Ibapah stock. Notes: Major elements are reported in percent(%). Trace elements are reported in parts per million (ppm). Uranium(U) and Thorium(Th) were determined by delayed neutron analysis, all others by spectrochemical methods. Symbols: L means present at levels below the lower limit; G means present at levels above the upper reporting limit; H means cannot be determined due to interference.

Sample	1 Si%-S	2 Al%-S	3 Fe%-S	4 Mg%-S	5 Ca%-S	6 Na%-S	7 K%-S	8 Ti%-S	9 P%-S	10 Mn ppm-S
MBQ335	16	4.3	1.50	1.20	16.00	3.3	1.6	0.19	0.05	360
MBQ681	31	8.5	1.80	0.77	2.40	2.8	4.0	.19	.06	540
MBQ682	35	7.8	4.60	0.40	2.00	3.6	4.7	.22	.06	570
MBQ684	36	6.7	1.90	0.18	0.55	2.2	4.1	.11	.06	320
MBQ687	29	5.6	20.00G	0.28	2.30	2.3	4.2	.48	.07	1400
MBQ688	19	3.8	20.00G	0.17	0.80	2.1	3.0	.85	.11	2400
MBQ737	33	8.5	8.10	0.48	3.60	3.0	3.8	.34	.07	630
MBQ738	18	3.4	20.00G	0.20	1.10	1.4	1.9	.75	.07	1800
MBQ756	37	6.4	0.24	0.21	1.00	2.5	4.6	.07	.04	200L
MBQ325	28	5.5	20.00G	.20	1.4	2.1	2.8	.59	.06	1200
MBQ336	26	5.0	20.00G	.17	1.3	2.0	2.6	.58	.06	1100

Sample	11 Ag ppm-S	12 Ba ppm-S	13 Be ppm-S	14 Co ppm-S	15 Cr ppm-S	16 Cu ppm-S	17 Ga ppm-S	18 La ppm-S	19 Li ppm-S	20 Mo ppm-S
MBQ335	1.0L	930	1.9	9.1	26	16.0	12	75	180	10L
MBQ681	1.0L	880	4.8	3.7	19	5.8	18	74	50L	10L
MBQ682	1.0L	900	4.0	4.6	40	5.4	20	380	50L	10L
MBQ684	1.0L	770	4.2	2.1	17	3.4	19	57	50L	10L
MBQ687	1.0L	880	3.7	14.0	170	9.1	33	480	50L	10L
MBQ688	1.0L	440	5.3	26.0	240	12.0	48	580	50L	0H
MBQ737	1.0L	870	4.6	6.2	59	7.3	25	380	50L	10L
MBQ738	1.0L	330	3.6	22.0	250	10.0	43	980	50L	0H
MBQ756	1.0L	1100	2.5	1.0	10L	2.5	11	21	50L	10H
MBQ325	1.0L	560	7.5	14.0	150	6.5	34	720	50L	10L
MBQ336	1.0L	510	4.0	13.0	130	5.5	33	670	50L	10L

Sample	21 Ni ppm-S	22 Pb ppm-S	23 Sc ppm-S	24 Sr ppm-S	25 V ppm-S	26 Y ppm-S	27 Zn ppm-S	28 Zr ppm-S	29 Th ppm	30 U ppm
MBQ335	20.0	21	10L	1900	68	29	50L	160	16	7.6
MBQ681	9.4	11	10L	360	38	27	50L	93	34	5.0
MBQ682	9.6	10L	10L	340	97	33	50L	81	158	16.9
MBQ684	6.0	10L	10L	220	37	22	50L	20	47	6.8
MBQ687	23.0	10L	12	320	310	85	50L	370	328	87.9
MBQ688	42.0	10L	20	170	320	88	0H	950	583	149.0
MBQ737	13.0	29	10L	340	140	52	50L	240	233	27.5
MBQ738	37.0	19	18	110	480	120	0H	560	642	168.0
MBQ756	3.2	12	10L	250	14	12	50L	20	14	2.4
MBQ325	24	10L	14	190	310	86	50L	680	348	93.7
MBQ336	22	10L	13	180	290	77	50L	570	337	104.0

Table 2.--Correlation chart of all pairs of elements for the igneous rock samples and for the sediment samples. Coefficients used are standard *z* coefficients. Igneous rock coefficients are below the diagonal (blanks). Sediment coefficients are above the diagonal. (For explanation of symbols see Table 1). Significance levels of *z* coefficients: At $p = \leq .01$ igneous samples ±2.58, sediment samples ±2.65; At $p = \leq .001$ all samples ±3.5.

