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Chemical Data For Soils Over and Around the Velma Oil Field, Stephens County, Oklahoma

by

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ILLUSTRATIONS

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ABSTRACT

The Velma structure is a faulted, asymetrical anticline whose axis runs northwest-southeast. Oil production is centered over the anticlinal axis. Seeping hydrocarbons and/or associated compounds may produce a locally reducing environment resulting in reduction, mobilization, and redistribution of iron and manganese within near-surface rocks and soils. The most extreme alteration in rocks is seen over the crest of the anticline where carbonate cements have been replaced by hematite cements. Alteration of soil chemistry is seen following a DTPA soil test, wherein the amounts of chelate-extractable iron and manganese fall into two distinct populations: 1) higher concentrations over the oil field, and 2) lower concentrations constituting the background, which is presumably unaffected by hydrocarbon microseepage.

INTRODUCTION

Previous work on techniques for the direct detection of buried hydrocarbons (Donovan, 1974; Henry and Donovan, 1978; Dalziel and Donovan, 1980; Donovan, and others, 1981; and Roeming and Donovan, in press) has demonstrated that seeping hydrocarbons and (or) associated compounds, may produce a locally reducing environment resulting in reduction, mobilization, and redistribution of iron and manganese within near-surface soils and rocks. This report, a compilation of soil chemical data presented in relation to the structure and previously mapped epigenetic facies of the Velma oil field area, Oklahoma (fig. 1), provides additional information on possible surface manifestations caused by microseepage of hydrocarbons. These soil chemical data are obtained from use of a chelating extractant, diethylenetriaminepentaacetic acid (DTPA) (Lindsay and Norvell, 1978).

GEOLOGY OF THE VELMA AREA

General Geology

Literature abounds on the geology and oil development of Stephens County, Oklahoma (Moore, 1921; Powers, 1926; Tomlinson, 1927; Gouin, 1926, 1956; Davis, 1950; and Rutledge, 1954, 1956; and numerous others).

The Velma structure is a faulted asymetrical anticline. Rutledge, (1954) provides a brief summary of the geological history of the area:

"Rocks of Permian, Pennsylvanian, Mississippian, and Ordovician ages have all yielded much oil production in this area. The Velma oil field is a part of a large very complexly folded and faulted structure located near the southern limit of the Anadarko basin where 7000 feet (2134 m) of marine Pennsylvanian strata were deposited. These strata were subjected to

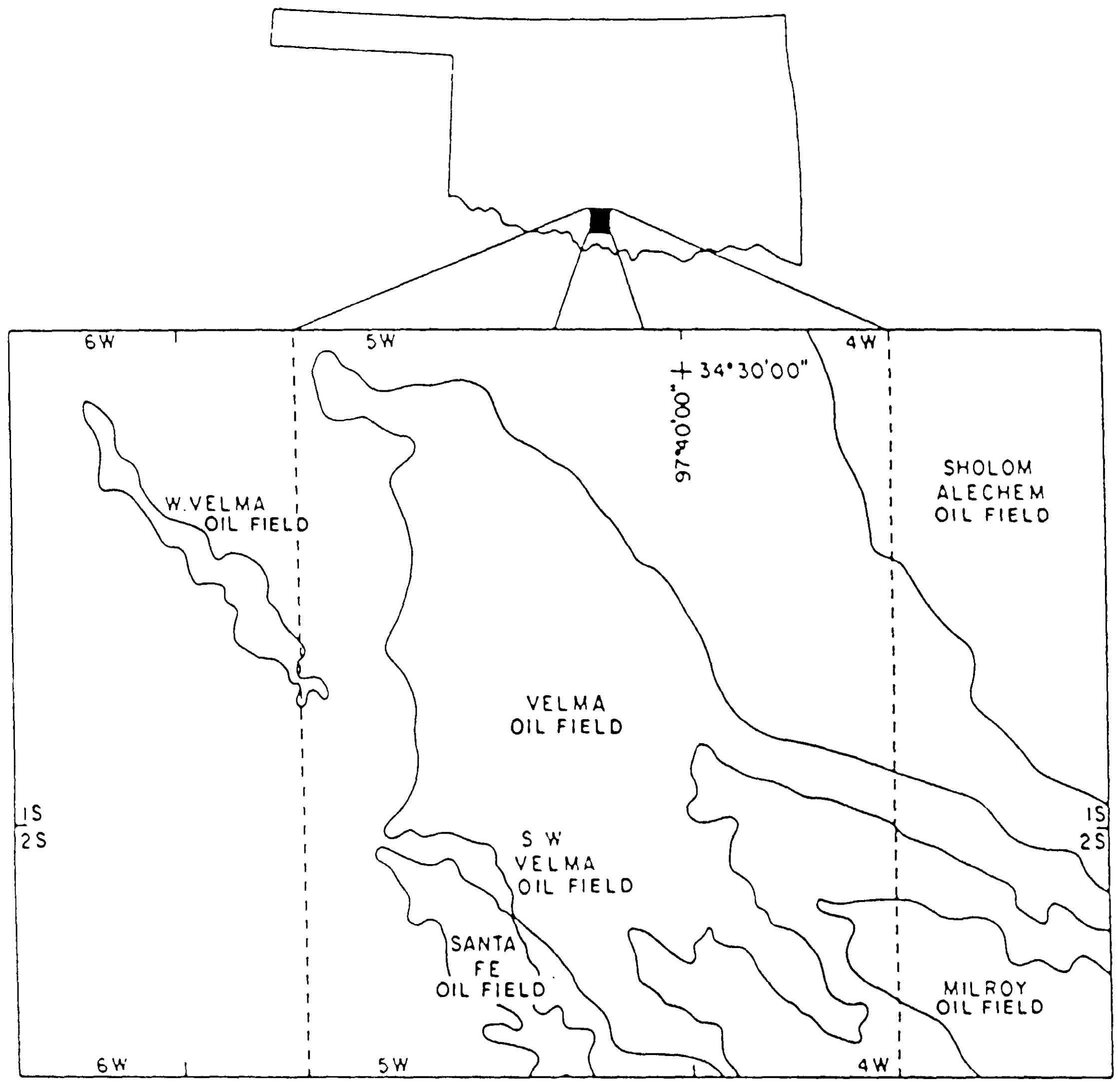

Figure 1. Location map for the Velma quadrangle and Velma oil field, Oklahoma. From Donovan, and others, 1981.

uplift, folding, and faulting which reached two periods of great intensity: 1) post-Morrow [lower Pennsylvanian] and 2) post-Hoxbar [upper Pennsylvanian]. Following each deformation, the newly formed structure was deeply truncated by erosion. After the late Hoxbar deformation and subsequent erosion, the complicated Velma structure was covered by 1,000 feet (305 m) and more of red Permian sediments. These sediments have since been arched into a pronounced mappable surface structure, accompanied by minor faulting."

The axis of the Velma anticline is asymetrical and trends northwest to southeast. The steep side is to the northeast, while the gentle side is to the southwest and runs into the syncline between this fold and the Loco anticline (Gouin, 1926). The geology described above is schematically shown in figures 2 and 3.

Abundant oil seeps led to surface mapping and the subsequent discovery of the oil field in 1917 (Gouin, 1926). Primary oil production is from sands within the Pennsylvanian Springer formation at a depth of approximately 3,200 ft (975 m). Deepest production is from an oolitic limestone of Ordovician age at approximately 9750 ft (2975 m). Permian sandstone and Mississippian limestone are also oil producers in the Velma area. Average gravity of the oil is 29° API. It is relatively viscous and saturated with dissolved gas at the original reservoir pressure (Davis, 1950). By 1967, the Sho-Vel-Tum giant oil field complex, of which Velma is a part, had produced 742,835,000 barrels of oil and an unrecorded amount of gas; reserves for the complex were estimated at 158,288,000 barrels of oil at that time (Halbouty, 1968).

