

UNITED STATES DEPARTMENT OF THE INTERIOR  
GEOLOGICAL SURVEY

Chemical characteristics of the uranium-vanadium deposits  
of the Henry Mountains Mineral Belt, Utah

by

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Open-File Report 84-367

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

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1984

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# Chemical Characteristics of the Uranium-Vanadium Deposits of the Henry Mountains Mineral Belt, Utah

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## ABSTRACT

This report summarizes the analytical results for 237 samples of sandstone and 244 samples of mudstone from the Henry Mountains mineral belt of Utah. The data were statistically treated to determine which elements were enriched or depleted in these primary tabular-type uranium-vanadium deposits compared to unmineralized parts of the host rocks. Along with uranium and its radioactive daughter products, the mineralized sandstones in the Henry Mountains mineral belt are enriched in Al, Be, organic carbon, Co, Cr, Cu, Fe, Ga, K, Mg, Mo, Na, Ni, Pb, S, Se, Sr, Ti, V, Y(?), and Zr. Silica is depleted in the mineralized sandstones compared to unmineralized sandstones. A comparison of mineralized mudstones to unmineralized mudstones suggests that, in addition to uranium and its radioactive daughter elements, the mineralized mudstones are enriched in Al, B, Be, organic carbon, Co, Cr, Cu, Ga, K, Mo, Sc, Se, Sr, and V. Manganese, calcium, and mineral carbon are depleted in the mineralized mudstones.

## INTRODUCTION

The goals of this study are to summarize some of the existing geochemical data for the primary tabular-type uranium-vanadium deposits and related rocks in the Henry Mountains mineral belt of southeastern Utah, and to determine which elements are enriched or depleted in the ore deposits relative to unmineralized rocks. Mineral deposits in the Henry Mountains region occur in the Salt Wash Member of the Morrison Formation. Northrop (1982) points out that the deposits are localized in synclines and are associated with organic matter. Detailed descriptions of the deposits and the geology of the Henry Mountains mineral belt are presented in Peterson (1980).

## NATURE OF THE DATA AND STATISTICAL TREATMENT

The elements considered in this study, the limits of determination for each element and the analytical techniques used are shown in figure 1. The wet chemical techniques noted in figure 1 are combustion idiometric titration and gravimetric methods for sulfur, combustion thermal conductivity for total carbon, and volumetric methods for mineral carbon. Organic carbon was determined by difference. Most of the other data are from 6-step semiquantitative emission spectrographic analysis. These data are presented as midpoints (.15, .2, .3, .5, .7, and 1.0) of geometric brackets whose boundaries are 0.12, 0.18, 0.26, 0.38, 0.56, 0.83, and 1.2. Thus, there are six brackets for every order of magnitude; the boundaries and midpoints for higher or lower values are the same as these except for the position of the



decimal. The precision of a reported value in 6-step data is approximately plus-or-minus one bracket at the 68-percent confidence level and plus-or-minus two brackets at the 95-percent confidence level (Motooka and Grimes, 1976). Twelve samples were analyzed for 23 elements by induced neutron activation analysis.

Large sets of spectrographic analytical data such as these inevitably include results from samples that contain too little of certain elements to permit accurate determinations of their abundances. Data for such samples in these results were presented in two categories. One category was for samples with such a low concentration of some element that no evidence for the presence of the element was found (N in the data for "not detected"); the other category was for samples in which the element was present but at too low a concentration to permit an accurate determination (L in the data for "less than the limit of determination"). A technique known as Cohen's method (which is described by Miesch, 1967, and is part of the USGS STATPAC program) was used to estimate most probable values of the geometric means and geometric deviations for these censored distributions. The calculation is based on the following factors: (1) the logarithm of the limit of determination; (2) the number of concentration values that are below (or in the case of data sets containing G (greater than) values, above ) the limit of determination and (3) the total number of samples. The geometric mean and geometric deviation of the analytical values within the limits of determination are computed and then the geometric mean and geometric deviation of the entire distribution, assuming log-normality, are estimated using equations developed by Cohen (1959, 1961). In censored distributions (N's, L's, or G's present), where a high percentage of the analyses are outside the limits of determination, the geometric means obtained by Cohen's method should be considered only as indicating the probable order of magnitude of the means of the samples which are within the limits of determination.

As a first step in determining the characteristics of the deposits and related rocks, the 481 available samples were divided into seven groups. These groups are: sandstones with greater than 1000 ppm uranium, sandstones with greater than 100 ppm uranium (this set includes those samples with greater than 1000 ppm uranium), sandstones with less than 100 ppm uranium, sandstones with less than 20 ppm uranium (this is a subset of sandstones with less than 100 ppm uranium), mudstones with more than 100 ppm uranium, mudstones with less than 100 ppm uranium, and mudstones with less than 20 ppm uranium (this is a subset of mudstones with less than 100 ppm uranium).

