Information Circular
Number 10

UNIVERSITY EXTENSION
The University of Wisconsin

Geological and Natural History Survey
George F. Hanson, State Geologist and Director

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Available from the Geological and Natural History Survey, The University of Wisconsin, 1815 University Ave., Madison, Wis. 53706. Price $1.50.

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ABSTRACT

A spring-sampling technique was utilized as a low-cost method of regional geochemical coverage to attempt to detect zinc ore bodies in the Upper Mississippi Valley Zinc-Lead District. In a 900-square-mile area in southwest Wisconsin, 7210 spring water samples were collected.

Data indicate a regional gradient of zinc abundance in spring water. The 80th percentile (0.30 ppm) of the overall zinc distribution was used as a criterion to delineate broad areas for exploration and to indicate the zinc potential of the various geological formations.

A method of interpretation based on the concept of trend analysis was used to screen significant data that may be related to ore. An empirical index was used to select 81 exploration targets from the significant data. Five targets have been drill-tested to date, and zinc mineralization was intersected in several holes in each target. The area covered by the survey is divided into five geochemical subregions whose economic potential is evaluated on the basis of mining history and geological and geochemical features.

INTRODUCTION

As part of a program conducted by the U. S. Geological Survey in cooperation with the Geological and Natural History Survey, University Extension, The University of Wisconsin, since the early part of the postwar period, geological mapping covered a large part of the southwest Wisconsin zinc-mining area, and the effectiveness of several geochemical methods for the detection of zinc ore bodies was tested in several areas of the region (12, 14). Groundwater sampling from springs in a three-square-mile area near the village of Tennyson was tested and found more effective than other water-sampling methods. Since 1965, the spring-sampling technique has been used by the author as a method of regional geochemical coverage.

The author developed, with the cooperation of S. M. Wu and R. W. Heins, field and laboratory procedures and a method of interpretation of field data which are described in detail in three previous papers (5, 6, 7). Between 1967 and 1968, the author was engaged by the Geological and Natural History Survey to extend the spring-sampling survey to cover most of the Wisconsin portion of the Upper Mississippi Valley Zinc-Lead District. The value of a statistic of the overall zinc distribution (0.30 ppm) was used to delineate broad areas of interest for mining exploration purposes. A method based on the concept of trend analysis led to the selection of exploration targets.

The present paper describes the results of the geochemical coverage of the north half of the Upper Mississippi Valley Zinc-Lead District in three aspects: overall distribution, stratigraphic distribution, and areal distribution of zinc abundance in spring water. The area is divided into five geochemical subregions whose zinc potential is evaluated on the basis of the results of the geochemical survey. All data are on file with the Geological and Natural History Survey.

REGIONAL SETTING

About two-thirds of the 2000-square-mile area of the Upper Mississippi Valley Zinc-Lead District lies in the southwest corner of Wisconsin. The remainder is in the neighboring states of Iowa and Illinois. A heavy broken line shows the boundaries of the district on Figure 1, and a heavy solid line shows the limits of the 900-square-mile geochemical coverage.

The district is a submaturely dissected plateau averaging 900 feet in elevation, with a maximum local relief of 300 feet. The plateau is bounded on its north side by a cuesta of Middle Ordovician rocks known as Military Ridge, and on its back slope by Upper Ordovician rocks and by Silurian outliers known locally as "mounds." The back slope is well dissected in a dendritic pattern by seven rivers flowing into the Mississippi and by their tributaries. The seven watersheds are shown on Figure 1.

The sedimentary series overlying the Precambrian basement is about 2000 feet thick and includes Cambrian sandstone; Ordovician limestone, dolomite, and sandstone with subordinate shale; and Silurian dolomite and shale. Details of the stratigraphy of Ordovician rocks are shown on Figure 2. Karst features such as sink holes, caves, and disappearing streams are not common in the carbonate formations of the district. A structural pattern of gentle anticlinal and synclinal folds and small faults is superimposed on a regional dip of about 18 feet-per-mile to the south (12). Small to intermediate-sized folds, with a structural relief of 100 feet or less, crisscross broader regional folds.

Of the two aquifers present in the district, the upper one, composed of the Galena, Decorah and Platteville formations, feeds most of the springs in the area. Recharge to the aquifers occurs mainly during the period of snowmelt and peak precipitation, from April through June. Average recharge is six to seven inches per year, or about one-fifth of the total yearly precipitation. Five semiconfining shale horizons (Figure 2) impede the downward movement of groundwater through the upper aquifer and promote lateral movement toward spring outlets.

About 35 per cent of the springs sampled in southwest Wisconsin occur along the outcrop of shale beds or other zones of lesser permeability. The remainder issue from joints or other bedrock openings. Discharge from the springs ranges from 0.25 to 30.0 gallons per minute (gpm). Many of the larger springs, in the 5.0-30.0 gpm range, issue from the Platteville Formation. The average spring density is eight springs per square mile, but a marked clustering of springs is noted along the flanks of regional synclines and along the outcrops of the shale beds included in the Decorah and Platteville formations (7). Additional hydrologic data, including spring discharge, iron content, hardness, and pH, which were collected in conjunction with the geochemical survey for zinc, are on file with the Geological and Natural History Survey.

ECONOMIC GEOLOGY

The Upper Mississippi Valley Zinc-Lead District is one of several base-metal districts with stratiform zinc-lead deposits which occur in the central part of the United States. In the Upper Mississippi Valley District, lead mining flourished between 1850 and 1880. Zinc mining began about 1860 and has continued to the present time, while lead is now recovered only as a by-product of zinc mining.