Epigenetic Facies

The character of the rocks directly over and adjacent to the Velma anticline is highly variable. Detailed mapping and analysis indicated that the lithologic, diagenetic, and mineral variations represent late diagenetic alteration caused by petroleum microseepage (Donovan, and others, 1981).

Figure 4 illustrates the epigenetic facies mapped in the Velma region. Three facies are distinguished in surface rocks: 1) uncemented sandstone- a fine-grained, friable, red-brown sandstone consisting of quartz and lesser amounts of feldspar (<10 percent). Adjacent to the flanks of the anticline, the red sandstone appears bleached (discolored) due to loss of iron; 2) a carbonate cemented variety of facies (1). These rocks are tightly cemented by isotopically peculiar carbonate cements along the crest of the anticline. Rocks of this facies grade into facies (1) near the flanks and are much less tightly cemented; and 3) rocks having carbonate cements replaced by hematite cement. This facies is comprised of an upper massively cemented zone which grades downward into a less completely hematite cemented zone. Only remnants of this zone remain in place on the anticline, but rubble covers a considerable area indicating a greater areal extent in the past. Abundant epigenetic pyrite (Ferguson, 1977) is distributed throughout rocks of the shallow subsurface and the chemical variability displayed in both buried and exposed rocks over the oil field is attributed by Donovan, and others (1981) to the effects of petroleum microseepage.

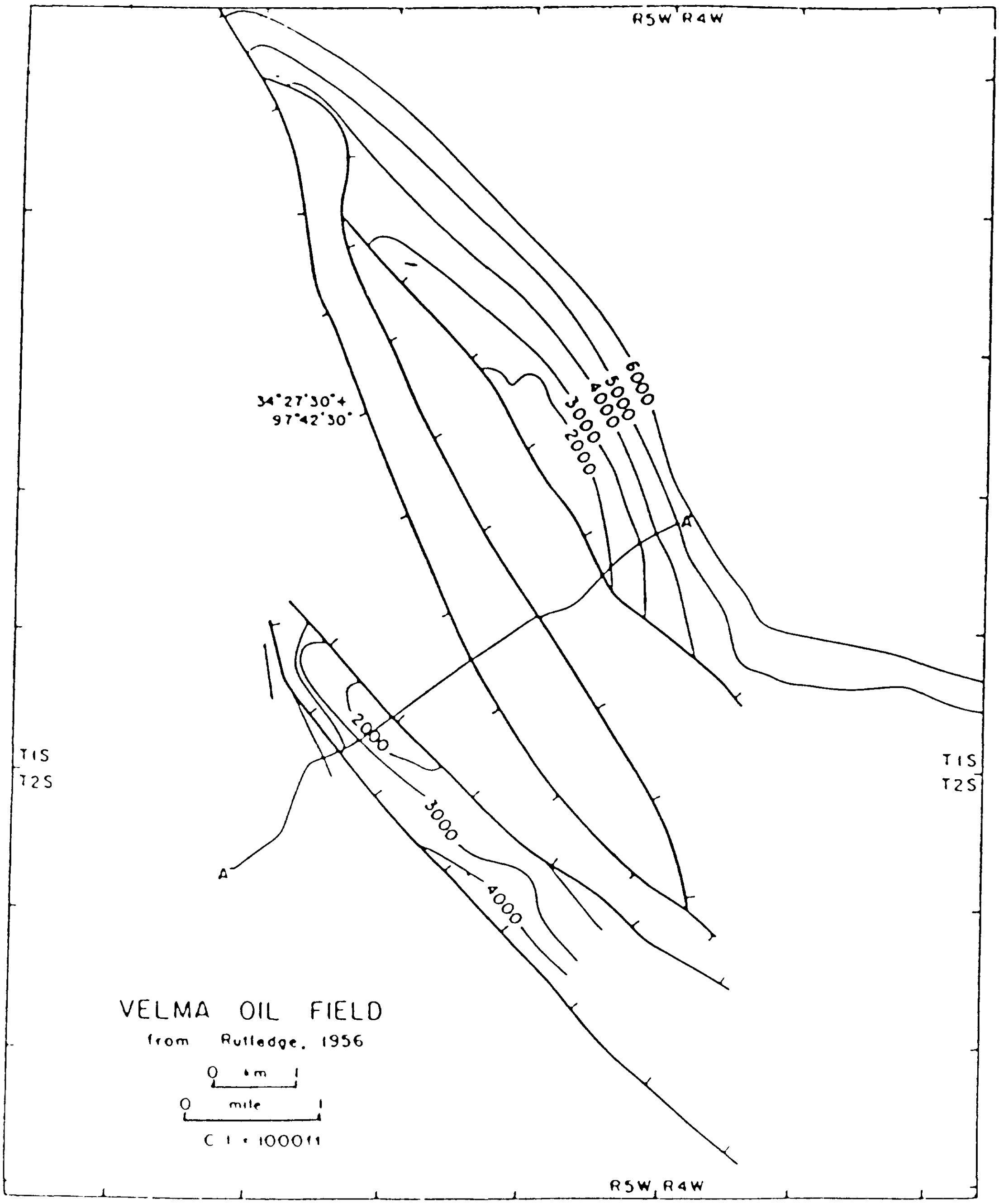

Figure 2. Structure map of the Velma anticline. Contours drawn on top of the "A" sandstone of the Sims zone of the Springer Formation, or on top of the Springer, where the "A" has been removed by erosion. Contour interval 500' (~152m). From Rutledge, 1956.

