

SUBSURFACE GEOCHEMICAL EXPLORATION OF STRATABOUND
COPPER IN LOWER PERMIAN REDBEDS
IN NORTH-CENTRAL OKLAHOMA

By

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Bachelor of Science

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Brooklyn, New York

1974

Submitted to the Faculty of the Graduate College
of the Oklahoma State University
in partial fulfillment of the requirements
for the Degree of
MASTER OF SCIENCE
May, 1978

Thesis

1978

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PREFACE

This thesis introduces an additional stratabound, redbed copper deposit to the growing list of Midcontinent occurrences. This north-central Oklahoma deposit has been defined in the shallow subsurface of Grant County through well-cuttings and electric logs. Paleoenvironmental considerations have been shown to be important in understanding the origin of this deposit. Furthermore, recent developments in low temperature geochemistry have been applied to study its origin.

This writer would like to thank Dr. Zuhair Al-Shaieb, thesis adviser, for his enthusiastic support and guidance of this investigation. Thanks are also due to Dr. Gary Stewart and Dr. Alex Ross, who served on the thesis committee and who made valuable suggestions regarding this text. Dr. Gary Stewart is especially appreciated for his assistance on stratigraphy and statistics and for his constructive criticism of the manuscript. Dr. Pieter Berendsen of the Kansas Geological Survey is thanked for introducing this writer to the Midcontinent redbed copper problem and for encouraging its further study. Appreciation is extended to the Oklahoma Geological Survey Core and Sample Library for permitting use of their well-cuttings. The Oklahoma City Geological Society Well Log Library is thanked for providing access to electric logs.

Finally, this writer would like to express sincere gratitude to his wife, Joan, for her unyielding support, assistance, and understanding.

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CHAPTER I

INTRODUCTION

The area of investigation is located in north-central Oklahoma, and includes all of Grant and the western one-third of Kay Counties. This area extends from the southern half of T.29N. to T.25N. and from R.8W. to R.1W. consisting of over 1290 square miles (Figure 1). Surface geology is rather simple as exhibited by lower Permian strata striking essentially north-south with dip ranging from 25 to 35 feet per mile to the west (Figure 2). The oldest rocks in the study area are the Wellington Formation which is exposed principally in Kay County. The Garber Sandstone overlies the Wellington and occupies the central portion of the study area. The Hennessey Shale overlies the Garber and is exposed in the western third of Grant County. The youngest units are the Quaternary deposits associated with the Salt Fork River and its tributaries. Topography is strongly related to differential erosion of north-south striking, gentle west-dipping strata which may form east-facing cuestas.

More than 50 copper-sulfide bearing locations have been reported in Oklahoma across the broad Permian belt. For the most part, these occurrences are limited to the surface, restricted in areal extent and most reports contain only brief descriptive remarks. Only two areas have been studied extensively: the Creta District, Jackson County, and to a lesser extent the Mangum District, Greer County, Oklahoma (Figure 3; Table I).

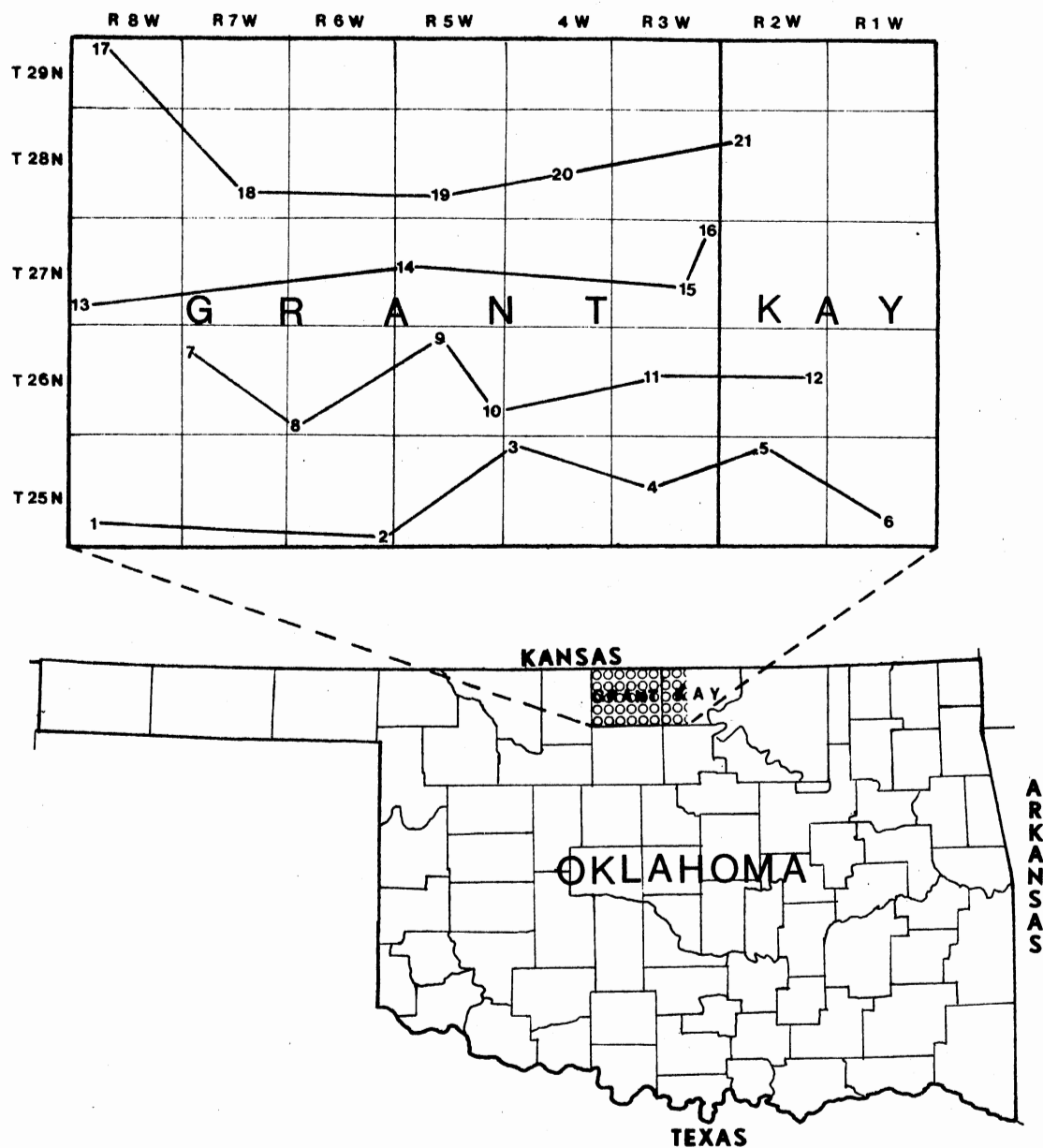


Figure 1. Index Map of Study Area

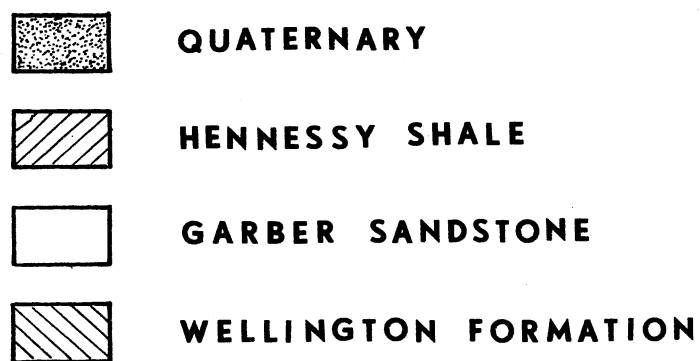
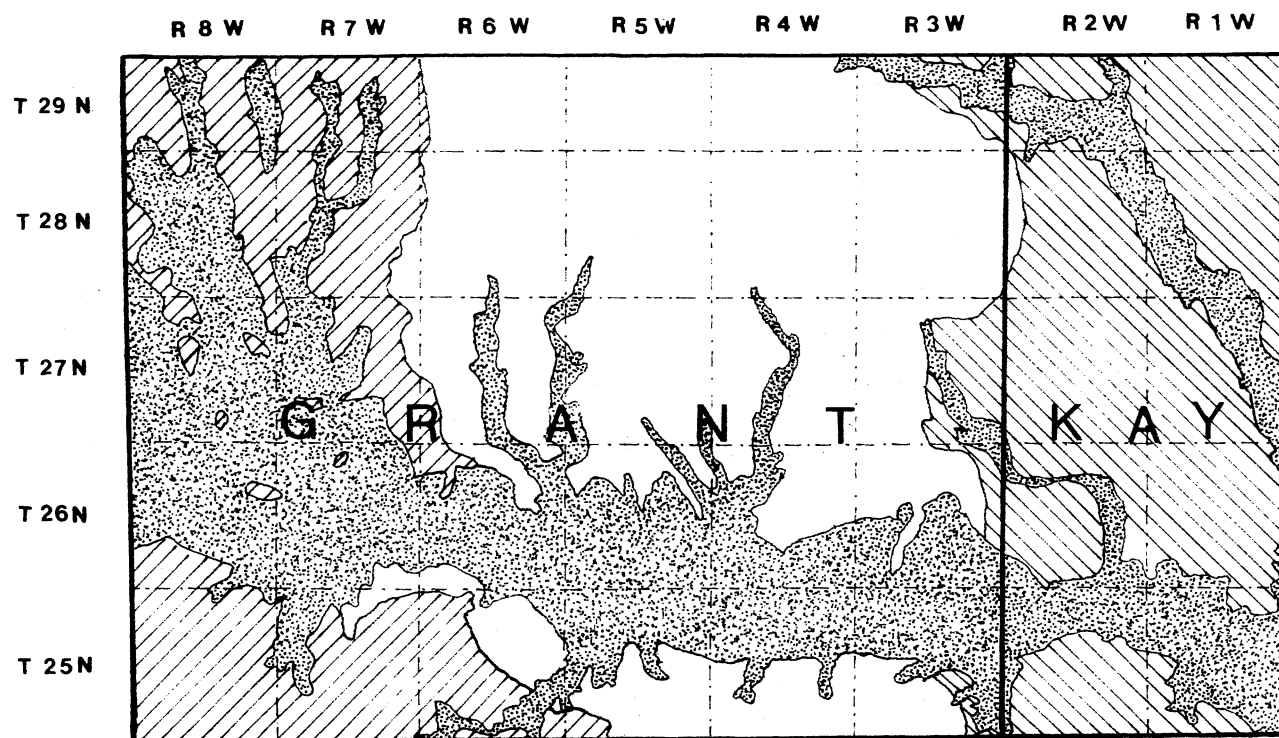