Sediments

	Percent										Parts per million														
Element	Si-S	Al-S	Fe-S	Mg-S	Ca-S	Na-S	K-S	Ti-S	P-S	Mn-S	Ba-S	Be-S	Co-S	Cr-S	Cu-S	Ga-S	La-S	Ni-S	Pb-S	Sr-S	V-S	Y-S	Zr-S	Th-NA	U-NA
*Si-S	--	3.51	-1.32	1.03	0.41	3.06	2.12	-2.26	-1.33	-2.60	3.54	-0.38	-2.48	-2.78	-3.00	-1.33	-2.30	-2.84	-0.15	2.05	-2.75	-2.34	-2.52	-2.54	-2.75
*Al-S	-5.60	--	-0.38	2.87	0.48	1.53	3.02	-1.28	-0.17	-1.30	2.14	0.62	-1.12	-1.66	-1.53	-0.86	-1.44	-1.33	0.13	1.62	-1.83	-1.12	-1.18	-1.51	-1.72
*Fe-S	-2.92	7.36	--	0.41	0.19	-2.18	-0.50	2.75	2.20	1.85	-1.58	1.84	3.99	3.85	2.90	2.58	3.98	2.89	-0.53	-0.51	3.46	3.13	3.10	3.81	3.00
*Mg-S	-3.91	9.11	12.65	--	0.21	0.13	2.80	-0.10	0.97	0.40	0.44	1.33	0.26	-0.32	-0.06	0.63	-0.34	0.29	0.40	0.33	-0.51	0.35	0.18	-0.22	-0.30
*Ca-S	-4.63	6.35	7.67	8.00	--	-0.15	-0.56	-1.04	-0.70	-1.10	1.72	-1.26	-0.53	-0.30	0.64	-1.39	-0.06	-0.86	1.77	2.93	-0.28	-0.84	-0.06	-0.44	-0.84
*Na-S	1.74	4.08	0.61	1.52	0.34	--	1.01	-2.58	-2.54	-2.79	1.98	-1.24	-3.11	-3.11	-4.19	-2.28	-2.72	-3.16	0.31	0.77	-2.80	-2.46	-3.74	-2.86	-2.72
*K-S	0.24	4.98	1.28	2.25	-0.29	6.47	--	-0.84	0.72	-0.08	1.16	0.77	-0.63	-1.16	-1.16	0.12	-1.26	-0.48	-0.70	0.41	-1.33	-0.41	-0.93	-0.89	-0.85
*Ti-S	-4.83	11.32	10.79	13.66	7.90	2.46	3.75	--	1.80	3.44	-2.90	2.02	4.12	4.09	2.88	3.57	3.93	4.37	-0.82	-1.80	4.27	4.57	4.65	4.06	4.82
*P-S	-1.98	8.28	6.79	8.22	6.35	4.37	3.03	9.17	--	2.65	-1.57	2.26	2.76	2.15	2.27	3.22	1.56	2.83	-1.01	-1.00	1.71	2.38	2.01	2.21	2.13
*Mn-S	-3.02	6.17	8.33	10.40	5.43	0.73	2.47	9.53	6.75	--	-2.94	1.60	3.52	3.14	2.69	4.84	2.58	5.24	-0.65	-2.28	3.08	4.51	3.42	3.39	4.12
**Ba-S	-2.83	5.21	4.44	5.38	5.77	0.59	5.16	5.10	2.23	2.12	--	-1.26	-2.82	-2.69	-1.88	-3.20	-2.31	-3.33	0.35	4.01	-2.64	-3.02	-2.25	-2.77	-3.16
**Be-S	-0.97	2.19	3.41	2.10	-0.45	2.48	0.21	0.90	3.51	2.95	-2.79	--	2.05	1.48	1.02	2.26	1.24	1.94	-1.11	-0.91	1.20	1.89	1.66	1.43	1.45
**Co-S	-1.82	5.59	9.92	11.59	7.99	2.88	2.28	9.95	8.75	8.32	4.51	1.45	--	5.92	3.69	4.32	4.18	