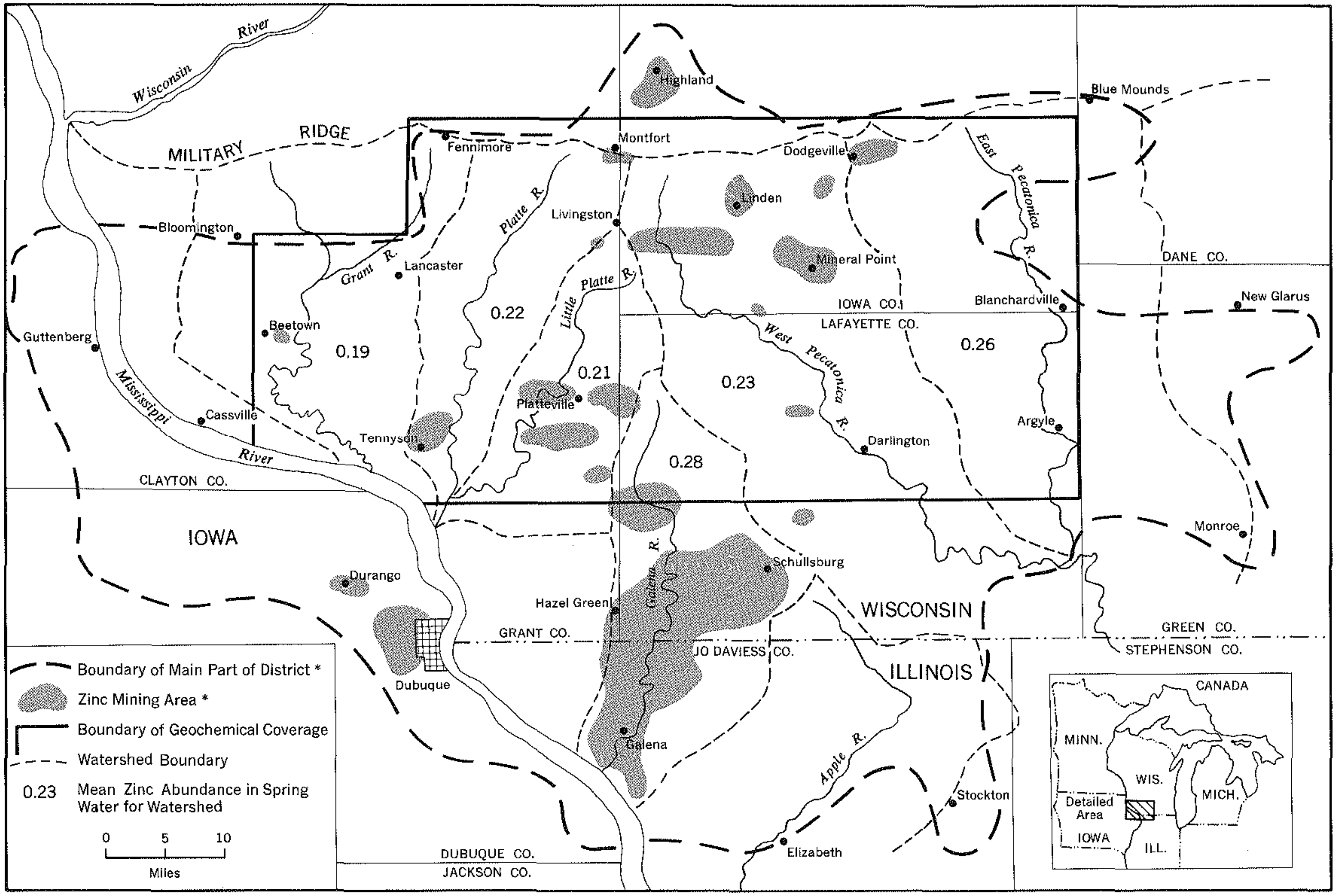
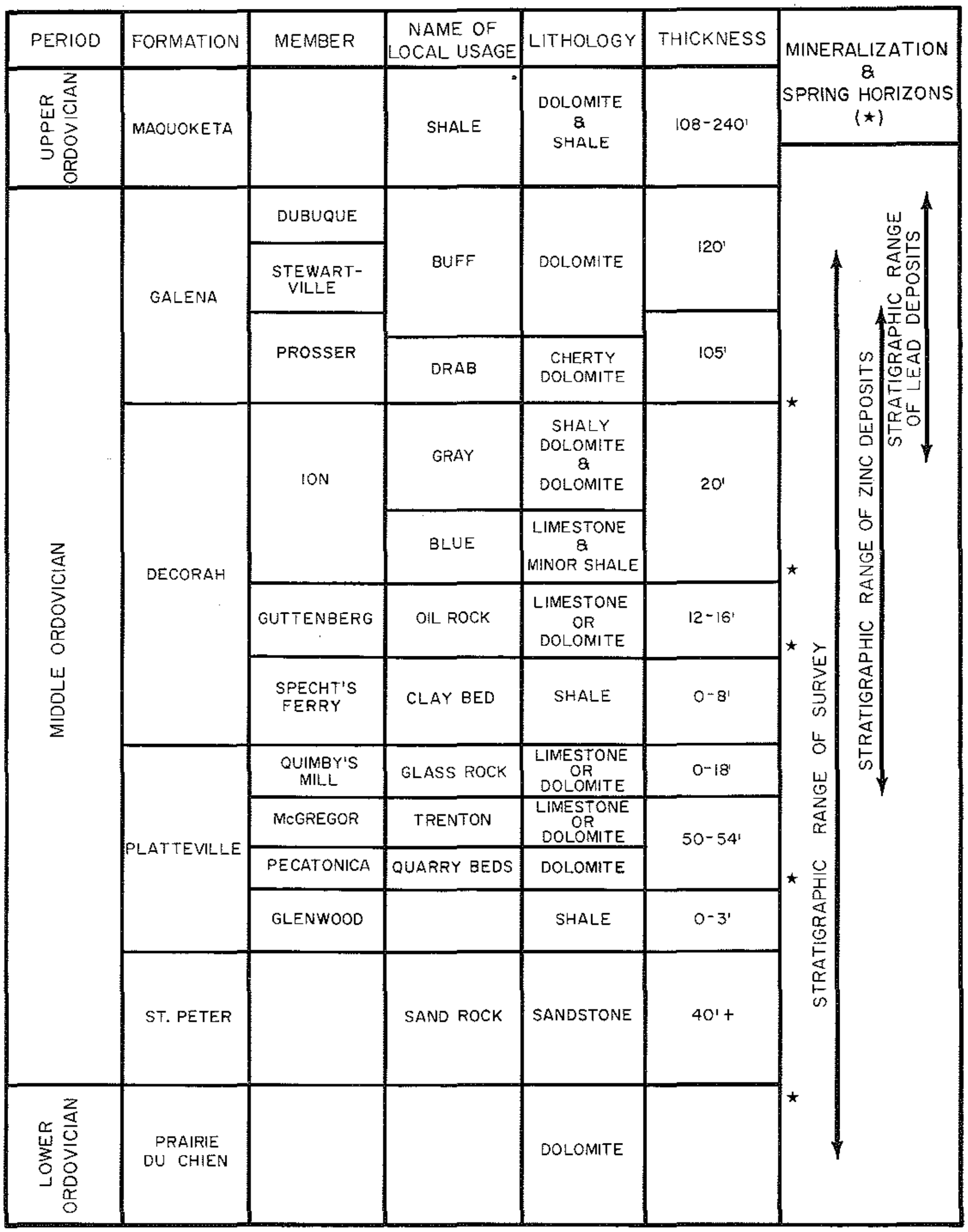


Figure 1. - Index map and mean zinc abundance in spring water for watersheds.



PERIOD	FORMATION	MEMBER	NAME OF LOCAL USAGE	LITHOLOGY	THICKNESS	MINERALIZATION & SPRING HORIZONS (★)
UPPER ORDOVICIAN	MAQUOKETA		SHALE	DOLOMITE & SHALE	108-240'	
MIDDLE ORDOVICIAN	GALENA	DUBUQUE	BUFF	DOLOMITE	120'	
		STEWART-VILLE				
		PROSSER	DRAB	CHERTY DOLOMITE	105'	★
	DECORAH	ION	GRAY	SHALY DOLOMITE & DOLOMITE	20'	
			BLUE	LIMESTONE & MINOR SHALE		★
		GUTTENBERG	OIL ROCK	LIMESTONE OR DOLOMITE	12-16'	★
		SPECHT'S FERRY	CLAY BED	SHALE	0-8'	
	PLATTEVILLE	QUIMBY'S MILL	GLASS ROCK	LIMESTONE OR DOLOMITE	0-18'	
		McGREGOR	TRENTON	LIMESTONE OR DOLOMITE	50-54'	
		PECATONICA	QUARRY BEDS	DOLOMITE		★
		GLENWOOD		SHALE	0-3'	
	ST. PETER		SAND ROCK	SANDSTONE	40'+	
LOWER ORDOVICIAN	PRAIRIE DU CHIEN			DOLOMITE		★

Figure 2. - Stratigraphic column for southwest Wisconsin showing spring horizons. Stratigraphy modified from A.V. Heyl.

Two types of deposits are found in the district— shallow gash-vein deposits which supplied the bulk of the early lead production, and deeper flat-and-pitch zinc deposits which are of primary economic interest at the present time. About 200 of the 400 known zinc deposits were found to contain only a few thousand tons of ore. The remaining 200 deposits range in size from about 20,000 tons to 2,000,000 tons with a median of about 280,000 tons. The total production of all deposits mined up to 1964 was about 56,000,000 tons which yielded about 1,800,000 tons of zinc metal. The U. S. Bureau of Mines Report of Investigation No. 8208, published in 1964, describes present mining practices and mining economics in the district.

Flat-and-pitch deposits generally occur along the flanks of secondary folds, at their intersection, or near fault zones (12). The stratigraphic range of these deposits is about 250 feet within the Middle Ordovician formations (Figure 2). Mining history indicates that the Decorah Formation is the most commonly mineralized formation throughout the district, and that the Platteville Formation is more commonly mineralized in the eastern and southeastern parts of the district than elsewhere.

The traditional method of prospecting for zinc deposits is by low-cost cable-tool drilling. Systematic gridding and geological guidance of the drilling have been introduced by the U. S. Geological Survey with considerable success. More recently, geophysical guidance by very low frequency electromagnetic or induced polarization methods has gained acceptance. Geochemical methods, including soil and ground-water sampling, have been found to be very useful locally, but no attempt had been made prior to the present investigation to conduct regional surveys.

At the present time, most of the mining activity is concentrated in the Hazel Green-Shullsburg-Galena area (Figure 1), where three 1000-ton-per-day (tpd) flotation mills are operated by the American Zinc Company and the Eagle Picher Company. An 800 tpd mill is operated by the New Jersey Zinc Company in the Cuba City area. Although about 100 zinc deposits had been opened in the area covered by the survey prior to this investigation, only four mines were in operation in 1967 (Plate 1).