Figure 2. Geologic Map of Study Area

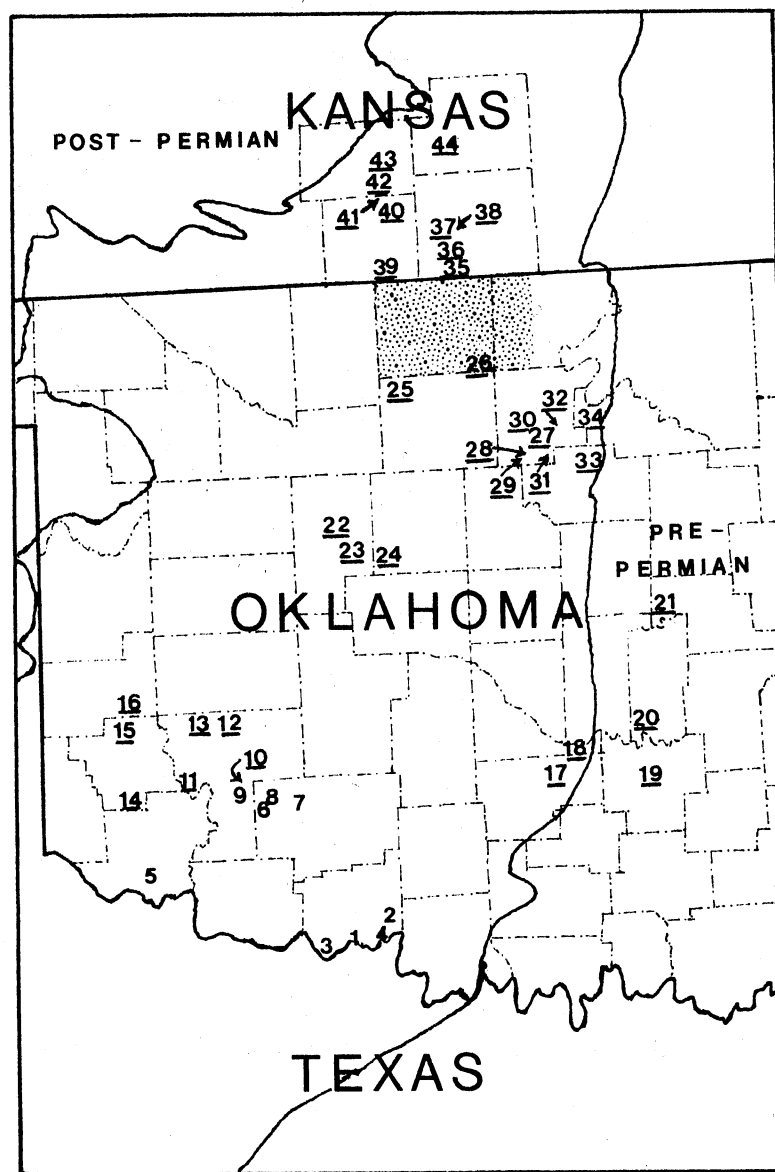


Figure 3. Midcontinent Distribution Map of Redbed Copper Occurrences

TABLE I
COPPER OCCURRENCES OF THE MIDCONTINENT PERMIAN BELT

Location No.	County	Location	Remarks	Source
1	Cotton	Sec. 2 and 3, T.5S., R.11W.	Chalcocite replacing wood fragments with some malachite and azurite	Johnson, 1969 Fay, 1975
2	Cotton	SW $\frac{1}{4}$, SE $\frac{1}{4}$, Sec. 35, T.4S., R.10W.	Chalcocite nodules in sandstone coated with malachite	Fath, 1915 Johnson, 1969
3	Cotton	Sec. 30 T.4S., R.12W.	No data	Johnson, 1969 Fay, 1975
4	Cotton	Sec. 10 T.5S., R.10W.	No data	Johnson, 1969 Fay, 1975
5	Jackson	Sec. 3, 4, 9, 10, 15, 16 T.1S., R.22W.	Creta District: Thin green-gray copper shale in the Flowerpot Shale, average copper content 3.8%. Mainly malachite and chalcocite, with minor brochanite and cuprite	Ham and Johnson, 1964
6	Comanche	Sec. 31, T.3N., R.15W.	No data	Johnson, 1969 Fay, 1975
7	Comanche	Sec. 19, T.3N., R.14W.	No data	Johnson, 1969

TABLE I. (Continued)

Location No.	County	Location	Remarks	Source
8	Comanche	Sec. 19, T.31N., R.15W.	Hale Copper Mine, average copper content 0.35%	Shead, 1926
9	Kiowa	Sec. 8, T.3W., R.16W.	No data	Johnson, 1969
10	Kiowa	SE $\frac{1}{4}$, Sec. 7, T.4N., R.16W.	Kiowa Copper Company	Shead, 1926
11	Kiowa	Sec. 2, T.4N., R.20W.	No data	Johnson, 1969 Fay, 1975
12	Kiowa	Sec. 22, T.7N., R.17W.	No data	Johnson, 1969
13	Kiowa	Sec. 11, T.7N., R.19W.	No data	Johnson, 1969 Fay, 1975
14	Greer	Sec. 21, 22, 27, 28, 34, T.4N., R.22W.	Mangum District, Meadows Copper Shale Member of the Flowerpot Shale, malachite and chalcocite are the ore minerals	Johnson, 1976
15	Greer	Sec. 27 T.7N., R.23W.	No data	Johnson, 1969
16	Beckman	Sec. 29, T.8N., R.22W.	No data	Johnson, 1969 Fay, 1975

TABLE I. (Continued)

Location No.	County	Location	Remarks	Source
17	Garvin	Sec. 7, 8, 18, 20 T.8N., R.1E.	Malachite in Garber Sandstone, Paoli, solution-front body, chalcocite and native copper	Johnson, 1969 Shockey and others, 1974 Redfield, 1927
18	McClain	SW $\frac{1}{4}$, Sec. 33, T.5N., R.2E.	Malachite in red sandstones and shales of the Stillwater Formation	Redfield, 1927 Merritt, 1940
19	Pontotoc	Sec. 29 T.4N., R.6E.	Chalcocite in sandstone, average copper content 12.3%	Shead, 1929
20	Seminole	SW $\frac{1}{4}$, NE $\frac{1}{4}$, Sec. 34, T.6N., R.5E.	Malachite mineralization	Shead, 1929
21	Okfuskee	SE $\frac{1}{4}$, SW $\frac{1}{4}$, Sec. 31, T.17N., R.7E.	Malachite with minor azurite, chalcocite, chrysocolla, and native copper, copper content 15.4%	Merritt, 1940 Shead, 1926
22	Blaine	Sec. 15, T.17N., R.11W.	No data	Johnson, 1969 Fay, 1975
23	Blaine	Sec. 29 T.16N., R.10W.	No data	Johnson, 1969
24	Kingfisher	Sec. 7, T.15N., R.9W.	No data	Johnson, 1969

TABLE I. (Continued)

Location No.	County	Location	Remarks	Source
25	Garfield	NE $\frac{1}{4}$, SE $\frac{1}{4}$, Sec. 8, T.24S., R.3W.	Native copper in the Hennessey Shale with 40% copper	Haworth and Bennett, 1901 Reiter, 1920
26	Grant	NE $\frac{1}{4}$, Sec. 5, T.25S., R.3W.	Chalcocite replacing wood fragments	Merritt, 1940
27	Noble	NE $\frac{1}{4}$, NW $\frac{1}{2}$, Sec. 35, T.21N., R.1W.	Galena reported from the bottom of a 40 foot shaft	Shelton, 1971
28	Noble	E $\frac{1}{2}$, Sec. 3, T.20N., R.1W.	Upper-middle Wellington Formation	Shelton, 1971
29	Noble	W $\frac{1}{2}$, Sec. 19, T.20N., R.1E.	Lower Insect Bed, upper-middle Wellington Formation	Shelton, 1971
30	Noble	E $\frac{1}{2}$, Sec. 3, T.21N., R.1W.	Lower Insect Bed, upper-middle Wellington Formation	Raasch, 1946
31	Noble	SW $\frac{1}{4}$, SE $\frac{1}{4}$, Sec. 25, T.21W., R.3E.	Fort Riley Limestone	Shelton, 1971 Heine, 1975
32	Noble	NW $\frac{1}{4}$, SE $\frac{1}{4}$, Sec. 16, T.22N., R.2E.	Lower Wellington Formation	Shelton, 1971

TABLE I. (Continued)