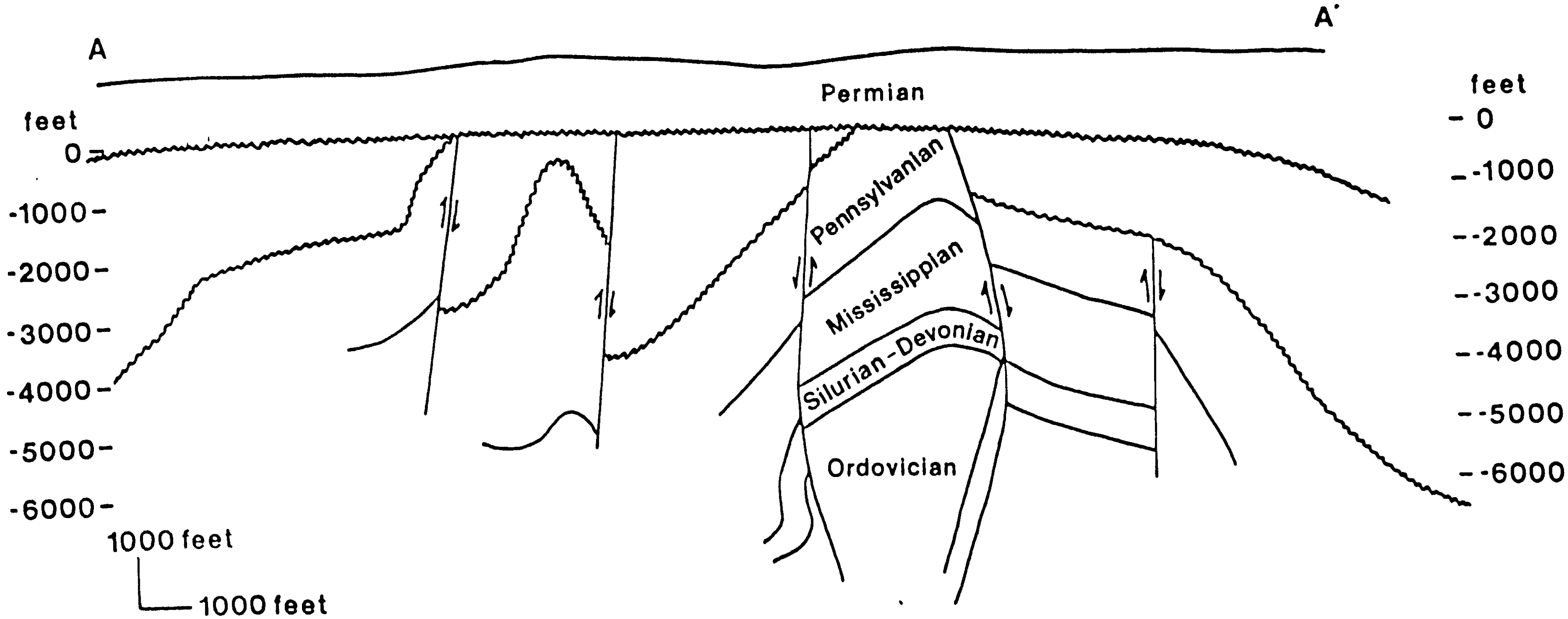

Figure 3. Structural cross section (A-A'of figure 2) through the Velma anticline. From Rutledge, 1956.

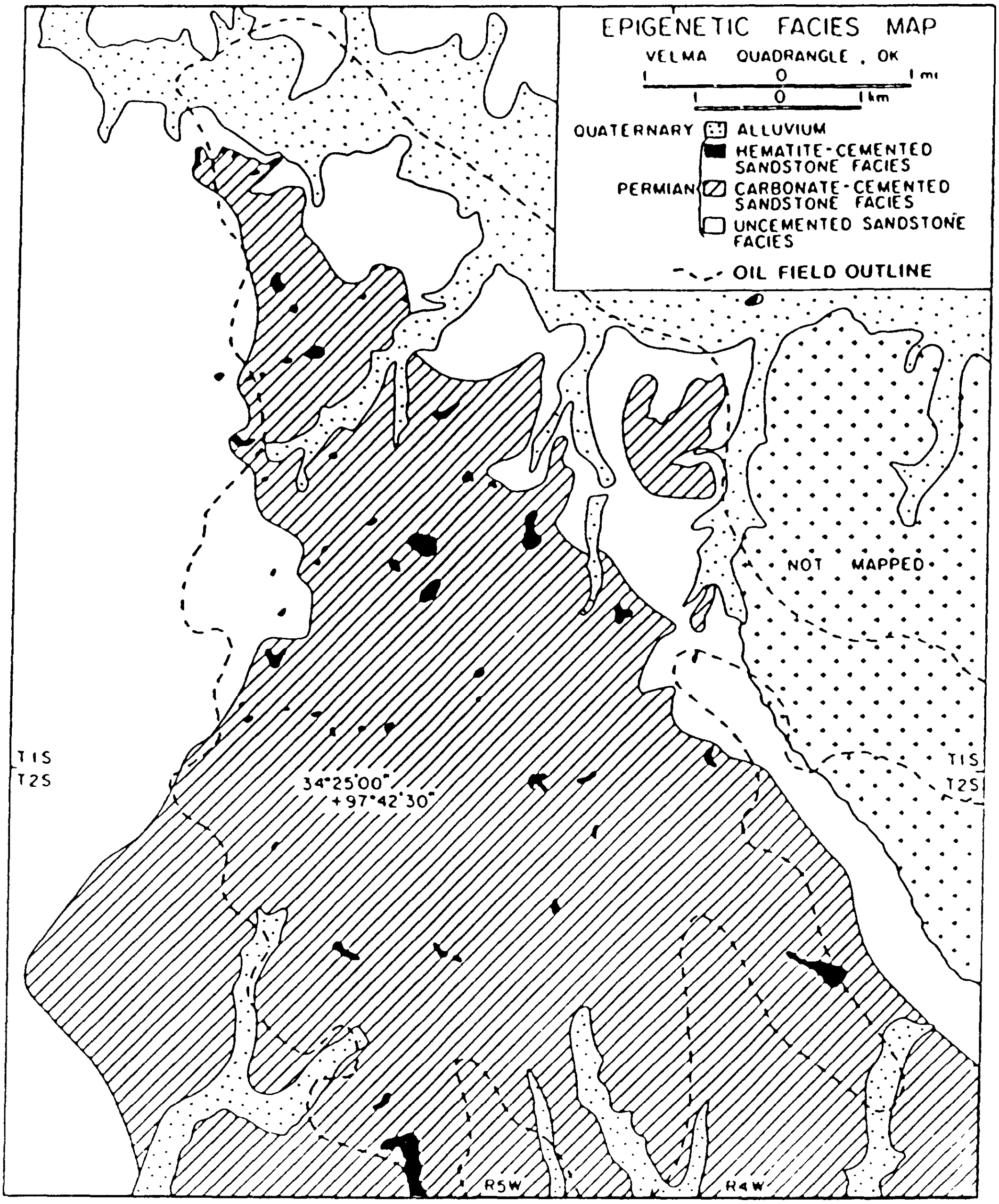

Figure 4. Epigenetic facies map of the Velma quadrangle and Velma oil field, Oklahoma. From Donovan, and others, 1981.

METHODS OF SOIL ANALYSIS

Soil samples were collected during the summers of 1980 and 1982. The sample grid was approximately 1 mi (1.6 km) off the oil field and somewhat closer, 1/2 mi (0.8 km), on the field (fig. 5). Samples were collected at a depth of approximately 1 ft (0.3 m) below the surface, bagged, air dried in the laboratory, and stored until analyzed.

Ten grams of sieved (<1 mm size fraction) soil were combined with 20 ml of the DTPA extracting solution (Lindsay and Norvell, 1978). The mixture was then agitated on a wrist-action shaker for two hours to allow for complexation. After shaking, the mixture was filtered by gravity and the filtrate analyzed by atomic absorption spectrophotometry for extractable iron and manganese with a ± 10 percent accuracy by dry weight of the soil. DTPA was used as the chelating agent in this study because of its proven effectiveness to complex iron and manganese in the +II state (Wallace, 1963). A more detailed explanation on chelation and chelating agents in soils can be found in Viets, 1962, Wallace, 1963, or Roeming and Donovan, (in press).

The soil chemical data are presented on maps (figs. 5, 6 and 7) and in tabular form (Appendix). Part per million (ppm) concentrations were derived using the following formulas:

1) $\text{dilution factor} = \dfrac{\text{ml final solution}}{\text{ml original solution}}$

2) $\text{concentration} = \dfrac{(\text{ppm meter})\ (\text{dilution factor})\ (\text{ml solution to volume})}{\text{grams sample}}$.

DISCUSSION AND SUMMARY

Figures 6 and 7 are isopleth maps of DTPA extractable iron and manganese over and surrounding the Velma oil field. Iron and manganese values are generally higher over the oil field than in the surrounding area. Mean values for iron and manganese over the oil field versus off the oil field are 29.95 ppm vs. 22.37 ppm, and 62.91 ppm vs. 39.65 ppm respectively. The anomalously high areas trend northwest-southeast and occur over the axis of the Velma anticline. Manganese values are higher than iron values in most instances throughout the study area (75 percent of the sample localities). This may be accounted for in part by the relatively moist climate (average precipitation 33 in per annum) of the region (Warren, and others, 1952) and by subtle variations in redox gradient and pH (Krauskopf, 1957).

