Table 2. Subdivisions ("splitting") of the Main Phosphorite in the Zin Valley (cut off > 20% P_2O_5).

Sub Area	Borehole No.	Layer 1		Barren (m)	Layer 2		Barren (m)	Layer 3		Barren (m)	Layer 4		Barren (m)	Layer 5		Barren (m)	Layer 6	
		Thick.(m)	P_2O_5(%)		Thick.(m)	P_2O_5(%)		Thick.(m)	P_2O_5(%)		Thick(m)	P_2O_5(%)		Thick.(m)	P_2O_5(%)		Thick.(m)	P_2O_5(%)
Zinim	1	1.2	24.3	1.2	←		3.4m– 21.4 %	→		1.8	0.4	21.6	1.4	1.2	25.8	17.4	1.0	20.8
	4	1.2	24.1	1.2	←		2.6m– 22.6 %	→		1.4	1.0	22.7	1.0	1.2	24.0	–	–	–
	6	1.8	21.3	0.4	1.0	19.4	←	1.2 *	→		0.8	22.2	1.0	2.0	22.0	14.0	0.6	22.9
	10	0.6	21.6	0.4	0.4	20.4	0.4	0.8	20.4	2.0	0.8	25.6	0.8	0.4	24.0	–	–	–
Nahash Zame	1	1.2	21.9	1.8	0.6	19.6	1.4	1.2	20.7	2.4	0.6	19.6	2.2	1.0	19.0	–	–	–
	4	0.8	21.2	1.0	0.6	21.0	1.4	0.6	21.9	2.0	1.0	24.1	1.8	0.8	25.1	–	–	–
	8	1.0	20.9	0.8	←		3.8m– 22.4 %	→		2.0	1.2	24.3	0.8	1.0	23.7	17.0	1.0	22.0
	12	0.6	20.0	2.2	1.2	21.8	1.6	0.4	22.7	2.4	0.8	22.8	1.2	1.2	23.3	–	–	–
	15	0.8	20.2	2.4	0.6	20.7	1.8	0.6	21.3	2.4	0.6	19.5	2.2	0.6	21.3	–	–	–
	18	–	–	–	–	–	–	1.0	21.2	←	4.2 *		→	1.0	24.7	15.2	1.4	20.4
VIII	2	0.8	19.8	←	3.0 *		→	0.8	21.4	2.0	0.4	24.2	0.8	1.0	20.5	–	–	–
VII	1	1.8	23.4	2.4	←		2.2m– 22.9 %	→		2.2	0.4	31.1	1.6	2.0	21.6	–	–	–
	4	0.6	20.0	2.4	0.6	20.7	←	4.6 *	→		0.8	22.2	–	–	–	–	–	–
	7	1.4	21.2	2.0	←		2.4m– 21.5 %	→		2.4	0.6	25.0	1.8	–	–	–	–	–
VI	1	1.4	20.4	2.4	←		2.2m– 21.3 %	→		2.0	1.0	23.6	2.2	0.4	21.9	17.0	0.6	21.1
	4	2.0	22.2	1.0	←		2.0m– 22.4 %	→		2.2	1.2	25.0	1.2	0.4	17.8	–	–	–
	6	1.0	21.0	2.4	1.0	21.2	←	2.8 *	→		1.0	21.1	1.6	0.4	17.4	–	–	–

* Barren interval (in m).

Layer 6 is part of the Upper Unit of the Mithash Formation (not part of the Main Phosphorite as defined in this wirk).

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RESOURCE EVALUATION USING HYDROGEOCHEMICAL AND STREAM SEDIMENT RECONNAISSANCE DATA

Michael Beyth and Carlotta McInteer[1]

Background

During a sabbatical year at the Los Alamos Scientific Laboratory (LASL), the authors carried out comprehensive data evaluations using results from hydrogeochemical and stream sediment reconnaissance (HSSR) from the Rocky Mountain states and Alaska. Detailed output data are published on open-file through the U.S. Department of Energy. The following is a brief summary of methods employed, based on the draft report.