Location No.	County	Location	Remarks	Source
33	Payne	Sec. 23, T.20N., R.3E.	Cuprified wood fragments in sandstone	Merritt, 1940 Rogers, 1916 Heine, 1975
		SE $\frac{1}{4}$, Sec. 22, T.20N., R.3W.	Chalcocite replacing wood fragments in sandstone with secondary coating of malachite and azurite	Tarr, 1910
34	Pawnee	Sec. 19, T.22N., R.3E.	Chalcocite nodules and replacements of wood	Merritt, 1940 Fischer, 1937
		Sec. 23, 24, T.22N., R.3E.	Chalcocite, malachite and azurite in limestone conglomerate in the Stillwater Formation	Merritt, 1940 Rogers, 1916
35	Sumner	Sec. 13, T.35S., R.3W.	Malachite in thin carbonate bed in lower Ninnescah Shale	Swineford, 1955
36	Sumner	Sec. 27, 34, 35, T.33S., R.3W.	Malachite in the Milan Dolomite Member	Wagh and Brady, 1976
37	Sumner	SE $\frac{1}{4}$, SE $\frac{1}{4}$, SE $\frac{1}{4}$, Sec. 30, T.32S., R.3W.	Malachite with minor azurite in thin dolomite bed	Wagh and Brady, 1976
38	Sumner	Sec. 15, T.35S., R.3W.	Malachite in thin carbonate bed and gray shale below	Cox, personal observation

TABLE I. (Continued)

Location No.	County	Location	Remarks	Source
39	Harper	Sec. 24, T.34S., R.6W.	Malachite in Runnymede Member	Waugh and Brady, 1976
40	Harper	SW $\frac{1}{4}$, NW $\frac{1}{4}$, NW $\frac{1}{4}$, Sec. 18, T.31S., R.5W.	Malachite in Runnymede Member	Waugh and Brady, 1976
41	Harper	Sec. 10, T.31S., R.6W.	Malachite in Runnymede Member	Waugh and Brady, 1976
42	Kingman	Sec. 20, T.30S., R.6W.	No data	Waugh and Brady, 1976
43	Kingman	Sec. 27, 35 T.28N., R.6W.	Malachite in Runnymede Member	Waugh and Brady, 1976
44	Sedgwick	Sec. 15 T.28S., R.3W.	Malachite in Milan Dolomite Member	Waugh and Brady, 1976

A subsurface geochemical exploration investigation of this type is timely in the development of understanding Oklahoma redbed stratabound copper-sulfides. A copper-sulfide trend in north-central Oklahoma has been traced into the subsurface on a regional basis, both across its strike and down-dip throughout approximately 720 square miles in Grant County. To the knowledge of this writer, no similar undertaking has yet been reported in Oklahoma.

Geologic controls of redbed stratabound copper-sulfide mineralization in Oklahoma, the Midcontinent and indeed the world are still controversial. Timing of mineralization, sources of metals and mechanisms that brought metals to its present distributions are still unclear. Although this investigation is designed to solve a problem of local interest, it should contribute information to the problem of Midcontinent stratabound copper.

Objectives

The primary objectives of this investigation are to: (1) determine the variation of copper, zinc, and lead sulfides in the Wellington Formation and parts of the lower Garber Sandstone, (2) delineate and interpret mineralized copper, zinc, and lead horizons, (3) statistically interpret geochemical data, (4) compare mineralization to lithofacies and environments of deposition, and (5) relate mineralization style to surrounding regional copper occurrences.

Previous Investigations

Accounts of redbed copper occurrences began in Oklahoma with Haworth and Bennett (1901) who described native copper in the Hennessey Shale

near Hillsdale, Garfield County (Figure 3; Table I). This remarkable occurrence was termed "common" looking red clay shales with crevices occupied by sheets of metallic copper from 1/2 inch to 2 inches wide. The copper-bearing zone was 6 inches thick and composed of material not much different from barren rock above or below.

Gould and others (1908) reported numerous copper occurrences from the following counties: Pottawatomie, Lincoln, Logan, Noble, Garfield, Major, Woods, Kingfisher, Blaine, Caddo, McClain, and Greer (Figure 3; Table I). Early estimations of copper concentrations and distributions by small prospect pit and tunnel operations proved grades to be subeconomic.

Tarr (1910) studied the petrography of a copper occurrence in northeastern Payne County, where copper-sulfide minerals replaced wood fragments and formed nodules in positions conforming to initial dips of the enclosing sandstones (Figure 3; Table I). Copper minerals reported include chalcocite, chalcopyrite, malachite, azurite, and minor chalcantite.

Fath (1915) recorded copper mineralization in southeastern Cotton County, along the Red River (Figure 3; Table I). Chalcocite, malachite, and azurite are associated with sandstones and shales of the Wichita Formation in the form of chalcocite nodules, fine dissemination of malachite, and cuprified wood.

Rogers (1916) prepared polished sections of redbed copper from Payne County to compare with those of Sierra Ocura and Nacimiento Districts, New Mexico (Figure 3; Table I). Reiter (1920), Redfield (1927), and Shead and others (1929) reviewed various mining attempts and reported on some of their ore grades.

Fischer (1937) and Fischer and others (1961) related geochemical cycles of associated deposits of copper-vanadium-uranium-silver in sandstones and shales of the Permian, Triassic, and Jurassic of the Midcontinent.

Merritt (1940) reviewed, updated and compared copper-sulfides in the following counties: Garvin, Payne, Pawnee, Grant, Garfield, Comanche, Cotton, Jefferson, and Okfuskee. He noted that copper phases occurring in these areas had similar paragenesis, which suggested similar origin.

Stroud and others (1970) conducted a Bureau of Mines study on the production potential of Permian redbed copper in Texas, Oklahoma, and Kansas. Estimates were made for the commercial possibilities for low-grade, medium-volume, strip-mine operations of 6 to 12 inches of pay zones at 0.5 to 1.5 percent copper.

Shockey and others (1974) described in detail a possible copper-silver solution-front origin for the Paoli occurrence, Garvin County, briefly mentioned earlier by Redfield (1927) (Figure 3; Table I). Host rocks for solution-front developments were sandstone paleochannels in the lower Permian Wellington Formation, with average grades of 0.75 percent copper and 6.0 ounce per ton of silver. Primary ore minerals are chalcocite and native silver, with secondary minerals of malachite and azurite.

Heine (1975) geochemically explored for redbed copper in portions of Noble, Payne, and Pawnee Counties (Figure 3; Table I). Mineralization is mainly in the form of chalcocite nodules, replacement of carbonaceous materials, and pyrite, with coatings of secondary malachite and azurite. Of considerable interest is his suggestion that the bedrock copper distribution coincides with known subsurface "highs".

Interest in redbed copper in Oklahoma dramatically increased in 1962 with discovery of disseminated malachite in an extensive 6 inch thick shale bed in the Flowerpot Shale at Creta, Jackson County (Figure 3; Table I). Eagle-Picher Industries Inc. announced on March 19, 1965, their intentions to construct a copper mill at Creta and to strip-mine this copper seam at a rate of 500 tons per day. The Creta discovery renewed interest in prospecting the Permian redbeds of Oklahoma, Kansas, and Texas for additional deposits. This resulted in a second discovery of copper shale at Mangum, Greer County, by the Lobaris Copper Company (Figure 3; Table I). Eagle-Picher Industries Inc. mined the copper shale from 1965 to 1975, but when the price of copper dropped to below 65 cents per pound, and production costs continued to rise, this operation was closed down (Johnson, 1976).

Methods of Investigation

Conventional surface geochemical surveys traditionally sample soils, rocks, stream sediments, water, vegetation, and air to detect subsurface mineral concentrations (Levinson, 1974). Sampling media, as listed above, would have limited capability in defining subsurface mineralization unique to this area because:

1. copper-sulfides are restricted to thin (less than one foot) beds of shales, silty shales, and carbonates,
2. the southern half of the study area is covered by thick fluvial deposits of the Salt Fork River, and
3. exposures of bed rock are quite limited, generally small and discontinuous.

As a result of these limitations, this study departs from standard

practice to take advantage of the existence and availability of well-cuttings from the shallow subsurface. Petroleum exploration and production in Grant and western Kay Counties have been moderately intensive, so that well-cuttings and electric logs are fairly common for this area. Since a surface geochemical exploration program probably could not adequately define mineralization in this area, a subsurface investigation is called to explore with this under-utilized source of geochemical and lithologic data.

Sampling Method

Twenty-one wells were selected for this study from Grant and western Kay Counties (Table II; Figure 1). Considerable effort was made to find wells that were as evenly spaced as possible and that were also sampled for well-cuttings at shallow depths. Although the resulting distribution is far from ideal, it is the best that could be done with available resources. For all wells, except Well Number One (Plate 1), a ten foot sampling interval was used. Where samples were not collected by the driller, those intervals were omitted. Random sampling of well-cuttings is controlled by the driller and must be assumed to be representative of the entire interval.

Well-cuttings were examined with a binocular microscope and described in detail with special emphasis on lithology, texture, and evidence of mineralization. Twenty-two thousand feet of lithologic sections were constructed from data derived from well-cuttings and electric logs (Maher, 1964).