5.73	-0.80	-1.47	4.63	5.27	4.51	4.89	4.78
**Cr-S	-2.77	5.42	7.97	9.84	5.97	1.33	-0.28	8.85	6.84	6.87	2.56	0.98	11.32	--	4.02	2.15	5.30	4.69	-0.71	-1.34	6.82	4.65	4.41	5.92	5.41
**Cu-S	0.51	1.45	3.68	3.36	2.42	-0.53	-0.47	2.64	3.17	3.34	1.03	1.95	2.86	2.19	--	2.41	3.30	3.41	1.89	-0.65	3.58	2.99	3.77	3.47	3.08
**Ga-S	-1.31	6.32	4.21	4.10	1.26	5.39	5.17	5.60	7.97	4.51	-0.70	4.78	4.29	2.96	0.08	--	2.71	5.58	-0.88	-2.43	3.12	5.37	3.07	3.72	4.24
**La-S	-3.75	6.33	7.58	9.71	6.05	-0.14	1.60	10.11	4.37	5.90	5.02	-0.43	6.78	6.15	2.09	1.92	--	3.57	-0.47	-1.10	6.18	3.85	4.34	5.74	4.57
**Ni-S	-2.17	5.17	8.95	12.06	7.77	1.81	1.12	11.15	9.53	8.48	3.41	0.98	13.51	10.97	3.09	4.26	7.90	--	-0.65	-2.04	4.22	6.43	4.37	4.65	5.40
**Pb-S	2.42	.31	-1.60	2.18	2.84	2.34	5.38	-1.38	1.54	-0.44	1.33	-0.08	-3.67	-4.17	0.30	-0.17	-1.93	-3.19	--	0.42	-0.55	-0.58	-0.25	-0.60	-0.77
**Sr-S	-5.07	7.41	6.97	8.66	12.03	1.33	1.29	1.29	5.60	3.94	9.77	-1.45	7.81	6.36	1.82	0.61	5.83	7.12	-1.95	--	-1.40	-2.00	-1.05	-1.57	-1.99
**V-S	-2.36	4.62	7.55	10.04	7.02	1.33	0.70	9.68	7.84	8.39	2.79	0.22	11.94	10.21	2.68	3.70	7.50	14.01	-3.70	6.55	--	4.53	4.42	6.30	5.92
**Y-S	-4.26	8.91	8.58	9.22	4.66	2.36	4.00	9.84	6.48	7.93	3.60	3.02	5.89	5.09	2.11	6.20	6.38	6.79	0.26	4.61	4.91	--	4.16	4.94	5.83
**Zr-S	-2.79	4.61	7.35	7.02	7.55	-1.87	-0.39	6.58	4.55	4.49	4.82	-0.02	4.71	4.74	3.98	1.69	7.41	6.18	-1.88	6.14	4.80	5.39	--	4.15	4.15
**Th-DN	-3.23	5.49	4.23	5.81	2.76	-0.89	2.31	7.60	3.29	4.12	3.19	-1.51	3.23	4.48	0.48	2.52	7.93	5.07	-0.02	3.37	3.88	5.33	4.86	--	6.30
**U-DN	-0.26	3.72	4.15	3.29	0.26	2.86	2.69	3.24	2.32	3.57	-0.47	4.27	1.79	1.25	2.36	4.57	2.92	2.39	2.68	-0.13	1.81	5.79	1.45	0.54	--

Igneous samples

*Percent
**Parts per million

the alluvium samples. Coefficients in the lower half of the matrix are those for the igneous rock samples. Figure 2 shows these correlations in a schematic form. Transformation of r to z correlation coefficients was introduced by Fisher (1948).