COVERAGE BY SPRING SAMPLING

The sampling of groundwater at spring outlets is not a new geochemical technique. The method has been successfully used during the past 15 years in the USA, the USSR, and elsewhere as a guide in locating bodies of ore (10, 20). During the early postwar years, a limited program of spring-sampling was done in southwest Wisconsin by the U. S. Geological Survey (14), and the program of regional coverage described in this report was begun in 1965.

Development of the Spring-Sampling Method

Water sampling is preferable for regional coverage, and soil sampling is often more suitable for detailed coverage of small areas (10). Stream water sampling is largely ineffective in the district because of the rapid precipitation of heavy metals which occurs in a carbonate environment after a short contact with the atmosphere (14). Ground-water sampling from wells is not satisfactory because of possible contamination by piping, casings, etc. Ground-water sampling at spring outlets is a valid geochemical method as long as the zone of oxidation reaches at least the upper part of the primary halo which surrounds most metal deposits.

Field confirmation of the effectiveness of spring sampling in southwest Wisconsin was obtained in the mid-1950s when a rich body of zinc ore was discovered near the village of Tennyson by drilling within the drainage basins of several springs which showed high zinc readings (12, 14). The coverage completed since 1965 amounts to half of the area of the district (about 900 square miles) in Grant, Iowa, and Lafayette Counties. In the survey 7210 spring-water samples were collected.

Field and Laboratory Procedures

A thorough search for springs was carried out in each first-order watershed. Detection of springs was greatly helped by a study of the topography and stratigraphy of the area to be sampled. The elevations of shale beds, along which springs are known to cluster, were traced on topographic maps. Altimeter readings were taken at the spring outlets and on the nearest available exposure of one of the marker beds. Examination of vegetation was also very helpful. Spring locations were plotted on seven-and-one-half-minute topographic quadrangle maps with a scale of one inch to 2000 feet.

Measurements of pH, zinc, iron, and hardness of spring water were made by colorimetric methods. Iron and pH determinations were made immediately upon returning from the field; then the remainder of the samples was acidified for zinc determination at a later date. The pH was measured with a Hellige comparator. The iron determination was made by the phenanthroline method, and the zinc concentration by the dithizone method. Titration by a Hach kit was used to measure the total hardness of the spring water. A more detailed description of the field and laboratory procedures appeared in a previous paper (5).

Method of Interpretation of Field Data

The method of interpretation of field data is fully described in a previous paper (6). It is based on the concept of trend analysis which leads to the separation of nonsystematic changes of possible economic significance from continuous regional changes. The field data define a response surface which is analyzed by means of three components: a regional-trend component which varies continuously throughout the surveyed area, a local-trend or anomaly component which is discontinuous, and a residual component.

In this investigation, the regional-trend component is defined as the arithmetic mean of all field data within four-square-mile sections, and the anomaly component is defined as the mean of all positive deviates on the trend within quarter-square-mile cells (6). Section and cell sizes were determined empirically to fit the conditions prevailing in the district. Figure 3 shows how the trend is calculated within a four-square-mile section. The trend value (Z) is calculated by combining the mean zinc value of each of the 16 cells making up the section by means of the formula shown on Figure 3 and is plotted at the centroid of the section. Trend components of contiguous sections are contoured to depict the trend surface. Anomaly surfaces are constructed by contouring the anomaly components within groups of adjacent cells as shown on Figure 4.

Residual components are defined as the positive deviates on the anomaly. They indicate a sharp and possibly significant increase in zinc abundance and are used to identify significant readings among the rest of the field data. Significant data are grouped into clusters. Each cluster is then considered a single significant unit which is rated by an empirical index and classified in one of four categories of priority. The first priority clusters are used to identify exploration targets. The limits of these exploration targets are determined by topographic and hydrologic considerations. Figure 5, which covers the same area as Figure 4, shows how the clusters are used to locate exploration targets.

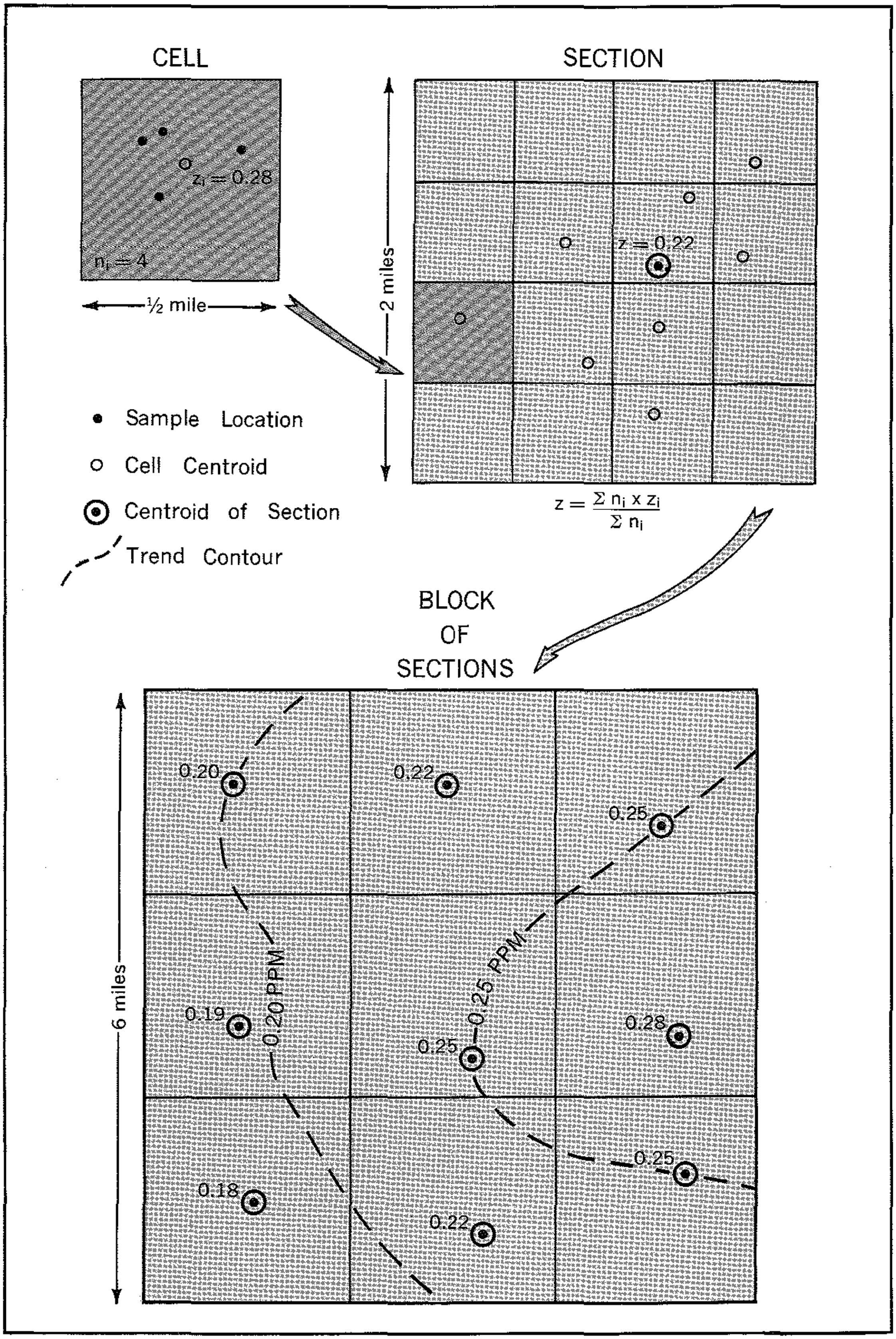
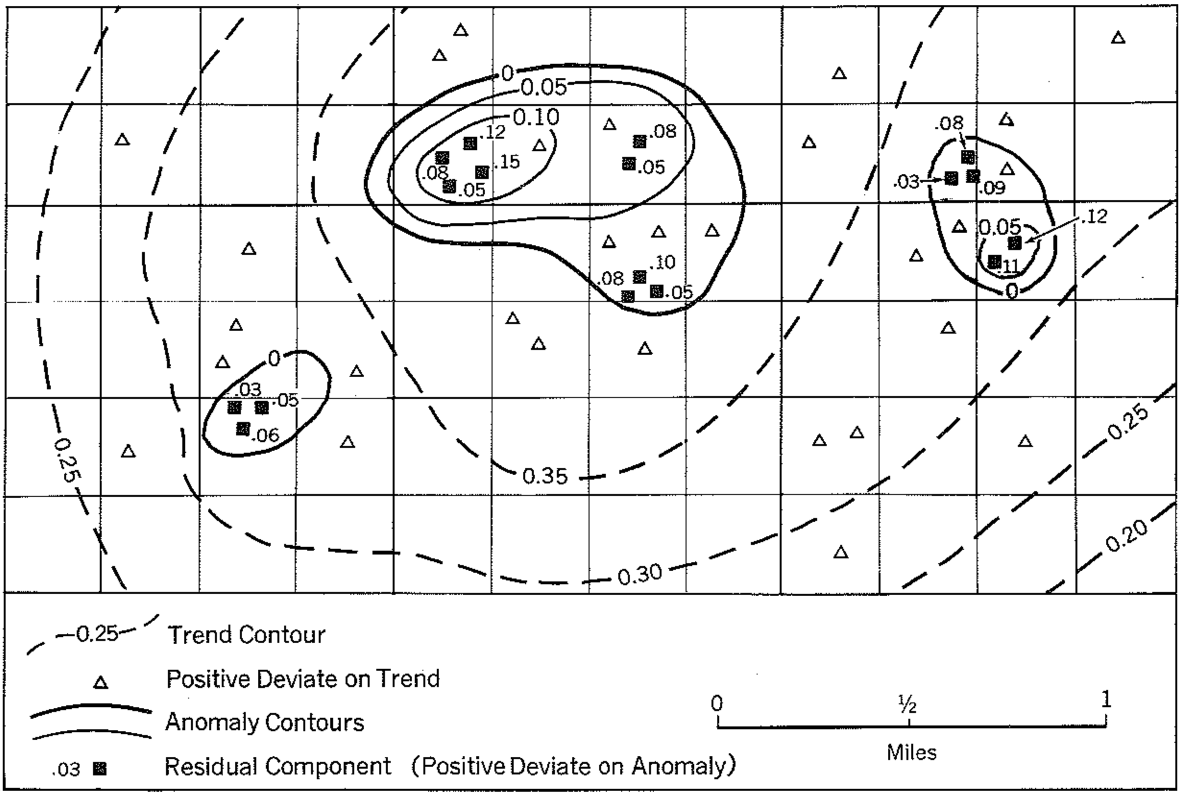