TABLE II
WELL LOCATIONS AND SAMPLING INTERVALS

Well No.	Well Title	Location	Sampling Interval (in feet)	Number of Samples
1	Helmerich and Payne, Grouse No. 1	Sec. 29, T.25N., R.8W.	220-1720	78
2	Gutowsky, Smith No. 1	Sec. 36, T.25N., R.6W.	130-1700	156
3	Carter, Kirley No. 1	Sec. 6, T.25N., R.4W.	100-1220	112
4	Reda Pump Co., Booher No. 3	Sec. 16, T.25N., R.3W.	350-920	57
5	Marland, Kreiger No. 1	Sec. 4, T.25N., R.2W.	150-620	40
6	Halco-Meyers, Davis No. 1	Sec. 27, T.25N., R.1W.	100-450	45
7	W.A. Daleney, Jr., Shoneweis No. 1	Sec. 7, T.26N., R.7W.	350-1560	121
8	Barnes, Davis No. 1	Sec. 31, T.26N., R.6W.	300-1520	114
9	Carter, Kolarik No. 1	Sec. 4, T.26N., R.5W.	460-1410	93
10	Bu-Vi-Bar, Hurst No. 1	Sec. 25, T.26N., R.5W.	90-1240	115
11	Jay Simmons, Stockton No. 1	Sec. 16, T.26N., R.3W.	180-1020	82
12	Zephyr, State No. 1	Sec. 13, T.26N., R.2W.	180-500	30
13	Shell, Foster No. 1	Sec. 30, T.27N., R.8W.	350-1750	137
14	T. C. Wylie, Younger No. 1	Sec. 27, T.27N., R.5W.	280-1200	84
15	Appleton, Martin No. 1	Sec. 23, T.27N., R.3W.	170-700	46
16	Boucher, Nelson No. 1	Sec. 1, T.27N., R.3W.	140-770	37
17	Sinclair, Hedrixon No. 1	Sec. 17, T.29N., R.8W.	400-1180	107

TABLE II (Continued)

Well No.	Well Title	Location	Sampling Interval (in feet)	Number of Samples
18	Gypsy, Bilderback No. 1	Sec. 27, T.28N., R.7W.	90-1660	155
19	Continental, Kretschmar No. 1	Sec. 28, T.28N., R.5W.	330-1380	97
20	Wentz, Wirtz No. 1	Sec. 22, T.28N., R.4W.	100-1140	104
21	Helmerich and Payne, Roth No. 1	Sec. 8, T.28N., R.2W.	80-610	53

Stratigraphic Method

From the lithologic sections, four east-west stratigraphic cross sections were constructed where rock-stratigraphic correlations were established. Cross sections were also used to place geochemical data in a lithologic and stratigraphic framework for later interpretation (Plates 1, 2, 3, and 4).

Geochemical and Mineralogical Methods

More than 1,800 well-cutting samples were analyzed for copper, lead, and zinc concentrations in accordance with standard atomic-absorption practices. Background, threshold, and anomalous values were determined statistically. The various mineral phases have been determined by ore microscopic methods.

Chemical Analysis

Copper, zinc, and lead concentrations were determined using a Perkin-Elmer 403 double-beam atomic-absorption spectrophotometer, with instrument settings for the various elements in accordance with manufacturer's specifications. Prior to actual analysis of samples, atomic-absorption spectrophotometer photo-cell lamps were pre-warmed until background noise reached a minimum and readings were consistent. Furthermore, previously determined samples were regularly checked for reproducibility. Multiple readings of each sample were taken and averaged values were recorded.

One gram of -80 mesh powdered sample was placed in a beaker with 20 ml of aqua regia. After digestion for 18 hours at room temperature and 6 hours at 100°C, samples were cooled, filtered, and diluted to 50 ml.

Clay Mineral Analysis

A maximum of two samples were taken at each well, the first 50 feet from the base of the Wellington Formation, and the second 100 feet from the top of the Wellington. Individual samples were disaggregated by hand using mortar and pestle. Care was taken to minimize structural modification of clays during disaggregation. The clay size fraction was separated from the coarser by dispersion of the clays with distilled water, and removed by pipette. The mixture of clay and water was carefully and uniformly distributed on a porcelain slide and dried under heat lamps. Two slides were prepared for each sample, one was used for normal and heat treatments, and the other for glycolation treatment only. Normal samples were dried under heat lamps where the temperature did not exceed 75°C. Heated samples were placed in a muffle furnace for one hour at 400°C. Glycolated samples were placed in an atmosphere saturated with ethylene glycol.

Copper-Sulfides in Oklahoma

The Midcontinent Permian copper belt extends from Kansas, through Oklahoma and the study area, into Texas. Copper-sulfides have been reported throughout much of the Permian and can be divided stratigraphically into three mineralization times:

1. Wolfcampian Series copper of Pawnee and eastern Payne Counties,
2. Leonardian Series copper of north-central and south-central Oklahoma and south-central Kansas, which includes the area under investigation, and
3. Guadalupian Series copper of south-western Oklahoma, which includes the Creta and Mangum Districts (Figure 3; Table I).

Low-temperature chalcocite and malachite in shales, sandstones, and carbonates are the principal copper minerals in Oklahoma. Chalcocite is dominant in the subsurface whereas malachite is found only at the surface and extreme shallow subsurface. Other primary copper minerals thus far reported include: digenite, djurleite, chalcopyrite, bornite, tenorite, atacamite, and native copper. Secondary copper minerals include: azurite, covellite, brochantite, botallackite, callaghanite, and cuprite (Haworth and Bennett, 1901; Tarr, 1910; Fath, 1915; Rogers, 1916; Merritt, 1940; Dingess, 1976). Most of these copper phases are rare and are not expected to contribute to the economic potential of any given area in Oklahoma.

CHAPTER II

STRATIGRAPHY OF THE LOWER PERMIAN

Wellington Formation

The Wellington Formation was named by Cragin (1896, 1897) from exposures near Wellington, Sumner County, Kansas (Figure 3), just 15 miles north of the study area. More detailed and extensive work on the nature of the Wellington followed with the investigations of Norton (1939), Ver Wiebe (1937), Raasch (1946), Swineford (1955), Tasch (1960, 1961, 1963a, 1963b, 1964), and Shelton (1971).

Stratigraphic Framework

The Wellington Formation in Oklahoma is the lowest unit of the Sumner Group of the Leonardian Series of early Permian time. It is approximately equivalent to the Wellington Formation of Kansas, and the uppermost portion of the Wichita Group of central Oklahoma and Texas (Dunbar, 1940; Dunbar and others, 1960).

Boundaries

The upper limit of the Wellington is defined differently in Kansas, where its type section is located, than in Oklahoma. North of the state line, the top of the Milan Dolomite Member marks the top of the Wellington (Swineford, 1955). However, to the south, the base of the lowest

thick sandstone bed of the Garber Sandstone marks the top of the Wellington (Aurin and others, 1926; Green, 1937).

Reports on Wellington Formation thickness from surface surveys vary: (1) Ver Wiebe (1937) measured 570 feet, (2) Clark and Cooper (1927) measured 670 feet, (3) Raasch (1946) measured 822 feet, (4) Swineford (1955) and Zeller (1968) both reported 700 feet, which included about 100 feet of the Hutchinson Salt Member, and (5) Shelton (1971) measured 850 feet. These measurements were made of rocks exposed at the surface in various parts of north-central Oklahoma and south-central Kansas, with little said about the subsurface. Thickness of the Wellington in the subsurface is problematic, because it undergoes facies change as well as some apparent thickening. Maximum thickness in the subsurface is attained in the western portions of Grant County where it is approximately 1,060 feet (Figure 4).

Lithologic Character

The Wellington consists mainly of red, brownish-red, and gray, silty shales with thin lenticular sandstones and carbonate beds (Shelton, 1971; Raasch, 1946; Ver Wiebe, 1937). A thick sequence of evaporites in the middle of the Wellington dominates well-cuttings and electric log responses; evaporites are discussed in more detail later in the text (see p. for Wellington evaporites discussion). Three fundamental trends in the character of the Wellington can be observed along strike and down dip:

1. The color-change line between redbeds and non-redbeds migrates from near the top of the Wellington in northern Kay County to near the middle, in south-eastern Grant County (Anderson, 1941).

LOWER PERMIAN			
LEONARDIAN SERIES			
SUMNER GROUP			
Wellington Formation	Garber Ss	HAYWARD MEMBER	
		LUCIEN MEMBER	
		UPPER SHALES MEMBER	
		UPPER EVAPORITES MEMBER	
		MIDDLE SHALES MEMBER	
		LOWER EVAPORITES MEMBER	
		LOWER SHALES MEMBER	

Figure 4. Stratigraphic Column of the Lower Permian

2. The sandstone content progressively increases to the south whereas dolomite and shale increase to the north (Clark and Cooper, 1927).
3. The evaporite content increases down dip as sandstone decreases.

Environments of Deposition of the Wellington Formation

The Wellington Formation, in this area, was deposited on the eastern shelf of the restricted, hypersaline Permian sea, the waters of which were unsuited for diverse life forms of that time. Much of the Wellington is barren of fauna and flora, with only thin, intermittently fossiliferous beds that may contain conchostraca, mollusca, eurypterids, paleolimuliids, reptiles, insects, carbonaceous plant debris, spores, pollens, and silicified wood fragments (Tasch, 1964).

In general, the Wellington is thought to have alternated between shallow marine and tidal-flat conditions. During transgressive marine phases, thick evaporite sequences were deposited in the deeper parts of the basin, while near-shore and on tidal-flats thin carbonate beds were deposited. During regressive phases, Wellington sedimentation was more terrestrially influenced as broad tidal-flats extended out over the shrinking Permian sea. On these broad lowlands, puddles, ponds, lakes, timbered lands, creeks, and occasionally channels may have been locally important (Dunbar, 1924; Raasch, 1946; Tasch, 1963a; Shelton, 1971).

Division of the Wellington Formation in the Shallow Subsurface

Numerous methods of dividing the Wellington Formation have been

suggested as a result of surface-mapping (Ver Wiebe, 1937; Raasch, 1946; Billings, 1956; Shelton, 1971). No matter how successful these approaches may have been at the surface, they cannot be applied to the subsurface because:

1. lithologic facies change in the down dip direction, along with apparent thickening;
2. thick evaporite sequences in the subsurface that are not found at the surface; and
3. correlation of key beds at the surface to electric logs and well-cuttings in the subsurface is difficult.

Figure 4 shows the way that shallow subsurface strata have been divided for the purpose of this study. This classification is not intended for use at the surface because it is based strictly on subsurface rock-stratigraphic characteristics (i.e., well-cuttings and electric logs).

Lower Shales Member. The informal "Lower Shales Member" is the oldest unit in the Wellington Formation overlying the Herington Limestone, and being overlain by the informal "Lower Evaporites Member". The Lower Shales Member ranges from 60 to 90 feet thick, averaging 70 feet. This unit consists principally of gray shales interstratified with minor amounts of red shales. The Lower Shales include an evaporite bed that can be found throughout the subsurface of the study area. In the western portions of Grant County the evaporite bed is found near the top of the Lower Shales Member; however, to the east it migrates down section to about the middle of this unit, where it splits into two evaporite beds (Plates 1, 2, 3, and 4). These beds represent the first indication, in this area, that the Permian basin became evaporitic.