As indicated by the distribution of rubble, the hematite facies as mapped today is much more restricted than it was in the past. Therefore, attempts at correlating anomalous iron and manganese in soils with this facies are difficult. However, the area of anomalously high iron and manganese soil values occurs over the hematite-cemented facies within the oil field production zone and covers a broader areal expanse presumably indicative of the earlier extent of the hematite cemented facies.

Alteration of soil chemistry and variations in rock cementation over the structurally complex Velma oil field are suggested to be attributed to reduction, dissolution, mobilization, and reprecipitation of transition elements due to hydrocarbon microseepage. The presence of microseepage-induced changes in the subsurface may then be detected on the surface by

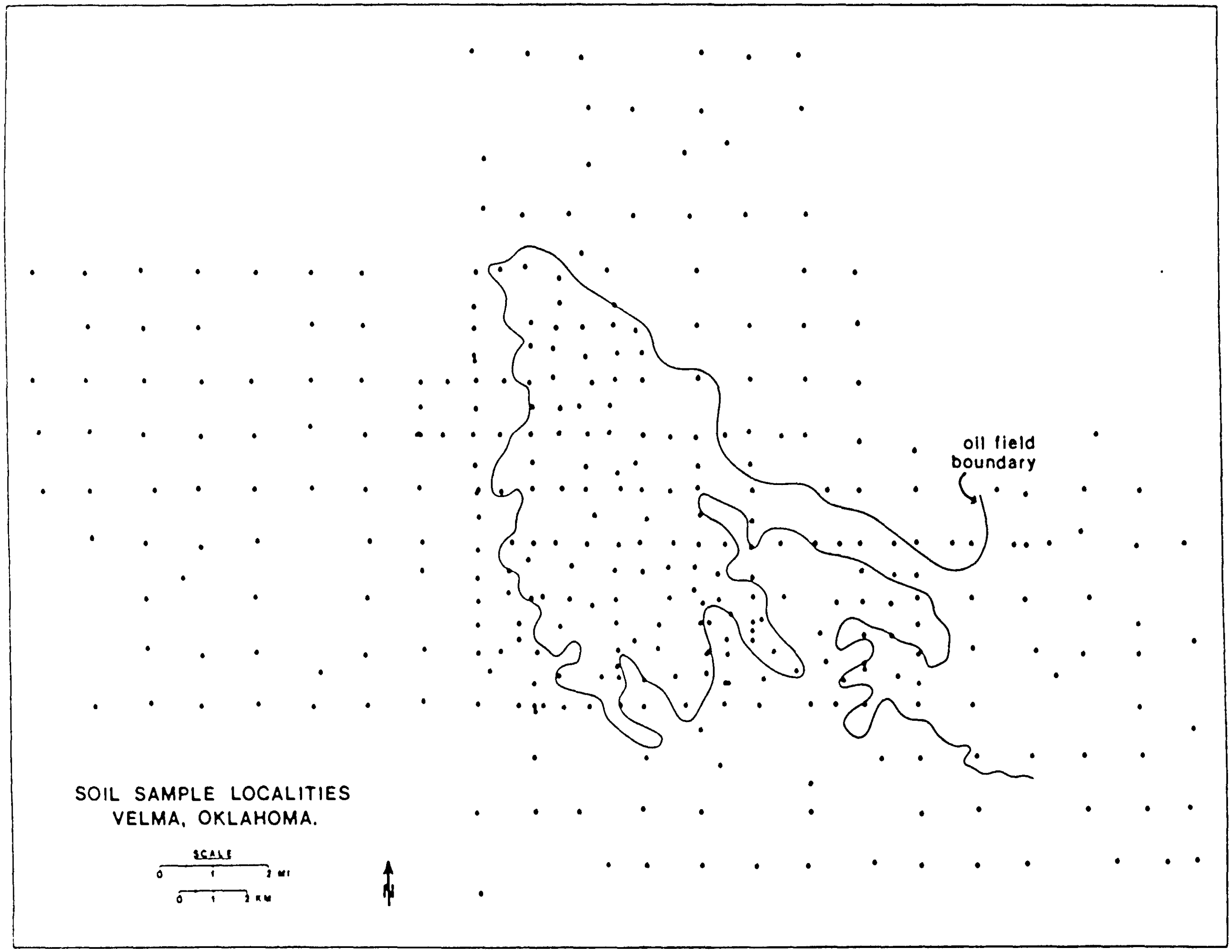

Figure 5. Soil sample locality map, Velma oil field, Oklahoma.

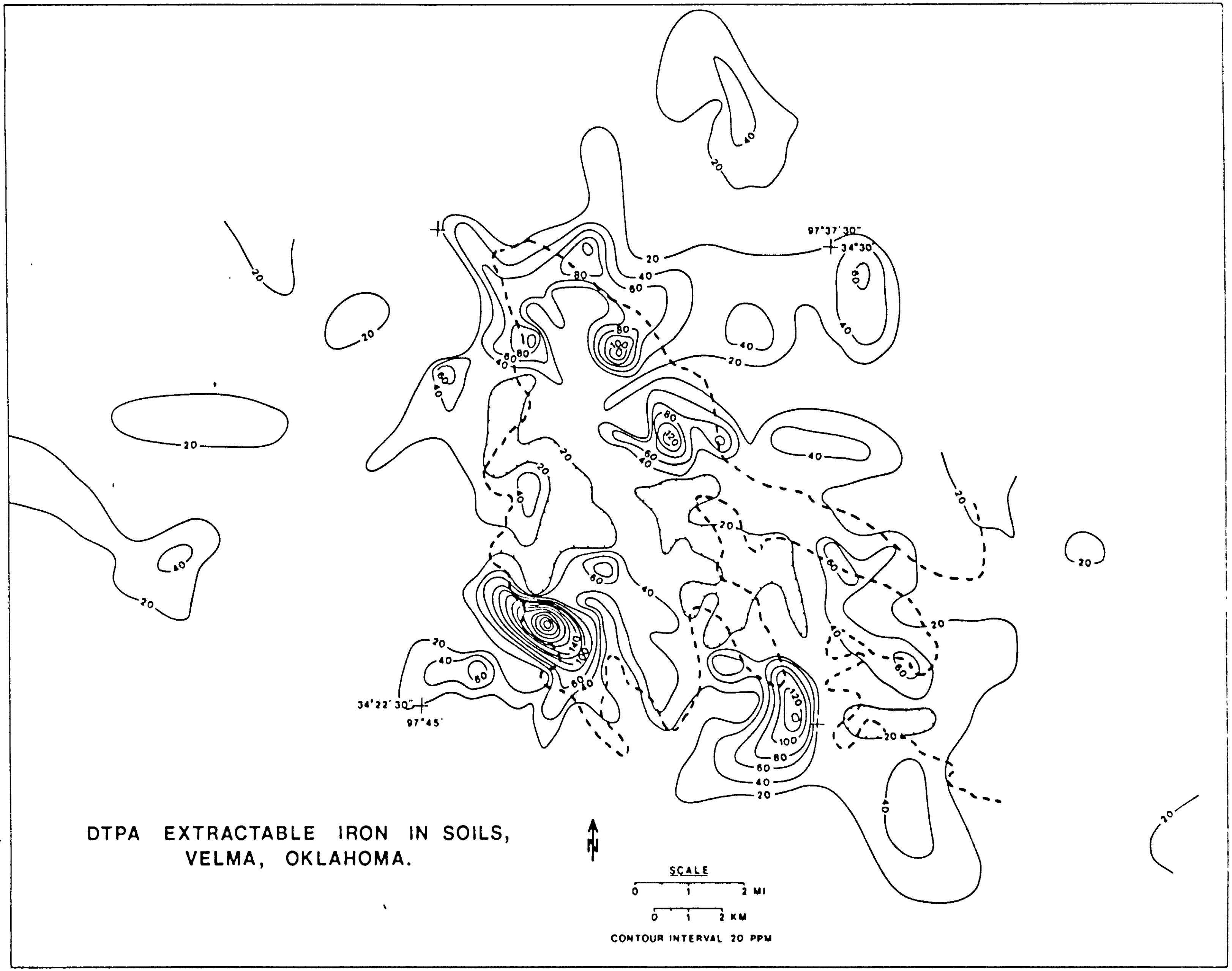

Figure 6. Isopleth map of DTPA extractable iron in soils, Velma oil field, Oklahoma. Isopleth interval 20 ppm. Dashed line indicates oil field boundary.

