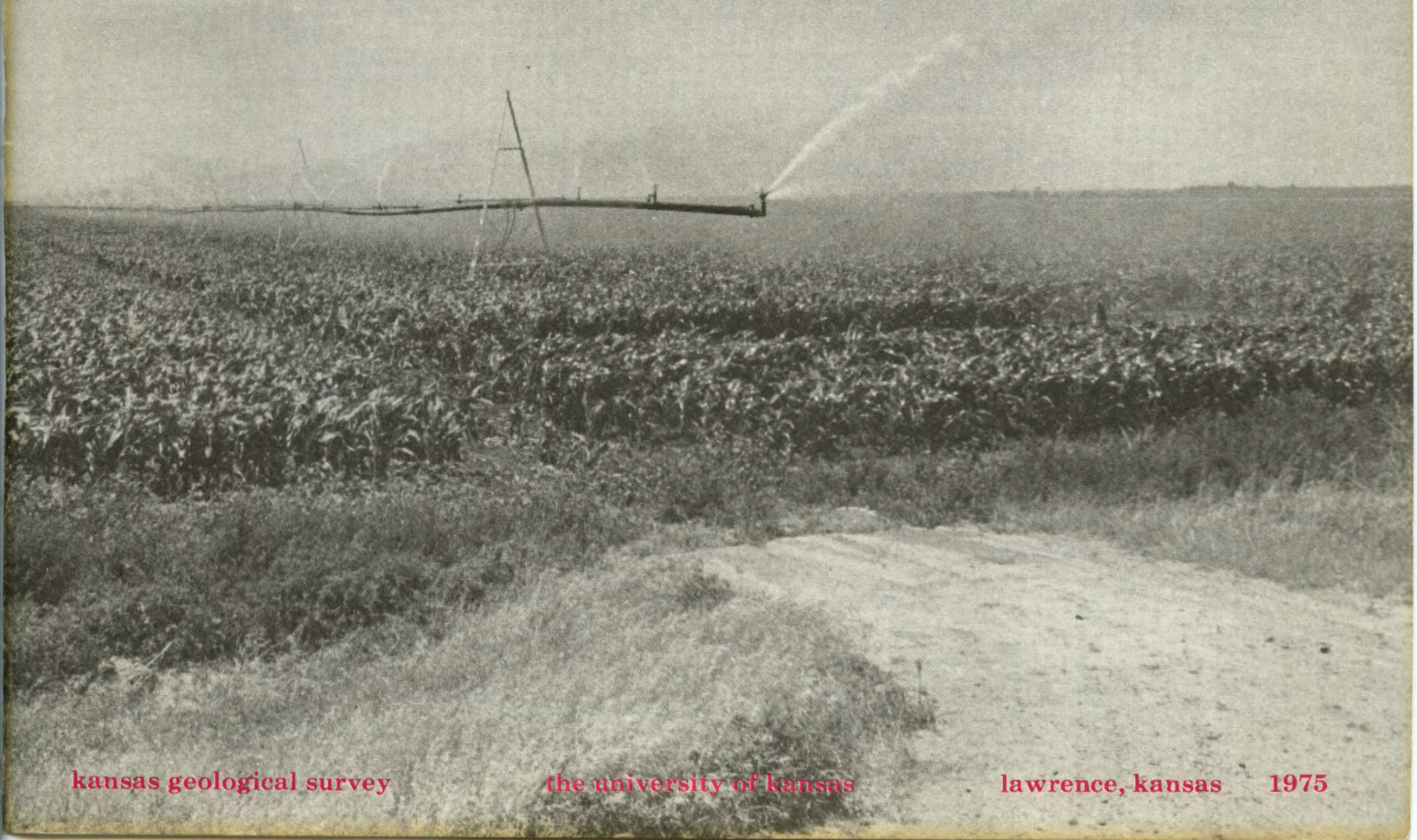
Chemical Quality of Irrigation Waters in West-Central Kansas

Chemical Quality Series 2



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CHEMICAL QUALITY OF IRRIGATION WATERS IN WEST-CENTRAL KANSAS

CHEMICAL QUALITY SERIES 2

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ABSTRACT

The principal aquifer in southern Wallace, Greeley, Wichita, Scott, and Lane Counties is the Ogallala formation. Analysis of ground water samples collected from 154 irrigation wells in this 4 1/2 county area during summer of 1974 indicate waters of this region are basically calcium-magnesium bicarbonate in nature. Higher salinities and increased sulfate contents are observed for wells in parts of the Scott Basin area, which appear to be in association with saline soils.

Compiled chemical quality data and chemical quality contour maps for the area of study are presented. This report represents the first phase of a program directed toward establishing base line chemical quality data for irrigation waters in western Kansas.

INTRODUCTION

The primary objective of this study is a set of unified ground water chemical quality data for irrigation wells of the hydrogeologic observational network in west-central Kansas, i.e., southern Wallace, Greeley, Wichita, Scott and Lane Counties (Figure 1). Most of the 154 wells used in this study derive water from the Ogallala formation of Pliocene age, exceptions being wells in southeastern Scott County which are associated with the Niobrara Chalk of Cretaceous age or undifferentiated Quaternary-Ogallala sequences. Bedrock in southern Wallace County is the Pierre Shale of Cretaceous age and the Niobrara Chalk in the remainder of the area of study (Stullken _et al._, 1974; Keene and Pabst, 1971). Historical chemical quality data exist for about 21% of the wells considered in this investigation, but variations in time-location and sampling conditions make evaluation of potential changes in quality of the ground water system difficult to assess using these data alone.

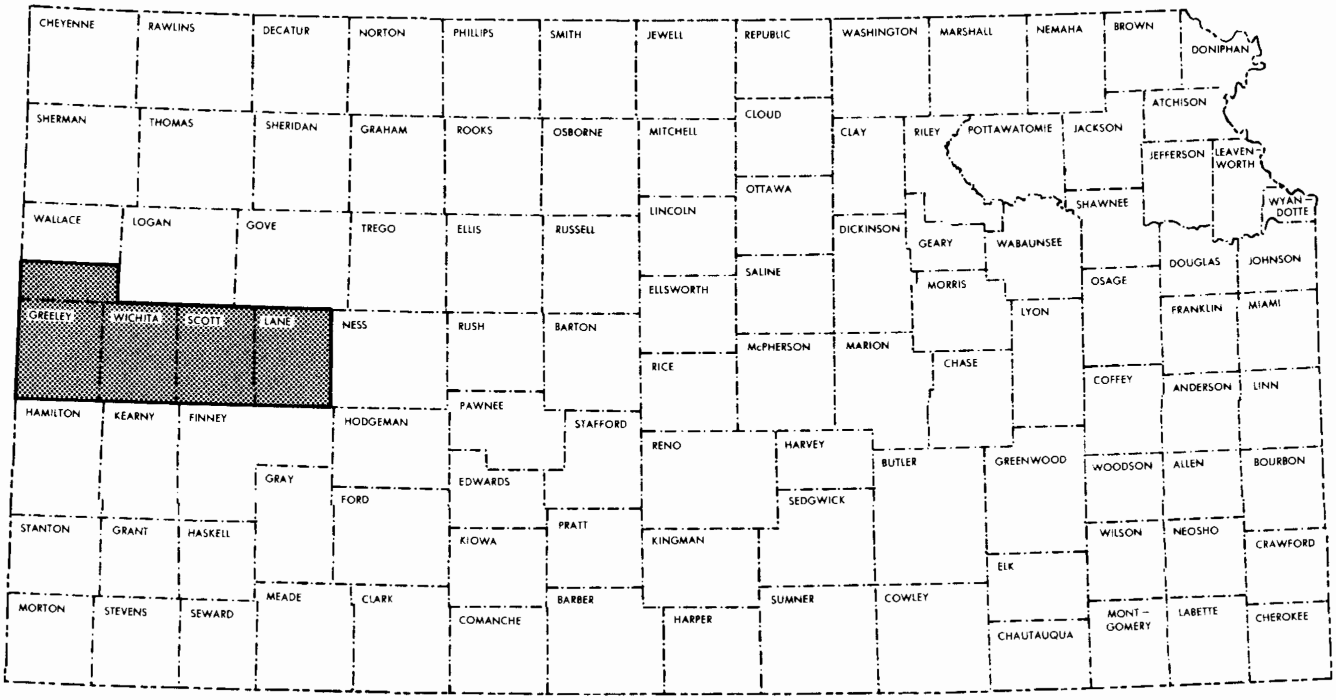

Figure 1. - Index map of Kansas showing area discussed in this report.

Well locations listed are in accordance with the Bureau of Land Management numbering system. The location is composed of the township, the range, and the section number, followed by letters that indicate the subdivision of the section in which the well is located. The first letter denotes the 160-acre tract; the second, the 40-acre tract; and the third, the 10-acre tract (Figure 2).

COLLECTION AND ANALYSIS

Ground water samples were collected over a three-day period during the high production portion of the season, July 30 - August 1, 1974, from pumping wells which had been in operation for some time prior to sampling. Water samples from the producing wells were found to be free of suspended material, thus eliminating the need for field filtration. Samples were collected at the wellhead whenever possible to minimize the possibility of contamination.

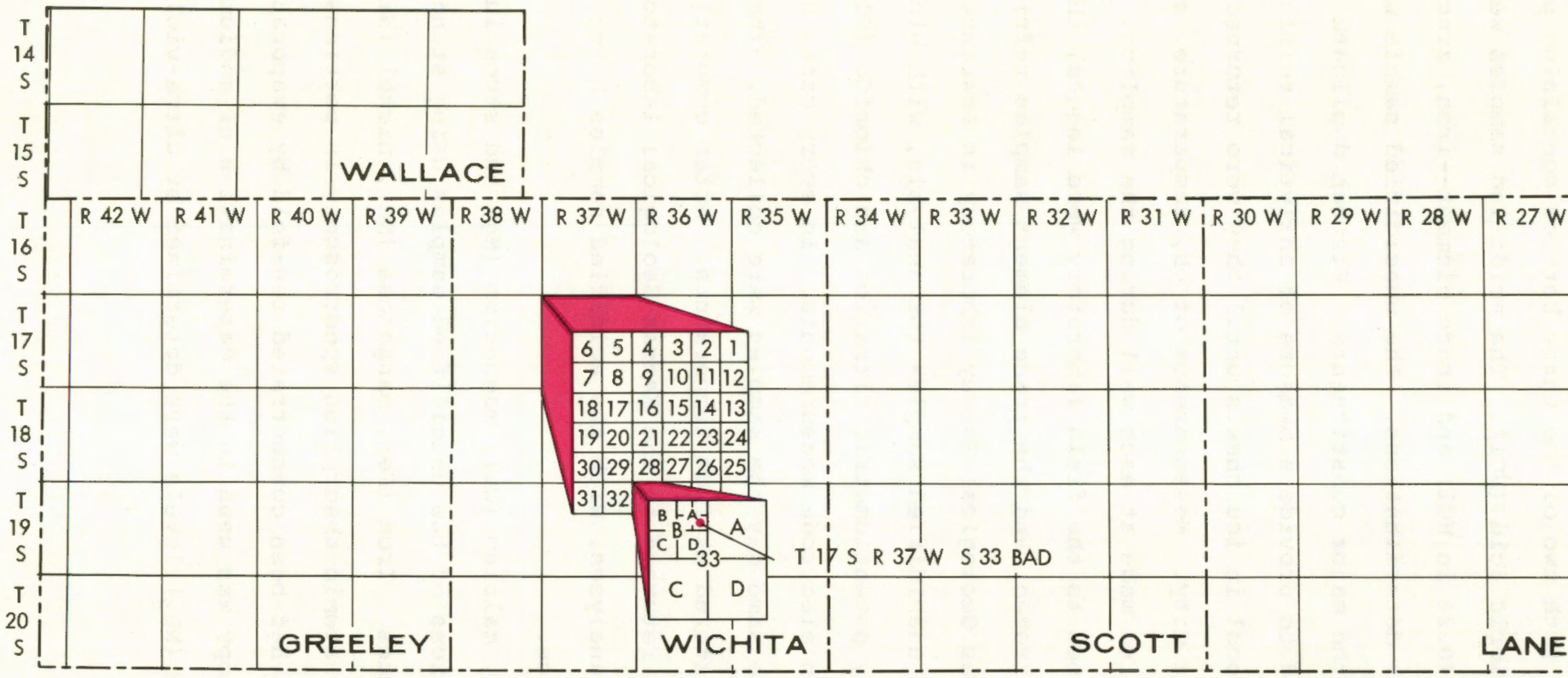

Figure 2. - Well location system used in this report.

Three types of samples were collected in acid-rinsed polyethylene bottles at each well, with two of the three bottles containing premeasured amounts of hydrochloric acid (HCl). The acidified samples were used in nitrate-phosphate (0.2% in HCl) and trace element--iron, zinc, manganese, and nickel--(1% in HCl) determinations. The unacidified sample was used in the determinations of the major constituents. Fifteen duplicate sets of samples also were collected to provide a measure of analytical reliability. All samples were kept cool in ice chests until they were returned to the field laboratory in Scott City. Measurements of pH, temperature, and specific conductance were also made at each well during the sampling.

Samples returned to the field laboratory were logged, the nitrate-phosphate samples frozen, and the trace element samples refrigerated for return to the Kansas Geological Survey laboratory in Lawrence. Portions were withdrawn from the unacidified samples for analysis, with bicarbonate (HCO_3) being determined by potentiometric titration and chloride (Cl) and fluoride (F) by specific-ion electrode measurements. In every case, HCO_3 determinations were made the same day the samples were collected. The unacidified samples were then stored at room temperature. After completion of the field work, samples were returned to the Kansas Geological laboratory in Lawrence for the remaining analyses, with the acidified samples being transported in ice chests under ice.

Silica (SiO_2), calcium (Ca), magnesium (Mg) and strontium (Sr) were determined in portions of the unacidified samples using standard atomic absorption techniques. Iron (Fe), manganese (Mn), nickel (Ni), and zinc (Zn) were determined by atomic absorption spectroscopy in portions of the acidified samples which had been concentrated ten-fold by evaporation. Flame emission spectroscopy was used in the determination of sodium (Na) and potassium (K). Nitrate (NO_3) levels were determined by ultra-violet absorption spectroscopy.

In the case of phosphate (PO_4), total PO_4 determinations were made on 24 samples whose locations were widely dispersed in the area of study. The remaining samples were screened to a 0.12 mg/l ortho-PO_4 level and total PO_4 measurements were made on those samples showing above the screening level. Analytical methods for the determinations mentioned above are found in Standard Methods (American Public Health Association, 1971).

Sulfate (SO_4) determinations were made using a modification of the atomic absorption technique of Dunk et al. (1969). An acidified stock solution containing barium chloride and excess sodium chloride, added as a flame buffer, was added to portions of the unacidified water samples. After standing for 12 hours, relative concentrations of excess barium in the solutions were measured and related to the amounts of SO_4 originally present by comparison with standard SO_4 solutions treated in a similar manner.

An ammonia specific-ion electrode was used to check for the presence of ammonium (NH_4) salts in samples taken from the delivery pipe down-stream from the wellhead where fertilizer contamination would be a possibility.

Compiled chemical quality data for ground waters from the irrigation wells as determined for this study are listed by county and location in Appendix A. Concentration data are given in ppm (parts per million or mg/l) for all species except the trace elements. Concentrations of Fe, Mn, Zn, and Ni are given in ppb (parts per billion or μg/l). Standard deviations for the various analyses as based upon the 15 sets of duplicate samples are given in Table 1.

MAPPING OF CHEMICAL QUALITY DATA

A computerized plotting program using a weighted octant search routine was used in the interpretation of the ground water chemical quality data (Sampson, 1973). For a grid node to be seen in the program, at least two octants must contain a total of at least five wells, with one of the octants

Table 1

Standard Deviations of Chemical Determinations

Determination	$\pm\sigma$
SiO_2	2.8 ppm
Ca	0.7 ppm
Mg	0.5 ppm
Na	0.3 ppm
K	0.03 ppm
HCO_3	1.2 ppm
SO_4	4.0 ppm
Cl	0.6 ppm
F	0.02 ppm
NO_3	0.3 ppm
Sr	0.05 ppm
Fe	7.6 ppb
Mn	0.7 ppb
Zn	17.8 ppb
Ni	4.3 ppb

$$\pm\sigma = \sqrt{\frac{1/2 \sum_{i=1}^{N} r_i^2}{N}}$$

r_i = range for analysis of sample pairs

N = numbers of sample pairs

having at least three wells. Further restraints limit the number of wells considered per octant to three, with at least one well in the octant being within 12 miles of the grid node before the octant is considered. The weighting factor used was $1/D^6$, where D is the distance from the well to the grid node. The distance between grid nodes was taken as 3/4 mile.

The assignment of absolute confidence levels for contour lines at the boundaries of the mapped area or in regions of limited sample data is a difficult problem at best. Generally speaking, the reliability of contour lines on the maps generated by the plotting routine is expected to be a function of the well density distribution, i.e., greatest in regions of high well density. Figure 3 gives the distribution of wells within the area of study. However, the confidence in the contour interval can never exceed that of the analytical data upon which it is based. Data from south-central Scott County indicate waters of widely varying composition exist and can be detected with a sufficient degree of confidence in wells no more than 1-2 miles apart. In this study, regions of relative reliability of the contour intervals have been designated on the basis of several criteria (Figure 4).