Lower Evaporites Member. The informal "Lower Evaporites Member" overlies the Lower Shales Member and underlies the informal "Middle Shales Member". The unit is as thick as 325 feet in the extreme western wells and thins eastward to as little as 195 feet, with an average thickness of about 250 feet. The Lower Evaporites Member consists mainly of evaporite beds interstratified with gray shales. These evaporite beds seem to increase in thickness to the west whereas the relative shale content increases to the east (Plates 1, 2, 3, and 4).

Middle Shales Member. The informal "Middle Shales Member" overlies the Lower Evaporites Member and underlies the informal "Upper Evaporites Member". The unit is as thick as 215 feet in the eastern wells and thins to 115 feet to the west. Average thickness is 155 feet, and consists mainly of gray shales, silty shales, and several evaporite beds that can be traced across most of the subsurface. The easternmost wells in the section contain thin carbonate beds interstratified with gray shales; the carbonates may be associated with near-shore and tidal-flat deposits (Plates 1, 2, 3, and 4).

Upper Evaporites Member. The informal "Upper Evaporites Member" overlies the Middle Shales Member and underlies the informal "Upper Shales Member". The maximum thickness of this unit is 170 feet and thins to 30 feet in the east, averaging 130 feet. This unit consists of evaporite beds interstratified with gray shales. These evaporite beds are thinner and less continuous than those in the Lower Evaporites Member. The Upper Evaporites Member loses most of its identity midway in the sections as a result of increases in shale content (Plates 1, 2, 3, and 4).

Upper Shales Member. The informal "Upper Shales Member" overlies the Upper Evaporites Member and underlies the Garber Sandstone. Maximal thickness of 460 feet is reached in the eastern portions of Grant County and thins westward to 360 feet and averages 410 feet. The Upper Shales Member consists of shales, silty shales, minor siltstone beds, with thin carbonate and evaporite beds. Furthermore, the color-change line varies from the middle of the Upper Shales to near its base. Above the color-change line redbeds are dominant whereas below the line, gray shales and silts persist. The transition is gradational and occurs over a 50 to 150 foot interval, and consists of red and gray interstratified beds. The Upper Shales Member is where substantial copper mineralization has occurred (Plates 1, 2, 3, and 4).

Wellington Evaporites

The general term "evaporites" is used in this thesis to include gypsum, anhydrite, halite, and other salts. Mineral phases of these evaporites cannot be determined readily using electric logs and well-cuttings, so this writer has lumped them together under a general heading. X-ray diffraction analysis of well-cuttings could distinguish insoluble evaporites, but all soluble salts are usually dissolved by freshwater based-drilling muds.

The work of Jordan and Vosburg (1963) permits some speculation regarding the nature of the Wellington evaporites. According to them, both the Upper and Lower Evaporites Members are actually part of the same stratigraphic facies that has been separated by the Middle Shales Member, just west of Grant County. They have determined further that the Upper Evaporites Member contains exclusively anhydrite, whereas the

Lower Evaporites Member contains anhydrite and salt, interbedded in approximately equal proportions.

A test well was drilled in central Grant County (SW corner, SW $\frac{1}{4}$, SE $\frac{1}{4}$, sec. 32, T.27N., R.5W.) to determine the specific distribution of Wellington evaporites (Jordan, 1961). This test hole was drilled with a salt-brine mud to recover salts and determine more accurately the evaporite distribution. Gamma-ray, latero and sonic logs were run to assist in defining evaporite beds as well as distinguishing between salt and anhydrite (Figure 5). Average sonic velocity for anhydrite is 20,000 feet per second (interval transit time of 50 microseconds per foot) whereas average sonic velocity for rock salt is 15,000 feet per second (interval transit time of 66.7 microseconds per foot); the two evaporite types may thus be distinguished (Tixier and others, 1959).

Garber Sandstone

The Garber Sandstone was named for the town of Garber, Garfield County, where the rock unit is well exposed and came into use gradually as it was made popular by local geologists (Figure 4).

Stratigraphic Framework

The Garber Sandstone in Oklahoma is in the upper half of the Sumner Group, of the lower middle Leonardian Series, of the lower Permian. In Kansas, the Garber is equivalent to the Ninnescah Shale (which includes the Runnymede and Stone Corral Members), whereas in Texas it correlates with the lower half of the Clear Fork Group (Dunbar, 1940; Dunbar and others, 1960; Johnson, 1976).

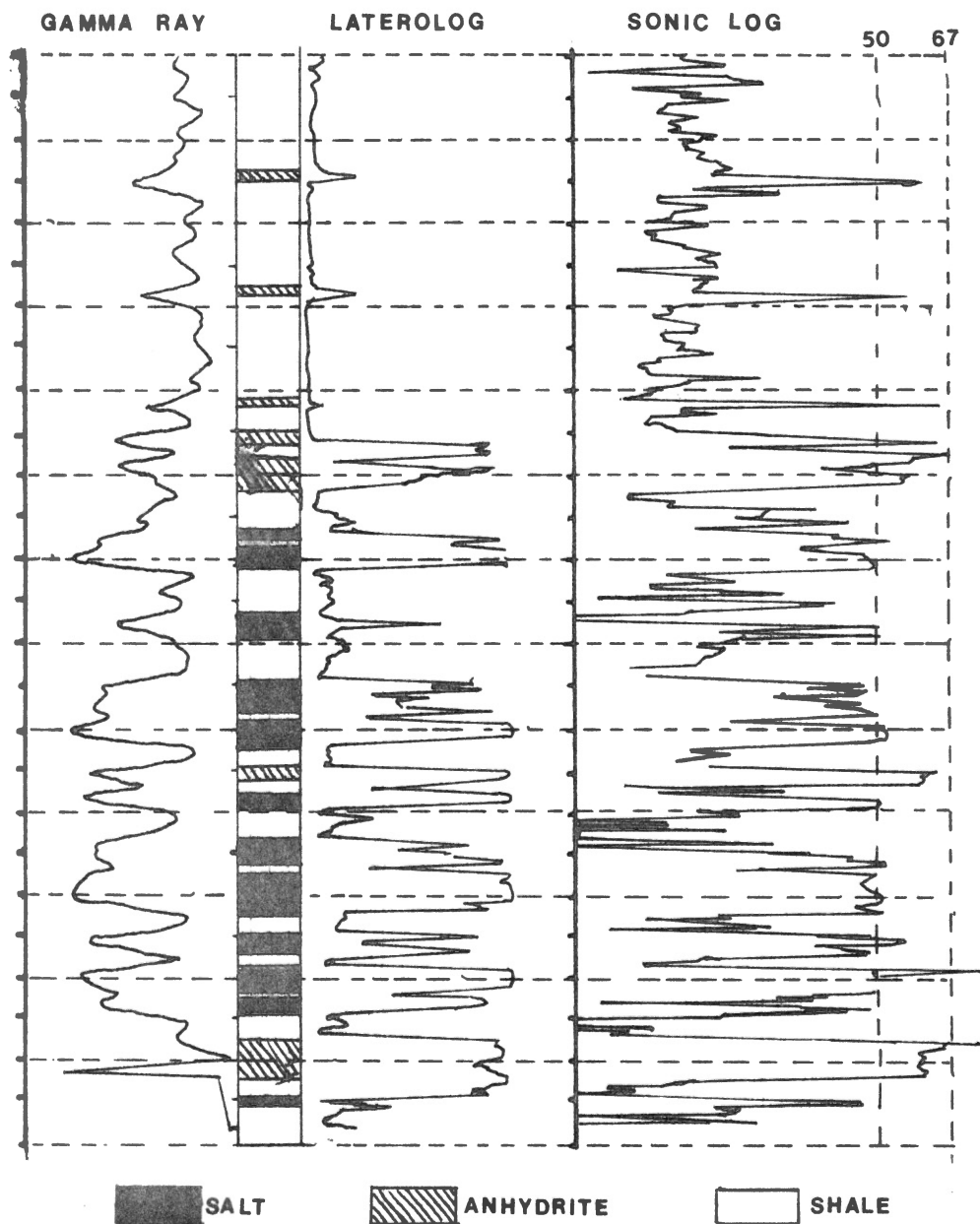


Figure 5. Test Well of Wellington Formation Evaporites (SW Corner, SW $\frac{1}{4}$, SE $\frac{1}{4}$, Sec. 32, T.27N., R.5W)

Boundaries

The upper boundary of the Garber Sandstone is marked by the uppermost thick sandstone above which clay-shales of the Hennessey Shale dominate. The lower contact with the Wellington Formation is defined by the lowermost thick sandstone of the Garber (Aurin and others, 1926).

Lithologic Character

Surface studies of the Garber Sandstone have led to its division into the Lucien Shale Member and the Hayward Sandstone Member. The Lucien Shale Member is the lower unit and consists mostly of red, laminated, partially fissile shale, interbedded with several red sandstones. The lowest sandstone forms a bench used to mark the Garber-Wellington contact. These sandstones contain medium- and small-scale cross bedding, initial dip, and some evidence of channeling. Thickness of the Lucien Shale is approximately 250 feet. The Hayward Sandstone Member is the upper unit consisting of thick ledges of massive, red sandstones, interstratified with fissile shale and siltstone beds. The sandstones generally are lenticular, with medium- and small-scale cross bedding. Thickness of this member is approximately 350 feet (Aurin and others, 1926; Clark and Cooper, 1927; Dott, 1932; Green, 1936; Shelton, 1971).

Environments of Deposition of the Garber

Sandstone

Like the Wellington Formation, the Garber Sandstone was deposited on the eastern flanks of the Permian basin. Hypersaline conditions prevailed into the Garber environment thus limiting faunal and floral

populations and diversity, but not so hypersaline as to precipitate evaporites.