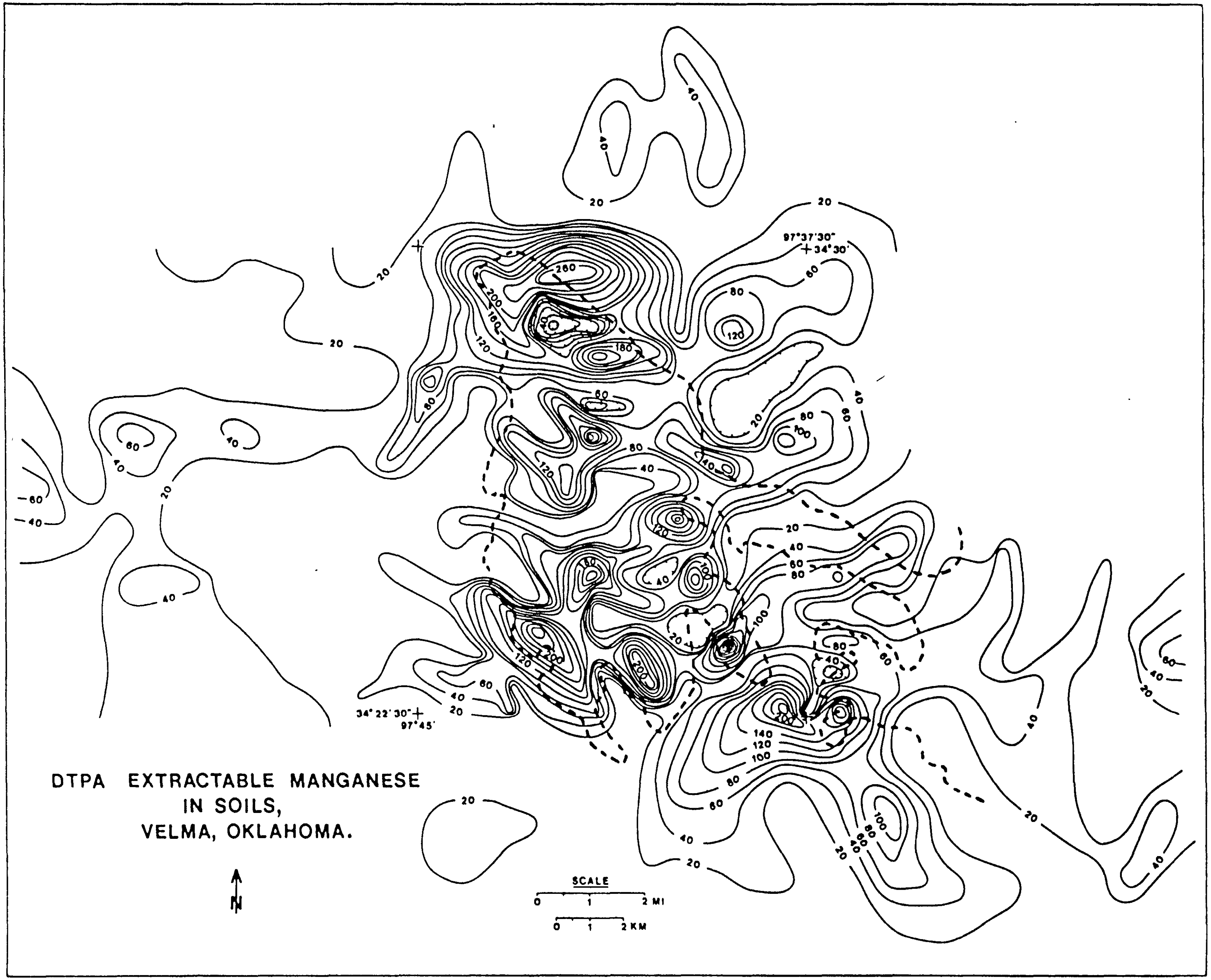

Figure 7. Isopleth map of DTPA extractable manganese in soils, Velma oil field, Oklahoma. Isopleth interval 20 ppm. Dashed line indicates oil field boundary.

measurement of chelate extractable iron and manganese in surface soils and by mapping of epigenetic facies changes.

ACKNOWLEDGEMENTS

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APPENDIX

Sample No.	Lat./Long.		Soil DTPA-Extractable Mn ppm	Fe ppm
1	34° 29.53'	97° 39.94'	33.6	31.2
2	34° 28.69'	97° 39.94'	16.8	28.8
3	34° 28.67'	97° 38.94'	136.0	51.2
4	34° 28.67'	97° 37.90'	48.0	12.0
5	34° 28.71'	97° 36.90'	55.2	46.4
6	34° 29.52'	97° 36.88'	65.6	61.2
7	34° 29.52'	97° 37.89'	51.2	36.0
8	34° 27.77'	97° 36.87'	59.2	9.0
9	34° 27.81'	97° 37.90'	12.0	7.8
10	34° 26.94'	97° 37.90'	129.6	45.6
11	34° 26.82'	97° 36.88'	70.4	44.8
12	34° 26.07'	97° 36.87'	34.4	15.8
13	34° 26.07'	97° 38.50'	17.8	19.8
14	34° 25.20'	97° 36.88'	14.4	6.0
15	34° 26.05'	97° 38.94'	72.8	28.0
16	34° 27.00'	97° 38.98'	13.4	12.0
17	34° 27.79'	97° 38.97'	16.8	4.3
18	34° 27.80'	97° 39.94'	66.4	15.2
19	34° 27.80'	97° 41.02'	74.4	17.4
20	34° 27.81'	97° 41.55'	67.2	28.8
21	34° 27.77'	97° 41.98'	71.2	27.2
22	34° 27.39'	87° 41.64'	11.8	11.6
23	34° 26.95'	97° 41.67'	235.2	56.0
24	34° 26.95'	97° 42.09'	28.0	26.8
25	34° 27.39'	97° 42.23'	121.6	30.4
26	34° 26.95'	97° 42.60'	49.6	24.0
27	34° 27.35'	97° 42.59'	46.4	26.0
28	34° 27.35'	97° 43.12'	48.0	25.6
29	34° 26.92'	97° 43.15'	104.0	39.2
30	34° 26.92'	97° 43.73'	17.4	15.4
31	34° 26.92'	97° 44.25'	18.4	29.6
32	34° 26.92'	97° 44.80'	35.2	28.8
33	34° 26.92'	97° 44.25'	128.0	52.8
34	34° 27.37'	97° 45.25'	32.0	21.6
35	34° 27.77'	97° 45.25'	26.4	18.6
36	34° 27.77'	97° 44.72'	132.8	67.2
37	34° 27.77'	97° 44.20'	33.6	29.6
38	34° 27.32'	97° 44.20'	35.2	28.8
39	34° 27.77'	97° 43.65'	31.2	22.4
40	34° 27.75'	97° 43.17'	61.6	16.8
41	34° 26.42'	97° 44.21'	10.4	23.2
42	34° 26.05'	97° 44.15'	16.8	37.6
43	34° 26.03'	97° 43.72'	15.6	22.4
44	34° 26.06'	97° 43.14'	42.0	47.2
45	34° 26.49'	97° 43.13'	11.2	19.2
46	34° 26.42'	97° 42.11'	142.4	22.4
47	34° 26.06'	97° 42.13'	140.8	17.8
48	34° 26.06'	97° 42.57'	63.2	17.2
49	34° 26.31'	97° 41.54'	6.4	22.8