Regions of good reliability are those in which a well is within 2 miles of the grid node and six octants about the grid node contain one well each within a distance of 6 miles of the grid node. In the case of isolated wells, it is assumed that the concentrations are well known in the immediate vicinity of the wells and regions of good reliability exist within areas 1/2 mile from the wells. Regions of fair reliability are taken to be those areas between the defined boundaries for good and poor regions. Regions of poor reliability are assumed to exist when no well is within 4 miles of a grid node or when fewer than three octants about a grid node contain one well each within a distance of 6 miles of the grid node. Contouring is cut-off in regions where the distance from the grid node to the nearest well is greater than 6 miles.

Contour intervals for the chemical quality maps (Appendix B) were chosen so as to divide the total concentration range of each species into four portions. The approximate contour levels chosen were mid-range between minimum and mean, the mean, and mid-range between mean and maximum.

The chemical quality contour maps are of two types, those based upon areal variation in concentration of a given species and those showing areal variation of the percent of total milliequivalents of cation/anion of a given species. The former are useful in gaining a feeling for relative intensities of the chemical species in different portions of the system; whereas the

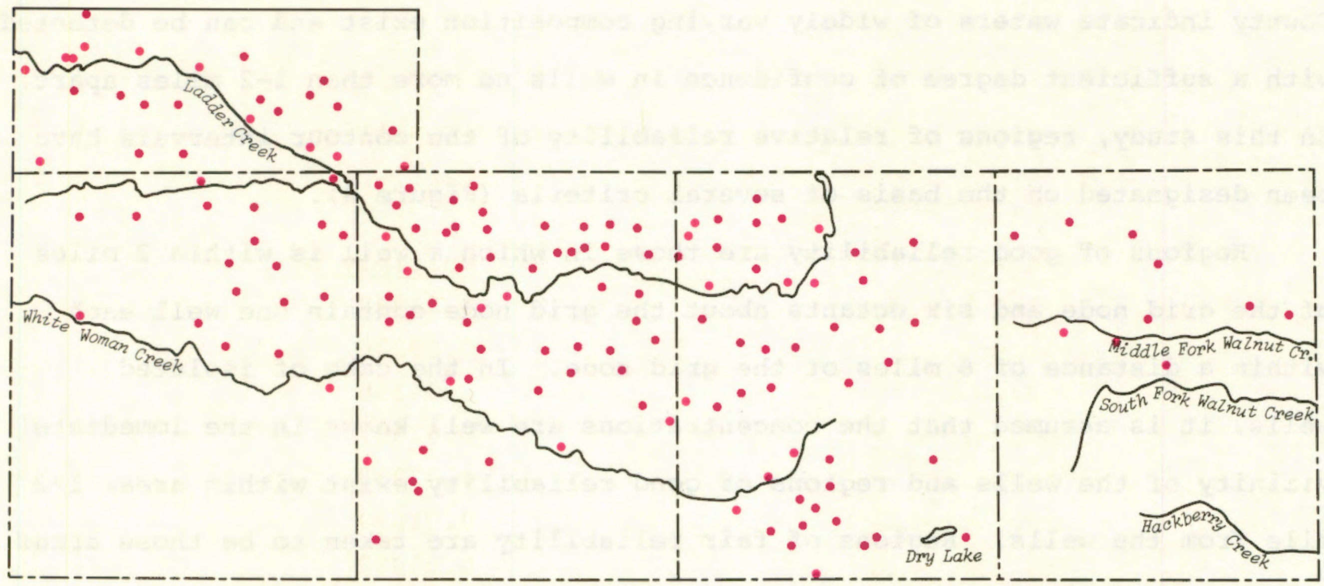

Figure 3. - Irrigation well distribution in the study area. Principal drainage systems in the area are also indicated.

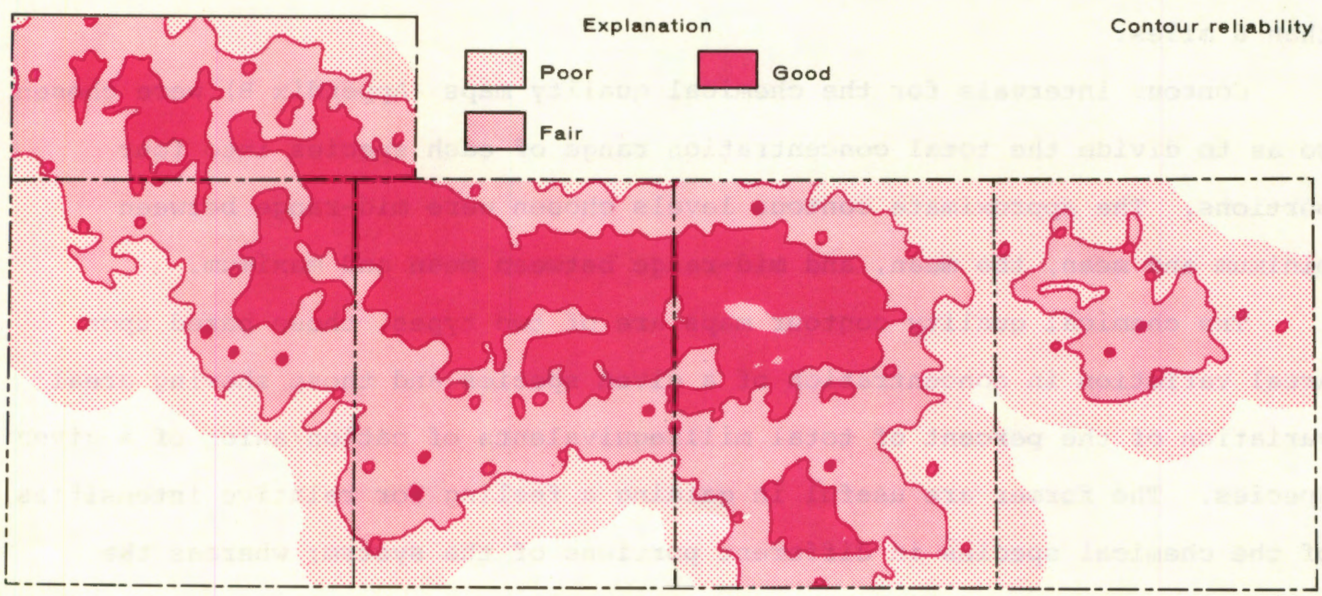

Figure 4. - Contour reliability map for the chemical quality contour maps of Appendix B.

latter show similarities or differences in the nature of the solutes in different parts of the ground water system. Table 2 lists factors for conversion of ppm to milliequivalents per liter.

Table 2

Factors for Conversion of Parts Per Million to Milliequivalents Per Liter

Species	Multiply by
Calcium	0.04990
Magnesium	0.08226
Sodium	0.04350
Potassium	0.02557
Strontium	0.02283
Bicarbonate	0.01639
Sulfate	0.02082
Chloride	0.02821
Fluoride	0.05264
Nitrate	0.01613

RESULTS AND DISCUSSION

Figures 5 and 6 show ground waters for the area of study are basically Ca-Mg-HCO_3 waters which grade into SO_4-rich waters in localized regions (Piper, 1944; Stiff, 1951; Hem, 1970). The relative importance of the various major chemical species, expressed as percent of the total milliequivalents of cations/anions, in relation to the make-up of the dissolved solids in the ground water system is illustrated in maps of Appendix B. It appears that Ca is prominent along the northern and southern margins of the mapped area, becoming greatest in parts of the southern margin. HCO_3 is most pronounced along the northern margin and southwest portion of the study area. Na tends to exhibit a maximum influence in the general area north of the Ladder Creek area (Figure 3). Major contributions from Mg, SO_4, and Cl appear to be confined to a general central region between Ladder Creek and White Woman Creek (Figure 3) extending to the southern part of Lane County.

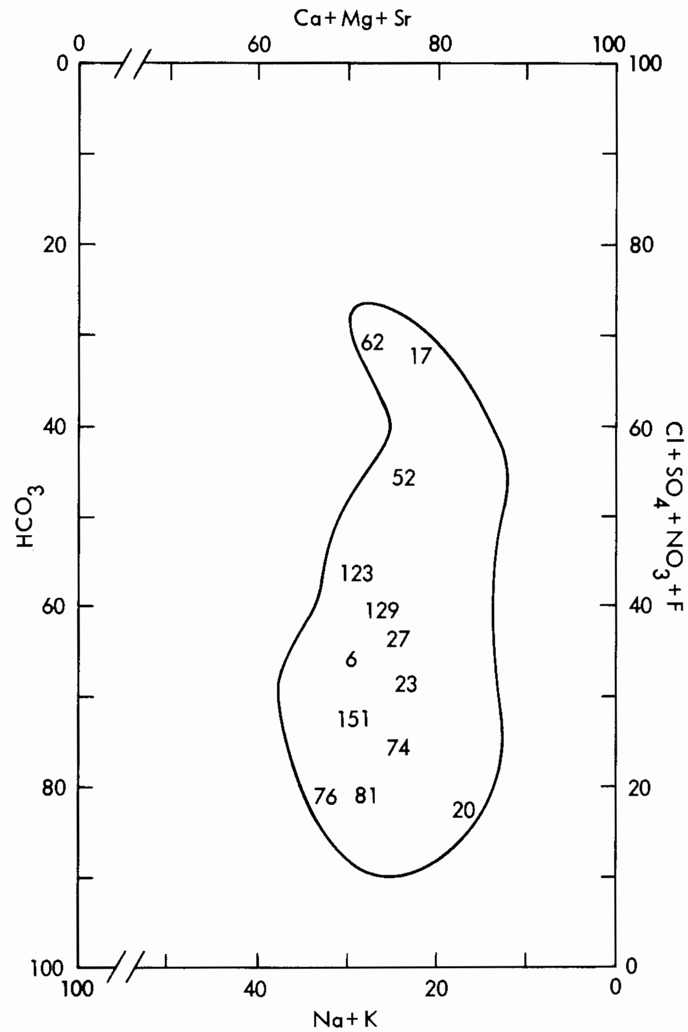

Figure 5. - Modified Piper diagram for ground waters in the study area. Well numbers correspond to those found in Appendix A.

The Stiff diagrams in Figure 6 are positioned over the corresponding well locations on the base map. From these diagrams it is possible to obtain a feeling for the areal variation in both the dissolved solid content and compositional make-up of the dissolved solids in ground water samples from the study area. The amount of dissolved solids in these waters tends to increase in a general northwest and southeast fashion, becoming high locally in portions of the Scott Basin area of south-central Scott County. Well 17 in western Greeley County also appears to be anomalously high. This same overall behavior is noted for most of the areal concentration contour maps of Appendix B. Systematic areal patterns or relationships are not readily apparent for the PO_4 data. Locally high PO_4 values may reflect fertilizer contamination in wells.

The combining capacities of the various major chemical species, expressed as milliequivalents per liter in the Stiff diagrams, reflect the following compositional trends for the dissolved solids in the bulk of the ground water samples:

Ca > Mg with Na and K contributing lesser amounts

HCO_3 > SO_4 with Cl and NO_3 contributing lesser amounts

Three exceptions to these general trends in composition do occur. Well 17 is a shallow well located along White Woman Creek in Greeley County. The Stiff diagram for this well shows the water there to be a Ca-SO_4 rich water, which is atypical of other ground water samples in the study area. The high Ca-SO_4 content of this water possibly reflects effects of surface leaching of gypsum from the soil. Historical data for this well from March, 1972, represent basically a Ca-Mg-HCO_3 type water with a specific conductance of 710 micromhos, as compared to 1270 micromhos from this study. It is impossible at present to state whether this represents a permanent change in chemical quality or a temporary effect resulting from local recharge during irrigation.

Wells 150, 151, and 154 in southwest Wichita County are associated with HCO_3 waters in which the combining capacity of Mg exceeds that of Ca. Waters of this type could arise as a result of loss of Ca by calcite precipitation

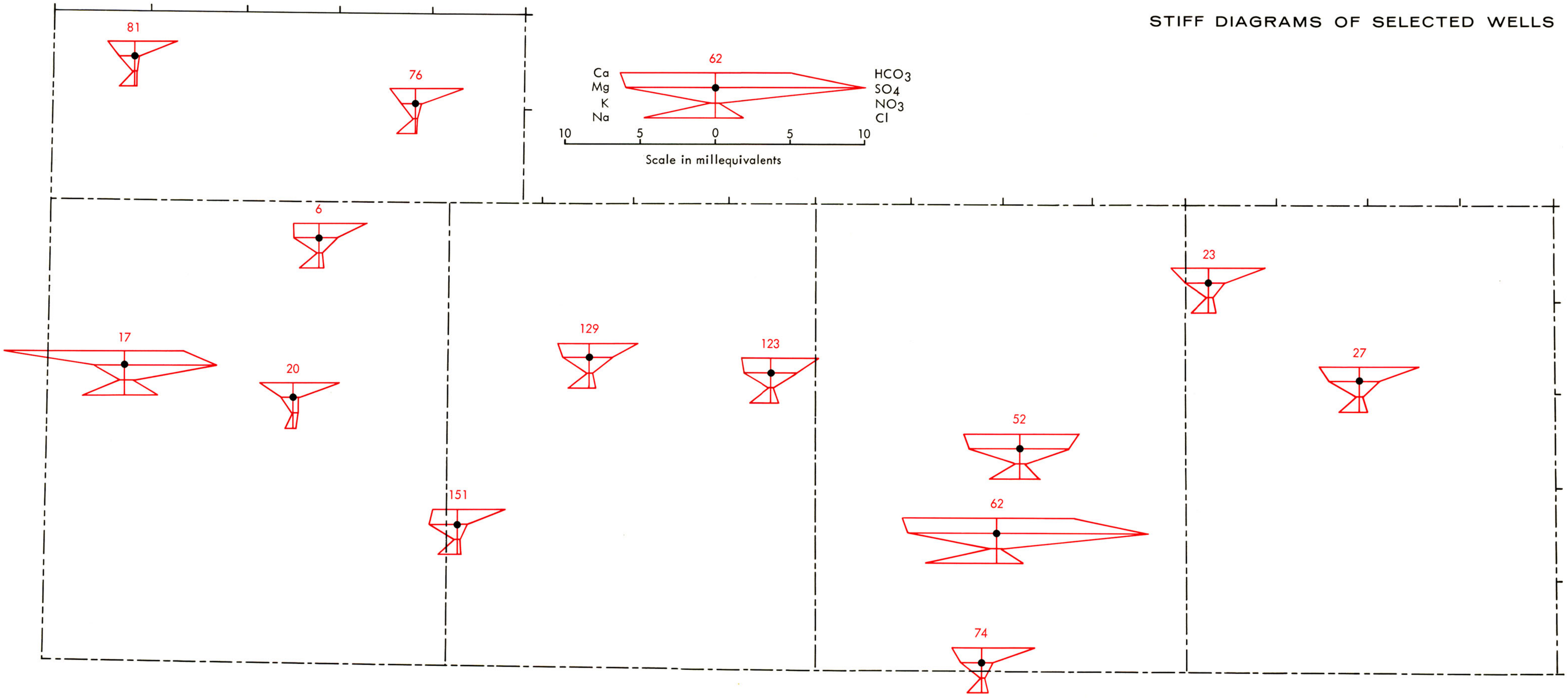

Figure 6. - Areal distribution of Stiff diagrams for selected wells. Well numbers correspond to those found in Appendix A.

from saturated solutions or from differential leaching of Mg and Ca in calcareous deposits associated with shallow depressions in the area. Additional field work would be necessary in order to elucidate the origins of these waters.

Wells 62, 67, and 69 in the Scott Basin area produce waters in which the cation distribution in the Stiff diagrams is similar to that of ground waters found in the middle portion of the study area (Wells 6, 129, 123, 52, 74, and 27 of Figure 6), but with SO_4 exceeding HCO_3 by 1.5-2 to 1. There are other well waters, however, within the Scott Basin area which are of lower salinity and have HCO_3 as the predominate anion, indicating a localized cause for the higher salinity and SO_4 content in these three wells.

Figure 3 shows the termination of White Woman Creek in south-central Scott County, at a point corresponding to the intersection with the Scott Basin depression. A soil survey of Scott County (Sallee and Hamilton, 1965) indicates the presence of saline soils in the Scott Basin area (Figure 7). The regions of saline soil occurrence coincide remarkably well with locations of ground waters having higher salinity and SO_4 content. This suggests the possibility that salts accumulated in the soil from waters entering Scott Basin, probably in large part from White Woman Creek, may be responsible for the variable chemistry of the ground waters in this area.

Table 3 represents correlation matrices based upon percent of total milliequivalents of cations/anions for wells in Townships 14 through 18, excluding well 17 in Greeley County, and the 14 wells of the Scott Basin area. Positive correlations significant at the 95% confidence level for wells in Townships 14-18 include Mg-SO_4, Mg-Cl, Na-K, Na-HCO_3, K-HCO_3, and Cl-SO_4. These relationships suggest close association between Na and K and that both tend to enter this portion of the groundwater system as bicarbonates and not chlorides. Mg apparently enters in association with SO_4 and Cl.