Introduction

The scope of the HSSR program (U.S. Department of Energy) includes uranium, thorium, lithium, and several other elements as selected by each participating laboratory. LASL reports analyses for 42 elements in addition to uranium. Sediment samples are analysed for Be and Li by emission spectrography, and for Ag, Bi, Cd, Cu, Nb, Ni, Pb, Sn and W by X-ray fluorescence. Sediment samples are also analysed for Al, Ba, Ca, Cl, Dy, K, Mg, Mn, Na, Sr, Ti and V using neutron activation with a short time delay before analysis; and for Au, Ce, Co, Cr, Cs, Eu, Fe, Hf, La, Lu, Rb, Sb, Sc, Sm, Ta, Tb, Th, Yb and Zn by using neutron activation with a long time delay before analysis. Water samples are analyzed by fluorometry for uranium.

The information resulting from the HSSR is made public as open-file reports through the DOE Grand Junction, Colorado, office and at other DOE regional offices across the United States. The results are reported by U.S. Geological Survey quadrangle maps.

Various statistical analyses and geological interpretation supported by mineralogical and leaching experiments of the stream and lake sediments using HSSR data have been carried out at LASL. Their approach in these studies is to support evaluation of national uranium and strategic or commercially important mineral resources.

In a LASL Brief 80-10, David A. Freiwald discusses the U.S. energy sources and minerals crisis and recommends that industry be stimulated to explore for new mineral resources domestically by increasing the noncompetitive government programs like the DOE's NURE program where collected samples could be analyzed for several minerals.

The HSSR multielement analyses greatly enhances the overall program. Several of these additional elements are useful for evaluating the uranium data in a more thorough manner; but of even more significance is their importance as essential raw materials. In effect, the HSSR has assumed a key role in evaluating the long range minerl resources of the U.S., both for energy planning and for future economic growth.

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[1] Los Alamos Scientific Laboratory

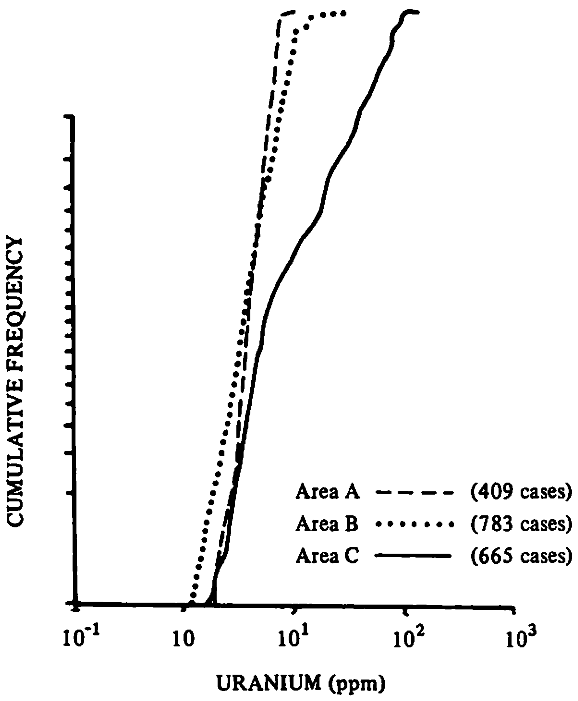

Fig. 1 a.