Summary statistics, shown in Appendix 1, were calculated by computer using the USGS STATPAC programs. Similar presentations of the data for primary tabular uranium deposits in the Ambrosia Lake district and in the Smith Lake district are included in Spirakis and others (1981) and in Pierson and others (1983). The detection ratios reveal how many values had to be estimated in order to arrive at the geometric means for each element in each data set. According to Fisher (1950), the logarithms of geochemical data approach a normal distribution more closely than do the untransformed values in ppm or percent; consequently, geometric means (which are based on the logarithms of the data) are a better measure of the central tendency of the data than are arithmetic means. The geometric means, therefore, were used to identify differences in the concentrations of the elements among the groups of mineralized and background samples.

Tests for statistical significance of differences between the above mentioned sample groups for a given element were made utilizing a "t" test described by Natrella (1963, p. 26-28). Summary statistics used in the test are the means and variances of the logarithmic values and the number of samples in each group. A standard table giving percentiles of the "t" distribution was used to determine whether the observed differences were significant at the 95-percent confidence level. It is this significance that is referred to in the observations. The samples were not collected in anticipation of statistical treatment; consequently, they were not collected in a truly random manner and are not ideally suited for statistical tests.

## OBSERVATIONS AND DISCUSSION

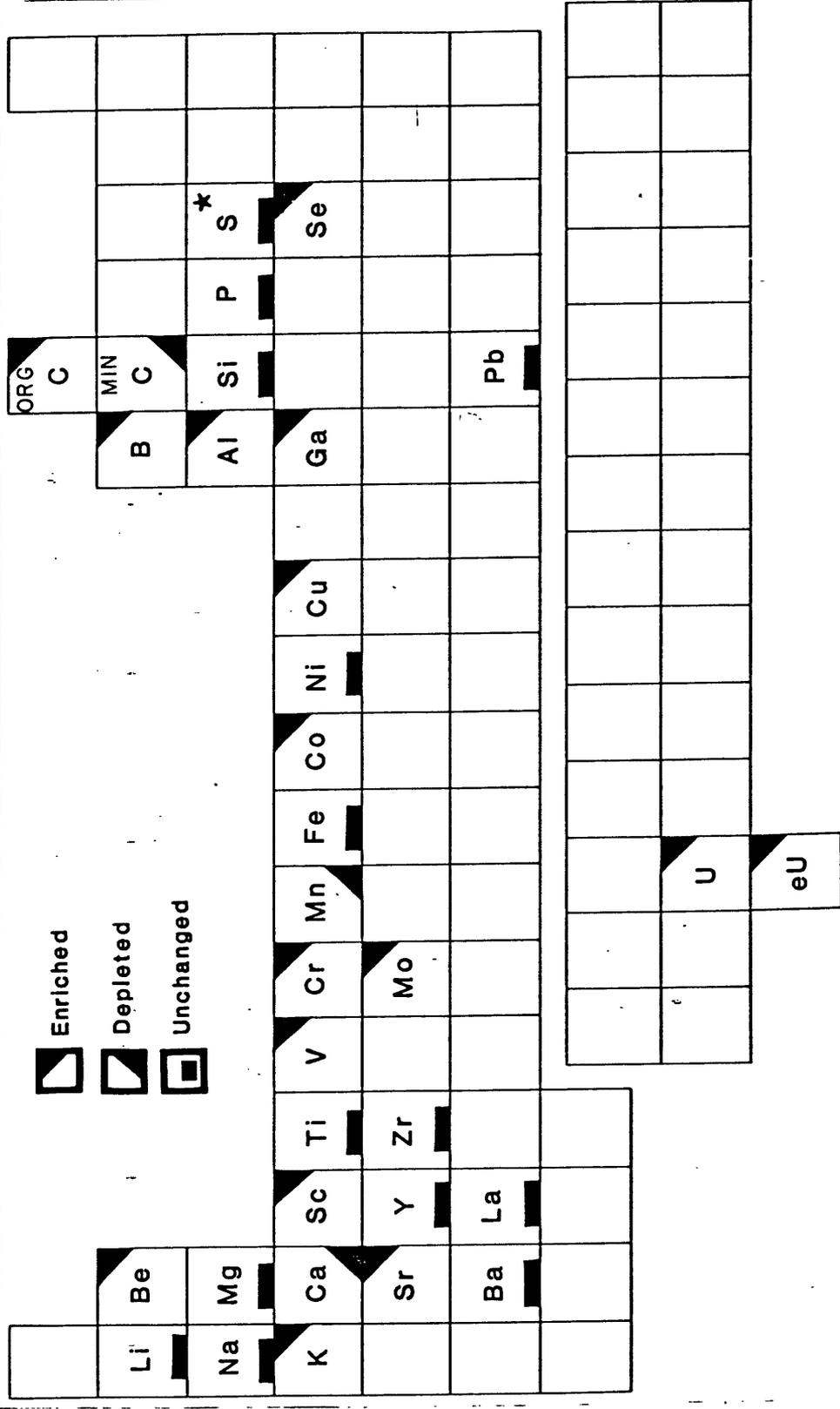
Figure 2 shows which elements are enriched, depleted, or unchanged in abundance in mineralized sandstone (more than 100 ppm uranium) compared to unmineralized sandstone (less than 100 ppm uranium) in the Henry Mountains mineral belt. Those elements enriched along with uranium and its radioactive daughter products in the sandstone deposits include Al, Be, organic carbon, Co, Cr, Cu, Fe, Ga, K, Mg, Mo, Na, Ni, Pb, S, Se, Sr, Ti, V, Y(?), and Zr. No significant difference in the abundances of B, Ba, mineral carbon, Ca, Mn, and P were detected between mineralized and unmineralized sandstones. Silica is the only element found to be depleted in the sandstone ores.