In the Scott Basin area positive correlations significant at the 95% confidence level include Mg-Na, Mg-SO_4, K-HCO_3, Ca-K, and Ca-Cl. In addi-

TABLE 3. Percent of Total Milliequivalents of Cations/anions Correlation Matricies

A. 128 wells located in Townships 14 through 18, exclusive of Well 17 in Greeley County

	%Ca	%Mg	%Na	%K	%Sr	%HCO_3	%SO_4	%Cl	%F	%NO_3
%Ca	1.000	-.434	-.666	-.245	-.251	.114	-.279	.067	-.136	.463
%Mg		1.000	-.291	-.219	.372	-.570	.489	.500	.041	-.358
%Na			1.000	.420	-.032	.346	-.188	-.481	.108	-.219
%K				1.000	-.221	.636	-.603	-.473	.320	-.072
%Sr					1.000	-.262	.269	.188	-.153	-.142
%HCO_3						1.000	-.887	-.844	.200	.080
%SO_4							1.000	.554	-.236	-.276
%Cl								1.000	-.102	.020
%F									1.000	-.198
%NO_3										1.000

95% Confidence level = .146

B. 14 Wells located in Scott Basin Area

	%Ca	%Mg	%Na	%K	%Sr	%HCO_3	%SO_4	%Cl	%F	%NO_3
%Ca	1.000	-.862	-.871	.732	-.704	.436	-.541	.605	-.261	.180
%Mg		1.000	.514	-.693	.842	-.538	.569	-.442	.116	-.023
%Na			1.000	-.641	.359	-.282	.416	-.578	.265	-.276
%K				1.000	-.346	.808	-.798	.158	.284	.160
%Sr					1.000	-.240	.293	-.507	.209	.083
%HCO_3						1.000	-.963	-.096	.704	.373
%SO_4							1.000	-.125	-.582	-.553
%Cl								1.000	-.556	.216
%F									1.000	.028
%NO_3										1.000

95% Confidence level = .458
90% Confidence level = .365

tion, Ca-HCO_3 and Na-SO_4 are found to be significant at the 90% confidence level. The lack of positive correlation between Na-K, Na-HCO_3, and Mg-Cl noted previously and the positive correlations between Mg-Na, Mg-SO_4, and Na-SO_4 are consistent with the notion that salts enriched in Na-Mg-SO_4 content have been added locally to the ground-water system in the Scott Basin area, possibly through leaching of the saline soils found there. The Piper diagram (Figure 8) and general trend of increasing salinity with increasing sulfate content for wells in the Scott Basin area also are consistent with this conclusion.

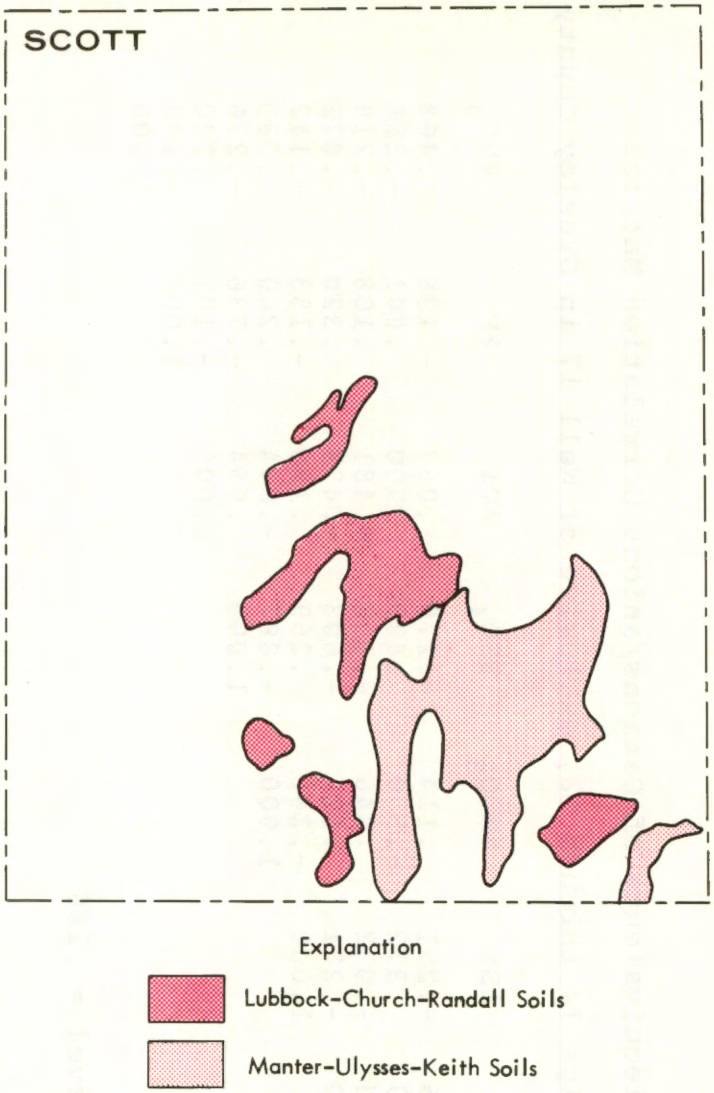

Figure 7. - Map showing occurrence of Church silty clay loam and Ulysses silt loam saline soils in Scott County. Modified after Sallee and Hamilton (1965).

The concentration data for the trace elements (Fe, Mn, Zn, and Ni) show positive correlations for Fe-Zn and Mn-Ni for the study area as a whole. These associations are the same as those cited by Jenne (1968) for trace element associations in soils. Conclusions based upon the zinc data may be open to some question, however, due to the large uncertainty involved in the duplicate sets of zinc determinations (Table 1). Problems with zinc contamination in pumping wells have been noted by Carpenter and

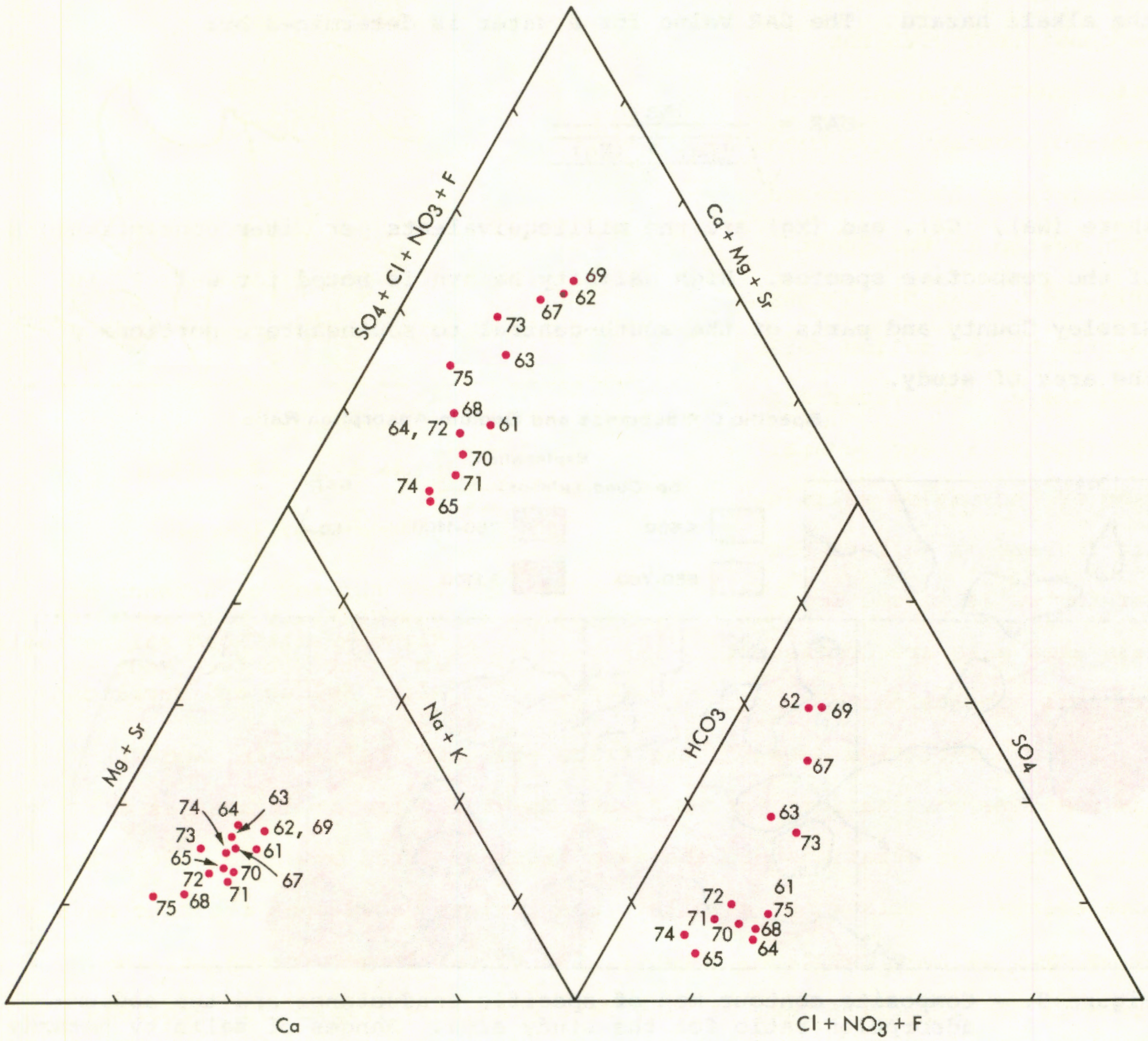

Figure 8. - Piper diagram for ground waters from the Scott Basin area. Well numbers correspond to those found in Appendix A.

Miller (1969) in their study of saline waters in Saline County, Missouri, and may be a factor here.

With respect to irrigation quality, groundwaters in the study area are of low alkali hazard, but range from medium to high in salinity hazard (U.S. Salinity Laboratory Staff, 1954). Medium and high salinity hazards are represented by ranges in specific conductance of 250-750 and 750-2,250 micromhos, respectively. Figure 9 is a composite areal plot of specific conductance and the sodium-adsorption ratio (SAR), which is used to define the alkali hazard. The SAR value for a water is determined by:

$$SAR = \frac{(Na)}{\sqrt{\frac{(Ca) + (Mg)}{2}}}$$

where (Na), (Ca), and (Mg) are the milliequivalents per liter concentrations of the respective species. High salinity hazard is noted for well 17 in Greeley County and parts of the south-central to southeastern portions of the area of study.

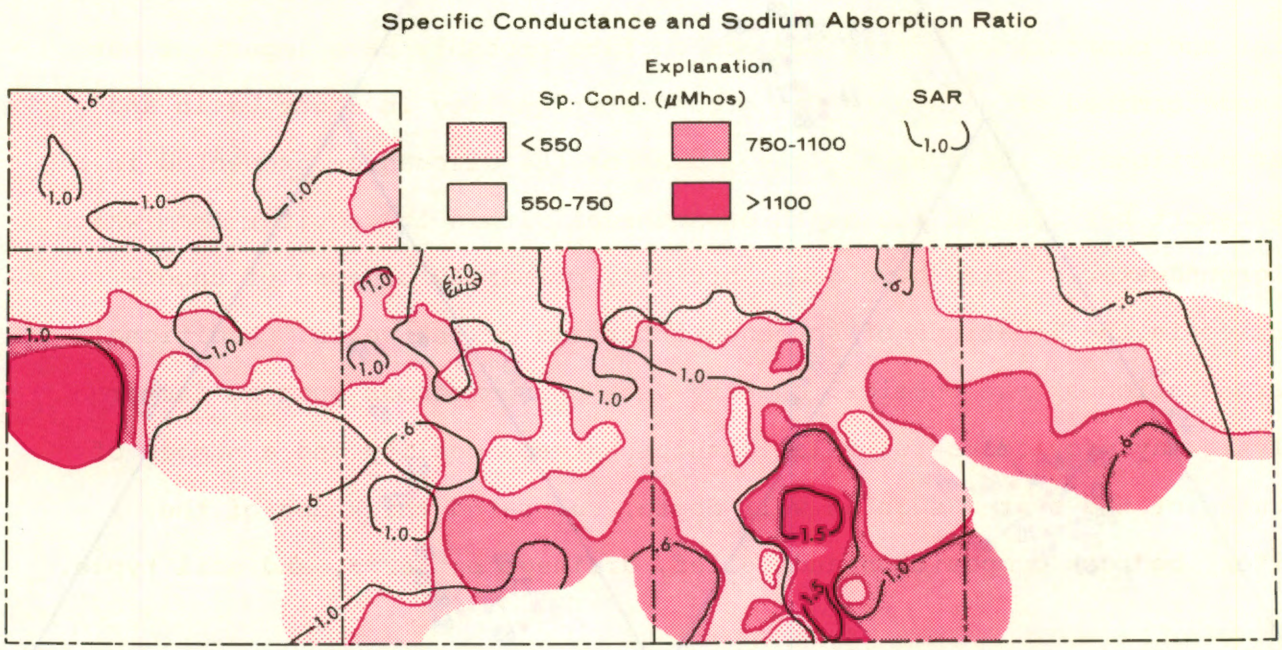

Figure 9. - Composite contour map of specific conductance and the sodium-adsorption ratio for the study area. Ranges of salinity hazard, based upon conductivity expressed in micromhos/cm at 25°C: low (100-250), medium (250-750), high (750-2,250), and very high (2,250). SAR values correspond to low alkali hazard throughout the study area.

U.S. Public Health Service (1962) recommended maximum values for drinking water of 500 ppm for dissolved solids, 250 ppm for SO_4, and 45 ppm for NO_3 are approached or exceeded locally within the 4 1/2 county area. The high fluoride background approaches and exceeds the recommended upper limit of 1.7 ppm in the eastern half of the area of study.

Comparison of the data collected during this study with historical data from 1970-1972, shows an average increase of 8% in the specific conductance, excluding well 17 in Greeley County, and 73% in the NO_3 content for 21 wells. It is uncertain at this point whether these values represent true changes in chemical quality or reflect only seasonal changes since most of the historical data represents samples collected during the first half of the year, and under unknown pumping conditions. Also, sample preservation represents another unknown factor in the historical NO_3 data since the nitrogen balance in water samples may be changed through biological activity (American Public Health Association, 1971).

In conclusion, it should be noted that other factors such as the relief and composition of the bedrock surface probably have important but yet undetermined effects upon the groundwater quality in Scott Basin and other portions of the system. Also, most of the discussion presented in this report has ignored the depth of interval within the aquifer from which the groundwater samples have been obtained, primarily because of uncertainties in the locations of screened intervals of the wells. Additional interpretation of the chemical quality data using methods such as factor analysis may provide useful relationships between quality and a number of features of the system such as well depth, saturated thickness of the aquifer, bedrock composition and relief, drainage patterns, and soil types.

ACKNOWLEDGMENTS

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APPENDIX A:

Chemical Quality Data

Greeley County

Well Number	Well Location	Date of Collection	SiO_2 ppm	Ca ppm	Mg ppm	Na ppm	K ppm	HCO_3 ppm	SO_4 ppm	Cl ppm	F ppm	NO_3 ppm	Total PO_4 ppm
1	16 39W 2BDC	7/30/74	30	40	20	31	5.4	189	60	21	1.5	13	
2	16 39W 18BBC	7/30/74	32	36	20	27	4.5	192	44	11.7	1.1	12	
3	16 39W 22DCB	7/30/74	40	44	20	31	4.6	186	60	21	1.6	13	
4a	16 39W 25CBB	7/31/74	38	43	20	29	4.8	189	56	14	1.5	12	
5	16 40W 6BAA	8/1/74	22	34	16	28	4.9	201	34	6.4	1.4	12	.19
6	16 40W 15ACC	7/30/74	37	34	19	29	4.5	189	56	10.7	1.4	12	.05
7	16 40W 35BBA	7/30/74	44	45	19	30	4.7	192	76	11.8	1.3	12	
8	16 41W 5CCC	7/30/74	27	42	11.6	17	3.9	191	26	3.8	.9	14	
9	16 41W 20BAD	7/30/74	38	47	21	27	4.1	183	70	23	1.0	18	
10	16 42W 22BCB	7/30/74	31	40	18	26	3.9	181	47	13	1.0	15	
11a	17 39W 6CCD	7/31/74	42	46	26	30	5.2	194	76	23	1.5	12	
12a	17 39W 19DBB	7/31/74	35	48	23	23	4.6	189	75	16	1.2	10	.37
13a	17 39W 22ABB	7/31/74	43	52	24	32	5.0	188	101	20	1.2	12	
14	17 40W 4DCB	7/30/74	45	47	21	36	5.0	168	96	17	1.3	12	
15a	17 40W 15CCB	7/30/74	40	51	19	31	4.2	174	80	24	1.2	14	
16a	17 40W 31BBA	7/30/74	30	48	14	19	4.4	185	47	7.8	.9	13	
17a	17 42W 27CBB	7/30/74	39	163	25	63	10.6	237	292	76	.6	38	.11
18a	18 39W 7BBD	7/30/74	30	51	17	16	3.7	181	66	10.4	1.0	14	
19	18 39W 23CCB	7/30/74	30	43	9.5	8	4.4	164	24	6.6	.8	17	
20	18 40W 4CBD	7/30/74	27	46	10.3	12	3.1	187	11.0	5.2	.9	18	

a - historical data available (Stullken et al., 1974, Keene and Pabst, 1971)