The purpose of the comparison is to illustrate changes in geochemical element covariation in a source rock and element covariation in a sediment derived from the source rock. Highly significant correlations are estimated to be those with a z correlation greater than ±2.58 (significant at the $p \leq .01$ level) for the igneous rock samples and ±2.65 for the alluvium samples. The significance level, $p \leq .01$ means that the probability of such a correlation occuring by chance is equal to or less than 1 in 100, 1 percent, or .01.

The greatest difference in the correlation of elements occurs between Ti and Mg in the igneous rock samples and Ti and Mg in the alluvium samples. In the igneous rock, z equals 13.66 for Ti and Mg. In the alluvium z is -0.10. This is a change from a high positive correlation, significant at the $p \leq .001$ level, to a correlation that is almost zero. Other similar changes occur; examples are Al and Ti; Pb and K; and in the other direction Th and U.

Th and U have an nonsignificant positive correlation in the igneous rock samples, but a very highly significant ($p \leq .001$ level) positive correlation in the alluvium samples. This increase in the correlation of U and Th is opposite to the general trend of decreasing correlation between elements, as the mechanical fractionation of the igneous rock takes place. The result of mechanical fractionation shows in the lower element correlations in the placer-type sands.

SEDIMENT
SIGNIFICANT ELEMENT CORRELATIONS

IGNEOUS ROCK
SIGNIFICANT ELEMENT CORRELATIONS

Si	••				••				•̲•̲	••			•̲•̲	•̲•̲			•̲•̲			•̲•̲				•̲•̲
●̲	Al		••			••																		
•̲•̲	●	Fe					••					●	●	••		●	••			••	••	••	●	••
●̲	●	●	Mg			••																		
●̲	●	●	●	Ca															••					
	●				Na				•̲•̲			•̲•̲	•̲•̲	●̲		•̲•̲	•̲•̲			•̲•̲		●̲	•̲•̲	•̲•̲
	●				●	K																		
●̲	●	●	●	●		●	Ti		••	•̲•̲		●	●	••	••	●	●			●	●	●	●	●
	●	●	●	●	●	••	●	P	••			••					••							
•̲•̲	●	●	●	●			●	●	Mn	•̲•̲		••	••	••	●		●			••	●	••	••	●
•̲•̲	●	●	●	●		●	●			Ba		•̲•̲	•̲•̲		•̲•̲		•̲•̲		●		•̲•̲		•̲•̲	•̲•̲
		●						●	••	•̲•̲	Be													
	●	●	●	●	••		●	●	●	●		Co	●	●	●	●	●			●	●	●	●	●
•̲•̲	●	●	●	●			●	●	●			●	Cr	●		●	●			●	●	●	●	●
		●	••				••	••	••			••		Cu		••	••			••	••	●	••	••
	●	●	●		●	●	●	●	●		●	●	••		Ga	••	●			••	••	••	●	●
●̲	●	●	●	●			●	●	●	●		●	●			La	••			●	●	●	●	●
	●	●	●	●			●	●	●	●		●	●	••	●	●	Ni			●	●	●	●	●
				••		●						●̲	●̲				•̲•̲	Pb						
●̲	●	●	●	●				●	●	●		●	●			●	●		Sr					
	●	●	●	●			●	●	●	••		●	●	••	●	●	●	●	●̲	V	●	●	●	●
●̲	●	●	●	●		●	●	●	●	●	••	●	●		●	●	●		●	●	Y	●	●	●
•̲•̲	●	●	●	●			●	●	●	●		●	●	●		●	●		●	●	●	Zr	●	●
•̲•̲	●	●	●	••			●	••	●	••		••	●			●	●		••	●	●	●	Th	●
	●	●	••		••	••	••		••		●				●	••		••			●			U

● Significant (p<.001) positive correlation

●̲ Significant negative correlation

•• Significant (p<.01) positive correlation

•̲•̲ Significant negative correlation

Si Element symbol (silicon)

Identify any space by element (symbol) in vertical column correlated with element (symbol) in horizontal row.

Figure 2.--Comparison of element correlations to show the trend from generally high element covariation in igneous rock to generally lower element covariation in derived sediment.