Sample No.	Lat./Long.		Soil DTPA-Extractable Mn ppm	Fe ppm
50	34° 26.09'	97° 41.48'	15.6	36.8
51	34° 26.49'	97° 41.17'	44.8	36.8
52	34° 26.91'	97° 41.05'	99.2	16.0
53	34° 26.89'	97° 40.50'	97.2	132.8
54	34° 26.89'	97° 40.00'	134.4	51.6
55	34° 26.42'	97° 40.00'	45.6	30.0
56	34° 26.08'	97° 40.00'	45.6	12.4
57	34° 26.04'	97° 41.05'	10.8	19.2
58	34° 25.57'	97° 40.96'	57.6	24.0
59	34° 26.04'	97° 40.50'	38.4	9.8
60	34° 25.64'	97° 39.95'	201.6	28.0
61	34° 25.19'	97° 40.00'	40.0	13.0
62	34° 26.90'	97° 39.43'	76.8	80.0
63	34° 26.90'	97° 38.39'	40.4	51.2
64	34° 26.45'	97° 39.00'	310.4	29.2
65	34° 25.56'	97° 38.95'	9.2	27.6
66	34° 25.65'	97° 41.96'	15.6	19.6
67	34° 25.62'	97° 44.18'	40.0	19.2
68	34° 27.85'	97° 42.70'	40.8	67.2
69	34° 28.30'	97° 42.70'	152.0	25.2
70	34° 28.35'	97° 43.11'	142.4	108.8
71	34° 28.64'	97° 42.65'	50.4	43.2
72	34° 29.05'	97° 42.57'	67.2	22.4
73	34° 28.36'	97° 43.11'	187.2	27.2
74	34° 28.64'	97° 42.12'	25.6	28.0
75	34° 28.19'	97° 42.10'	120.0	32.8
76	34° 28.23'	97° 41.00'	192.0	53.6
77	34° 28.21'	97° 41.48'	235.2	147.2
78	34° 28.60'	97° 41.14'	126.4	76.8
79	34° 28.68'	97° 41.55'	58.4	58.8
80	34° 29.02'	97° 41.53'	161.6	61.6
81	34° 29.57'	97° 41.67'	275.2	59.2
82	34° 29.59'	97° 43.20'	145.6	44.0
83	34° 29.55'	97° 43.68'	204.8	34.4
84	34° 29.53'	97° 44.15'	142.4	58.8
85	34° 29.00'	97° 44.20'	69.6	17.6
86	34° 28.64'	97° 44.20'	81.6	15.2
87	34° 28.13'	97° 44.20'	145.6	56.8
88	34° 29.43'	97° 42.58'	265.6	96.0
89	34° 29.80'	97° 42.14'	233.6	106.4
200	34° 25.10'	97° 44.20'	18.4	19.6
201	34° 24.27'	97° 44.20'	68.8	35.2
202	34° 23.42'	97° 44.20'	48.8	31.2
203	34° 22.60'	97° 44.22'	36.0	19.8
204	34° 22.58'	97° 43.18'	62.4	34.0
205	34° 23.44'	97° 43.10'	116.8	40.0
206	34° 22.60'	97° 42.08'	72.0	12.8
207	34° 22.60'	97° 41.08'	17.6	12.0
208	34° 25.15'	97° 39.00'	13.6	11.6
209	34° 24.35'	97° 38.96'	31.2	29.6

Sample No.	Lat./Long.		Soil DTPA-Extractable Mn ppm	Fe ppm
210	34° 23.65'	97° 39.00'	252.8	26.8
211	34° 25.20'	97° 40.09'	102.4	27.2
212	34° 24.46'	97° 40.10'	63.2	12.6
213	34° 25.20'	97° 41.10'	55.2	23.2
214	34° 25.20'	97° 42.13'	30.4	15.6
215	34° 24.20'	97° 42.05'	142.4	22.0
216	34° 24.35'	97° 42.97'	25.6	8.5
217	34° 25.20'	97° 43.14'	23.2	24.0
218	34° 22.56'	97° 42.55'	44.0	46.0
219	34° 22.59'	97° 41.51'	80.8	30.8
220	34° 23.00'	97° 41.08'	20.0	13.7
221	34° 23.00'	97° 41.54'	63.2	18.4
222	34° 23.04'	97° 41.86'	160.0	51.2
223	34° 23.04'	97° 42.66'	94.4	9.0
224	34° 23.48'	97° 41.55'	104.0	24.0
225	34° 23.90'	97° 41.57'	40.0	15.4
226	34° 23.62'	97° 41.24'	80.0	32.0
227	34° 24.30'	97° 41.57'	29.6	45.6
228	34° 24.75'	97° 41.58'	227.2	93.6
229	34° 25.17'	97° 41.50'	214.4	28.8
230	34° 25.20'	97° 42.70'	75.2	13.5
231	34° 24.82'	97° 42.40'	92.8	38.4
232	34° 24.30'	97° 42.45'	31.2	44.0
233	34° 23.83'	97° 42.65'	256.0	272.0
234	34° 22.58'	97° 40.28'	22.4	36.8
235	34° 22.60'	97° 39.55'	64.0	19.0
236	34° 22.57'	97° 38.89'	124.8	13.6
237	34° 23.10'	97° 39.87'	78.4	43.2
238	34° 23.42'	97° 39.89'	56.0	10.4
239	34° 23.90'	97° 40.00'	18.4	37.6
240	34° 25.20'	97° 40.50'	100.8	17.0
241	34° 24.80'	97° 40.57'	no data	33.6
242	34° 24.31'	97° 40.56'	103.2	40.0
243	34° 23.88'	97° 40.77'	74.4	42.0
244	34° 24.74'	97° 41.05'	81.6	26.0
245	34° 23.04'	97° 40.50'	214.4	45.6
246	34° 23.50'	97° 40.78'	201.6	48.8
247	34° 25.18'	97° 39.50'	96.0	24.8
248	34° 24.81'	97° 40.08'	35.2	24.8
249	34° 24.70'	97° 39.62'	145.6	40.0
250	34° 24.30'	97° 39.60'	53.6	19.0
251	34° 25.20'	97° 38.42'	29.6	16.6
252	34° 25.20'	97° 37.75'	60.0	58.4
253	34° 24.65'	97° 38.97'	17.0	16.6
254	34° 24.34'	97° 38.38'	107.2	27.2
255	34° 23.98'	97° 38.80'	124.8	29.2
256	34° 23.46'	97° 38.59'	50.0	37.6
257	34° 23.14'	97° 38.19'	108.8	113.6
258	34° 23.30'	97° 37.58'	70.4	30.8
259	34° 23.03'	97° 38.80'	49.6	31.2