Figure 3 presents conclusions as to the behavior of elements in mineralized mudstones compared to nonmineralized mudstones. In the mineralized mudstones, Al, B, Be, organic carbon, Co, Cr, Cu, Ga, K, Mo, Sc, Se, Sr, and V are enriched along with uranium and its radioactive daughters; manganese, calcium and mineral carbon are depleted. No significant differences were found in the abundance of Ba, Fe, La, Li, Mg, Na, Ni, P, Pb, S, Si, Ti, Y, and Zr between mineralized and unmineralized mudstones.

Of the elements Cu, Fe, Mo, Pb, Se, Sr, S, V, Y, Ba, Ca, and organic carbon, which were found to be typically enriched in primary tabular uranium deposits in the Grants Uranium region (Spirakis and Pierson, in press), only barium and calcium are not enriched in the primary tabular deposits in sandstones in the Henry Mountains mineral belt. The barium content of mineralized and unmineralized rocks in the Henry Mountains deposits is much lower than the barium content of mineralized and unmineralized sandstones in the Grants region. In the Ambrosia Lake area, the enrichment of barium in mineralized sandstones but not in mineralized mudstones was interpreted as an indication that barium was added to the deposits after the mudstones were compacted (Spirakis and others, 1981). Paragenetic relationships indicate that barite formed after the primary ore-forming process (Hansley, in press). Adams and Saucier (1981) note that the barium content is higher in oxidized rocks than in nonoxidized rocks in the Grants region. From these observations it seems likely that the barium enrichment in the primary deposits in the Grants region formed from the postmineralization oxidation of pyrite, associated with the ores, to sulfate; this newly formed sulfate then combined with barium to precipitate as barite. The absence of a barium enrichment in the Henry Mountain deposits is consistent with the conclusion that, since the deposits formed, they have remained below the water table and were protected from atmospheric oxidation.



Figure 3--Elements enriched, depleted, or unchanged in abundance in mineralized mudstones in the Henry Mountains mineral belt compared to unmineralized mudstones.



\* The result for sulfur is suspect due to the low number (9) of mineralized samples and the high geometric deviation of the data.

The growth of chlorite in the ore and the enrichment of the ore in aluminum requires the transport of aluminum to the deposits. As an inorganic complex, aluminum has a very low solubility in most natural waters; however, in the presence of certain organic complexing agents, the solubility of aluminum may increase by a factor of 100 (Lind and Hem, 1975). This suggests that aluminum and possibly other elements were transported to the ore deposits with mobile organic matter.

Although pyrite is known to be associated with the primary tabular deposits in the Henry Mountains and elsewhere, and both iron and sulfur were found to be enriched in the mineralized sandstones, neither iron nor sulfur was enriched in the mineralized mudstones compared to nonmineralized mudstones. The only other area in which data on mineralized mudstones are available is the Ambrosia Lake area (Spirakis and others, 1981). As in the mineralized mudstones in the Henry Mountains, iron was not enriched in the mineralized mudstones in the Ambrosia Lake area. This suggests that ore-stage pyrite did not precipitate in the mineralized mudstones.

The similar enrichments and depletions of many elements in the Henry Mountains ore deposits and in the ores in the Grants region suggest that the primary tabular deposits in both areas may have formed from similar processes.