Figure 2 illustrates the general trend from many significant correlations among elements in igneous rocks to much fewer significant or more nonsignificant correlations among elements in the derived sediment. Greatest decreases in geochemical covariation occur among the elements Si, Al, Fe, Mg, Ca, Na, K, P, Ba, Be, Pb, and Sr. The smallest decreases or actual increases in geochemical covariation occur among the elements Ti, Co, Cr, Cu, Ga, La, Ni, V, Y, Zr, Th, and U.

Many of the changes in covariation are noteworthy; such as the loss of significant correlations between other elements and Ca and Sr. Another element which loses most statistically significant correlations is Al, which seems tightly bound into the mineral structure of the igneous rocks, but varies in abundance almost completely independently of other elements when it becomes part of a sediment. Beryllium (Be), varies in abundance almost independently of the other elements, in the sand samples. The data used in this report can only suggest the drastic changes in the geochemical covariation that occur when a source rock is, in effect disintegrated and its parts reassembled to form a sediment. To interpret the changes in step by step fashion would require more samples and a designed experimental approach which was not attempted in this study.

To complete the statistical study of the geochemical data available, multivariate factor analysis was attempted for the two sets of samples. The raw data for the two sets were transformed to logarithms, symmetrical correlation coefficient matrices were prepared for each set and used as the basis for separate R-mode factor analyses, using the varimax method.

The factor analysis of the correlation matrix for the 126 igneous rock samples resulted in the selection of the four factors as best explaining the covariance of the elements. Tentative interpretation of the four factors is based on the reordered oblique projection matrix. The oblique projection matrix seems to provide the most reasonable logical grouping of the elements. Table 3 shows the element groups with tentative interpretive factor identifications. The oblique projection matrix is derived by an axis-fitting process from the varimax (table 4) matrix.

Factor analysis of igneous rock major and trace element geochemical variance produces element groupings that may be the end product of several processes. These processes may include original mineral segregation and crystallization (factors 1 and 3), later re-solution and recrystallization (factor 2), solution invasion, and enrichment or replacement of parts or all of the rock body (factors 2 and 4), selective weathering, oxidation, etc. Covariation between pairs of elements (such as Na and K) may be affected by more than one geochemical process acting on the rock body.

The major processes that apparently controlled the element covariation in the Ibapah stock are referred to as "trends". The elements which are grouped under a trend are components. Elements with loadings of 0.40 or more are shown in table 3. An element which is a primary component of one factor, can also be a secondary component of another factor if the secondary loading exceeds 0.40.

Factor 1 is identified as a base metals and ferromagnesian mineral trend. More subjectively it may represent the tendency of some parts of the rock body to vary in the direction of a mafic mineral segregation from the average biotite quartz monzonite mineral assemblage. This major factor,

Table 3.--Reordered oblique projection matrix showing factor element groups, element loadings, and apparent geochemical affinity of the group. Element symbols in parentheses are those which show a secondary relationship to the factor group. Based on analyses of 126 igneous rock samples.

Factor 1 Base metals and ferro magnesian mineral trend	Factor 2 Alkali metal mineral trend	Factor 3 Monzonite trend	Factor 4 Uranium-beryllium mineral trend
(Mafic mineral segregation)	(Lithium enrichment)	(monzonite vs. granite segregation)	(U-Be mineralization)
V: 1.00	Na: 1.00	Ba: 1.00	U: 1.00
Ni: 1.00	K: .77	Sr: .69	Y: .85
Co: .98	Li: .69	Al: .63	Be: .66
Cr: .98	Ga: .61	Th: .60	Cu: .54
Mg: .81		La: .54	
P: .75			
Fe: .72			
Ca: .71			
Ti: .68			
Mn: .68			
Pb: -.83	Zr: - .60	Si: - .50	
(Zr: .49)	(Cu: - .45)	(Ti: .49)	(Mn: .60)
(Sr: .55)		(Pb: .46)	(Pb: .55)
(La: .52)		(K: .60)	(Fe: .61)
		(Ca: .44)	(Al: .56)
		(Y: .40)	(Ga: .52)
			(Zr: .46)
		(Be: - .57)	(La: .45)
		(Li: - .43)	(Th: .43)

Table 4.--Reordered varimax factor matrix showing the four factors as defined by varimax loadings. Communalities are shown for all elements. Based on analyses of 126 igneous rock samples.