Sample No.	Lat./Long.		Soil DTPA-Extractable Mn ppm	Fe ppm
260	34° 22.94'	97° 39.45'	48.4	33.6
261	34° 25.20'	97° 37.29'	42.8	72.8
262	34° 25.20'	97° 36.82'	46.0	64.4
263	34° 24.77'	97° 36.82'	105.6	61.2
264	34° 24.28'	97° 36.82'	27.2	29.2
265	34° 24.20'	97° 37.40'	23.2	41.2
266	34° 23.67'	97° 36.82'	93.6	44.8
267	34° 22.93'	97° 37.70'	70.4	21.6
268	34° 23.12'	97° 36.82'	24.0	40.8
269	34° 22.94'	97° 37.28'	40.0	29.6
270	34° 22.55'	97° 36.80'	201.6	18.4
271	34° 22.55'	97° 37.46'	53.6	37.6
272	34° 22.55'	97° 37.90'	227.2	140.8
273	34° 25.15'	97° 35.80'	89.6	25.6
274	34° 25.15'	97° 36.25'	76.8	42.8
275	34° 24.64'	97° 36.25'	40.0	23.6
276	34° 24.64'	97° 35.80'	49.6	21.6
277	34° 24.27'	97° 35.80'	8.4	20.8
278	34° 24.20'	97° 36.32'	10.4	25.2
279	34° 23.85'	97° 35.80'	24.0	36.0
280	34° 23.66'	97° 36.33'	78.4	44.4
281	34° 23.37'	97° 35.80'	59.2	64.0
282	34° 23.01'	97° 36.22'	69.6	38.4
283	34° 25.15'	97° 34.77'	19.2	13.2
284	34° 25.15'	97° 33.72'	43.6	18.8
285	34° 24.28'	97° 34.75'	26.0	18.4
286	34° 24.28'	97° 33.71'	44.8	18.0
287	34° 23.42'	97° 33.55'	11.4	19.2
288	34° 23.48'	97° 34.75'	49.6	24.8
289	34° 22.54'	97° 34.77'	9.2	23.6
290	34° 22.55'	97° 35.80'	28.8	14.4
291	34° 22.88'	97° 35.80'	66.4	39.2
292	34° 21.69'	97° 36.20'	31.2	66.4
293	34° 21.68'	97° 36.55'	118.4	26.8
294	34° 20.78'	97° 35.80'	108.0	76.8
295	34° 19.95'	97° 35.80'	140.8	33.6
296	34° 19.99'	97° 34.75'	58.4	39.2
1001	34° 27.88'	97° 42.72'	71.2	19.2
1002	34° 28.20'	97° 44.23'	16.8	5.7
1003	34° 26.95'	97° 42.10'	118.4	19.8
1004	34° 25.94'	97° 44.23'	14.4	11.2
1005	34° 25.18'	97° 43.54'	2.5	6.6
1006	34° 25.15'	97° 41.51'	19.4	10.6
1007	34° 25.17'	97° 39.48'	15.4	7.0
1008	34° 25.20'	97° 37.77'	21.6	13.8
1009	34° 26.49'	97° 38.98'	10.7	17.2
1010	34° 24.30'	97° 41.58'	23.2	12.2
1011	34° 23.19'	97° 41.58'	41.6	19.0
1012	34° 22.93'	97° 39.89'	5.2	25.6
1013	34° 23.42'	97° 39.84'	69.6	38.4

Sample No.	Lat./Long.		Soil DTPA-Extractable Mn ppm	Fe ppm
1014	34° 22.89'	97° 39.55'	24.8	3.2
1015	34° 22.99'	97° 38.70'	3.6	25.6
1016	34° 24.30'	97° 39.00'	19.6	14.6
1017	34° 23.94'	97° 38.98'	24.8	14.8
1018	34° 23.68'	97° 39.00'	182.4	30.8
1019	34° 23.66'	97° 39.50'	8.4	11.6
1020	34° 23.40'	97° 39.50'	112.0	69.6
1021	34° 24.06'	97° 39.40'	18.8	12.3
1022	34° 24.32'	97° 39.58'	44.8	34.0
1023	34° 24.25'	97° 39.93'	28.0	13.3
1024	34° 23.87'	97° 39.83'	11.2	26.4
1025	34° 25.09'	97° 44.24'	21.6	8.4
1026	34° 24.64'	97° 44.22'	1.8	8.9
1027	34° 24.32'	97° 44.23'	15.0	16.7
1028	34° 23.90'	97° 44.23'	17.0	9.0
1029	34° 23.45'	97° 44.26'	5.7	5.3
1030	34° 22.62'	97° 44.18'	24.0	8.4
1031	34° 22.58'	97° 43.50'	30.4	6.2
1032	34° 22.58'	97° 42.97'	10.2	8.9
1033	34° 22.92'	97° 43.14'	9.0	2.5
1034	34° 24.96'	97° 43.28'	15.0	17.0
1035	34° 24.76'	97° 43.62'	16.0	36.8
1036	34° 24.40'	97° 43.63'	124.8	88.0
1037	34° 24.31'	97° 43.22'	62.4	68.8
1038	34° 23.88'	97° 43.47'	117.6	102.4
1039	34° 23.65'	97° 43.45'	108.8	42.4
1040	34° 23.46'	97° 43.80'	18.4	14.8
1041	34° 23.13'	97° 44.02'	67.2	72.0
1042	34° 27.80'	97° 45.29'	14.4	13.8
1043	34° 27.85'	97° 46.40'	14.5	9.6
1044	34° 27.83'	97° 47.32'	16.8	17.4
1045	34° 27.81'	97° 48.50'	14.0	7.8
1046	34° 27.81'	97° 49.48'	19.2	16.6
1047	34° 27.82'	97° 50.50'	16.6	7.8
1048	34° 27.82'	97° 51.67'	14.8	14.2
1049	34° 27.82'	97° 52.63'	20.8	18.7
1050	34° 29.55'	97° 52.67'	11.2	3.7
1051	34° 29.56'	97° 51.69'	18.4	11.0
1052	34° 28.71'	97° 51.63'	18.4	10.2
1053	34° 29.59'	97° 50.64'	12.4	13.0
1054	34° 28.68'	97° 50.55'	17.2	11.2
1055	34° 28.70'	97° 49.48'	7.6	9.7
1056	34° 29.55'	97° 49.50'	22.4	14.8
1057	34° 29.57'	97° 48.36'	16.0	24.8
1058	34° 29.55'	97° 47.33'	20.0	14.4
1059	34° 28.72'	97° 47.34'	24.0	17.3
1060	34° 28.70'	97° 46.37'	21.2	26.4
1061	34° 29.55'	97° 46.36'	10.2	12.4
1062	34° 26.96'	97° 45.30'	13.8	9.2
1063	34° 26.96'	97° 46.29'	20.8	12.6