The overall coarser texture of the Garber, in comparison to the Wellington, and the presence of multistoried, cross-bedded sandstones seems to indicate a transition from shallow marine evaporite and tidal-flat sedimentation of the Wellington to a Garber deltaic, interdeltiac, and tidal-flat sedimentation (Dott, 1932). Tanner (1959) suggests that what many geologists have considered to be a Garber Delta, could actually be a coastal long-shore deposit. Cross-bedding studies of the Garber produced current directions, 90 degrees from each other, which implies littoral sediment transportation and deposition.

To the south, the Garber Sandstone coarsens and thickens into a more characteristic delta complex. This delta, in central Oklahoma, is reported to have been deposited by a late Paleozoic stream called the Chert River. This stream is thought to have originated on the northern slope of the Llanoria land mass and drained northwest into Oklahoma (Oakes, 1947; Chenoweth, 1959).

The Garber Sandstone in the Subsurface

Establishment of the Wellington-Garber contact in the subsurface is problematic. Many workers using surface criteria have been successful in defining this contact (Aurin and others, 1926; Clark and Cooper, 1927; Patterson, 1933; Shelton, 1971); however, subsurface criteria are not as clearly discernible. The Garber Sandstone loses much of its clastic identity in the shallow subsurface of Grant County because it undergoes facies change. The many distinct sandstones that make up the Garber in central Oklahoma pinch-out to the north and become a nearly massive

sequence of red siltstones and shales in the study area. Electric logs and well-cuttings show no distinct breaks and cannot be used to establish or correlate the Wellington-Garber contact. In this study, the contact has been approximated by taking Shelton's (1971) composite section of the Wellington Formation, adding to it the thickness of evaporites present in the subsurface, while applying Jordan's (1961) test hole data. Since there is no other, more accurate method of establishing this contact, this approximation is used with appropriate skepticism. The Garber has not been divided since no suitable criteria could be defined.

Deposition Into the Permian Sea

The Wolfcamp Series of early Permian age is lithologically similar to the uppermost Pennsylvanian and is without significant changes in sedimentation style. Alternating off-shore and near-shore sedimentation resulted in cyclic layering of limestone, mudstone and dolomite. To the south, the Wichita-Amarillo archipelago furnished clastics and partially restricted the Permian sea (Jewett, 1932; MacLachlan, 1967). The Wolfcampian sea generally expanded from the start of the Permian to the middle of Wolfcampian time. By the middle of this epoch, the sea had transgressed to cover 25 percent more area than at the beginning of the Permian (Hills, 1942). This sea was typically normal marine, unstratified, and free circulating. However, by middle Wolfcampian time the Wichita-Amarillo archipelago was uplifted just enough to close the Wolfcampian sea to the south from the rest of the Permian sea. Restriction of the sea started a regressive trend that continued to the close of the Permian Period. Shrinking of the sea caused the Permian to the north to

lose its open, free circulating marine characteristics and become a saline sea (Hills, 1972).

The Leonardian sea continued to retreat from an earlier peak with only minor advances. For the first time in the Permian age, brackish and saline waters became widespread at the expense of the normal marine sea. The outline of the normal marine sea is usually farthest from the shore and is marked by deposition of gray to black sandstones and shales, with gray limestones and dolomites containing marine fossils. The saline sea is marked by the deposition of evaporites. The brackish sea is nearest to the shore and is most influenced by large amounts of clastics coming from streams (Hills, 1942).

A small advance of the Leonardian sea or a short period of free circulation is recorded by deposition of the Stone Corral Dolomite. Gradual uplift of the bordering land resulted in an influx of clastics, which contributed to the development of the Garber Delta. Stream activity is thought to have intensified, possibly swollen by increased rainfall in the upland drainage basins and choked with sediments. This influx of fresh waters further increased the stratification of the Leonardian sea, causing the brackish zone to increase in area (Hills, 1942; Clifton, 1944).

Sediment Source

There were four positive elements in the area of the eastern shelf of the Permian sea that were more or less active in the late Pennsylvanian through early Permian and influenced sedimentation in the study area: to the south were the Wichitas, Arbuckles, and Ouachitas, and to the east were the Ozarks. The Wichitas and Ouachitas are thought to have had greater relief and are considered to be responsible for supplying

most of the sediments (Miser, 1929; Van der Gracht, 1931; Green, 1936; Anderson, 1941; Tanner, 1959; MacLachlan, 1967).

Climate of the Lower Permian

The contrast between the humidity of the Pennsylvanian coal swamps and the aridity of the lower Permian evaporitic basin is remarkable (Dunbar, 1924). The Wellington Formation is the first Permian rock unit to reflect many characteristics of an arid environment (i.e., mud cracks, hopper crystals, very limited and dwarfed fauna, and abundant evaporites). At the peak of aridity, the Wellington evaporites were deposited; however, the severity of the climate seems to have ameliorated about middle Wellington time, as evaporite deposition ceased. At this time there was local deposition of plant debris within the Middle Shales Member. There is some indication, at least on a local level, that moist conditions existed with near normal marine waters. Dunbar (1924) documents this stay in aridity, as he skillfully recorded a brief moment in Wellington time: a relatively moist, swampy environment that left remains of logs, tree stumps, leaf impressions, and insect pods. The recurrence of aridity soon follows, as indicated by the renewed deposition of evaporites forming the Upper Evaporites Member.

CHAPTER III

RESULTS AND DISCUSSION

Interpretation of Geochemical Data

The management and interpretation of numerical data are crucial to understanding the geologic significance of this data. This phase of data synthesis is perhaps the most important part of exploration geochemistry, and if done well, will greatly enhance the value of the data. Assuming that a geochemical study has produced some apparent anomalous results, major questions arise: are these anomalies genetically related to mineralized bodies? And equally important, what defines anomalous results? The following discussion summarizes the methods of numeric synthesis and interpretation of the data presented in this thesis (Ahrens, 1954; Levinson, 1974).

Skewed Data Distributions

Concentrations of copper, zinc, and lead for this study are listed by well and depth in Appendix A, and can be shown to have skewed distributions. The data displayed as cumulative frequency curves for copper, zinc, and lead all produce "bell curves" with large positive tails extending into the higher concentrations (Figure 6 and Table III). This notion is supported further by Table IV and Figure 7, where large skewness and kurtosis values are reported for the parent population. Perhaps the most convincing evidence indicating these elements are not normally