Elements	Factor 1	Factor 2	Factor 3	Factor 4	Communality
Co	0.809*	0.235	0.343	0.110	0.84
V	.798*	.084	.321	.136	.77
Ni	.786*	.126	.387	.217	.83
Cr	.772*	.028	.316	.131	.71
P	.621*	(.415)	.257	.287	.71
Pb	-.651*	.380	.149	.137	.61
Na	.130	.822*	-.091	.003	.70
K	-.204	.803*	.328	.021	.79
Ga	.286	.617*	.015	(.461)	.68
Li	.289	.591*	-.242	(.410)	.66
Ba	.048	.192	.772*	-.308	.73
Sr	(.478)	.090	.699*	-.229	.78
La	.354	-.048	.686*	.226	.65
Ti	(.525)	.265	.673*	.276	.87
Al	.239	(.430)	.650*	.250	.73
Zr	.294	-.256	.637*	.249	.62
Th	.119	.022	.619*	.145	.42
Mg	(.605)	.140	.607*	.329	.86
Ca	(.564)	-.043	.584*	-.059	.66
Y	.226	.289	.559*	(.526)	.72
Fe	(.500)	.045	.539*	(.455)	.75
Si	-.139	.089	-.507*	.010	.28
U	-.094	.233	.152	.711*	.59
Be	.136	.190	-.270	.678*	.59
Mn	(.480)	.146	.386	.489*	.64
Cu	.143	-.227	.192	.439*	.30

*Primary factor components; (___) secondary factor components.

accounts for 41 percent of the variance in the correlation matrix. The major component elements are listed in table 3 in order of the relative degree to which they are affected by the factor. A numerical loading is given with each component. The abundance of Pb in the rock samples is negatively affected by factor 1. The elements Zr, Sr, and La are listed as secondary major components under factor 1 because their individual variances are to a greater degree affected by other factors.

Factor 2 is identified as an alkali metal mineral trend. More subjectively it may represent the effect of the invasion of pegmatitic veins by Li-, Na- and K-rich solutions which resulted in enrichment of the pegmatites with Li. This trend accounts for 12 percent of the variance in the correlation matrix. The amount of Zr in the pegmatites is negatively affected by this trend. A secondary negative component is Cu.

Factor 3 is identified as a monzonite trend. More subjectively it may represent a variation in composition towards a monzonite away from rock with the composition of quartz monzonite or granite. This trend accounts for 8 percent of the variance in the correlation matrix. The amount of the Si component is negatively affected as are the secondary components Be and Li by this trend towards a monzonite. As may be seen in Table 3 some of the other alkaline components are Al, La, K and Ca.

Factor 4 is identified as a uranium-beryllium mineral trend. More subjectively this is probably the reflection of the well known regional beryllium belt, the western end of which has been projected as far as the Deep Creek Mountains by Cohenour (1963). The commercial deposits of beryllium at Spor Mountain lie 55 km to the east. A similar Be-U factor was observed in factor analysis of the Spor Mountain "beryllium tuff" data by Cadigan and

Ketner (p. 24, 1980) This trend accounts for 6 percent of the variance in the correlation matrix. This is interpreted as a regional mineralization factor which has mobilized U, Y, Be and Cu principally and secondarily Mn, Pb, Fe, Al, Ga, Zr, La, and Th.

Table 4 shows the four factors, the varimax factor loadings and the communalities of the elements for the four factors. For example, the communality for Ti is 0.87 which indicates that 87 percent of the variation of occurrence of Ti is explained by the four factors. Only 28 percent of the variation in Si occurrence is explained by the four factors.

The interpretations made are qualified by the computed communalities. Communalities are the sum of squares of the rows of the loadings in table 4. Thus for uranium (U), four factors explain a total of 59 percent of the variance and factor 4, the uranium-beryllium factor alone explains 51 percent of the variance ($.711^2 = .51$) for U. For thorium, a total of 41 percent of the variance is explained by four factors and 38 percent is explained by factor 3 alone, the monzonite trend.