Figure 3. - Calculation and plotting of trend components.

Figure 4. - Plotting of anomaly and residual components.



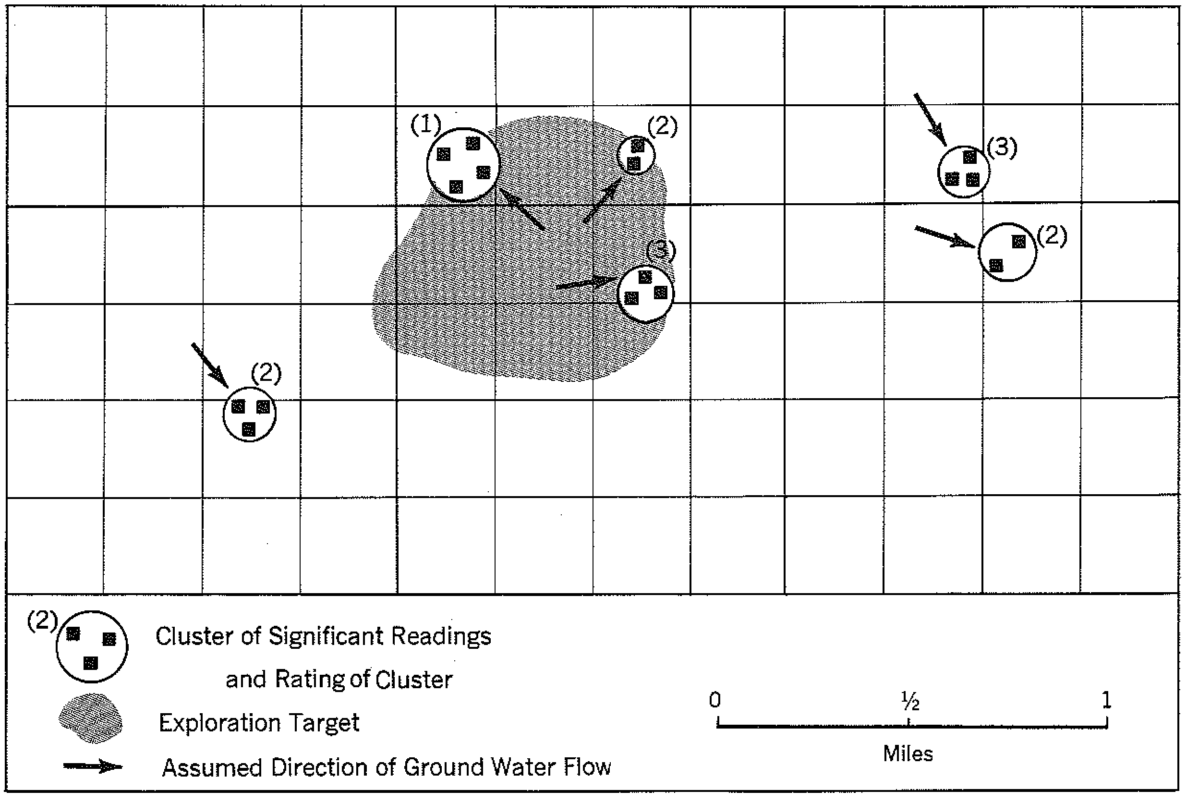


Figure 5. - Plotting of exploration targets.

OVERALL DISTRIBUTION OF ZINC ABUNDANCE IN SPRING WATER

In this investigation, six major watersheds were used to subdivide the region in order to bring out significant areal variations of zinc abundance. The 7210 field readings were sorted and tabulated by watersheds, as shown in Table 1. The arithmetic mean was calculated for each watershed distribution and the overall mean of 0.22 ppm was used as a statistical estimate of zinc abundance in the region. Table 1 also shows a regional gradient increasing from west to east, from 0.19 ppm in the Grant watershed to 0.26 ppm in the East Pecatonica watershed.

The numerical value of the gradient for each watershed is taken as the deviation of the watershed mean from the overall mean. The gradient was removed from the field readings in order to obtain a better representation of the actual distribution of zinc abundance in the region. For this purpose, the numerical value of the gradient of a watershed was subtracted from each field reading obtained in the watershed, and the corrected readings were resorted within the original classification. The resulting, corrected overall distribution of zinc abundance is shown in Table 2, and the histogram of the distribution is shown in Figure 6.

In previous studies (5, 6) the zinc abundance value of 0.30 ppm was found to have special economic significance in the region because it was associated with known zinc deposits. As a result, it was used as a criterion to delineate favorable prospecting areas. Calculations show that 0.30 ppm is the value of the 80th percentile of the corrected over-all distribution mentioned above.

STRATIGRAPHIC DISTRIBUTION OF ZINC ABUNDANCE

Numerous springs occur along four main horizons in the Galena, Decorah, and Platteville formations (Figure 2). The zinc abundance in spring water from these horizons is assumed to reflect approximately the zinc abundance in the corresponding strata, although there is undoubtedly some cumulative effect downward.

The ratio of the number of field readings equal or greater than 0.30 ppm to the total number of field readings obtained from a geological formation in a given watershed was used in this investigation as a criterion to evaluate the zinc potential of the various geological formations by watersheds. Table 3 shows the value of the ratio calculated as a percentage for each of the five geological formations included in four watershed groupings.

The ratio is also calculated for the watershed subtotals (Table 3, bottom line). The regional gradient, noted previously, is reflected in the increase of the ratio from west to east between the Grant and the East Pecatonica watersheds. Table 3 shows that in each watershed the Decorah Formation has the highest ratio value, and thus has the highest zinc potential, as confirmed by mining history in the district. The ratio of the Platteville Formation is not high in the western part of the area (Grant, Platte, and Little Platte watersheds), but it increases in an easterly direction considerably faster than the regional gradient. Mining in the district shows that the frequency of zinc mineralization in the Platteville Formation increases in a general southeasterly direction.