All wells reported are in the Ogallala Formation except those designated:

b - Quaternary undifferentiated

c - Quaternary undifferentiated - Ogallala Formation

d - Niobrara Chalk

e - Alluviam - Ogallala Formation

Lane County

Well Number	Well Location	Date of Collection	SiO_2 ppm	Ca ppm	Mg ppm	Na ppm	K ppm	HCO_3 ppm	SO_4 ppm	Cl ppm	F ppm	NO_3 ppm	Total PO_4 ppm
21	16 29W 26CCD	8/1/74	52	53	21	20	5.5	227	39	17	2.3	12	.19
22	16 30W 24DCC	8/1/74	48	52	21	23	5.6	216	43	19	2.3	16	
23	16 30W 29CDD	8/1/74	51	51	19	26	6.0	226	50	16	2.1	15	
24	17 27W 20CCC	8/1/74	53	55	20	21	5.4	227	42	16	2.6	14	
25	17 27W 26CCC	8/1/74	54	56	20	20	5.5	225	40	20	2.5	16	.07
26	17 28W 7BBB	8/1/74	56	54	23	26	6.0	221	53	22	2.5	14	
27	17 29W 36BAA	8/1/74	51	53	24	30	6.8	244	59	19	3.1	12	
28	18 28W 18ACC	8/1/74	68	83	48	29	9.4	317	91	69	3.4	29	.35
29	18 29W 4DAD	8/1/74	56	65	33	28	7.9	245	78	49	4.6	9	.18
30	18 30W 2AAA	8/1/74	57	71	33	41	8.3	242	155	32	3.1	15	

Fe ppb	Mn ppb	Sr ppm	Ni ppb	Zn ppb	Tempera-ture °C	Total Solids (Residue at 180°C)	Hardness as $CaCO_3$ Total ppm	Hardness as $CaCO_3$ Non-Carbonate ppm	Specific Conductance (micromhos at 25°C)	SAR	pH
10	2	1.0	4	21	15.0	309	183	28	525	1.00	7.4
7	0	1.1	1	2	16.0	302	172	15	460	.90	7.6
12	2	.7	2	4	16.0	338	191	38	540	.98	7.3
19	6	.9	13	4	16.0	320	191	36	495	.91	7.7
3	3	.8	1	5	16.5	292	154	0	420	.98	7.2
15	2	1.0	4	12	16.0	286	165	10	485	.98	7.8
8	2	1.0	5	4	15.0	330	191	34	525	.94	7.8
12	2	.7	4	8	19.0	232	153	0	390	.60	7.7
12	3	1.1	19	12	16.0	336	207	57	540	.82	7.7
9	1	1.0	1	4	17.0	294	174	26	460	.86	7.8
4	5	1.2	12	12	16.0	371	223	64	565	.87	7.7
5	7	1.1	14	5	16.0	315	214	59	525	.68	7.8
4	6	1.1	13	4	16.0	386	230	76	580	.90	7.6
14	2	1.0	4	3	17.0	368	203	65	570	1.10	7.6
23	2	1.1	3	11	15.0	361	206	63	570	.94	7.8
14	2	.8	3	4	16.0	288	177	25	455	.62	7.6
16	2	1.4	9	6	14.5	818	511	317	1270	1.21	7.6
7	1	1.0	2	0	16.0	312	198	50	455	.49	8.4
14	2	.4	1	13	16.0	219	146	12	332	.30	8.0
98	5	.7	4	73	15.0	243	158	5	385	.42	6.8

Fe ppb	Mn ppb	Sr ppm	Ni ppb	Zn ppb	Tempera-ture °C	Total Solids (Residue at 180°C)	Hardness as $CaCO_3$ Total ppm	Hardness as $CaCO_3$ Non-Carbonate ppm	Specific Conductance (micromhos at 25°C)	SAR	pH
6	2	1.0	0	50	16.0	352	218	32	500	.59	7.6
14	2	1.0	0	23	16.0	356	217	40	520	.68	7.6
14	1	1.0	7	3	16.0	358	208	23	540	.78	6.7
14	2	.7	3	10	16.0	358	221	35	510	.61	7.4
10	2	.7	2	15	17.0	357	223	38	510	.58	7.6
6	2	.8	8	7	16.0	373	230	49	540	.73	7.7
17	3	.9	3	21	15.0	392	231	31	601	.86	7.2
13	2	1.5	4	3	15.5	590	406	146	947	.63	7.2
8	1	1.1	7	6	18.5	471	300	99	733	.70	7.2
3	2	1.3	11	5	15.5	541	315	117	822	1.00	7.2

Scott County

Well Number	Well Location	Date of Collection	SiO_2 ppm	Ca ppm	Mg ppm	Na ppm	K ppm	HCO_3 ppm	SO_4 ppm	Cl ppm	F ppm	NO_3 ppm	Total PO_4 ppm
31	16 31W 31BCB	7/30/74	55	69	25	26	6.0	207	76	42	2.3	26	
32	16 33W 7CCC	8/1/74	35	52	19	29	5.4	196	41	30	2.0	17	.21
33a	16 33W 19CBB	8/1/74	27	42	15	30	4.9	205	39	9.6	2.0	13	.22
34	16 33W 21BCC	8/1/74	34	42	16	28	5.0	208	33	9.5	2.1	13	
35b	16 33W 25BCC	8/1/74	34	44	17	30	5.0	200	37	9.6	2.2	13	
36	16 34W 20DBC	7/31/74	25	40	18	28	4.8	200	35	7.6	1.7	13	
37	16 34W 22BDC	7/31/74	26	42	18	29	4.8	202	37	12	1.7	18	.08
38	16 34W 29CBB	7/31/74	25	43	18	29	4.9	205	47	10.4	1.7	15	
39	16 34W 34CBB	8/1/74	32	42	16	32	5.1	208	42	11.7	2.1	15	.48
40	17 31W 31BBB	7/31/74	59	80	35	34	7.9	234	114	62	2.1	32	
41a	17 32W 5ABB	7/30/74	56	69	21	36	6.3	237	78	31	2.2	24	
42	17 32W 16BBB	7/30/74	54	55	21	29	5.9	208	76	16	2.5	16	.10
43	17 32W 31BCB	7/30/74	58	55	24	31	6.2	207	63	34	2.6	23	
44	17 32W 34CAA	7/30/74	57	53	24	31	6.2	225	66	29	2.2	14	
45	17 33W 7BBB	8/1/74	44	48	19	35	5.7	212	55	20	2.3	30	
46	17 33W 14ACB	7/30/74	56	62	26	49	8.4	329	61	21	2.4	3	.29
47	17 33W 16ABC	7/30/74	53	58	22	39	6.8	288	63	19	2.5	6	
48	17 34W 6BCB	7/31/74	26	42	15	30	4.9	209	42	9.9	1.7	13	
49a	17 34W 16ACB	7/31/74	48	58	26	38	6.4	231	92	34	1.9	18	
50	17 34W 28CCB	7/31/74	52	47	25	32	6.4	202	78	21	2.1	13	
51	18 32W 14BBB	7/30/74	60	42	22	28	5.6	244	40	8.0	2.5	13	
52	18 32W 20CBB	7/30/74	60	73	40	45	8.3	238	154	46	2.2	24	
53	18 33W 3CCB	7/30/74	60	44	22	30	5.6	208	54	20	2.4	15	
54a	18 33W 5CCC	7/31/74	52	43	21	25	5.6	207	63	13	2.1	12	
55	18 33W 20CCD	7/30/74	52	53	20	24	5.8	222	48	22	1.6	19	
56	18 34W 1CBB	7/31/74	58	58	31	34	6.9	211	108	38	2.1	22	
57	18 34W 25BBD	7/30/74	55	51	23	31	6.2	239	57	20	1.6	9	.08
58	18 34W 30DDC	7/31/74	52	56	22	30	6.2	222	53	28	1.8	18	
59	18 34W 34BBC	7/31/74	43	47	22	28	6.7	239	46	19	1.2	15	
60d	19 31W 20BAD	8/1/74	29	86	14	28	7.6	262	47	45	.6	22	
61	19 33W 15DBD	7/31/74	40	77	36	59	6.8	333	99	46	2.5	48	
62c	19 33W 24ABB	7/31/74	37	125	71	107	10.8	312	483	65	2.1	15	.01
63c	19 33W 25DCD	8/1/74	34	94	43	53	9.4	313	192	43	2.1	23	
64c	19 33W 29CBB2	7/31/74	41	56	29	32	7.0	260	36	32	1.6	49	0.12
65c	19 33W 34DCC	7/31/74	26	48	16	26	6.6	226	23	18	1.4	15	
66c	20 31W 14CBC	8/1/74	25	112	49	66	13	298	216	88	1.4	36	
67a,c	20 32W 7CBA	7/31/74	39	152	66	88	15	368	407	85	1.4	36	0.16
68	20 32W 16DAD	7/31/74	30	76	18	27	7.5	245	45	46	.7	16	
69c	20 32W 21BBC	7/31/74	43	135	77	114	13	306	512	79	1.4	21	
70c	20 33W 2DBB	7/31/74	28	60	20	35	7.0	251	49	34	1.4	22	
71c	20 33W 10DBC	7/31/74	31	50	16	29	6.2	222	42	24	1.3	9	0.07
72	20 33W 17BAB2	7/31/74	33	65	20	29	7.9	242	60	30	.8	14	
73c	20 33W 21ABD	7/31/74	38	81	31	30	8.8	221	133	53	1.2	16	
74c	20 33W 35DBA	7/31/74	35	42	17	23	5.5	212	31	13	1.6	8	
75	20 34W 2DBC	7/30/74	29	99	20	23	9.4	271	68	46	.5	39	0.26

Fe ppb	Mn ppb	Sr ppm	Ni ppb	Zn ppb	Temperature °C	Total Solids (Residue at 180°C)	Hardness as $CaCO_3$ Total ppm	Hardness as $CaCO_3$ Non-Carbonate ppm	Specific Conductance (micromhos at 25°C)	SAR	pH
7	2	1.2	3	4	16.5	425	277	107	695	.68	7.3
8	1	1.0	1	4	16.5	343	211	50	470	.87	7.7
0	1	.9	9	2	16.0	282	168	0	450	1.01	6.7
0	1	.8	1	1	16.0	294	170	0	450	.93	6.8
4	2	.9	2	4	15.5	314	180	16	480	.97	6.8
2	1	.6	4	3	15.5	276	173	9	380	.93	6.6
8	1	.7	3	8	16.0	295	180	14	410	.94	6.5
13	2	.8	4	24	15.5	294	183	15	400	.93	7.2
6	1	.7	6	6	15.5	300	171	1	470	1.06	7.2
8	2	1.7	5	4	16.0	438	347	155	830	.79	7.3
54	3	1.0	6	14	16.5	431	258	64	695	.97	7.3
8	2	1.1	4	3	16.0	388	223	52	650	.84	7.2
11	3	1.1	2	24	16.0	407	238	68	600	.87	6.9
7	2	1.1	4	3	16.0	358	234	49	575	.88	7.1
0	1	1.0	4	3	15.0	367	200	26	550	1.08	6.8
22	2	1.2	6	4	17.0	438	265	0	762	1.31	7.2
6	2	1.0	6	5	16.5	402	235	0	722	1.11	7.2
17	2	.8	4	3	17.0	291	167	0	590	1.01	7.6
11	2	1.4	12	4	16.0	441	257	68	643	1.05	7.4
20	1	1.3	12	8	17.0	385	221	55	570	.94	7.7
14	2	1.0	4	10	16.0	325	195	0	510	.87	7.2
24	2	1.6	5	4	16.0	471	350	155	895	1.05	7.2
34	2	1.1	3	12	17.0	352	201	30	762	.92	6.8
2	2	1.1	0	2	17.0	338	197	27	450	.77	6.6
11	2	1.1	6	10	16.0	362	214	32	543	.72	7.2
12	5	1.4	29	6	17.0	450	275	102	730	.89	7.4
13	2	1.3	4	7	16.0	361	223	27	605	.90	7.2
26	3	1.2	6	12	16.5	384	234	52	589	.85	6.8
4	1	1.1	7	1	18.0	360	211	15	585	.84	7.0
15	2	.6	3	8	15.0	404	272	57	687	.74	7.0
16	6	1.6	17	4	16.0	582	344	71	976	1.38	7.2
32	10	3.5	83	8	17.5	1094	607	351	1510	1.89	7.2
10	3	2.0	1	24	15.5	654	413	156	1014	1.13	7.1
158	5	1.6	10	131	16.5	415	262	49	693	.86	7.0
10	3	.8	7	4	16.5	297	188	3	508	.81	7.1
21	2	3.3	0	3	14.0	789	483	239	1026	1.31	7.0
18	7	3.2	63	10	18.0	1044	653	351	1570	1.50	7.1
16	3	.9	15	4	19.0	381	264	63	679	.72	7.0
19	57	3.6	63	9	16.0	1208	659	408	1562	1.93	7.1
16	5	1.0	21	4	15.0	382	233	27	659	1.0	7.1
11	4	.9	26	5	16.0	319	192	10	548	.91	7.2
14	4	1.2	15	4	16.5	383	244	46	649	.81	7.1
19	4	1.5	17	11	17.0	526	332	151	814	.72	7.1
33	4	.9	12	4	16.0	279	177	3	462	.75	7.3
12	6	1.1	30	5	16.0	467	332	110	799	.55	7.1

Wallace County

Well Number	Well Location	Date of Collection	SiO_2 ppm	Ca ppm	Mg ppm	Na ppm	K ppm	HCO_3 ppm	SO_4 ppm	Cl ppm	F ppm	NO_3 ppm	Total PO_4 ppm
76	14 39W 36BCB	7/30/74	24	34	11.1	27	4.2	189	19	4.5	1.6	12	
77	14 40W 23ADD	8/1/74	15	34	10.1	21	4.0	173	0	5.1	1.1	11	
78	14 40W 29ABA	8/1/74	16	39	10.7	22	4.1	172	30	7.8	1.1	19	
79	14 41W 22BBB	8/1/74	19	34	10.7	22	3.8	178	15	6.2	1.1	12	
80	14 42W 2AAB	8/1/74	18	33	9.2	15	3.4	167	0	5.8	1.0	10	
81	14 42W 14DBD	8/1/74	18	35	11.4	23	3.9	170	14	6.9	1.1	12	
82	14 42W 22BDD	8/1/74	18	34	9.3	25	4.2	176	18	5.4	1.0	12	
83a	14 42W 22DBA	8/1/74	16	33	9.1	25	3.9	174	29	3.3	1.0	11	
84	14 42W 30BCA	8/1/74	22	46	15	27	5.1	193	46	17	1.0	20	
85a	15 38W 7BBB	7/30/74	26	39	14	28	4.7	179	49	14	1.5	19	
86	15 38W 14CCD	7/30/74	29	60	22	35	5.3	219	82	27	1.9	23	.06
87	15 38W 30CCB	8/1/74	24	39	15	28	5.4	192	30	8.4	1.4	13	.26
88	15 38W 36CBB	7/30/74	28	37	13	24	4.4	201	35	4.9	1.8	12	.11
89	15 39W 2BCD	7/30/74	24	34	12	28	4.4	181	34	7.2	1.6	14	
90	15 39W 6CBA	8/1/74	21	31	12	25	4.4	184	64	14	1.3	49	.08
91	15 39W 8ACC	7/30/74	25	33	14	28	4.5	190	30	9.3	1.2	13	
92a	15 39W 26BBB	7/30/74	25	36	15	28	4.7	191	46	6.1	1.2	13	
93	15 40W 7BBB	8/1/74	20	34	13	26	4.8	188	14	6.0	1.1	13	
94	15 40W 13BAA	8/1/74	21	38	15	25	4.8	189	14	10.5	1.2	21	
95	15 40W 30DBB	8/1/74	24	30	18	34	5.7	206	42	8.1	1.6	12	
96	15 41W 5ACB	8/1/74	21	40	15	25	5.0	190	39	9.6	1.1	14	.10
97	15 41W 10BAB	8/1/74	21	36	15	26	4.9	196	34	7.0	1.2	14	
98	15 41W 27CBC	8/1/74	24	30	18	35	5.7	200	46	8.8	1.5	12	.16
99a	15 42W 2BBB	8/1/74	20	36	16	29	5.0	192	38	7.0	1.2	12	.09
100	15 42W 32BDA	8/1/74	22	30	17	25	5.0	198	9	3.7	1.1	12	.15

*Water sample from well 90 was found to contain 13.3 ppm NH_4^+, not included in data for mapping or correlations.