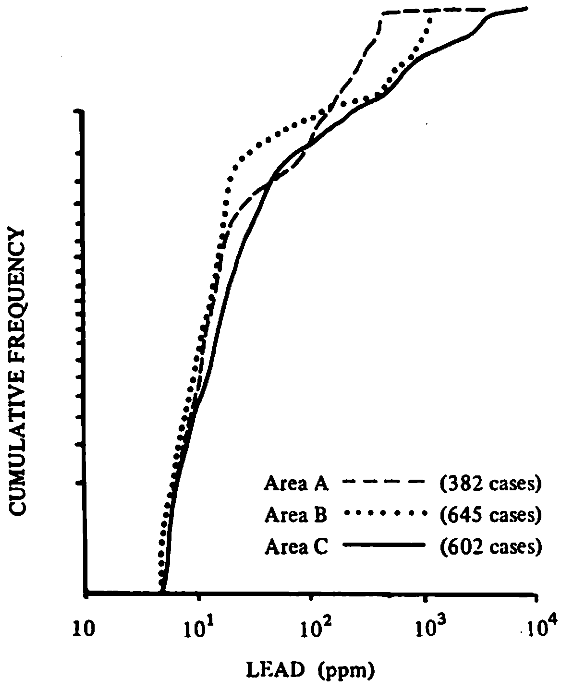

Fig. 1 b.

Figs. 1 a and b. Frequency distribution of uranium and lead on log probability paper for three different physiographic provinces in the Montrose quadrangle, Colorado. Area C, with its high background and frequency distribution, which is not along a straight line (not log normal), is most favorable for uranium exploration.

Analyses of HSSR data

ELEMENT DISTRIBUTION

The stream sediment or water can be regarded as a close approximation to a complete sample of rock and soil including metalliferous ore deposits upstream from the sampling point. The abundance of an element and its distribution in stream sediments within a study area is, therefore, an indicator of the mineralization potential for that area. Frequency distribution on log probability paper is a simple and most effective tool to evaluate the favourability of mineralization in the study area (Fig. 1a,b).

ELEMENT ASSOCIATIONS

The assemblage, or association of elements is important for understanding the type of mineralization and evaluating its economic significance. Multielement correlation and factor analysis can indicate various mineral associations for a studied area. For example, as shown in Figure 2, there is a strong and clear association of U, Th, REE and Hf in the Sand Wash Basin of Colorado. Associations of this type are also discovered through the statistical technique of "factor analysis". By means of this technique, underlying "factors" or element assemblages that tend to occur in nature are identified. The "loadings" of elements on factors reveal the importance of the different factors in determining relative element abundance. For example, in the Sand Wash Basin, uranium is highly loaded (0.98) on Factor 1. which represents primarily the elements just identified as having a strong association or correlation with uranium.

In a granitic terrain, such an element assemblage can indicate a source rock for uranium mineralization. In the Sand Wash Basin, data suggest a rare earth assemblage possibly of some commercial significance.

In Figure 3, factor matrix for the Sawatch Gunnison crystalline terrain in the Montrose quandrangle indicates that uranium is only partly correlative with REE, Th and Hf and therefore is loaded lowly (0.65) on Factor 1.