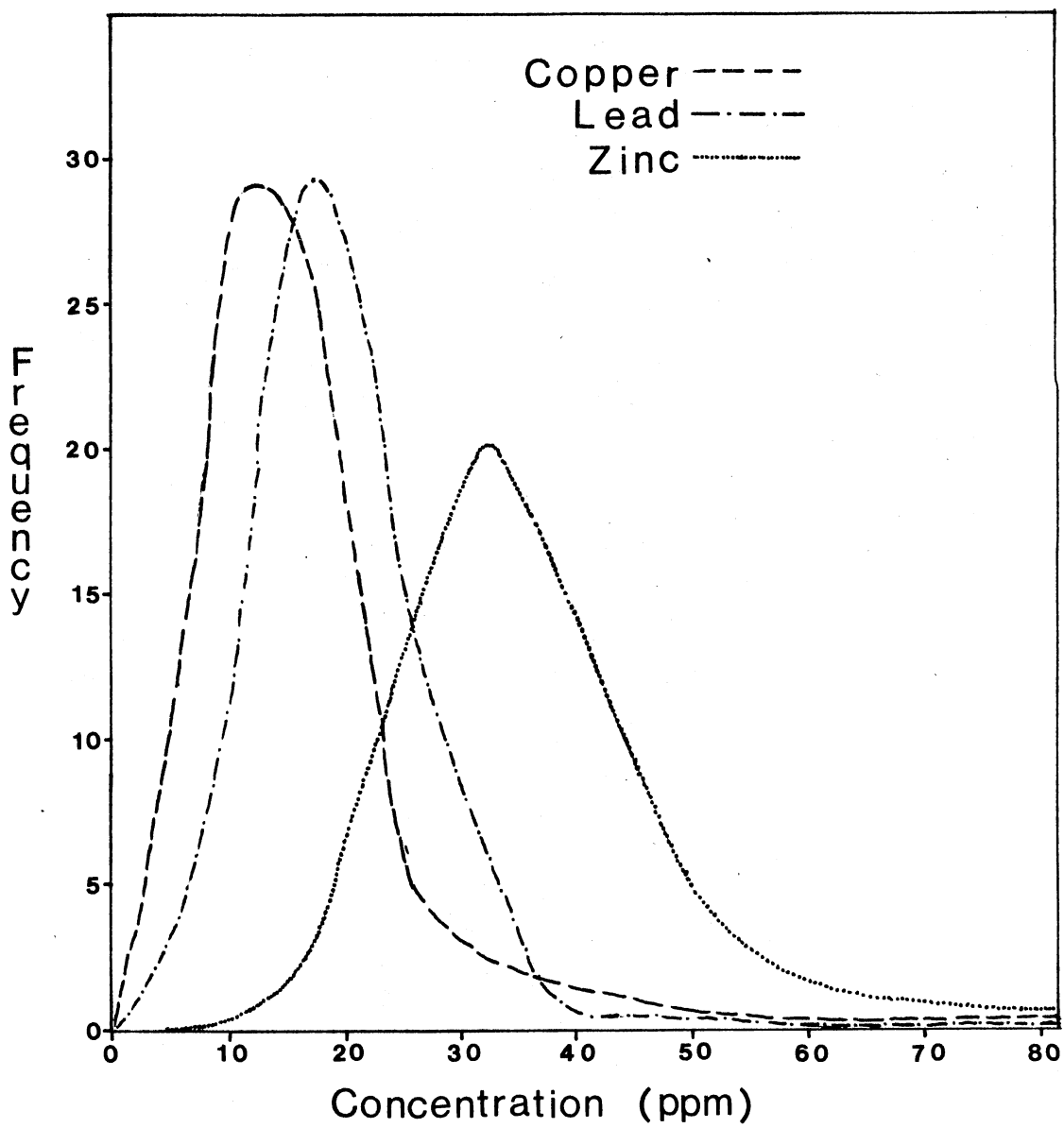


Figure 6. Frequency Curves for Copper, Zinc, and Lead

TABLE III
INDIVIDUAL AND CUMULATIVE PERCENT DISTRIBUTION FOR COPPER,
ZINC AND LEAD WITH ARITHMETIC INTERVALS

Interval (PPM)	Copper		Zinc		Lead	
	Individual Percent	Cumulative Percent	Individual Percent	Cumulative Percent	Individual Percent	Cumulative Percent
0-5	4.15	4.15	0.00	0.00	1.22	1.22
6-10	17.81	21.96	0.11	0.11	6.75	7.97
11-15	29.04	51.00	0.66	0.77	20.96	28.93
16-20	25.17	76.16	3.65	4.42	29.37	58.30
21-25	8.46	84.62	10.62	15.04	20.96	79.26
26-30	3.21	87.83	14.49	29.54	11.11	90.38
31-35	2.43	90.27	20.24	49.78	5.53	95.91
36-40	1.99	92.26	16.76	66.54	1.33	97.23
41-45	1.16	93.42	12.11	78.65	0.61	97.84
46-50	0.83	94.25	6.31	84.96	0.77	98.62
51-55	0.72	94.97	3.04	88.00	0.17	98.78
56-60	0.39	95.35	2.60	90.60	0.06	98.84
61-65	0.39	95.74	1.43	92.04	0.11	98.95
66-70	0.39	96.13	1.16	93.20	0.22	99.17
71-75	0.28	96.41	0.83	94.03	0.00	99.17
76-80	0.55	96.79	0.66	94.69	0.06	99.22

TABLE III. (Continued)

Interval (PPM)	Copper		Zinc		Lead	
	Individual Percent	Cumulative Percent	Individual Percent	Cumulative Percent	Individual Percent	Cumulative Percent
81-85	0.22	97.18	0.33	95.02	0.06	99.28
86-90	0.11	97.29	0.39	95.41	0.06	99.34
91-95	0.11	97.40	0.61	96.02	0.00	99.34
96-100	0.11	97.51	0.22	96.24	0.00	99.34
101-105	0.17	97.68	0.33	96.57	0.06	99.39
106-110	0.11	97.79	0.22	96.79	0.06	99.45
111-115	0.11	97.90	0.33	97.12	---	---
116-120	0.22	98.12	0.17	97.29	---	---
121-125	0.06	98.18	0.22	97.51	---	---
126-130	0.06	98.23	0.06	97.57	---	---
131-135	0.06	98.29	0.06	97.62	---	---
136-140	0.11	98.40	0.06	97.68	---	---
141-145	0.11	98.51	0.17	97.84	---	---
146-150	0.06	98.56	0.06	97.90	---	---
151-155	0.11	98.67	0.17	98.06	---	---
156-160	0.06	98.73	0.06	98.12	---	---
161-165	0.00	98.73	0.11	98.23	---	---
166-170	---	---	0.06	98.29	---	---

TABLE III. (Continued)

Interval (PPM)	Copper		Zinc		Lead	
	Individual Percent	Cumulative Percent	Individual Percent	Cumulative Percent	Individual Percent	Cumulative Percent
171-175	---	---	0.00	98.29	---	---
176-180	---	---	0.11	98.40	---	---
181-185	---	---	0.17	98.56	---	---
186-190	---	---	0.22	98.78	---	---
191-195	---	---	0.00	98.78	---	---
196-200	---	---	0.06	98.84	---	---

TABLE IV
STATISTICAL REVIEW OF COPPER, ZINC AND LEAD POPULATIONS

Statistical Review		Parent Population	Copper		Zinc		Lead	
			Mineralized Cu \geq 55	Barren Cu < 55	Mineralized Zn \geq 60	Barren Zn < 60	Mineralized Pb \geq 50	Barren Pb < 50
N	Cu	1807.00	97.0	1710.0	178.00	1630.00	37.00	1771.00
	Zn	1808.00						
	Pb	1808.00						
Mean	Cu	30.10	275.2	16.2	125.70	35.40	496.00	21.40
	Zn	43.80						
	Pb	31.10						
Standard Deviation	Cu	164.40	665.8	8.5	112.10	9.90	1303.00	7.20
	Zn	45.20						
	Pb	195.90						
Minimum Value (PPM)	Cu	0.50	55.0	0.5	60.00	8.00	50.00	0.00
	Zn	8.00						
	Pb	0.00						
Maximum Value (PPM)	Cu	5800.00	5800.0	53.0	850.00	65.00	6525.00	46.00
	Zn	850.00						
	Pb	6525.00						
Variance	Cu	27036.00	443249.0	71.3	12554.00	98.40	1697810.00	52.20
	Zn	2039.00						
	Pb	38394.00						
Standard Error of Mean	Cu	3.87	67.6	0.2	8.39	0.24	214.21	0.17
	Zn	1.06						
	Pb	4.61						

TABLE IV. (Continued)

Statistical Review		Parent Population	Copper		Zinc		Lead	
			Mineralized Cu \geq 55	Barren Cu < 55	Mineralized Zn \geq 60	Barren Zn < 60	Mineralized Pb \geq 50	Barren Pb < 50
Covariance	Cu	545.50	242.00	52.00				
	Zn	103.00			89.10	27.90		
	Pb	629.30					262.70	33.70
Skewness	Cu	27.00	6.60	1.49				
	Zn	9.20			3.59	0.44		
	Pb	28.20					3.90	0.44
Kurtosis	Cu	878.00	51.30	3.00				
	Zn	117.00			15.90	0.14		
	Pb	852.00					11.00	0.25

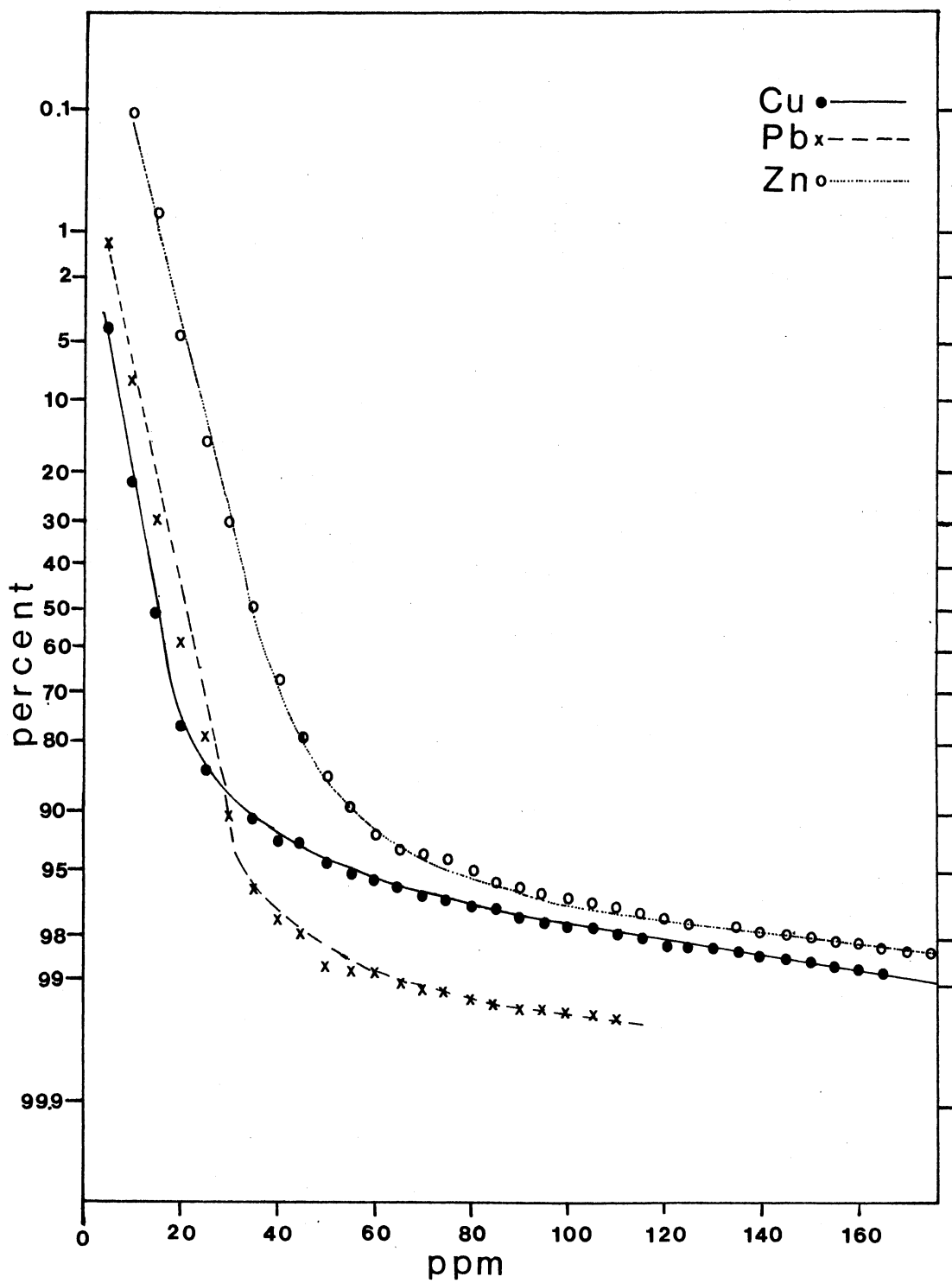


Figure 7. Probability Plot of Copper, Zinc, and Lead With Arithmetically Scaled Concentrations

distributed comes from plotting of cumulative frequency on probability-scale with arithmetic scale concentration (Figure 7). If the parent population was normally distributed, each element should plot as a straight line, with no breaks. However, from inspection of Figure 7, it is clear that copper, zinc, and lead cannot be represented by straight lines (Lepeltier, 1969; Tennant and White, 1959; Ahrens, 1954).