The four factors represent the four most important geochemical factors that can be related to variation in distribution of the elements used in the analysis. These factors account for 67 percent of the variance in the correlation matrix derived from the 126 samples of Tertiary igneous rocks.

Factor analysis was also attempted on the analytical data from the 11 samples of derived alluvium. At the rotation of the fourth factor a single element factor was produced. By convention this occurrence limited consideration to the first three factors. They are shown in table 5, the reordered varimax factor matrix. Primary and secondary components are shown as in table 3 together with numerical loadings.

Table 5.--The reordered varimax factor matrix for three factors derived from analytical data for 11 samples of alluvial sand. Element loadings in parentheses indicate high loadings for a second factor.

	Factor 1	Factor 2	Factor 3	Communality
	Heavy Mineral concentration	Mica (biotite) concentration	Chemical precipitation	
Zr	0.956*	-0.076	-0.093	0.93
Co	.951*	.003	-.256	.97
Cr	.949*	-.186	-.177	.97
Cu	.939*	-.174	.114	.92
Th	.932*	-.149	-.227	.94
La	.925*	-.199	-.071	.90
V	.924*	-.263	-.168	.95
Ni	.912*	-.030	-.394	.99
Fe	.906*	.139	.047	.84
Y	.901*	.002	-.380	.96
U	.891*	-.183	-.370	.96
Ti	.846*	-.104	-.389	.88
Ga	.811*	.129	(-.548)	.97
Mn	.796*	-.007	(-.498)	.88
P	.709*	.365	-.307	.73
Be	.527*	(.524)	-.395	.71
Ba	-.623*	.353	(.609)	.88
Si	-.679*	(.593)	.248	.87
Na	-.861*	.161	.022	.77
K	-.260	.887*	-.207	.90
Al	-.339	.887*	.237	.96
Mg	.112	.878*	.033	.78
Ca	.079	-.019	.978*	.96
Sr	-.286	.279	.845*	.87
Pb	-.090	-.186	.515*	.31
Sc	(.670)	-.098	-.683*	.92

*Primary factor components; (___) secondary factor components.

The alluvial-lacustrine sands were, of course, formed under a different geologic environment than the igneous rocks. The emplacement factors were predominantly petrogenetic or geochemical for the igneous rock samples. They were predominantly hydrogeochemical (weathering and leaching), hydraulic and mechanical for the sand samples.

Factor 1 is identified as heavy mineral concentration; it is characterized by the concentration of Fe, Ti, Cr, Zr, and other elements related to resistant detrital minerals. The radioactive elements U and Th are primary components of the heavy mineral fraction and have no secondary relationships to the other two factors. Factor 1 accounts for 64 percent of the variance in the correlation matrix, probably a reflection of the sample bias towards the placer-type sands.

The concentration of light minerals, should show a negative correlation with this factor, and indeed Na, Si, K, and Al all have negative loadings. The light minerals would be mainly quartz, and feldspar, and clay.

Factor 2 is identified as a mica (biotite) and clay fraction concentration because of the high positive loadings for K, Al, and Mg. High positive secondary loadings appear for Si, and Be. Factor 2 accounts for 13 percent of the variance in the correlation matrix. This factor is in accord with the petrologic classification of the Ibapah stock as a biotite quartz monzonite.

Factor 3 is identified as a chemical precipitation factor. The grouping of the primary elements Ca and Sr is characteristic of sedimentary rocks. The negative loadings for Sc, Mn, and Ga suggests that other precipitated minerals may be competitive with those represented by Ca, Sr, and Pb, but are of less significance. The relatively high negative loadings for U and Be suggest that they occur in a precipitated mineral form as well as in a detrital mineral form. A high positive secondary loading for Ba suggests that Ba in barite probably occurs as a precipitated mineral in the sediment. The precipitated elements may be a contribution of the lacustrine environment in which part of the sands were deposited or reworked. Remnants of white chalky deposits in nearby areas, thought to be old Lake Bonneville sediments, contain high abundances of Ca and Ba.

The high communalities in table 5 probably reflect the low number of samples used in the study, and the resulting high values of the correlation coefficient _r_, on which the factor analysis is based.