Although the presence of zinc mineralization in the St. Peter Sandstone Formation cannot be fully discounted at the present time, it seems reasonable

TABLE 1

DISTRIBUTION OF ZINC ABUNDANCE IN SPRING WATER BY WATERSHEDS

Zinc Abundance in Spring Water in ppm	Number of Springs by Watershed					
	Grant	Platte	Little Platte	W. Pecatonica & N. Galena	E. Pecatonica	Total
0.03-0.10	272	255	198	384	172	1281
0.11-0.20	685	608	207	1030	360	2890
0.21-0.30	250	460	163	450	155	1478
0.31-0.40	69	117	82	327	182	777
0.41-0.50	40	121	33	217	85	496
0.51-0.60	1	5	6	67	68	147
0.61-0.70	2	8	1	2	2	15
0.71-0.80	2	14	2	12	1	31
0.81-0.90	1	4	3	8	3	19
0.91-1.00	1	3	2	11	0	17
1.01-1.10	2	1	1	14	13	31
1.11-2.50	1	0	0	17	9	27
Subtotal	1326	1596	698	2539	1050	7210
Mean Zinc Abundance in ppm	0.19	0.22	0.21	0.24	0.26	0.22
Regional Gradient	-0.03	0.00	-0.01	+0.02	+0.04	

TABLE 2

OVERALL DISTRIBUTION OF ZINC ABUNDANCE

Zinc Abundance in ppm*	Frequency
0.00-0.10	1504
0.11-0.20	2858
0.21-0.30	1506
0.31-0.40	624
0.41-0.50	516
0.51-0.60	49
0.61-0.70	25
0.71-0.80	28
0.81-0.90	20
0.91-1.00	26
1.01-1.10	27
1.11+	27
Total	7210

*After removal of gradient

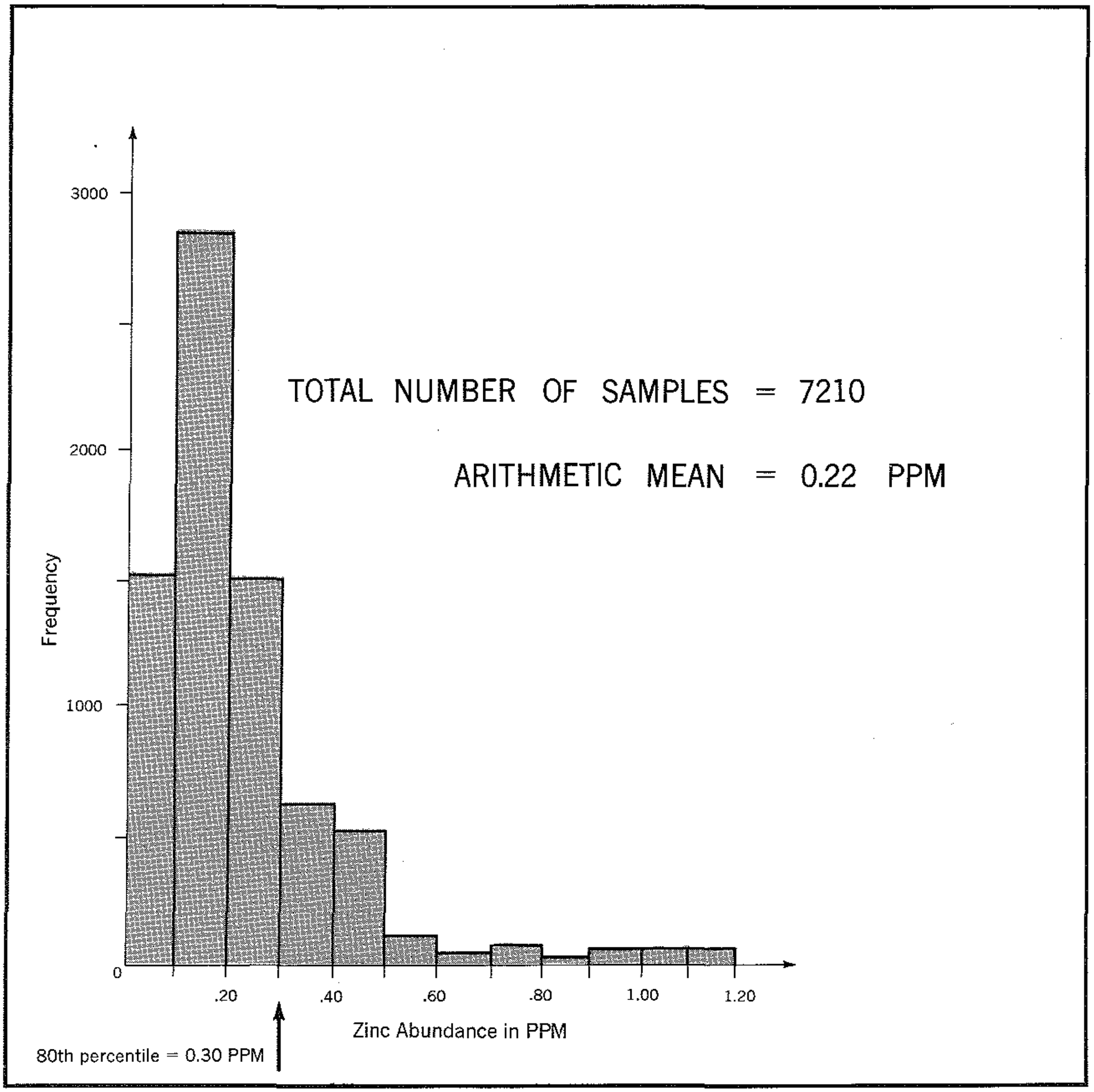


Figure 6. - Distribution of zinc abundance in spring water.

TABLE 3

STRATIGRAPHIC DISTRIBUTION OF SAMPLES BY WATERSHED GROUPINGS

Geologic Formation	Grant			Platte and Little Platte			W. Pecatonica and N. Galena			E. Pecatonica		
	A	B	C	A	B	C	A	B	C	A	B	C
Galena	172	20	11%	390	93	23%	1027	280	22%	126	35	28%
Decorah	754	90	12%	940	247	25%	903	273	30%	243	82	37%
Platteville	317	21	6%	827	117	14%	636	157	26%	531	158	30%
St. Peter	50	2	5%	77	3	4%	48	3	0.5%	107	3	3%
Prairie du Chien	33	2	6%	60	10	15%	26	2	1%	43	2	4%
Subtotals	1326	135		2294	470		2540	715		1050	280	
Watershed Ratio			10%			20%			26%			28%

Column A = Number of Samples

Column B = Number of Samples ≥ 0.30 ppm Zinc

Column C = Ratio (B/A) x 100

to assume that the few readings greater than 0.30 ppm obtained in that formation reflect some local leakage from overlying mineralized strata. Most of the 60 samples collected in the Prairie du Chien Group in the Platte and the Little Platte watersheds come from the Ellenboro-Livingston area. The sporadic presence of zinc mineralization in the Prairie du Chien Group in that area, which was indicated by a U. S. Geological Survey reconnaissance drilling program (12), is partly reflected by the ratio of 15 per cent for the Prairie du Chien Group shown in Table 3.

AREAL DISTRIBUTION OF ZINC ABUNDANCE

After removal of the regional gradient, trend values were calculated in each watershed as indicated in the summary of the method of interpretation of field data. The plot of trend values was then contoured throughout the coverage in order to depict the trend surface of zinc abundance of the region, as shown on Plate 1.

Among the 20 zinc-mining areas indicated on the geochemical map, 16 show a close areal correlation with the 0.30 ppm contours, emphasizing the economic significance of these contours. This significance is further enhanced by a comparison of the results of an aeromagnetic survey of the region (Figure 7) with the geochemical map (Plate 1). Figure 7 shows an approximate areal correlation in nine cases out of twelve between the 0.30 ppm contours and aeromagnetic highs about which ore producing areas of the district are generally clustered (13).

A procedure described previously (6) and summarized above was used to screen significant data which are commonly grouped in clusters. A total of 780 clusters was selected from 7120 field readings. The clusters were classified into four categories of priority for exploration as shown in Table 4. Eighty-five of these clusters are associated with known zinc deposits, leaving 695 clusters to be investigated for zinc mineralization. Of these, 81 are given first-priority rating as exploration targets. These targets are generally located on or near the 0.30 ppm trend contours. They range from 60 to 310 acres, with an average size of 170 acres or 0.28 square miles. Thus, the total area of the targets amounts to 23 square miles or 2.5 per cent of the initial coverage. Plate 1 shows the location and reference number of the exploration targets which are listed and briefly described in the appendix.