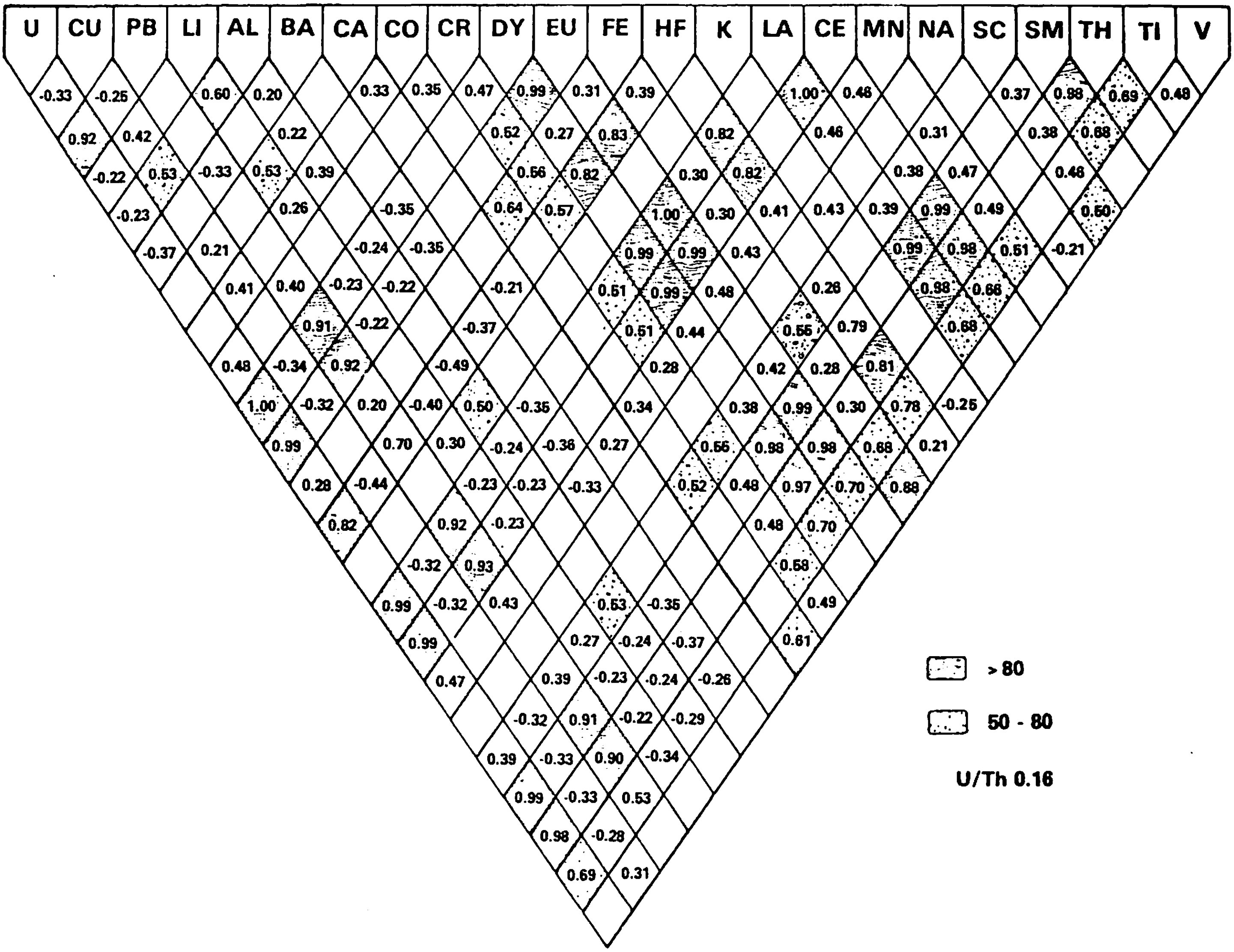

Fig. 2. Multielement correlation of sediments from the Sand Wash Basin, Craig, Colorado.

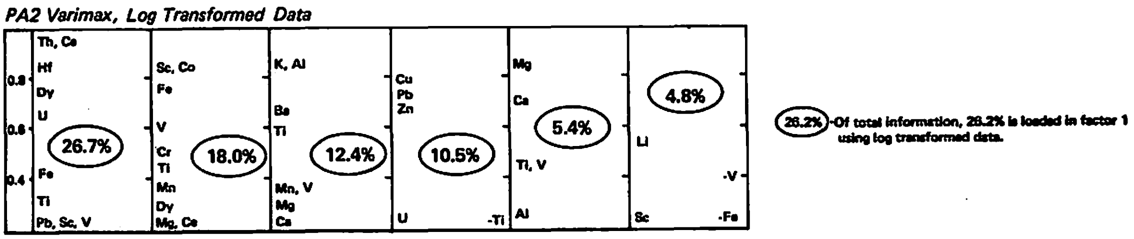

Fig. 3. Factors of the Sawatch Gunnison crystalline terrane, Montrose quadrangle, Colorado.

In some ways, uranium is correlative with base metals on Factor 4. This may indicate that uranium is in ore-forming minerals probably associated with base metals.