Fe ppb	Mn ppb	Sr ppm	Ni ppb	Zn ppb	Temperature °C	Total Solids (Residue at 180°C)	Hardness as $CaCO_3$ Total ppm	Hardness as $CaCO_3$ Non-Carbonate ppm	Specific Conductance (micromhos at 25°C)	SAR	pH
10	1	.6	3	2	16.0	243	131	0	400	1.03	6.6
37	4	.7	7	0	16.0	218	127	0	360	.81	7.0
17	4	.7	5	4	16.0	248	142	1	410	.80	7.3
6	2	.6	2	7	16.0	242	130	0	360	.84	7.2
8	2	.6	1	10	16.0	209	121	0	320	.59	7.4
3	2	.6	0	7	17.0	239	135	0	390	.86	7.3
0	2	.6	5	4	16.0	247	124	0	370	.98	7.4
9	3	.5	8	3	16.0	228	120	0	360	.99	7.4
2	1	.7	3	5	17.0	300	176	18	460	.89	7.3
6	2	.7	0	6	16.0	284	156	9	490	.98	6.2
16	2	1.2	1	8	16.0	420	242	62	680	.98	6.3
28	2	.8	6	4	16.0	269	163	0	440	.92	7.3
14	2	.9	3	8	16.0	257	147	0	410	.86	6.4
10	2	.7	4	3	16.0	246	137	0	410	1.04	6.8
22	2	.6	2	2	17.0	279	129	0	490	.96	6.9
5	1	.6	0	1	17.0	252	141	0	420	1.03	6.8
7	1	.7	0	2	18.0	264	152	0	430	.99	6.8
18	2	.6	12	16	16.0	260	141	1	410	.95	7.0
31	2	.7	4	21	16.0	286	156	0	440	.87	6.9
8	1	.8	6	2	17.0	295	150	0	470	1.21	7.0
12	2	.7	1	2	16.5	279	163	0	420	.85	7.2
2	0	.8	15	3	16.5	270	154	0	413	.91	7.2
11	3	.8	1	73	17.0	276	149	0	440	1.26	7.2
4	4	.8	4	14	17.0	279	157	0	415	1.01	7.2
1	2	.8	1	5	17.0	269	147	0	375	.90	7.2

Wichita County

Well Number	Well Location	Date of Collection	SiO_2 ppm	Ca ppm	Mg ppm	Na ppm	K ppm	HCO_3 ppm	SO_4 ppm	Cl ppm	F ppm	NO_3 ppm	Total PO_4 ppm
101a	16 35W 20CCC	7/31/74	24	48	20	29	5.2	195	74	21	1.6	16	
102a	16 35W 27BBC	7/31/74	24	41	17	27	4.8	200	35	8.6	1.6	13	
103	16 35W 31DBA	7/31/74	26	65	21	29	6.0	204	73	40	1.5	18	
104a	16 36W 21CCC	7/31/74	24	41	16	32	5.2	194	52	15	1.7	15	0.01
105	16 36W 25BBB	7/31/74	24	49	18	30	5.2	193	23	23	1.6	22	0.22
106a	16 36W 34CCC	7/31/74	23	40	16	32	5.3	210	40	10.0	1.7	11	
107	16 36W 35CCC	7/31/74	25	41	16	31	5.4	206	36	13	1.7	12	0.09
108	16 36W 36CBC	7/31/74	24	43	16	31	5.4	202	35	17	1.6	13	
109	16 37W 4DCC	7/30/74	27	41	15	34	4.8	208	36	9.3	2.0	12	
110	16 37W 15CCC	7/30/74	25	44	18	30	5.4	195	46	19	1.9	15	0.34
111	16 37W 17BBB	7/30/74	25	49	19	33	5.8	187	69	26	1.7	18	0.18
112	16 37W 27ABC	7/31/74	24	37	16	33	5.3	205	39	8.1	1.6	13	
113	16 37W 29BBB	7/30/74	23	41	18	32	5.8	209	45	15	1.7	14	
114a	16 37W 30ACB	7/30/74	25	42	20	38	6.0	205	58	23	1.6	19	
115	16 38W 5BBB	7/31/74	24	37	15	26	5.1	194	33	8.6	1.2	13	
116	16 38W 10ABB	7/30/74	24	36	15	27	5.0	191	40	10.1	1.4	11	
117	16 38W 16ACC	7/30/74	24	55	28	38	6.6	205	103	28	1.6	19	0.05
118	16 38W 26BBB	7/30/74	29	46	20	28	6.2	224	48	18	1.3	10	
119	16 38W 29ADB	7/30/74	38	45	21	31	5.6	188	58	26	1.3	17	
120a	17 35W 2BBB	7/31/74	25	41	14	31	4.8	206	41	7.4	1.6	12	
121	17 35W 15CDC	7/30/74	48	50	24	32	6.1	190	77	43	1.9	18	
122a	17 35W 18ACB	7/30/74	43	54	27	40	7.5	258	79	28	1.9	7	
123a	17 35W 27CCC	7/30/74	49	42	22	33	6.1	190	82	20	2.1	13	0.07
124	17 36W 5CCD	7/31/74	26	42	17	31	5.4	224	46	10.4	1.5	9	
125e	17 36W 10CBB	7/31/74	32	43	20	35	5.5	226	62	14	1.6	9	
126	17 37W 3AAB	7/31/74	32	41	20	30	5.2	229	30	9.3	1.5	7	
127	17 37W 8BAA	7/30/74	37	58	25	39	6.3	239	94	34	1.6	15	0.23
128	17 37W 13CDD	7/31/74	38	66	27	29	6.3	233	71	39	1.3	12	
129a	17 37W 22CCC	7/30/74	48	41	20	32	5.4	196	65	16	2.0	11	
130	17 37W 38CCC	7/30/74	50	47	24	34	5.6	189	88	25	1.9	15	
131	17 38W 10AAB	7/30/74	40	59	21	35	5.4	180	101	40	1.7	15	0.05
132a	17 38W 21BBB	7/30/74	54	50	27	36	5.6	200	103	26	2.1	13	
133a	17 38W 24ACC	7/30/74	42	44	22	30	5.5	193	70	23	2.0	14	
134	17 38W 27ACD	7/31/74	44	44	23	32	5.2	189	70	19	1.8	11	
135	17 38W 28CCC	7/31/74	45	47	24	26	5.2	189	73	18	1.4	12	
136	18 35W 2ACB	7/30/74	56	54	23	34	6.4	202	72	32	2.0	16	
137	18 35W 8BBC2	7/30/74	51	52	27	30	6.0	202	85	34	2.0	16	
138	18 35W 17DAA	7/31/74	47	43	19	22	5.0	197	31	17	1.6	16	
139a	18 35W 34ABB	7/31/74	49	54	21	31	5.8	222	62	26	1.9	16	.26
140	18 36W 2DCB	7/30/74	50	38	19	27	5.3	195	50	11.8	2.0	10	
141	18 36W 9BBB	7/30/74	48	51	25	30	5.8	227	76	22	1.7	15	
142	18 36W 15DAD	7/31/74	44	46	20	25	4.9	184	46	22	1.6	21	
143a	18 36W 29ABB	7/30/74	42	38	14	20	4.1	181	29	12	1.9	15	2.41
144a	18 37W 3CCC	7/30/74	44	55	26	32	5.8	185	101	33	1.6	23	
145a	18 37W 19AAD	7/31/74	37	54	20	15	4.4	181	62	22	1.0	24	
146a	18 37W 21BBB	7/31/74	38	67	24	17	4.8	168	81	44	.9	32	
147	19 35W 1AAA	7/30/74	45	86	29	29	7.4	244	107	53	1.5	27	
148	19 36W 15BAA	7/30/74	46	71	28	37	7.9	244	138	33	1.4	14	.47
149	19 37W 22AAB	7/31/74	50	63	34	34	7.9	254	96	41	.9	26	
150	19 38W 14AAB	7/31/74	44	31	21	37	6.2	205	50	8.9	2.0	13	
151	19 38W 18DCC	7/31/74	44	31	22	29	5.4	194	32	10.3	2.0	14	.01
152	19 38W 26CCB	7/31/74	49	41	18	31	5.8	210	32	10.7	1.4	15	
153	19 38W 35BAB	7/31/74	46	42	16	26	5.4	190	41	10.8	1.0	13	
154	20 38W 17CBD	7/31/74	28	33	25	32	5.4	194	46	22	1.3	16	

Fe ppb	Mn ppb	Sr ppm	Ni ppb	Zn ppb	Temperature °C	Total Solids (Residue at 180°C)	Hardness as $CaCO_3$ Total ppm	Hardness as $CaCO_3$ Non-Carbonate ppm	Specific Conductance (micromhos at 25°C)	SAR	pH
5	2	.8	14	3	15.5	320	205	45	640	.88	6.6
11	2	.7	0	2	15.5	278	174	10	450	.89	6.5
56	3	1.1	7	2	18.0	398	250	83	600	.80	6.4
14	6	.8	25	6	16.5	288	170	10	460	1.07	7.2
4	5	1.0	8	3	16.0	302	196	38	525	0.93	7.2
9	3	.8	4	4	17.0	289	167	0	460	1.08	7.3
10	4	.8	10	4	16.0	294	168	0	470	1.04	7.2
26	7	.8	14	31	18.0	302	176	10	482	1.02	7.2
14	2	1.0	9	15	17.0	283	167	0	447	1.14	7.2
7	2	1.0	2	8	16.0	307	184	24	500	.96	7.2
0	1	1.0	2	3	16.0	343	202	49	550	1.01	7.2
16	4	.7	13	3	16.0	270	160	0	425	1.13	7.3
26	4	.9	6	50	16.0	308	179	8	504	1.04	7.2
8	2	1.1	6	10	16.0	336	188	20	552	1.21	7.2
17	4	.8	11	3	16.0	260	157	0	420	.90	7.2
2	1	.7	0	9	16.0	262	151	0	435	.96	7.2
14	1	1.4	6	21	16.0	425	253	85	670	1.04	7.2
2	1	1.0	2	3	16.0	316	200	16	506	.84	7.3
12	1	1.0	4	2	16.0	354	200	46	555	.95	7.2
11	2	.7	0	18	17.0	279	161	0	470	1.06	7.3
21	4	1.3	11	0	17.0	407	226	70	610	.93	7.5
13	5	1.4	10	8	17.0	420	247	35	660	1.11	7.4
12	1	1.2	6	0	17.0	383	196	40	560	1.03	7.6
22	5	.9	18	3	17.0	307	177	0	465	1.01	7.2
6	5	1.1	14	11	17.0	337	189	4	515	1.11	7.2
35	7	.8	8	6	17.0	294	185	0	455	.96	7.2
7	1	1.2	4	3	16.5	416	248	52	662	1.08	7.2
34	8	1.1	15	14	16.5	424	277	86	645	.76	7.1
7	2	1.1	4	6	17.0	328	188	27	505	1.02	7.3
0	1	1.3	11	6	16.0	382	216	61	561	1.01	7.3
24	2	1.3	1	3	16.0	432	236	88	648	.99	7.2
21	1	1.4	13	28	16.5	427	236	72	621	1.02	7.2
12	3	1.1	8	0	16.5	356	204	46	548	.91	7.4
33	9	1.0	26	16	16.0	358	207	52	530	.97	7.8
3	7	1.0	12	15	16.0	359	218	63	530	.77	7.8
15	2	1.2	14	8	17.0	389	230	64	615	.98	7.5
16	5	1.4	4	24	17.0	417	244	78	610	.84	7.5
15	4	1.1	57	11	17.0	310	186	24	480	.70	7.7
14	3	1.2	8	0	16.0	388	223	41	590	.90	7.4
26	2	1.1	6	18	17.0	314	173	13	500	.89	7.6
69	3	1.4	12	0	17.0	392	232	46	620	.86	7.4
0	4	1.1	9	10	16.0	331	198	47	525	.77	7.8
8	1	.8	14	0	17.0	273	155	7	430	.70	7.4
40	7	1.3	9	17	17.0	416	246	94	660	.89	7.3
5	2	.8	5	10	16.0	317	218	70	495	.44	7.6
24	4	1.1	6	2	16.0	388	266	128	600	.45	8.0
15	2	1.5	12	0	17.0	508	334	134	800	.69	7.5
40	2	1.3	10	2	16.0	426	292	92	760	.94	7.5
53	2	1.7	11	14	15.0	486	300	91	810	.85	7.5
4	1	.9	17	8	16.0	315	165	0	510	1.25	7.8
14	1	.9	6	14	16.0	291	170	11	470	.97	7.8
6	1	.8	3	6	15.0	312	178	6	500	1.01	7.3
4	2	.7	4	6	15.0	301	172	16	480	.86	7.3
7	2	1.2	9	4	16.0	305	187	28	530	1.02	7.8

APPENDIX B:

Chemical Quality Contour Maps

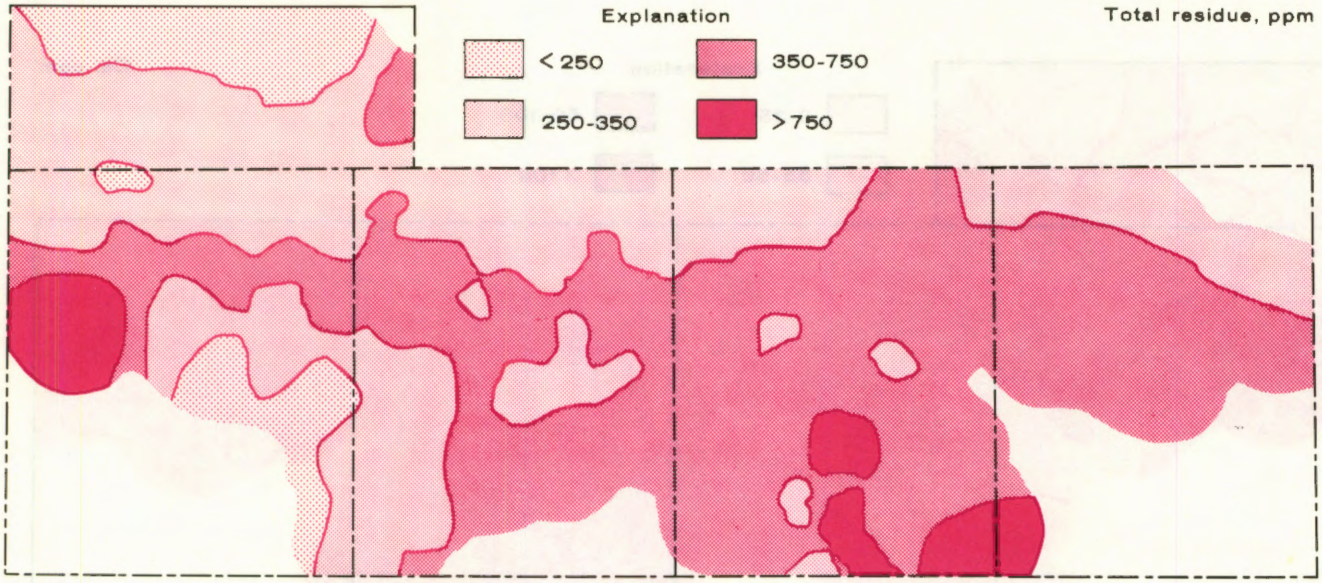

Figure 10

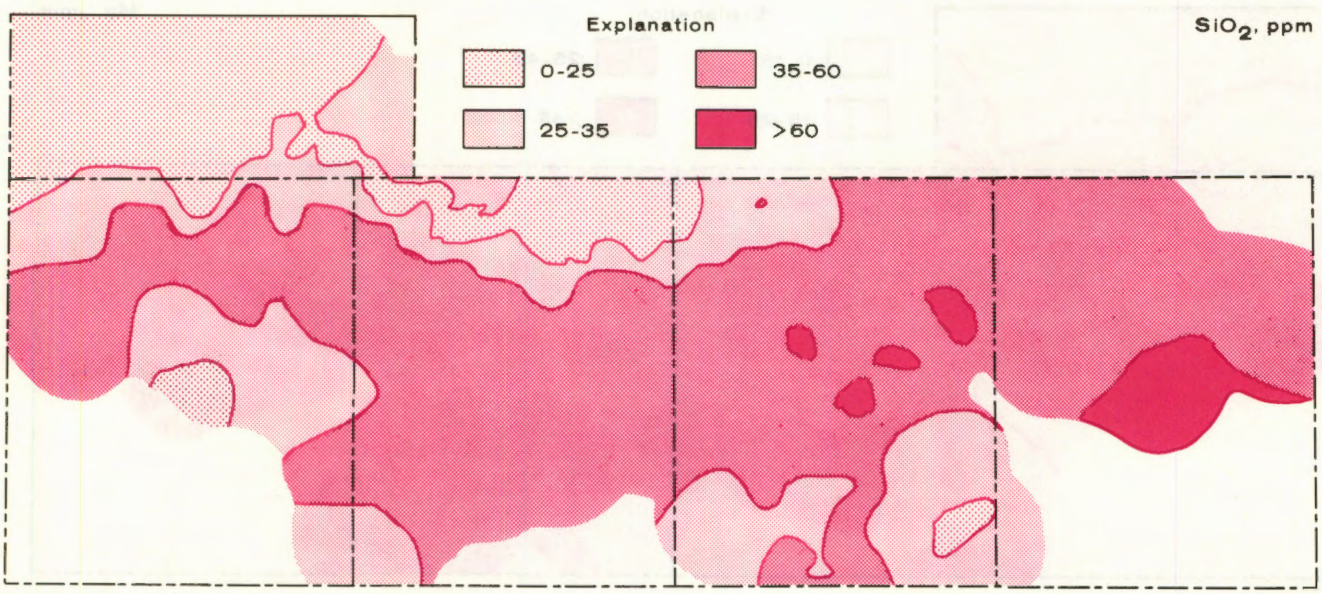

Figure 11

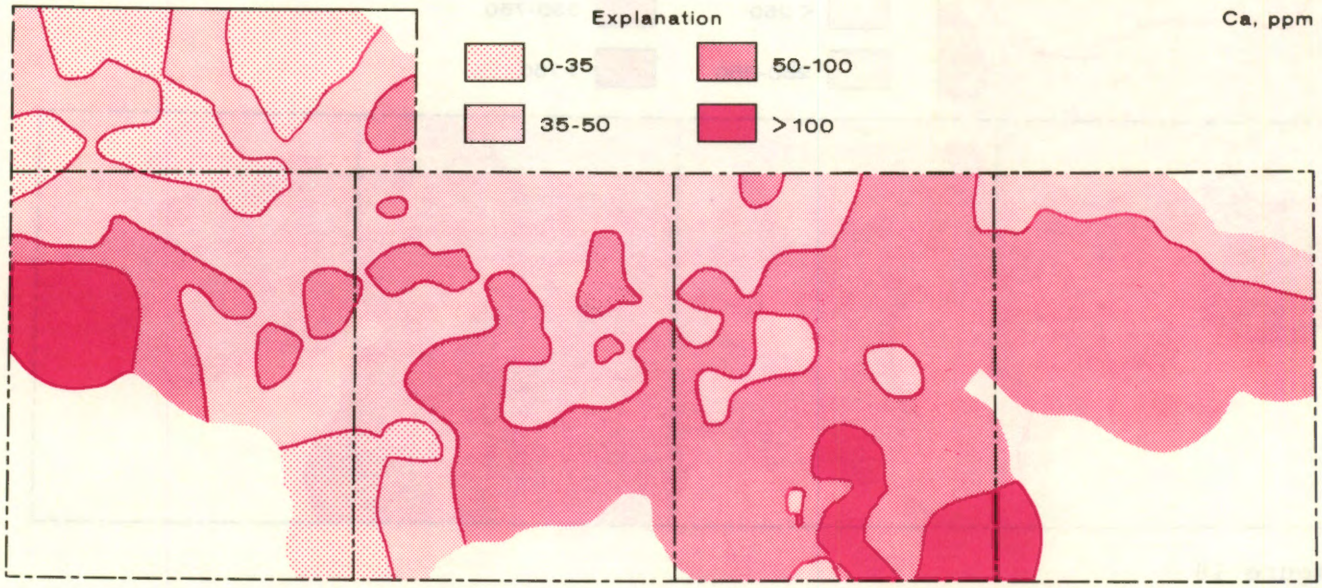

Figure 12

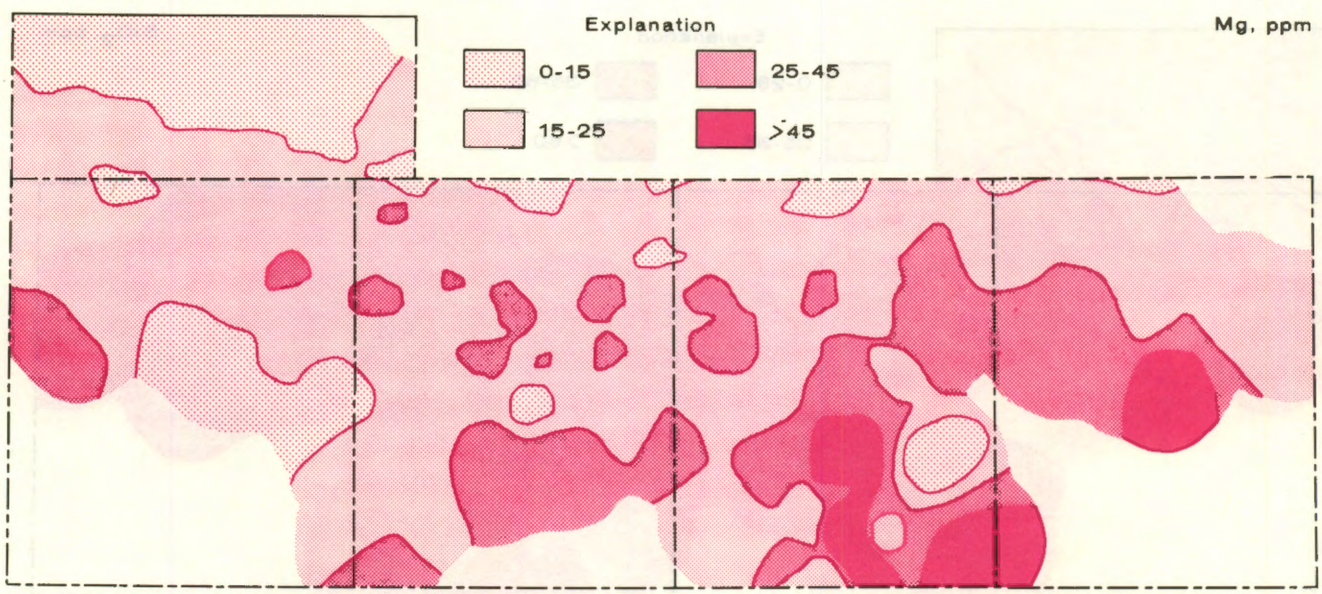

Figure 13

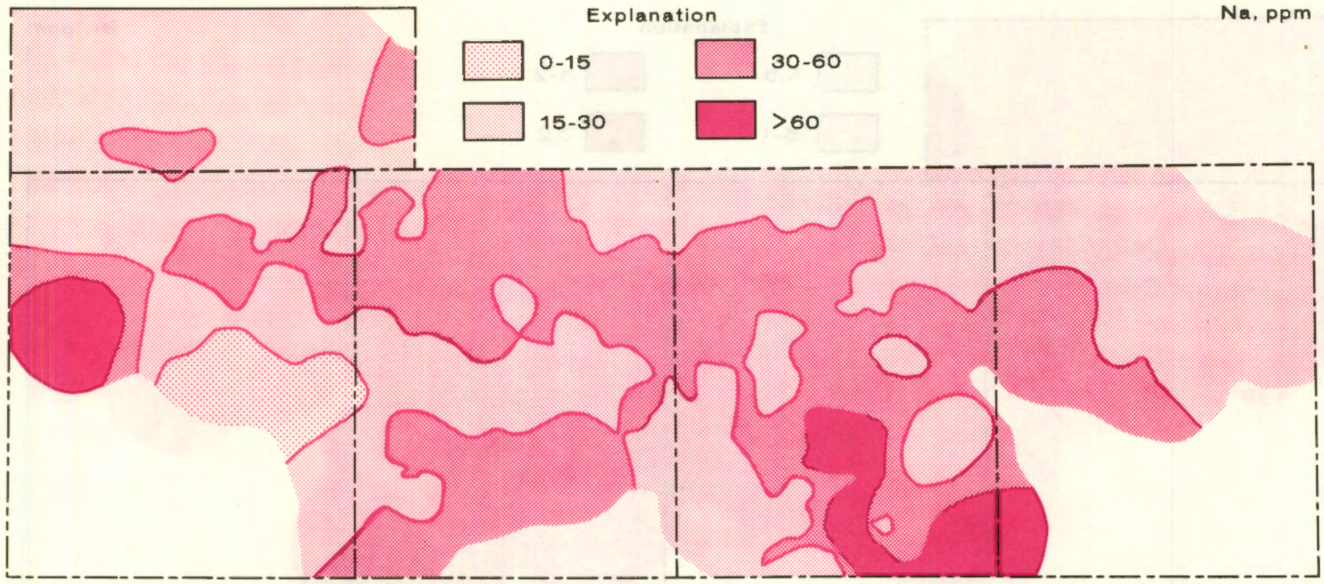

Figure 14

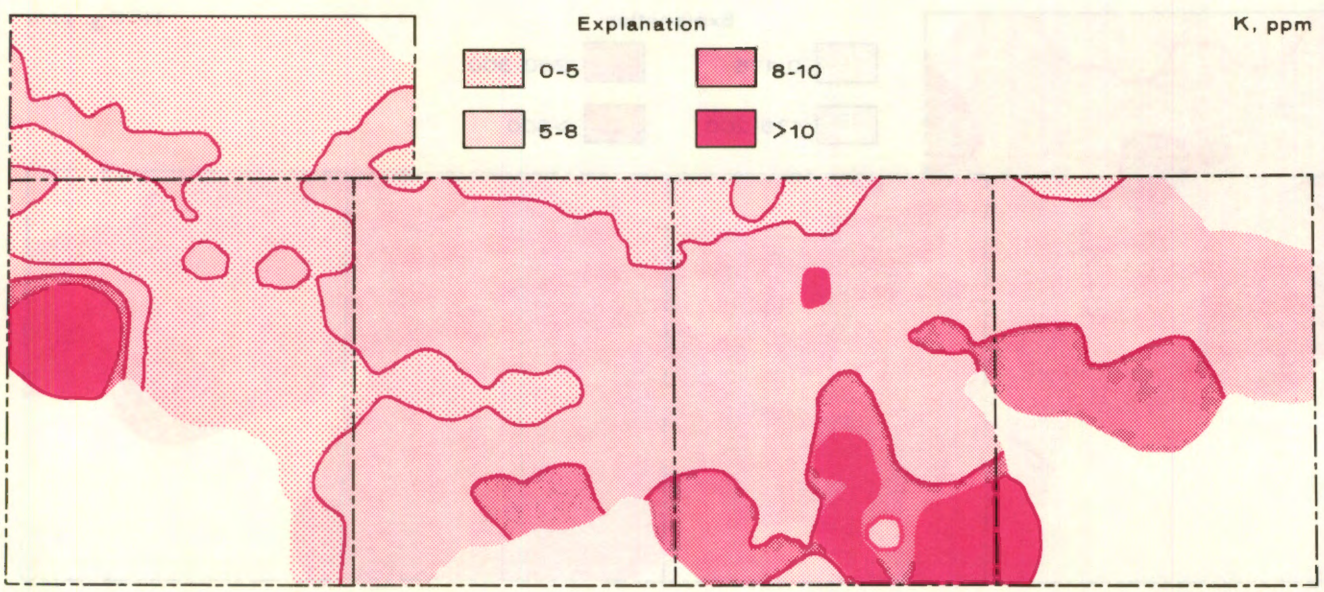

Figure 15

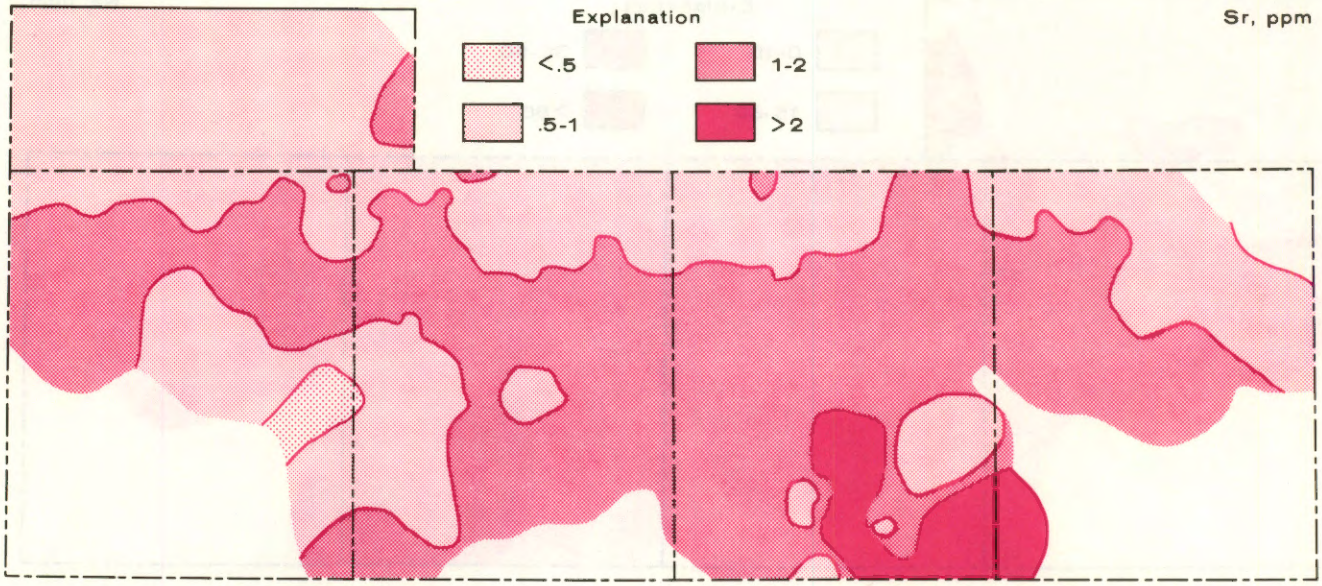

Figure 16

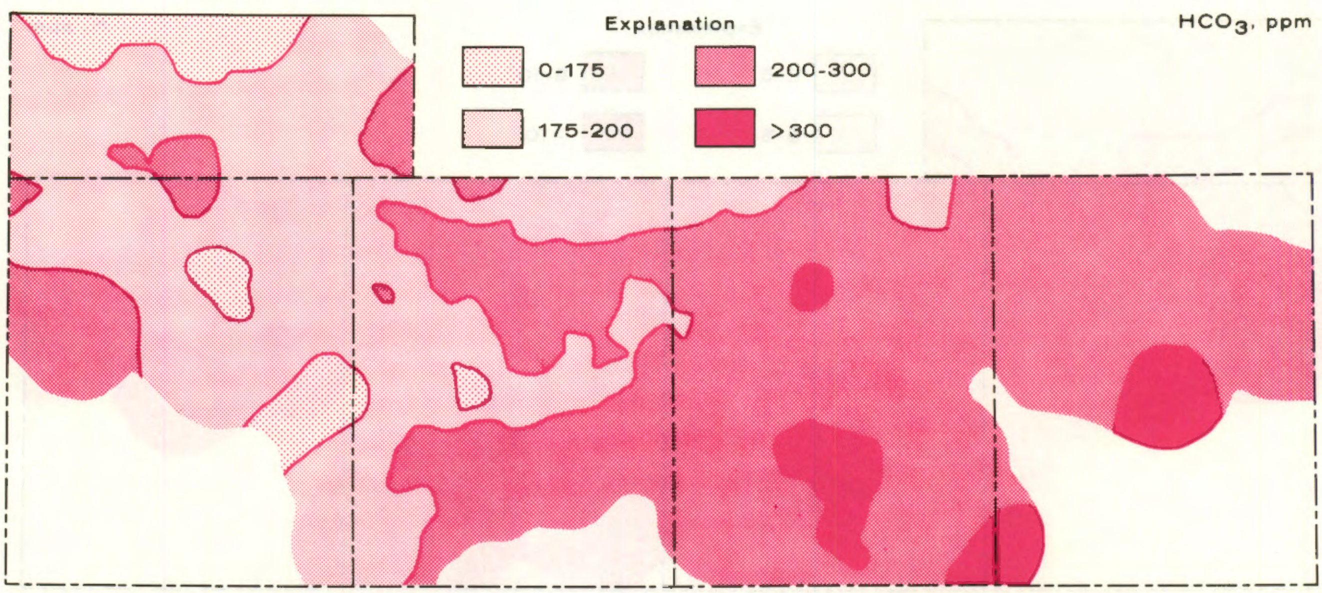