ECONOMIC EVALUATION OF RESULTS OF THE GEOCHEMICAL SURVEY

Plate 1 shows that the intensity of the geochemical relief and the distribution of exploration targets vary greatly throughout the region. The area is divided into five subregions numbered A, B, C, D, and E on the basis of the geochemical relief pattern (Figure 8).

The zinc potential of each subregion was evaluated by a rating based on five factors, mainly mining history, geological features, geochemical relief, the number of exploration targets, and "unfavorable" factors (Table 5).

TABLE 4

RATING OF CLUSTERS OF SIGNIFICANT DATA

Priority Rating	Number of Clusters Associated with Known Deposits	Number of Clusters Not Associated with Known Deposits	Total
1	67	81	148
2	14	167	181
3	4	307	311
4	0	140	140
Subtotal	85	695	780

TABLE 5

RATING OF GEOCHEMICAL SUBREGIONS

Subregions / Rating Factors*	A	B	C	D	E
Mining History	2	1	4	2	3
Geological Features	2	1	2	1	3
Geochemical Relief	3	1	2	1	4
Number of Targets	2	1	2	2	4
Unfavorable Factors	Dispersion of targets	Some land now leased	No record of zinc production	Some land now leased	Small number of scattered targets
Final Rating	3	1	2	1	4

*Rating Index:
1 - excellent
2 - good
3 - fair
4 - poor

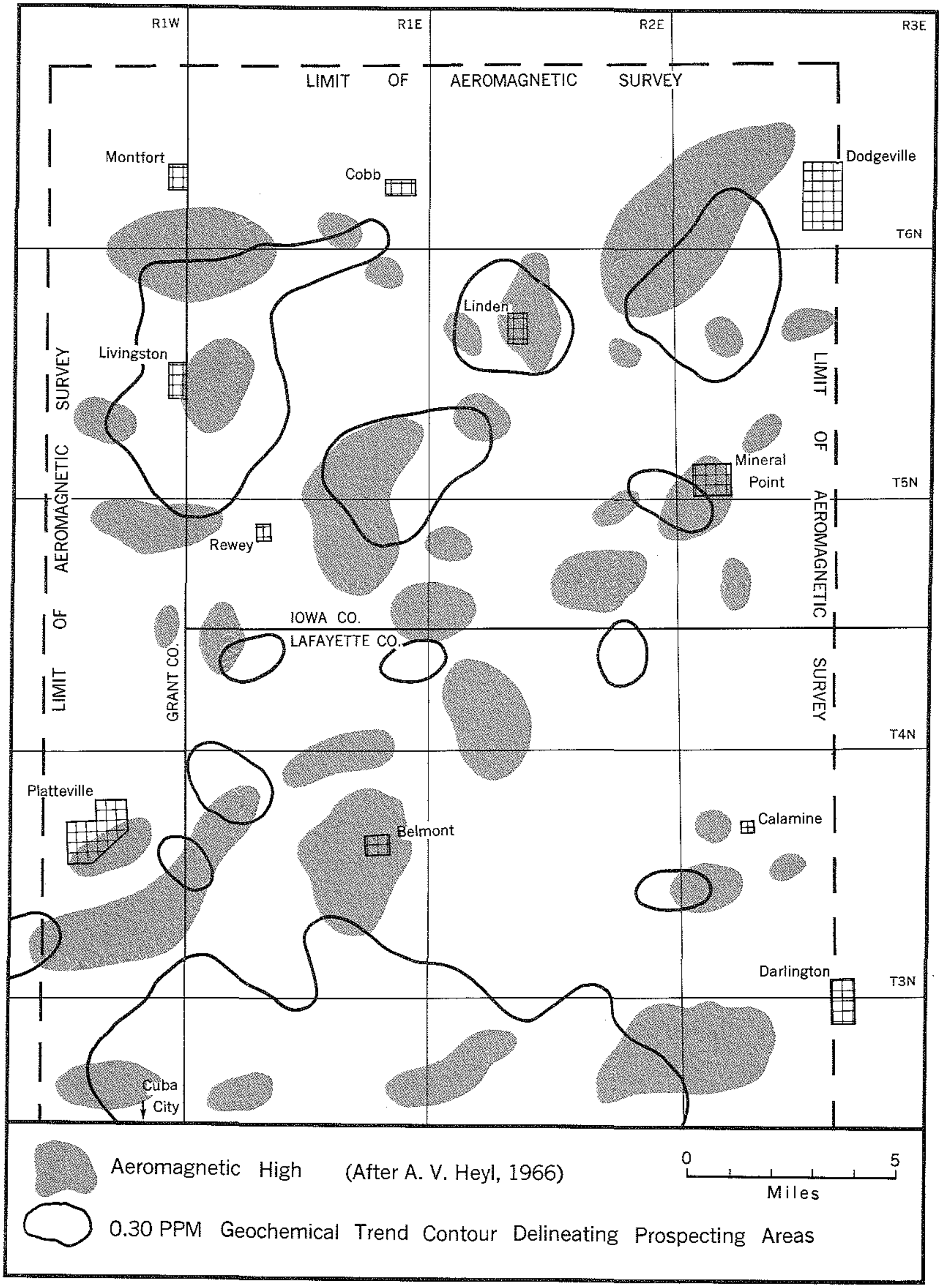


Figure 7. - Comparison of aeromagnetic and geochemical data.

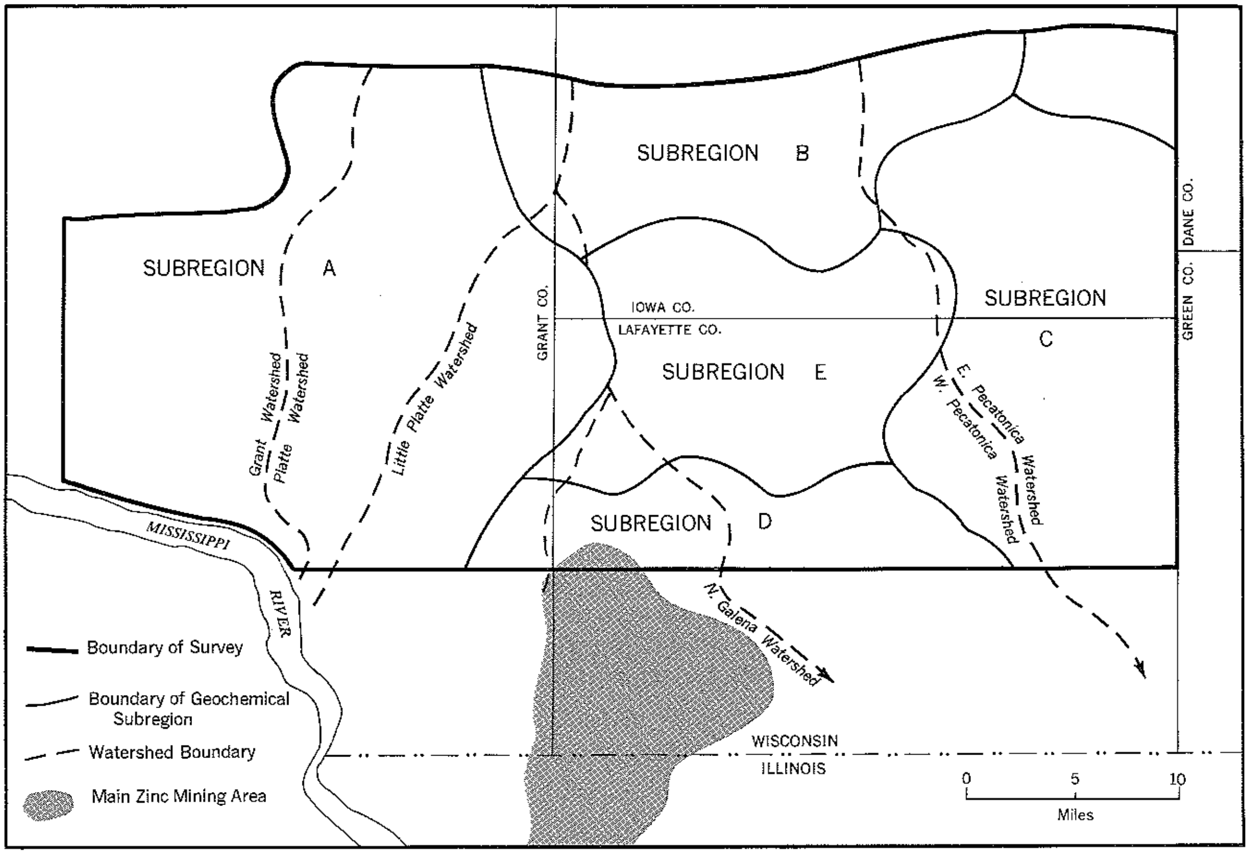


Figure 8. - Geochemical subregions.