In some cases it is preferable to work on specific problems such as the fovourability of uranium mineralization in the Early Tertiary granitic plutons of the Alaska Range. Out of 49 sediment samples collected from drainage basins of granitic plutons, 17 were found favourable. These samples are partly identified by "cluster analysis", a technique that studies patterns of occurrence of different elements. In cluster analysis, a statistical "distance" is defined between two sets of measured data; data sets being defined as more "distant" to the extent that they are dissimilar. A "cluster" of measurements is a set of data, none of which are very distant from the others. A dendogram, such as in Figure 4, illustrates along the vertical axis, the distance between adjacent sets of data. Those data groups that have small inter-group distance reveal themselves on the dendogram as clusters, that is, groups of samples with element concentrations that tend to be closely associated. By studying the common features of sediment samples that turn up in the same cluster, the geochemist hopes to identify common characteristics for those samples. For example, clusters that are favourable for uranium mineralization are studied in order to find out what (location, rock type, etc.) they have in common.

The mineralogical association of uranium with certain elements in the sediment samples is analyzed by leaching, X-ray diffraction, and microprobe techniques.

Mapping to Show Favourable Areas for Mineralization

Three different types of maps are used to locate favourable areas for mineralization:

1. Factor score maps in which the most significant factor or mineral assemblage is scored for all sediment samples, and contoured. Favourable areas for specific mineral assemblages can be evaluated.
2. Maps in which drainage basins for anomalous high concentrations of an element in stream sediment or water are delineated. The probable location of mineralization and the geology controlling it can be estimated.
3. "Kriging" is a method of developing contour maps that illustrate constant levels of certain concentrations of elements in sediment or water. This method was developed for HSSR data at LASL by K. Cambell and H. N. Planner, and indicates favourable areas for mineralization (Fig. 5).

Various significant metal assemblages can be plotted on a final map indicating favourable areas for mineralization. The map includes concentrations above the detection limit for additional important elements like W, Sb, Sn and Au. Such a map shows the relationship among these various assemblages and metals.

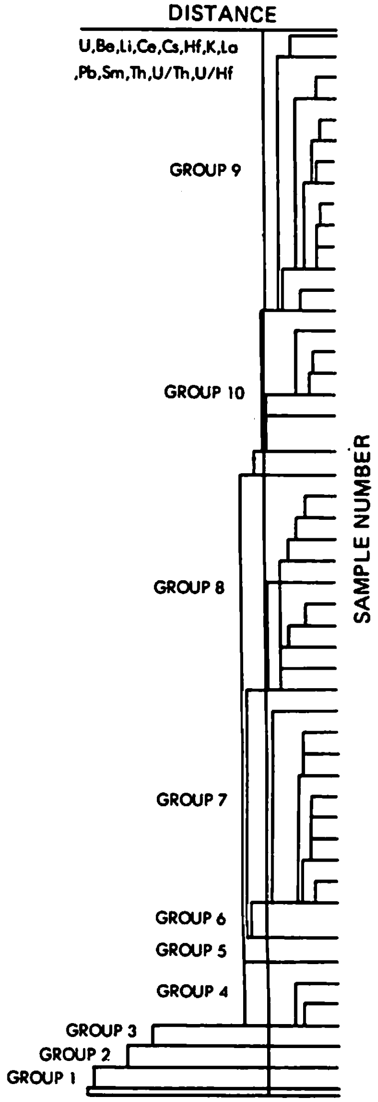

Fig. 4. A dendogram of 49 sediments from the Alaska Range. Groups 1 through 4; 6 and 8, are most favorable for uranium mineralization.

Summary

Hydrogeochemical and stream sediment data combined with data processing techniques provide a relatively cheap and effective method for metal exploration. It should be stressed that highly automated modern analytical techniques and sophisticated data evaluation, especially for unexplored areas, are of importance. These methods could be applied in Israel either for mineral exploration or environmental studies.