Sample No.	Lat./Long.		Soil DTPA-Extractable Mn ppm	Fe ppm
1064	34° 27.12'	97° 47.38'	25.2	14.4
1065	34° 26.96'	97° 48.43'	46.4	36.8
1066	34° 26.95'	97° 49.46'	33.2	28.8
1067	34° 26.96'	97° 50.52'	72.8	32.0
1068	34° 27.06'	97° 51.60'	17.0	7.7
1069	34° 27.00'	97° 52.57'	36.8	13.0
1070	34° 26.06'	97° 52.51'	74.4	25.6
1071	34° 26.10'	97° 51.64'	6.3	5.8
1072	34° 25.33'	97° 51.52'	30.3	35.2
1073	34° 26.11'	97° 45.31'	12.6	6.3
1074	34° 26.10'	97° 46.29'	16.6	18.8
1075	34° 26.10'	97° 47.40'	17.0	13.4
1076	34° 26.06'	97° 48.45'	2.6	4.8
1077	34° 26.10'	97° 49.50'	16.0	6.2
1078	34° 26.06'	97° 50.36'	33.6	6.2
1079	34° 25.16'	97° 49.49'	1.9	23.2
1080	34° 24.65'	97° 49.85'	56.0	41.6
1081	34° 25.20'	97° 50.46'	21.6	9.6
1082	34° 24.32'	97° 50.62'	41.2	26.0
1083	34° 23.56'	97° 50.56'	33.6	10.0
1084	34° 22.57'	97° 51.55'	13.8	14.0
1085	34° 22.63'	97° 50.47'	23.2	10.6
1086	34° 22.60'	97° 49.51'	24.8	9.8
1087	34° 23.40'	97° 49.49'	31.2	15.8
1088	34° 22.64'	97° 48.43'	27.2	8.4
1089	34° 23.46'	97° 48.48'	24.0	8.2
1090	34° 24.35'	97° 48.48'	6.6	5.0
1091	34° 25.26'	97° 48.41'	18.2	7.8
1092	34° 25.21'	97° 46.29'	6.6	5.6
1093	34° 25.23'	97° 45.26'	8.5	16.4
1094	34° 24.77'	97° 45.28'	32.0	10.0
1095	34° 24.19'	97° 46.33'	16.6	7.2
1096	34° 23.36'	97° 46.36'	11.0	9.0
1097	34° 22.59'	97° 46.36'	19.6	9.3
1098	34° 22.60'	97° 47.40'	27.2	9.7
1099	34° 23.12'	97° 47.28'	8.0	5.1
1100	34° 22.65'	97° 45.28'	3.2	25.2
1101	34° 23.50'	97° 45.28'	35.2	19.1
1102	34° 30.40'	97° 40.00'	11.6	11.8
1103	34° 31.45'	97° 40.19'	12.9	10.8
1104	34° 31.60'	97° 39.39'	49.6	40.0
1105	34° 32.16'	97° 39.90'	22.8	14.6
1106	34° 33.05'	97° 39.92'	41.6	39.2
1107	34° 33.06'	97° 39.06'	13.6	8.2
1108	34° 33.05'	97° 38.04'	18.4	8.3
1109	34° 32.17'	97° 38.00'	8.4	14.6
1110	34° 30.40'	97° 37.95'	21.6	9.9
1111	34° 30.40'	97° 39.05'	2.8	6.6
1112	34° 30.42'	97° 41.18'	19.4	11.4
1113	34° 30.43'	97° 42.40'	8.2	6.0

Sample No.	Lat./Long.		Soil DTPA-Extractable Mn ppm	Fe ppm
1114	34° 30.40'	97° 43.29'	17.4	6.4
1115	34° 30.50'	97° 44.05'	23.2	8.6
1116	34° 31.36'	97° 44.05'	23.2	13.0
1117	34° 31.28'	97° 42.07'	22.4	35.2
1118	34° 32.19'	97° 42.00'	11.3	7.4
1119	34° 33.00'	97° 42.27'	13.0	8.5
1120	34° 33.07'	97° 43.24'	11.6	18.5
1121	34° 33.07'	97° 44.30'	16.2	12.0
1122	34° 32.12'	97° 41.16'	56.0	16.6
1123	34° 21.71'	97° 41.06'	0.8	11.6
1124	34° 20.86'	97° 41.14'	4.7	6.2
1125	34° 20.84'	97° 42.34'	19.6	9.0
1126	34° 20.83'	97° 43.15'	21.6	11.6
1127	34° 21.69'	97° 43.15'	4.0	6.0
1128	34° 22.31'	97° 43.16'	16.4	11.3
1129	34° 20.78'	97° 44.25'	23.2	12.4
1130	34° 19.50'	97° 44.23'	19.0	7.6
1131	34° 19.96'	97° 41.80'	19.2	19.0
1132	34° 19.95'	97° 41.06'	17.9	8.4
1133	34° 19.95'	97° 40.00'	4.4	12.9
1134	34° 19.95'	97° 39.00'	20.0	6.8
1135	34° 19.95'	97° 38.00'	29.6	3.9
1136	34° 20.85'	97° 37.95'	11.2	9.0
1137	34° 21.30'	97° 37.95'	9.7	16.0
1138	34° 20.87'	97° 39.98'	44.8	11.9
1139	34° 21.60'	97° 39.65'	93.6	32.0
1140	34° 22.11'	97° 40.02'	52.8	14.8
1141	34° 26.66'	97° 35.85'	21.2	18.9
1142	34° 26.05'	97° 35.76'	14.0	7.4
1143	34° 24.30'	97° 35.80'	11.7	6.8
1144	34° 24.28'	97° 32.55'	5.2	10.2
1145	34° 25.15'	97° 31.62'	19.2	10.2
1146	34° 25.16'	97° 30.74'	5.8	4.4
1147	34° 25.18'	97° 33.24'	17.4	9.0
1148	34° 25.16'	97° 33.95'	5.0	4.4
1149	34° 25.18'	97° 35.11'	2.8	9.0
1150	34° 25.97'	97° 33.69'	4.6	5.9
1151	34° 26.05'	97° 34.20'	12.8	25.2
1152	34° 26.90'	97° 32.32'	14.2	4.2
1153	34° 26.06'	97° 32.60'	7.2	10.4
1154	34° 26.03'	97° 31.56'	2.0	11.8
1155	34° 25.37'	97° 32.66'	3.6	30.4
1156	34° 23.40'	97° 32.74'	26.4	15.2
1157	34° 23.03'	97° 33.20'	44.8	14.2
1158	34° 23.60'	97° 30.60'	62.4	10.7
1159	34° 23.89'	97° 31.60'	18.6	16.8
1160	34° 23.40'	97° 31.67'	3.8	4.4
1161	34° 22.50'	97° 31.65'	5.8	12.6
1162	34° 23.18'	97° 36.88'	2.7	17.0
1163	34° 21.76'	97° 35.80'	10.8	21.6

Sample No.	Lat./Long.		Soil DTPA-Extractable Mn ppm	Soil DTPA-Extractable Fe ppm
1164	34° 21.72'	97° 36.51'	18.4	32.8
1165	34° 20.85'	97° 35.85'	21.6	9.0
1166	34° 19.95'	97° 35.84'	11.4	9.0
1167	34° 19.96'	97° 36.75'	15.4	8.0
1168	34° 19.95'	97° 34.75'	25.6	7.0
1169	34° 19.95'	97° 33.82'	24.0	16.2
1170	34° 20.77'	97° 34.78'	16.4	25.6
1171	34° 21.67'	97° 34.79'	4.8	15.0
1172	34° 21.70'	97° 33.70'	35.2	14.3
1173	34° 21.70'	97° 32.69'	25.6	8.6
1174	34° 21.70'	97° 31.62'	14.8	10.4
1175	34° 22.13'	97° 30.63'	4.4	12.1
1176	34° 20.81'	97° 32.70'	21.6	13.2
1177	34° 20.80'	97° 31.59'	16.9	7.8
1178	34° 20.81'	97° 30.72'	44.8	34.4
1179	34° 19.98'	97° 30.61'	18.6	9.9
1180	34° 19.96'	97° 31.18'	41.6	16.4
1181	34° 19.96'	97° 32.13'	13.8	15.2