Subregion A

This subregion has an area of about 350 square miles and includes portions of the Grant, Platte, and Little Platte river watersheds. Many good-grade zinc deposits of moderate size were mined in the Galena and Decorah formations during the past fifty years, particularly near Platteville, but only one mine located near Tennyson was operating in 1967. A sizable acreage of mining leases is being held in the vicinity of Cuba City, Rewey, and Tennyson.

A relatively low degree of mineralization in the Platteville Formation is indicated in the subregion by the rather low value of the ratio shown in Table 3. Furthermore, the thickness of the overlying shaley Specht's Ferry Member, which is up to eight feet, would make mining hazardous in the Platteville strata. Because of this combination of unfavorable factors, a systematic investigation of the Platteville Formation does not appear justified.

The geochemical map shows a gradual decrease of the geochemical relief in a westerly direction through the subregion. The 0.30 ppm contours delineate four new prospecting areas. The first two lie in Township 4N, Range 1E, and Township 3N, Range 1W. The third, in Township 3N, Range 1E, includes the sites of several U. S. Geological Survey drillholes which intersected some low-grade zinc mineralization. The fourth area lies in Township 4N, Range 1W, in the Ellenboro-Livingston area where several U. S. Geological Survey drillholes encountered some zinc mineralization in the Platteville Formation and Prairie du Chien Group. Seventeen exploration targets were found in the subregion, and five of them, located near Tennyson and Beetown, were drill-tested after geophysical traversing. Several drill holes intersected ore-grade mineralization in three of these targets.

On the basis of factors such as mining history and geological and geochemical features, the chances of finding additional zinc ore bodies in the Galena and Decorah formations in Subregion A are good. However, the great dispersion of exploration targets would call for expensive trucking of ore to a centrally located mill. Thus, the subregion is given a final rating of 3 (fair) in Table 5.

Subregion B

Subregion B, an area of 150 square miles, lies mostly within the West Pecatonica watershed. Much profitable mining was done during the past in the Rewey-Linden area, where several zinc deposits yielded in excess of 1,000,000 tons of ore, and to a lesser extent near Dodgeville, Mineral Point, and Montfort. Three mines were still in operation in 1967, and mining leases are still being held near Rewey, Linden, Dodgeville, and Mineral Point. Good zinc ore was mined from the Platteville Formation in several areas, particularly near Dodgeville. The high value of the geochemical ratio of the Platteville Formation in the West Pecatonica watershed (Table 3) and the extent of previous mining activities should encourage a systematic investigation of these strata, especially since the overlying Specht's Ferry Member is quite thin, which should be an aid in mining operations.

The geochemical relief is quite high in the central part of the subregion, but it falls off very rapidly northward along Military Ridge and decreases more gradually both southward and eastward. Three new prospecting areas are delineated by the 0.30 ppm contours in Subregion B. The first extends northeasterly between Livingston and Cobb; the second, situated between Linden and Dodgeville, includes several zinc prospects which achieved a small production of high-grade ore; and the third may represent the eastern extension of the Dodgeville zinc mining area. Many of the 27 exploration targets indicated by the survey are grouped within Township 5N, Range E, and Township 5N, Range 2E. One of the targets (B27), west of Livingston, is located near the site of five "ore holes" drilled in the 1950's by the U. S. Bureau of Mines (14).

As indicated in Table 5, Subregion B is given first rating for zinc exploration mainly on the basis of its mining history, favorable geochemical features, and concentration of exploration targets. Based on past mining activity, some additional geochemical coverage would be advisable in the area extending between Montfort and Highland.

Subregion C

This subregion of approximately 180 square miles extends southeasterly within the East Pecatonica watershed. Lead mining flourished during the past century and the early years of the present century in the Lamont-Argyle-Blanchardville area. Although zinc ore has been noted on a number of mine dumps (12) there is no record of zinc production, and no exploration program has been attempted in the area. A thorough investigation of the Platteville Formation in this subregion appears justified because of the high value of the geochemical ratio indicated in Table 3 for the East Pecatonica watershed.

The geochemical relief is rather high, but decreases sharply northeastward and more gradually westward. Six new prospecting areas are delineated by the 0.30 ppm contours. Two are situated near Argyle and Waldwick, and the other four between Lamont, Fayette, and Waldwick. Eighteen exploration targets are grouped mainly within Township 3N, Range 4E and Township 4N, Range 4E.

Although there is no record of zinc mining in the subregion, the prospect of finding bodies of zinc ore is good on the basis of such favorable factors as the concentration of targets, and good geochemical and geological ratings, as shown in Table 5. An eastward extension of the geochemical survey between Argyle and Monroe (Figure 1) would be advisable because of early lead mining activity in that area, and the common association of zinc ore below lead within the eastern half of the district.

Subregion D

Subregion D, an area of about 100 square miles, runs across the North Galena and West Pecatonica watersheds in an east-west direction. Numerous medium-size bodies of good-grade ore were mined during the past 50 years in Galena and Decorah Formations in the Cuba City area.

The geochemical map shows high geochemical relief between Cuba City and Darlington. This probably extends southward to the highly productive Shullsburg-Hazel Green area which is not covered by this survey. More than 25 per cent of the subregion is included within a single 0.30 ppm contour which possibly indicates an easterly extension of the Cuba City mining area toward Darlington. The favorable results of a U. S. Geological reconnaissance drilling program in the area, including one intersection of commercial ore west of Darlington, appear to confirm this assumption. Most of the 13 exploration targets indicated by the survey are grouped in Township 2N, Range 1E, and in Township 3N, Range 1E, within the 0.30 ppm contour.

Subregion D is given a first priority rating for zinc exploration because of a number of favorable factors including mining history, drilling results, geochemical features, and the concentration of exploration targets. Some additional geochemical coverage (about 100 square miles) is advisable in order to investigate a possible easterly extension of the Shullsburg mining area between Shullsburg and Darlington.

Subregion E

Subregion E covers about 120 square miles within the West Pecatonica watershed. Sporadic mining activity took place in several areas of the subregion during the past 50 years. A modest tonnage of high-grade zinc ore was mined from a cluster of three small deposits in Township 4N, Range 2E; and good zinc ore was mined from the Platteville Formation in Township 3N, Range 2E, west of Calamine.

The 0.30 ppm contours delineate two new areas of interest for prospecting which include two of the six exploration targets indicated by the survey. Since the geochemical relief is low and the targets are few and widely separated, Subregion E does not appear very promising for zinc exploration at the present time.

SUMMARY

A geochemical spring-water sampling survey to detect bodies of zinc ore was conducted in parts of Grant, Iowa, and Lafayette Counties in Wisconsin. A total of 7210 water samples was collected in a 900-square-mile area.

The overall zinc abundance in spring water is 0.22 ppm. A regional gradient of zinc abundance increases eastward. The 80th percentile of overall zinc distribution (0.30 ppm) was used as a criterion to indicate the zinc potential of the various geological formations of the region and to delineate broad areas of interest for mining exploration.

Clusters of significant data which may be related to ore bodies are screened and rated by means of a statistical method to identify specific targets for exploration. Eighty-one targets with a total area of 23 square miles, or 2.5 per cent of the initial coverage, were identified by this procedure.

The region is subdivided on the basis of geochemical features into five subregions numbered A through D. Subregion A covers the western part of the district in Grant County. Subregion B covers the northern edge, and Subregion C, the eastern reaches of the district. Subregion D extends west of Darlington, and Subregion E covers the central part of the region.

Subregions B and D appear to be prime areas for zinc exploration and are given first ratings. Subregion C also appears promising and is given a second priority for exploration. Subregion A is given third rating mainly because of the dispersion of exploration targets, and Subregion E appears least promising. Additional coverage (about 250 square miles) including the Montfort-Highland area in Subregion B, the Argyle-Monroe area in Subregion C, and the Shullsburg-Darlington area in Subregion D, is desirable because of mining history, geochemical features, and concentration of exploration targets in these areas.