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Appendix 1--Element abundances in primary tabular uranium-vanadium deposits of the Henry Mountains mineral belt.

Blanks mark geometric means and geometric deviations which were not presented because of a high proportion of N and L values in the data set.

G denotes that values greater than the upper limit of determination are present in the data.

G,L denotes that values both above and below the limits of determination are present in the data

Detection ratios of less than one and not followed by "G" indicate data sets that contain values below the limit of determination.

1) Due to problems with the Mn data, MnO data were used.

Henry Mountains  
Sandstones

Element or compound  
(limit of  
determination)

	More than 1000 ppm U				More than 100 ppm U				Less than 100 ppm U				Less than 20 ppm U			
	Geometric Mean	Geometric Deviation	Detection Ratio	Geometric Mean	Geometric Deviation	Detection Ratio	Geometric Mean	Geometric Deviation	Detection Ratio	Geometric Mean	Geometric Deviation	Detection Ratio	Geometric Mean	Geometric Deviation	Detection Ratio	
Al% (.05)	2.9	1.74	23/24 <sup>G</sup>	2.4	1.69	50/51 <sup>G</sup>	1.5	1.63	186/186	1.4	1.56	152/152				
B ppm (10)	12	3.20	13/24	13	2.89	29/51	13	2.30	113/186	13	2.13	92/152				
Ba ppm (2)	303	1.97	24/24	283	1.74	51/51	245	1.74	186/186	240	1.72	152/152				
Be ppm (1)	2.4	2.53	19/24	1.6	2.49	36/51		2.49	43/186			51/152				
Organic C% (.01)	.568	2.94	23/23	.437	2.57	49/49	.176	2.66	104/106	.151	2.51	73/75				
Mineral C% (.01)	.042	58.55	13/23	.179	18.75	36/49	.370	7.30	93/106	.386	6.93	66/75				
Ca% (.002)	2.18	3.56	24/24	2.87	3.33	49/51 <sup>G</sup>	2.07	4.23	185/186 <sup>G</sup>	2.11	4.39	152/152				
Co ppm (1)	37	4.16	22/24	13	6.50	42/51	2.0	2.97	144/186	1.9	2.55	120/152				
Cr ppm (1)	15	1.84	24/24	12	2.29	48/51	4.3	2.78	160/186	4.0	5.83	95/152				
Cu ppm (1)	12	1.94	24/24	8.4	2.43	51/51			39/106	4.0	2.53	131/152				
Fe% (.05)	1.7	1.91	24/24	7	4.44	36/41			83/186			61/152				
Ga ppm (5)	14	2.42	21/24	5.4	3.73	26/51			13/186			5/152				
K% (.1)	1.5	1.92	24/24	1.3	1.80	50/51	.8	1.79	179/186	.8	1.72	146/152				
La ppm (20)	21	2.23	12/24			16/51			37/186			35/152				
L1 ppm (50)	56	2.80	13/24			12/51			28/186			21/152				
Mg% (.002)	.46	2.03	24/24	.34	2.05	51/51	.14	2.79	136/186	.12	2.63	104/152				
MnO% (.001)	.039	2.28	14/14	.042	2.23	25/25	.032	2.62	24/24			14/14				
Mo ppm (3)	30	3.28	22/24	9.5	7.74	33/51			12/186			1/152				
Na% (.05)	.13	2.65	18/24	.11	2.82	36/51			41/186			26/152				
Ni ppm (2)	28	2.72	23/24	15	3.14	46/51	5.3	2.00	170/186 <sup>G,L</sup>	4.9	1.86	139/152				
Pb ppm (10)	.02	3.34	13/24	.02	2.68	26/51	.03	2.37	119/186 <sup>G,L</sup>	.03	2.50	98/152				
T-S% (.005)	.165	7.73	14/14	.157	6.19	25/25	.018	17.1	18/29			2/152				
Se ppm (.1)	234	7.42	21/23 <sup>G</sup>	70	8.43	49/51 <sup>G</sup>	.83	13.2	71/96	.010	7.23	9/17				
SiO <sub>2</sub> % (.002)	70.9	1.15	14/14	72.8	1.16	25/25	79.6	1.12	24/24	.34	13.7	45/70				
Sr ppm (5)	112	1.82	24/24	111	1.85	51/51	68	1.67	185/186	80.5	1.13	14/14				
Ti% (.02)	.08	1.77	24/24	.07	1.76	51/51	.06	1.67	181/186	65	1.65	151/152				
U ppm (.25)	5990	2.50	24/24	1052	6.23	51/51	2.5	5.61	186/186	1.3	3.06	152/152				
eU ppm (10)	4500	1.97	12/12	1004	4.95	25/25	23	5.98	19/31	22	5.93	124/152				
V ppm (7)	3320	7.98	21/24 <sup>G</sup>	937	1.12	47/51 <sup>G,L</sup>	31	7.73	154/186	11	1.33	99/152				
Y ppm (10)	38	2.35	22/24	20	2.83	40/51	10	1.41	113/186	11	1.33	99/152				
Zr ppm (10)	181	1.76	24/24	140	2.33	51/51	46	3.80	150/186	40	3.76	120/152				