Figure 17

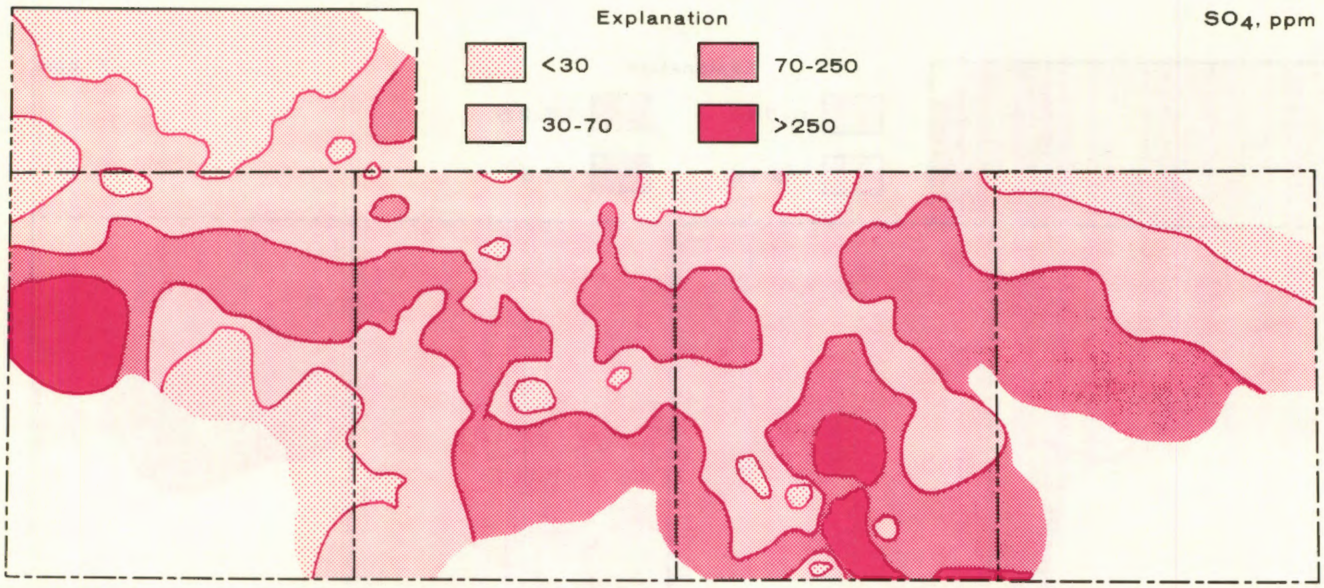

Figure 18

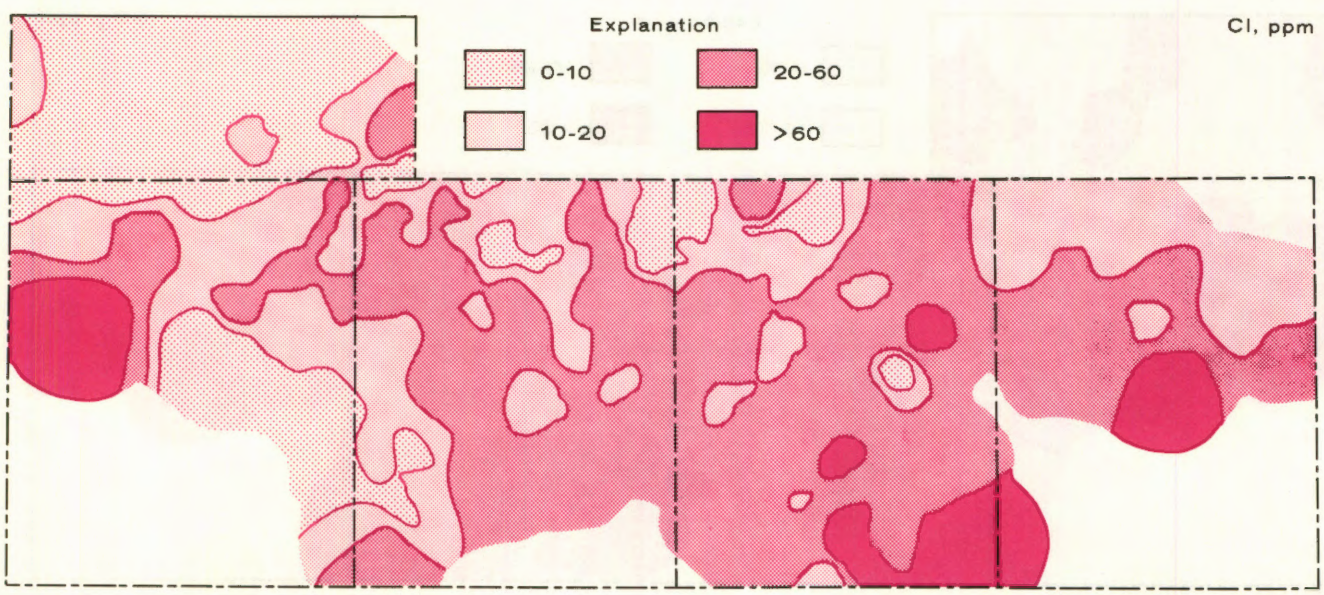

Figure 19

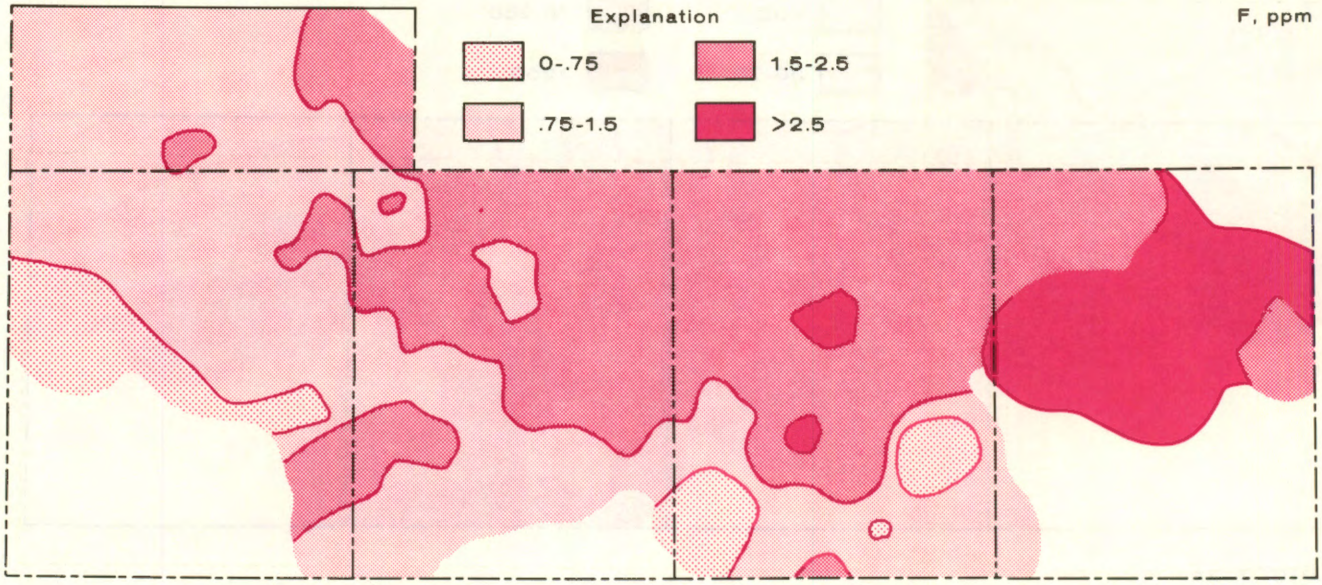

Figure 20

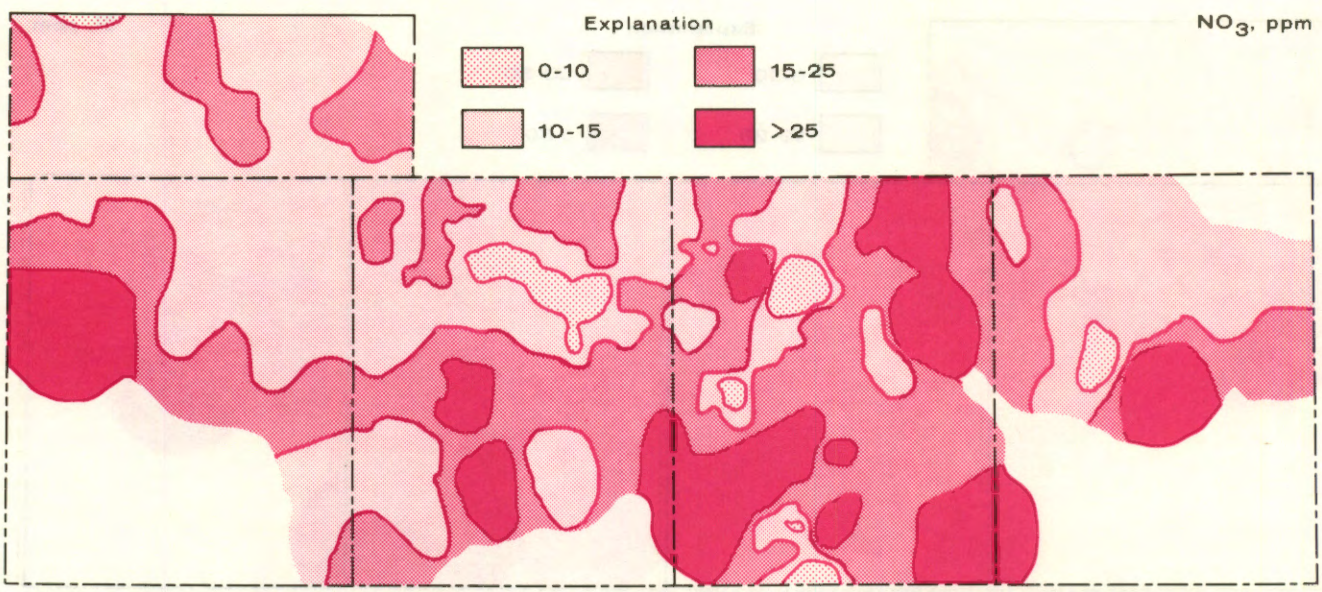

Figure 21

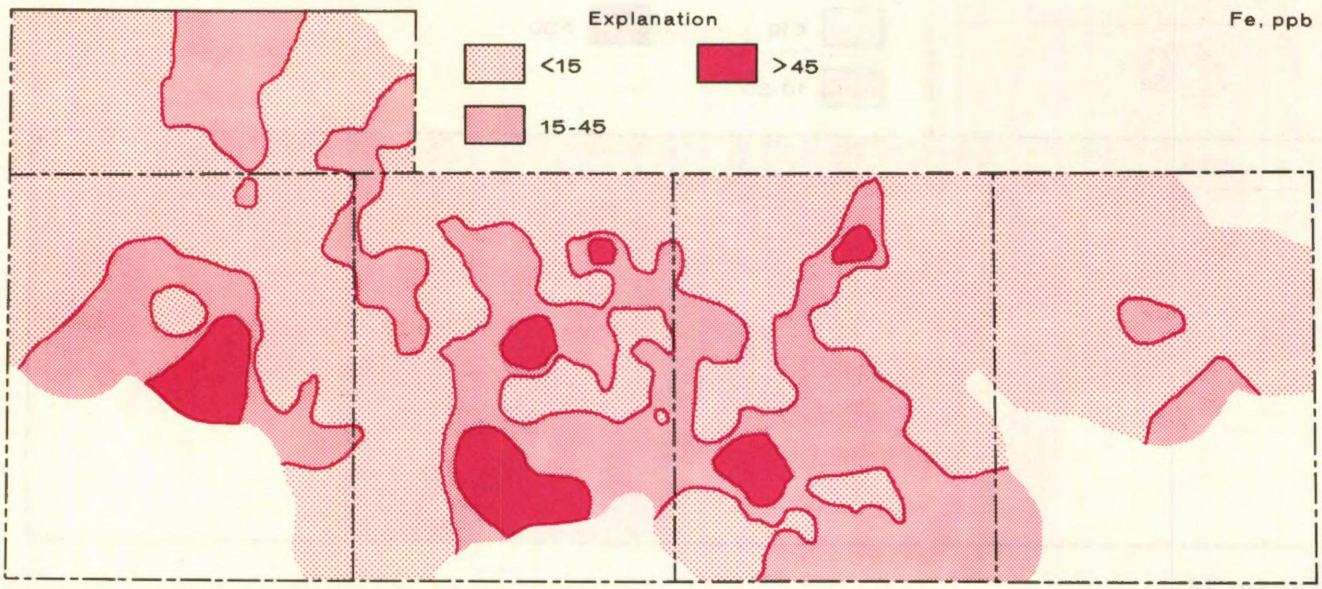

Figure 22

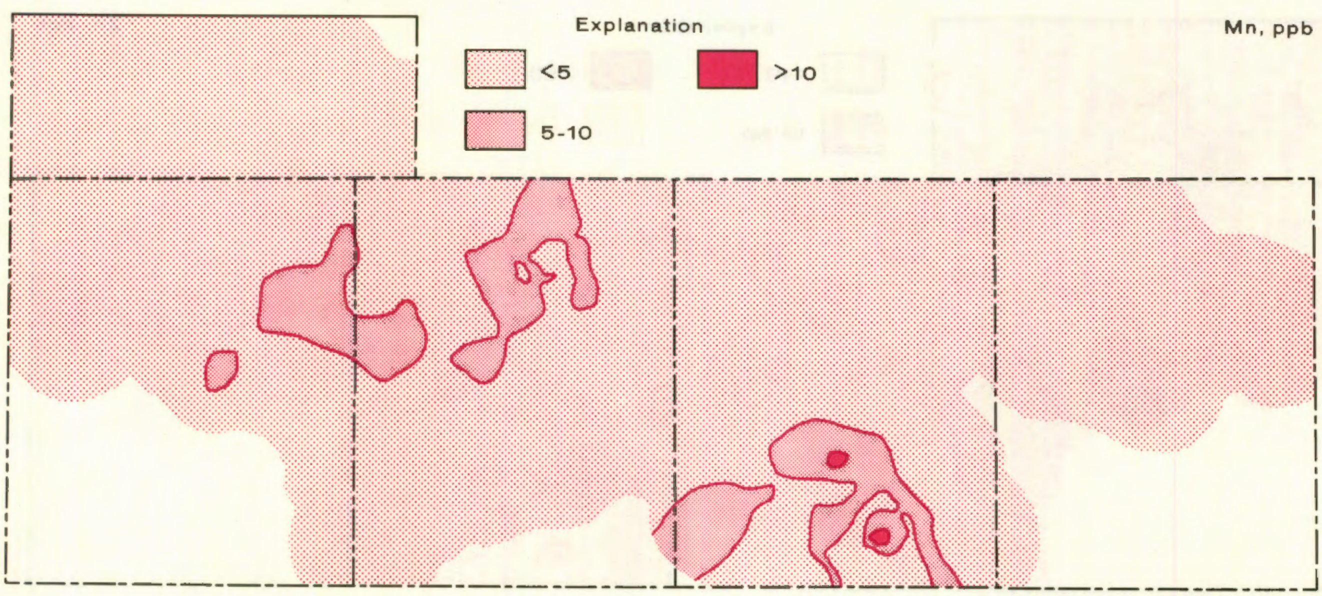

Figure 23

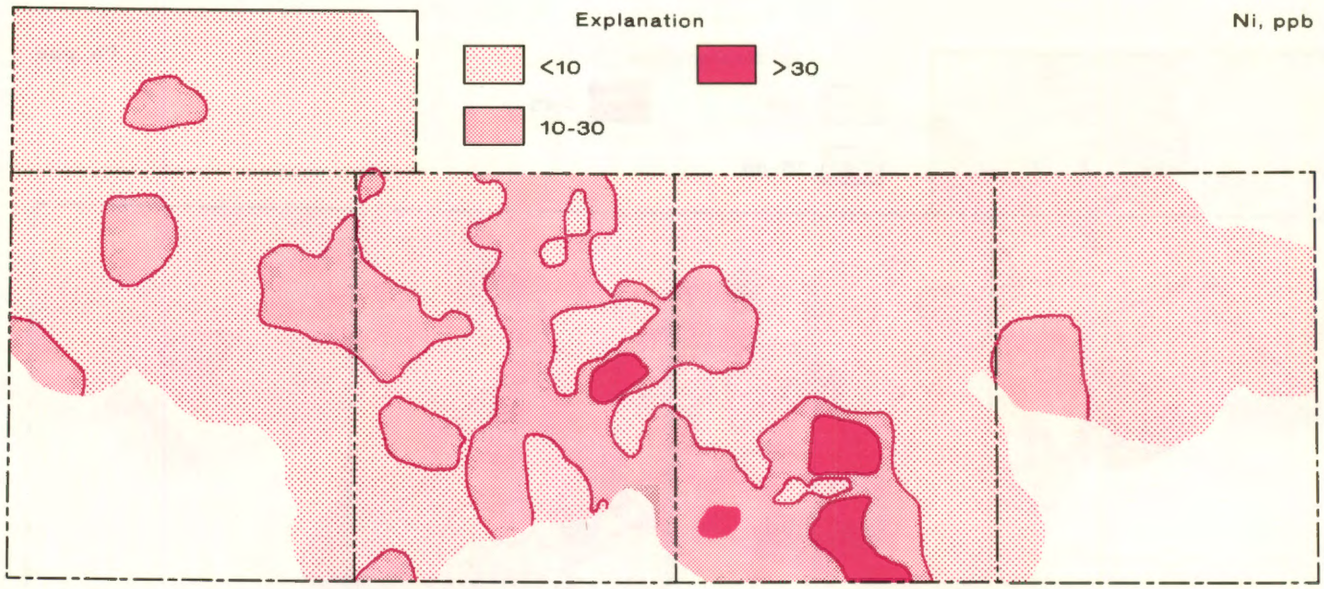

Figure 24

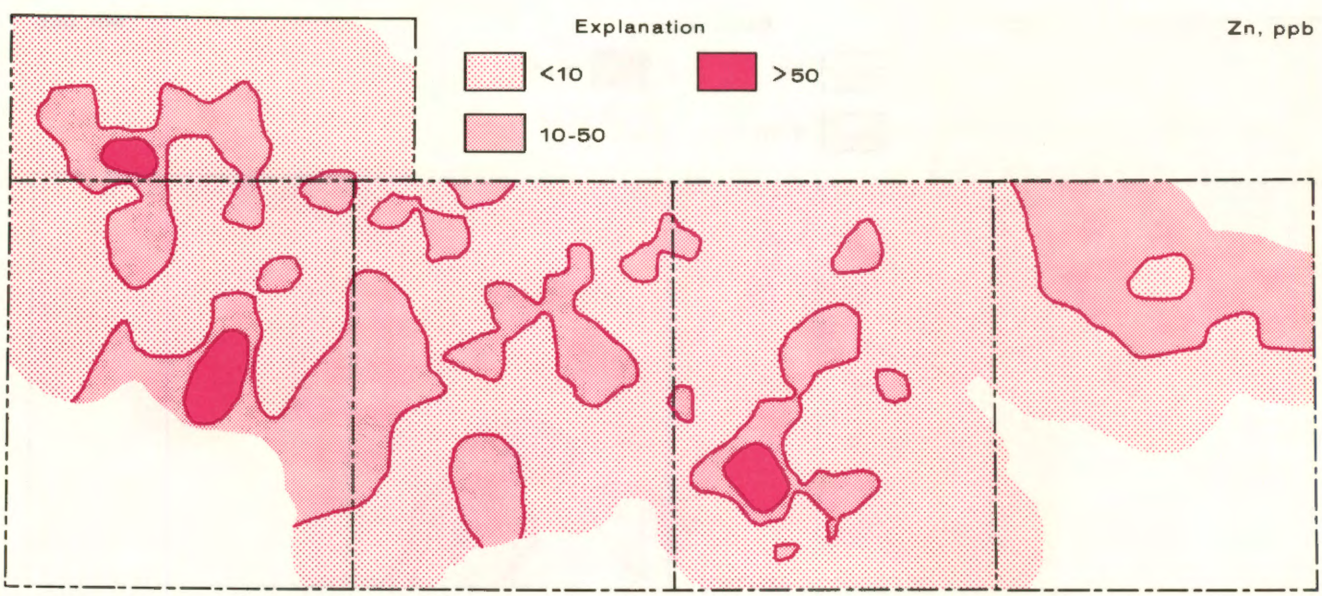

Figure 25