ACKNOWLEDGEMENTS

The author is greatly indebted to G. F. Hanson, Director of the Wisconsin Geological and Natural History Survey, and M. E. Ostrom, Associate Director, for the financial support of this study and the critical review of this paper.

Much is owed to S. M. Wu, Departments of Mechanical Engineering and Statistics, and R. W. Heins, Department of Minerals and Metals Engineering, The University of Wisconsin, for their collaboration in developing the methods utilized in this program.

The author also wishes to express his appreciation to A. V. Heyl, U. S. Geological Survey, Washington, D. C.; E. N. Cameron, Department of Geology and Geophysics, The University of Wisconsin; and W. A. Broughton, The University of Wisconsin Geological and Natural History Survey and Department of Geology, Wisconsin State University—Platteville, for their continued interest in this project and for their encouragement.

The diligent assistance in the field and laboratory of Lester R. Gust, Jr., Richard A. Agen, and Jeffrey R. Cooke, Wisconsin State University—Platteville, was greatly appreciated.

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APPENDIX

Location and Description of Exploration Targets

SUBREGION A

Ref. No. of Target	Location Tsp.	Range	Sec.	¼ Sec.	No. of Springs in Target	No. of Anomalous Springs	Highest Reading (ppm Zn)	Area of Target (Acres)
A1	4N	1E	20	W½-NE E½-NW	3	3	0.75	150
A2	4N	1W	25	W½-NW	3	1	0.60	100
A3	3N	1W	1	NE	4	3	0.75	180
A4	3N	1W	32	E½-NW NE¼-SW	5	3	0.80	160
A5	2N	1W	5	N½-SW	6	3	0.40	140
A6	3N	2W	36	S½-NE	6	4	1.40	70
A7	4N	1W	7	NE¼-SE	6	1	0.62	60
A8	4N	1W	7	N½-SW	4	2	0.46	120
A9	4N	2W	14	E½-SW W½-SE	9	3	0.78	160
A10	4N	2W	14	S½-NW NW¼-SW	6	4	0.50	160
A11	4N	2W	23	W½-SW	7	3	0.44	90
A12	5N	1W	32	SW	7	5	0.48	180

Note

Five more targets were located in this subregion but the specific locations are classified by the company holding the mining rights.

SUBREGION B

Ref. No. of Target	Location Tsp.	Range	Sec.	$\frac{1}{4}$ Sec.	No. of Springs in Target	No. of Anomalous Springs	Highest Reading (ppm Zn)	Area of Target (Acres)
B1	5N	3E	8	NE	6	4	1.05	150
B2	5N	3E	8	SW	9	4	1.12	180
B3	5N	3E	20	N$\frac{1}{2}$-SE	12	4	0.55	100
B4	5N	3E	19	S$\frac{1}{2}$-SW	3	3	1.10	110
B5	5N	2E	14	NW	7	5	0.60	190
B6	5N	2E	11	W$\frac{1}{2}$-NE E$\frac{1}{2}$-NW	7	6	1.15	200
B7	4N	3E	9	N$\frac{1}{2}$-NW	9	4	0.54	140
B8	4N	2E	1	NE	7	5	0.55	190
B9	5N	2E	4	W$\frac{1}{2}$-SW	10	5	0.50	120
B10	5N	2E	7	NW$\frac{1}{4}$-NE NE$\frac{1}{4}$-NW	2	1	0.68	80
B11	5N	2E	6	S$\frac{1}{2}$-NW N$\frac{1}{2}$-SW	8	5	0.42	150
B12	5N	1E	12	NE	7	4	0.53	180
B13	5N	1E	1	N$\frac{1}{2}$-SW	4	2	0.52	130
B14	6N	1E	25	N$\frac{1}{2}$-SW	6	5	0.58	150
B15	5N	1E	23	SW	12	5	0.53	200
B16	5N	2E	17	SW	11	6	0.52	200
B17	5N	2E	20	SW$\frac{1}{4}$-NE	5	2	0.51	70
B18	5N	1E	21	NE$\frac{1}{4}$-NE	7	3	1.00	60
B19	5N	1E	10	E$\frac{1}{2}$-NW W$\frac{1}{2}$-NE	8	5	0.53	200
B20	6N	1W	36	NE	2	2	1.03	180
B21	6N	1W	36	SE	3	2	0.80	140

SUBREGION B (contin.)

Ref. No. of Target	Tsp.	Location			No. of Springs in Target	No. of Anomalous Springs	Highest Reading (ppm Zn)	Area of Target (Acres)
		Range	Sec.	¼ Sec.				
B22	5N	1E	6	NW	3	1	2.80	140
B23	5N	1E	18	NW	9	4	3.00	200
B24	5N	1E	18	SE	6	2	3.00	140
B25	5N	1E	19	NE	6	4	3.00	180
B26	5N	1E	21	S½-NW	5	1	2.75	100
B27	5N	1W	22	SE	8	5	0.48	200

SUBREGION C

Ref. No. of Target	Tsp.	Range	Sec.	¼ Sec.	No. of Springs in Target	No. of Anomalous Springs	Highest Reading (ppm Zn)	Area of Target (Acres)
C1	6N	3E	34	SE-SW SW-SE	2	2	0.85	100
C2	6N	4E	30	W½-SW SE-SW	5	3	1.12	220
C3	6N	4E	30	S½-NE	3	2	0.88	100
C4	4N	4E	13	SE	6	4	1.07	150
C5	4N	4E	24 25	S½-SE NE-NE	6	4	0.56	240
C6	4N	5E	19	E½-NW	14	10	0.71	270
C7	4N	5E	17	W½-SE E½-SW	9	5	1.14	170
C8	3N	4E	11	W½-NW	6	3	1.18	100
C9	3N	4E	26	NW	7	4	1.02	130
C10	2N	5E	8	NW W½-NE	16	11	0.51	220
C11	2N	5E	4	S½-SE	8	6	1.12	190
C12	3N	4E	22	W½-SE SW	17	5	0.62	230
C13	3N	3E	24	NW N½-SW	14	10	1.06	260
C14	3N	4E	10	S½-SW W½-SE	14	3	0.53	230

SUBREGION C (contin.)

Ref. No. of Target	Tsp.	Location Range	Sec.	¼ Sec.	No. of Springs in Target	No. of Anomalous Springs	Highest Reading (ppm Zn)	Area of Target (Acres)
C15	3N	4E	5	S½-NW N½-SW	6	2	1.06	140
C16	4N	4E	22	SE E½-SW	18	13	1.05	300
C17	4N	4E	28	E½-SE S½-NE	11	7	0.54	210
C18	5N	4E	33 32	SW SE	13	12	0.55	310

SUBREGION D

Ref. No. of Target	Tsp.	Location Range	Sec.	¼ Sec.	No. of Springs in Target	No. of Anomalous Springs	Highest Reading (ppm Zn)	Area of Target (Acres)
D1	3N	3E	32	SE SW¼-NE	15	6	1.25	180
D2	2N	2E	11	S½-NE N½-SE	3	2	1.02	130
D3	2N	2E	3	W½-SE E½-SW	4	3	2.08	180
D4	2N	2E	8	NE	2	2	2.50	110
D5	3N	1E	35	SE	8	2	2.10	140
D6	3N	1E	35	NW	5	2	2.07	150
D7	3N	1E	34	NW¼-NE NE¼-NW	6	2	1.00	130
D8	2N	1E	9	S½-NE	4	1	2.20	100
D9	2N	1E	9	S½-NE	4	2	1.95	100
D10	2N	1E	4	S½-SW	4	2	2.85	120
D11	2N	1E	8	W½-NW	1	1	3.00	90
D12	2N	1W	12	N½-NE	2	2	2.08	150
D13	3N	1E	31	SW¼-SW	3	2	2.00	100

SUBREGION E

Ref. No. of Target	Tsp.	Location Range	Sec.	¼ Sec.	No. of Springs in Target	No. of Anomalous Springs	Highest Reading (ppm Zn)	Area of Target (Acres)
E1	3N	2E	24	NW	4	3	1.08	150
E2	4N	2E	23	W½-NW	7	2	0.48	110
E3	4N	3E	17	SE¼-SW SW¼-SE	5	4	0.50	100
E4	4N	2E	13	NW	6	4	0.48	180
E5	4N	1E	24	SE	11	8	0.45	200
E6	4N	1E	22	E½-SE	9	6	0.40	100