The three identified factors account for 87 percent of the variance in the correlation matrix based on the eleven sand samples.

Economic implications

Cadigan and others (1979) and Cadigan and Ketner (1980) are two economically oriented reports covering the area. Neither assigned a significant mineral resource potential to the area of the Ibapah stock and derived sediments. Both reports suggest the possibility of some economic production of uranium and thorium from the placer-type sand deposits. Data used in this study shows that the Ibapah stock samples contain a mean of 6 ppm U and a maximum of 45 ppm. Mean abundance of beryllium is 4.4 ppm and the maximum is 19 ppm. These data, based on surface samples do not suggest the presence of Be and U in economical significant amounts. The presence, however, of a uranium-beryllium factor suggests that it might be used as a geochemical exploration tool to evaluate drill-core from the Ibapah stock and the central part of the Deep Creek Range. The method would involve computing factor scores after the method of Steiner (1965). Computation of factor scores for individual samples would enable an exploration team to identify the samples and perhaps areas in the Ibapah stock which were most positively affected by the U-Be factor. This is done as follows:

1. Transform all igneous rock data into standard scores by dividing the data values for each element by the maximum value for the element. Or, by using a computer program like the USGS STATPAC z-matrix search program (VanTrump, 1978).
2. Multiply the standardized data values for the factor 4 primary and secondary component elements by the factor 4 loadings in table 4 or table 3 for each sample and sum the products for each sample. The sum is the factor score for that sample for the U-Be factor.

An exploration target, a trend, or identification of maximum effects of the regional beryllium belt can thus be localized, if present. This should be an improvement over relying only on concentrations of individual elements without applying the multielement information that exists among the Factor 4 primary and secondary component elements for the igneous rock samples.

Summary and conclusions

A comparison was made of the covariances of major and trace elements in 126 samples of granitic rocks and in 11 samples of sandy sediment apparently derived from the granitic rock. Intercorrelation of elements within each of the sets of samples was conspicuously different. The correlations were generally higher in the igneous rock samples.

Factor analysis of analytical data for the two sets of data suggested that the four major factors controlling variance within the igneous rock element correlations were related to petrogenesis and a regional mineralization trend. In detail they were (1) a mafic mineral segregation trend as opposed to a dispersal trend; (2) a lithium-sodium-potassium enrichment trend interpreted to result from solution invasion of the pegmatitic veins; (3) a monzonite trend as opposed to a granite formation trend; and (4), a uranium-yttrium-beryllium mineralization trend interpreted to be the effect of a region-wide mineralization which created the western central Utah "beryllium belt."

Sediment sample factor analysis produced three major factors: (1) the concentration of heavy minerals; (2) the concentration of mica (biotite) and clays; and (3) the concentration of precipitated minerals. The first two seem to reflect the hydraulic environment effecting the transportation and concentration of detrital minerals. The third is related to precipitation of minerals from either stream or lake waters, a factor commonly seen in sedimentary rocks or minerals precipitated from mineralized waters.

The results suggest that the close geochemical interrelationships of elements in an igneous granitic rock are not carried over into a sediment derived from that rock. New relationships evolve based on hydraulic, solution, and weathering properties.

Uranium and thorium show little mutual petrogenic relationship in the Ibapah stock, but on erosion of the stock, uranium- and thorium-bearing minerals respond similarly to the heavy mineral concentrating process and the result is a high statistical correlation of occurrence of U and Th. Assuming that the Th content of the igneous stock has remained fairly constant, it may be speculated on that the U tended to be more mobile. There seem to be three substantial reasons for poor correlation between U and Th in the igneous samples. One would be the effects of weathering (oxidation) and solution in the exposed stock. All samples were surface samples. A second reason might be late magmatic or contact metamorphic hydrothermal solution activity which might have moved or removed U from its original minerals. The third reason for the lack of correlation might be the effect of the regional "beryllium-belt" mineralization activity which produces high U-Be correlations, suggesting hydrothermal transportation of U away from Th.

These possible effects can only be offered as suggestions. Further study would be necessary to weigh the relative importance of the suggested U-migration processes.

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