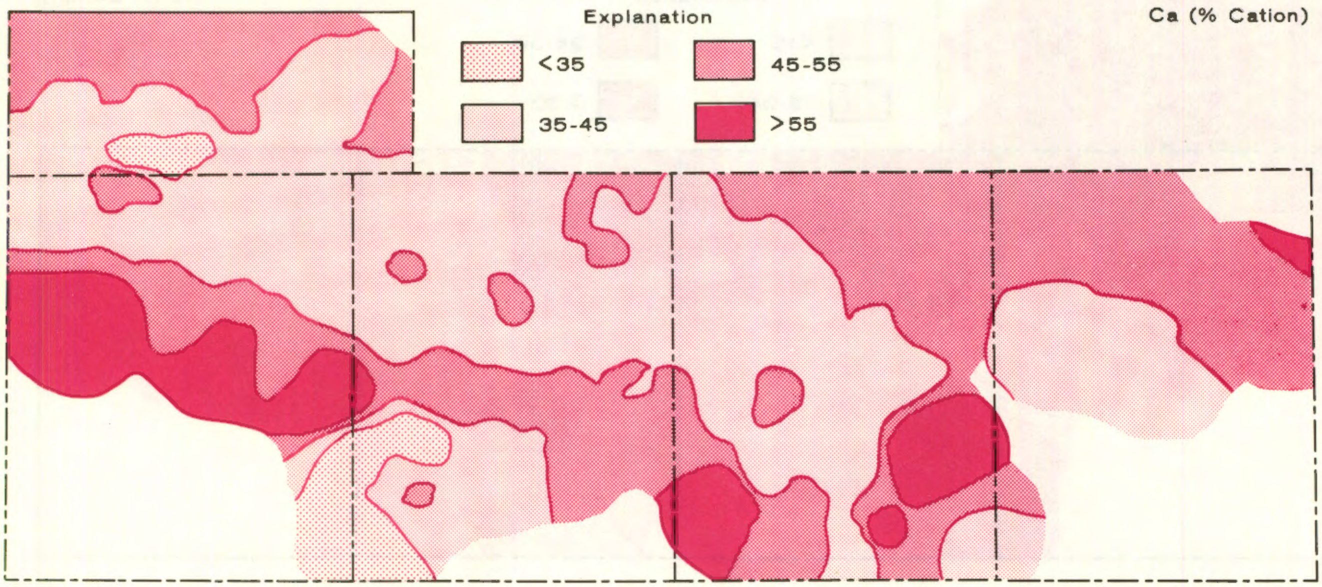

Figure 26

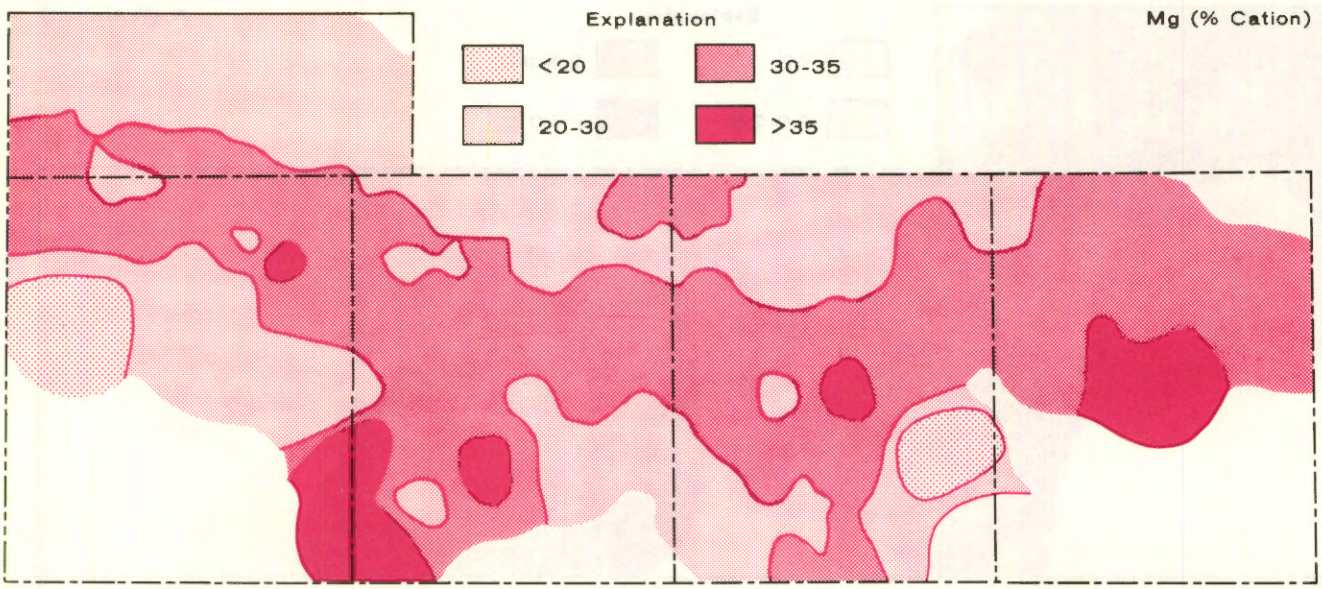

Figure 27

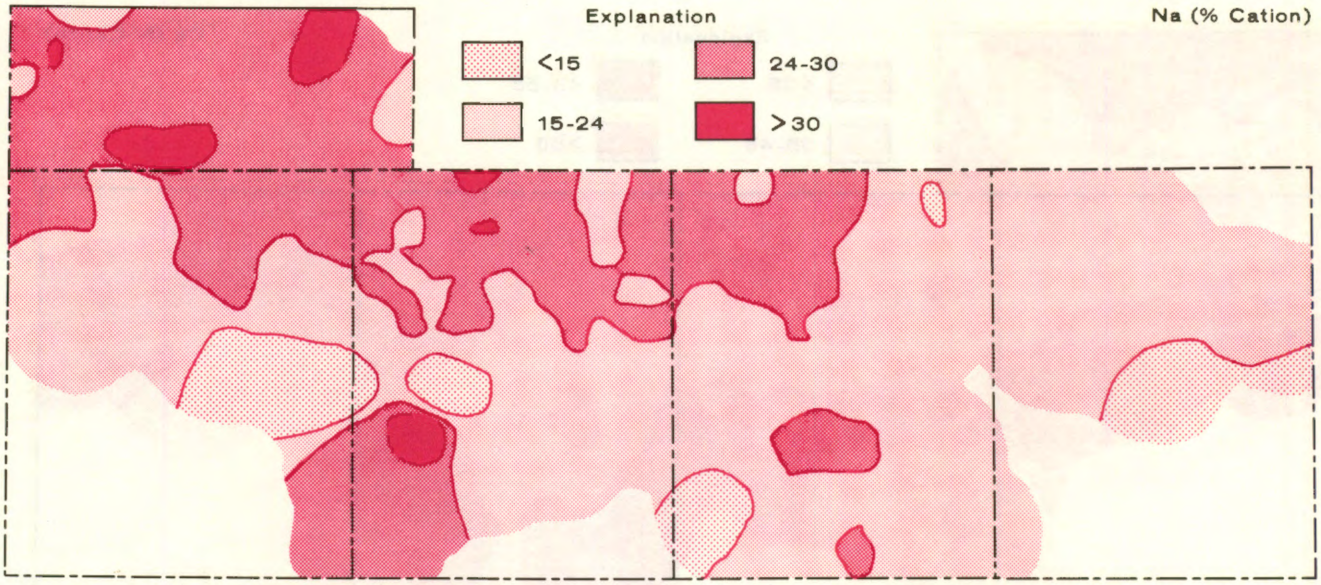

Figure 28

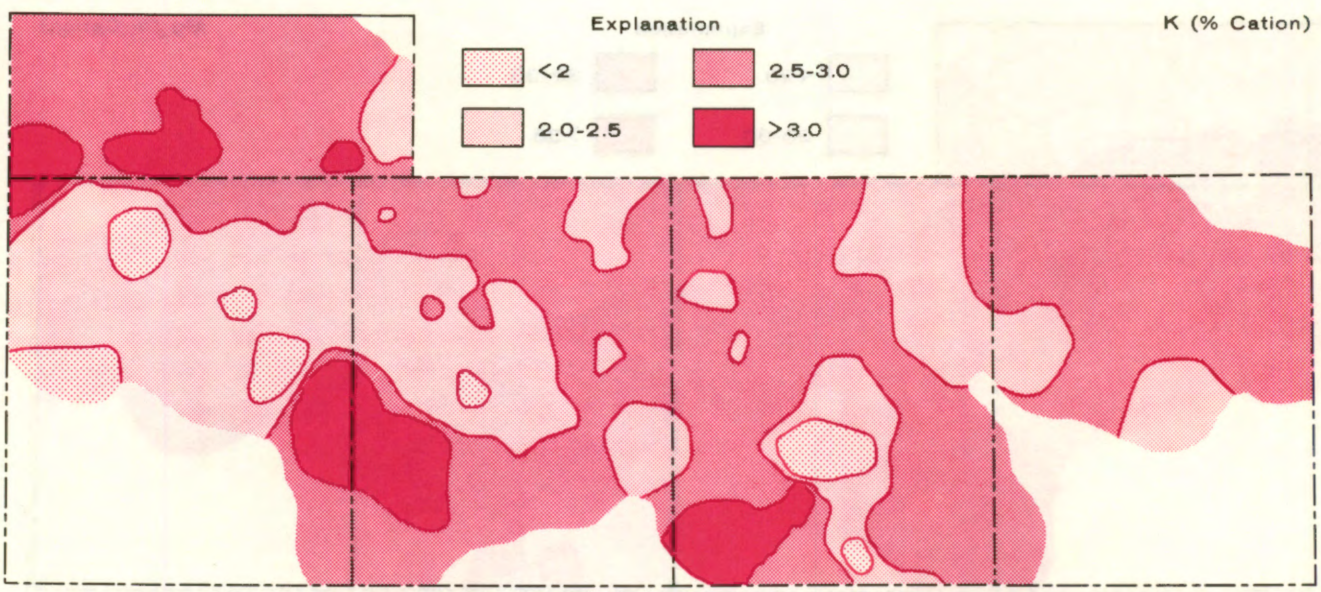

Figure 29

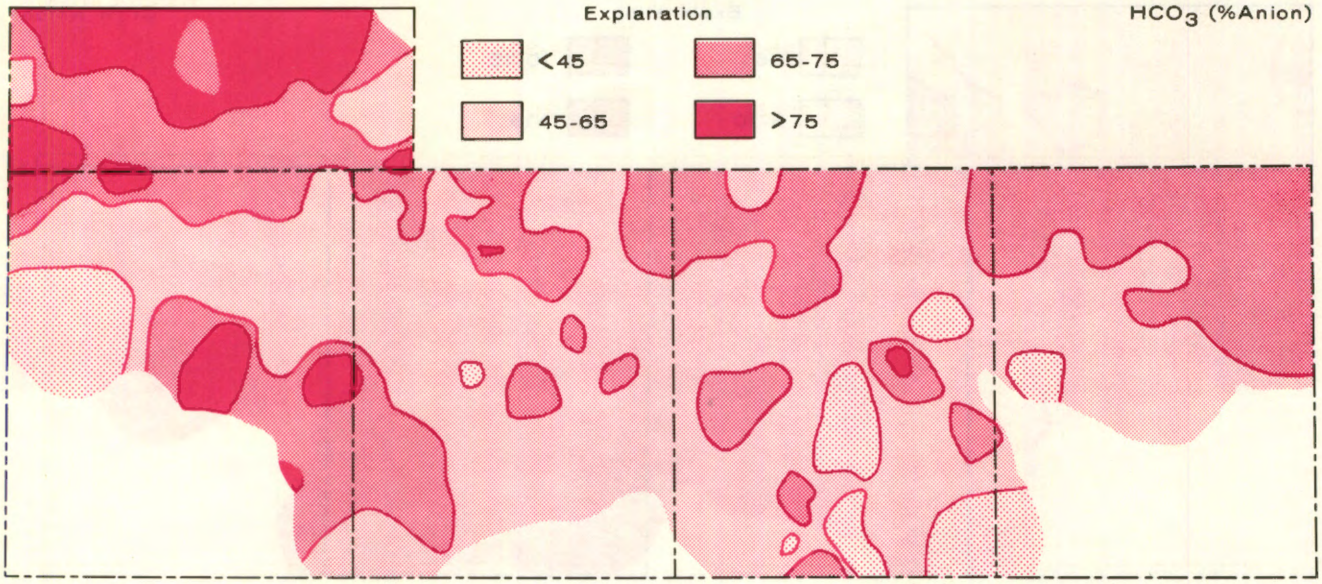

Figure 30

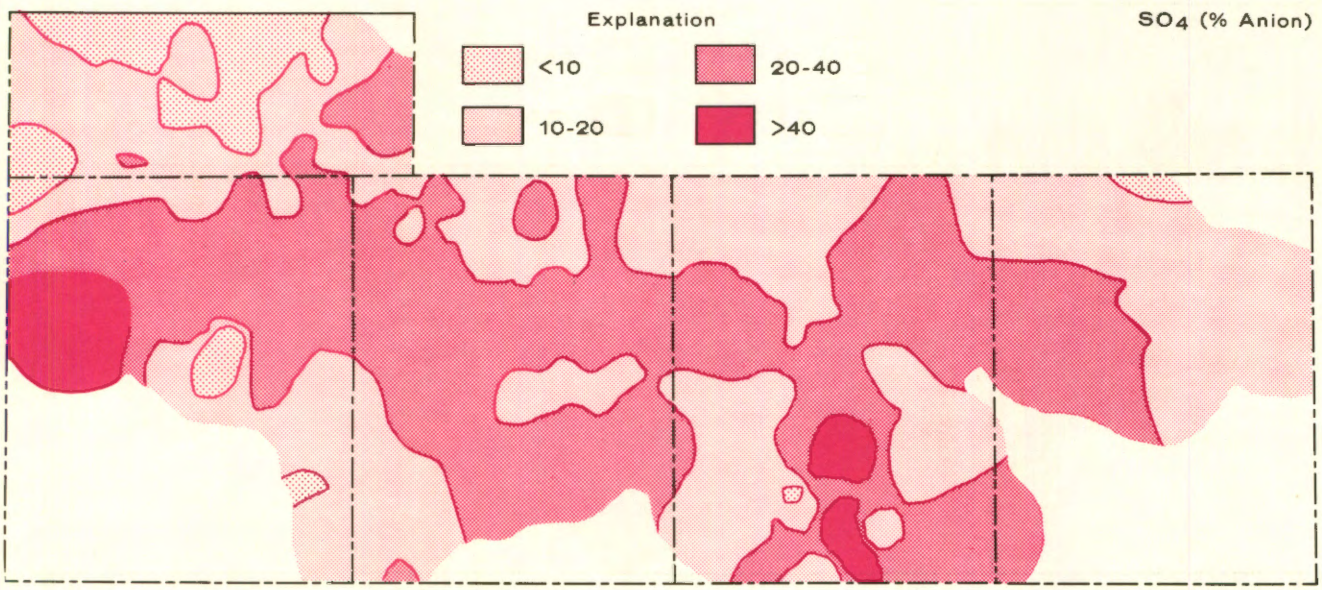

Figure 31

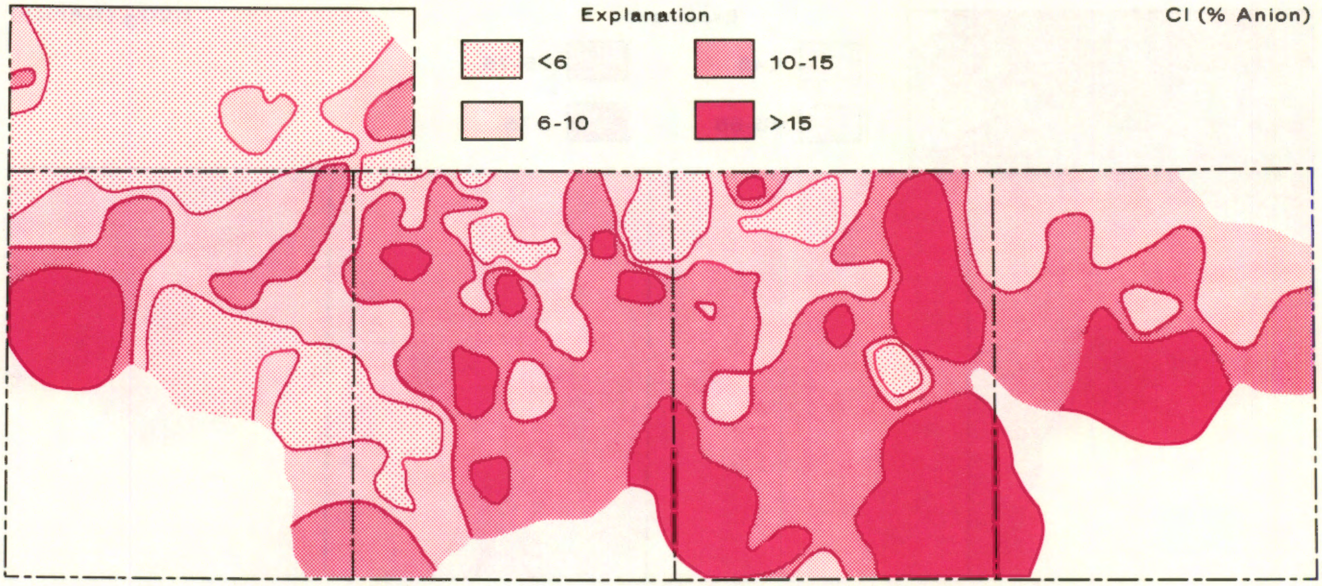

Figure 32

Chemical Quality of Irrigation Waters in West-Central Kansas

Hathaway and others.