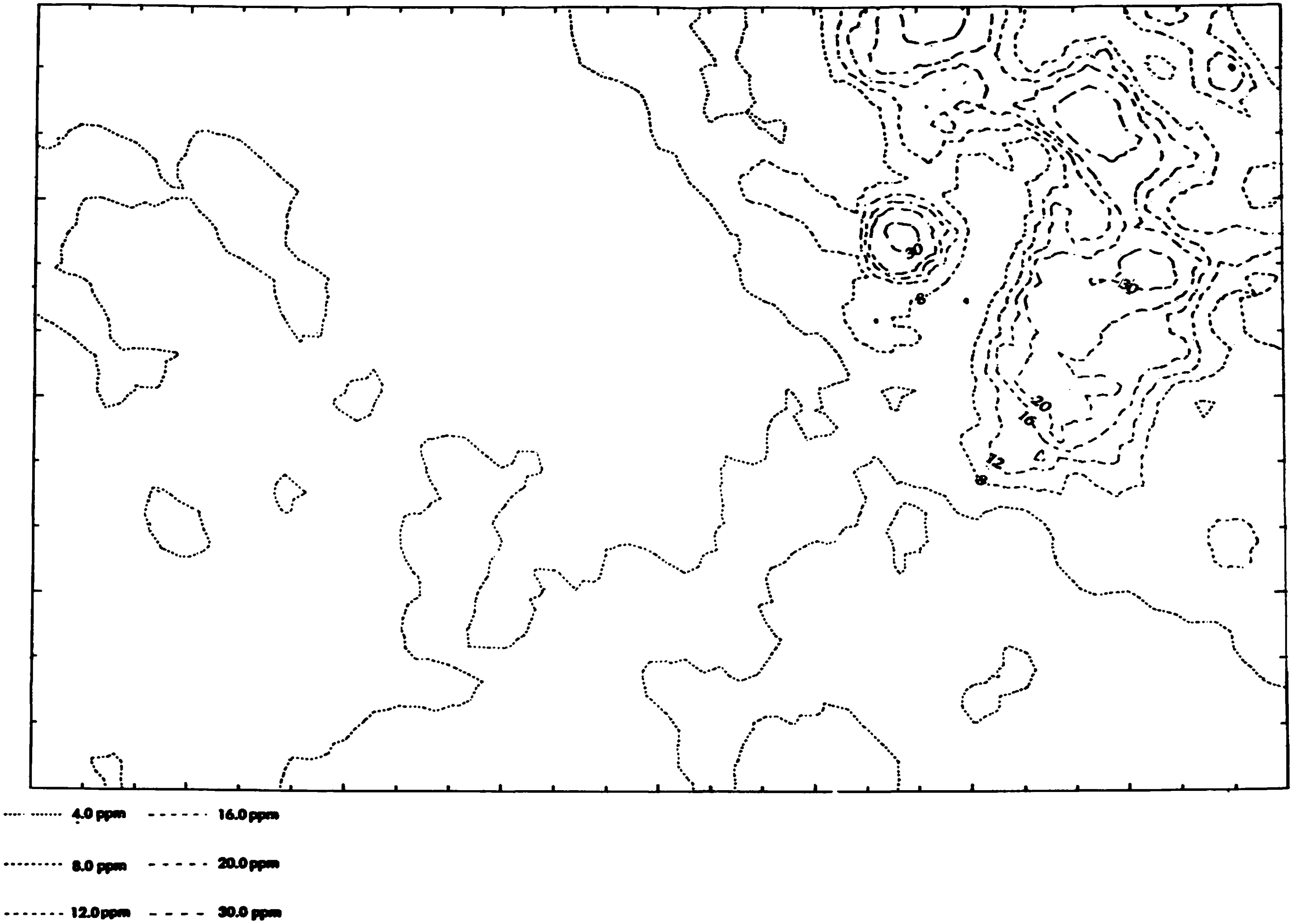

Fig. 5. Uranium (ppm) in sediments (based on log interpolation) in the Montrose quadrangle, Colorado.