Henry Mountains  
Mudstones

Element or compound  
(limit of  
determination)

	More than 100 ppm U			Less than 100 ppm U			Less than 20 ppm U		
	Geometric Mean	Geometric Deviation	Detection Ratio	Geometric Mean	Geometric Deviation	Detection Ratio	Geometric Mean	Geometric Deviation	Detection Ratio
Al% (.05)	9.3	1.32	14/20 <sup>G</sup>	7.4	1.45	200/224 <sup>G</sup>	7.2	1.45	180/196 <sup>G</sup>
B ppm (10)	96	1.48	20/20	69	1.54	223/224	68	1.56	195/196
Ba ppm (2)	278	1.25	20/20	288	1.28	224/224	291	1.28	196/196
Be ppm (1)	3.8	1.64	19/20	2.7	1.56	213/224	2.7	1.56	187/196
Organic C% (.01)	.535	1.90	18/18	.228	2.54	140/142	.197	2.45	114/116
Mineral C% (.01)	.080	5.88	14/18	.226	8.89	120/144	.210	10.20	95/116
Ca% (.002)	.65	2.02	20/20	1.70	3.24	222/224	1.71	3.34	195/196
Co ppm (1)	14	2.91	19/20	7.4	1.62	221/224	7.2	1.60	193/196
Cr ppm (1)	57	1.40	20/20	43	1.47	224/224	42	1.48	196/196
Cu ppm (1)	34	1.72	20/20	23	1.83	224/224	21	1.78	196/196
Fe% (.05)	2.6	1.51	20/20	2.7	1.65	224/224	2.8	1.67	196/196
Ga ppm (5)	29	1.68	19/20	13	2.03	180/224	12	2.03	154/196
K% (.1)	4.3	1.56	20/20	3.2	1.49	223/224	3.1	1.49	195/196
La ppm (20)	23	1.92	11/20	28	1.48	170/224	29	1.43	160/196
Li ppm (50)	117	4.06	13/20	89	2.47	168/224	87	2.41	148/196
Mg% (.002)	1.57	1.35	20/20	1.47	1.58	224/224	1.42	1.57	196/196
MnO% (.001)	.017	1.39	8/8	.028	1.47	52/52	.030	1.73	35/35
Mo ppm (3)	2.7	2.73	9/20			9/224			2/196
Na% (.05)	.23	3.18	16/20	0.19	3.46	170/224	0.17	3.79	142/196
Ni ppm (2)	20	1.71	20/20	19	1.38	224/224	19	1.38	196/196
P% (.02)	.03	4.22	11/20	.05	2.60	179/224	.06	2.40	166/196
Pb ppm (10)	18	2.50	14/20	15	1.93	167/224	14	1.83	144/196
T-S% (.005)	.063	9.42	7/9	.037	4.67	46/52	.027	3.80	29/34
Sc ppm (7)	14	1.54	18/20	8.8	1.95	158/224	8.3	2.00	132/196
Se ppm (.1)	56.6	5.04	17/17	2.1	8.49	129/138	1.3	6.10	102/111
SiO <sub>2</sub> % (.002)	62.5	1.10	8/8	60.8	1.11	52/52	60.3	1.12	35/35
Sr ppm (5)	269	1.56	20/20	162	1.47	224/224	156	1.48	196/196
Ti% (.02)	.35	1.35	20/20	.32	1.75	224/224	.32	1.80	196/196
U ppm (.25)	558	3.20	20/20	4.5	3.03	224/224	3.2	2.04	196/196
eU ppm (10)	688	1.96	10/10	40	2.10	42/43	27	1.64	27/28
V ppm (7)	491	3.39	20/20	109	2.13	224/224	96	1.86	196/196
Y ppm (10)	26	1.59	20/20	26	1.35	223/224	26	1.32	195/196
Yb ppm (1)	3.9	1.48	5/5	2.9	1.35	39/39	3.0	1.31	27/27
Zr ppm (10)	194	1.62	20/20	185	1.41	224/224	190	1.42	196/196