Multiple Populations

The distributions of copper, zinc, and lead in the study area are best represented by two distinct groups, a barren and a mineralized population. Evidence for this hypothesis comes from two sources. Binocular-microscopic examination of well-cuttings indicates that the vast majority of samples are devoid of any visible mineralization and constitutes the barren population; however, within some horizons evidence for mineralization is clear and these samples constitute the mineralized population. Statistical summary of geochemical data (Table IV) suggest multiple populations in several ways including large standard deviations with large positive skewness and kurtosis. Furthermore, Figure 8 shows two distinct populations for each element, each represented by a straight line (Lepeltier, 1969; Tennant and White, 1954).

Determination of Background, Threshold, and Anomalous Values

Geochemical exploration generates data which can be divided into two categories:

1. Background distribution--the normal range of concentration of elements exclusive of mineralized samples, and

2. Anomalous distribution--the concentration of elements above the upper limit of background and is related to mineralization.

Background and anomalous populations are separated by threshold values, which are defined as the upper limits of normal background variation; so that values higher than a threshold are therefore anomalous, possibly mineralized and worthy of further attention. Once a threshold value is determined for each element in a given rock, both background and anomalous concentrations are defined (Levinson, 1974; Lepeltier, 1969; Tennant and White, 1959). Hawkes and Webb (1962) suggest that thresholds can be calculated and set equal to the mean plus two standard deviations, but only if the data distribution represents a single population. Since there is evidence indicating that copper, zinc, and lead distributions are actually composed to two populations, the Hawkes and Webb (1962) formula is not applicable. Perhaps a more genetic method to determine threshold values in element distributions with multiple populations would be to plot such distributions on probability versus logarithmic concentrations (Figure 8; Table V). Best fitting straight lines may be drawn through each population and the intersection of two lines can be designated as a threshold point, separating background, and anomalous populations. Threshold values for copper, zinc, and lead have been determined in this manner for this study and are:

1. copper threshold = 55 ppm,
2. zinc threshold = 60 ppm, and
3. lead threshold = 50 ppm.

Copper, Zinc, and Lead Populations

Because the parent populations for copper, zinc, and lead are

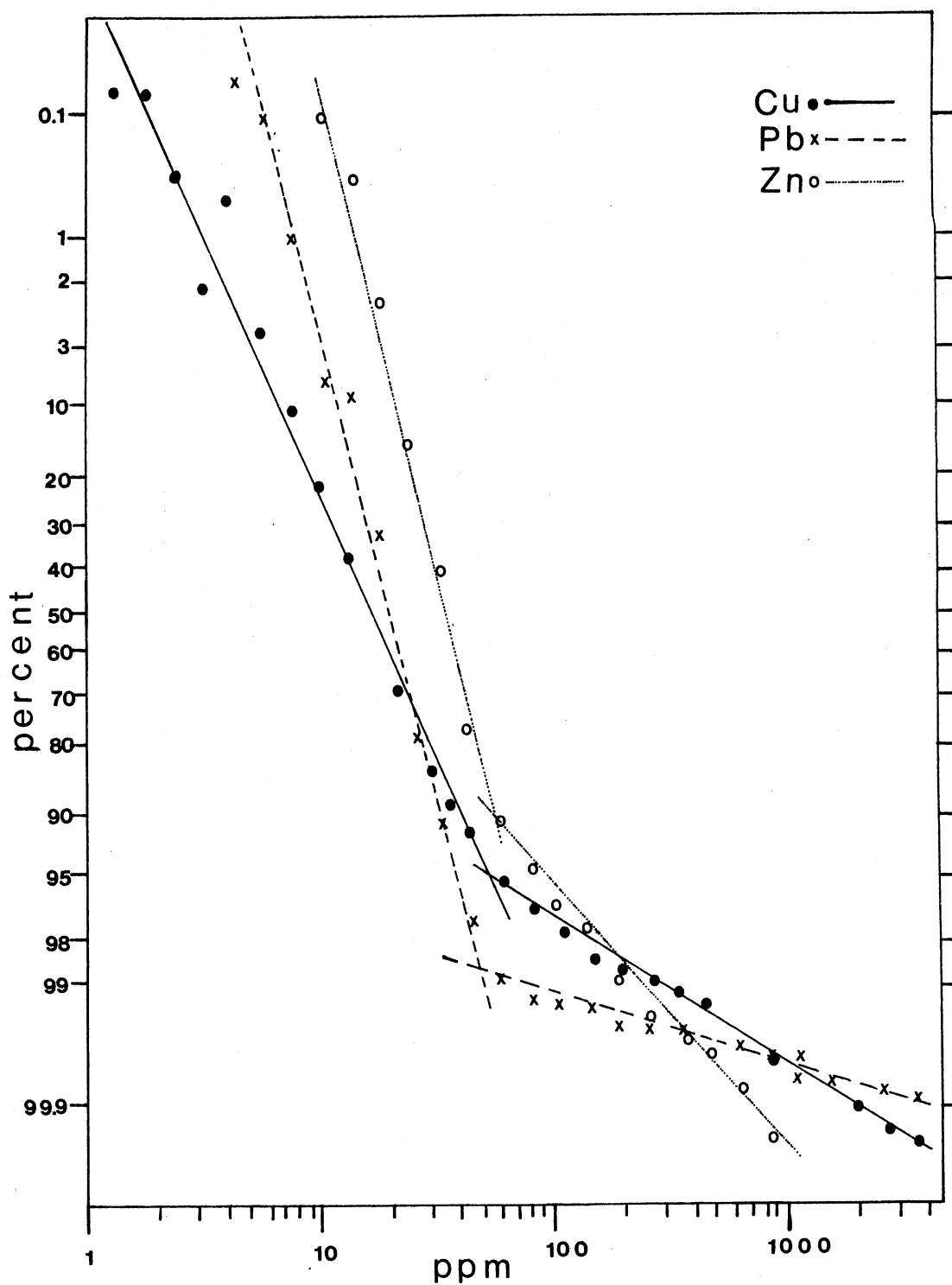


Figure 8. Probability Plot of Copper, Zinc, and Lead With Logarithmic Scaled Concentrations

TABLE V
INDIVIDUAL AND CUMULATIVE PERCENT DISTRIBUTION OF COPPER,
ZINC AND LEAD WITH LOG INTERVALS

	Log Interval*	Copper		Zinc		Lead	
		Individual Percent	Cumulative Percent	Individual Percent	Cumulative Percent	Individual Percent	Cumulative Percent
1	0.00- 1.30	0.06	0.06	---	---	0.05	0.05
2	1.30- 1.80	0.00	0.06	---	---	0.00	0.05
3	1.80- 2.40	0.28	0.33	---	---	0.00	0.05
4	2.40- 3.20	0.78	2.21	---	---	0.00	0.05
5	3.20- 4.30	1.33	2.44	---	---	0.00	0.05
6	4.30- 5.80	1.66	4.10	---	---	0.12	0.12
7	5.80- 7.80	6.09	10.18	---	---	0.00	0.12
8	7.80- 10.40	11.73	21.92	0.11	0.11	6.75	7.97
9	10.40- 13.90	15.66	37.58	0.22	0.33	1.22	9.18
10	13.90- 18.70	31.10	68.68	2.38	2.71	22.07	31.25
11	18.70- 25.04	15.94	84.61	12.33	15.04	48.01	79.26
12	25.04- 33.60	4.70	89.32	25.11	40.15	11.56	90.82
13	33.60- 44.90	3.99	93.30	36.39	76.55	6.53	97.35
14	44.90- 60.30	2.04	95.35	14.05	90.60	1.60	98.95
15	60.30- 80.80	1.61	96.96	4.09	94.69	0.28	99.23
16	80.80-108.30	0.89	97.84	1.99	96.68	0.22	99.45

TABLE V. (Continued)

	Log Interval*	Copper		Zinc		Lead	
		Individual Percent	Cumulative Percent	Individual Percent	Cumulative Percent	Individual Percent	Cumulative Percent
17	108.30- 145.10	0.72	98.56	1.16	97.84	0.05	99.50
18	145.10- 194.40	0.22	98.78	9.40	98.78	0.00	99.50
19	194.40- 260.60	0.11	98.89	5.53	99.34	0.05	99.56
20	260.60- 349.20	0.11	99.00	2.21	99.56	0.05	99.61
21	349.20- 467.90	0.22	99.22	2.21	99.78	0.00	99.61
22	467.90- 627.10	0.33	99.56	0.11	99.89	0.11	99.72
23	627.10- 840.50	0.17	99.72	0.05	99.95	0.00	99.73
24	840.50-1126.30	0.11	99.83	0.05	100.00	0.00	99.73
25	1126.30-1509.00	0.00	99.83	0.00	0.00	0.17	99.89
26	1509.00-2023.00	0.06	99.89	0.00	0.00	0.00	99.89
27	2023.00-2711.00	0.06	99.95	0.00	0.00	0.00	99.89
28	2711.00-3633.00	0.00	99.95	0.00	0.00	0.00	99.89
29	3633.00-4869.00	0.00	99.95	0.00	0.00	0.05	99.95
30	4869.00-6525.00	0.06	100.00	0.00	0.00	0.05	100.00

*Log interval = 0.127.

statistically complex, it would be useful to determine the statistical characteristics of the background and mineralized subpopulation separately for each element. Table IV is a statistical review of the parent, background, and mineralized populations which displays several important trends. The mineralized group, as expected, shows a manifold increase in the mean, since only values greater than a given threshold are being considered. But, because only anomalous values were included, with their wide range of concentrations, the standard deviation, variance, and the standard error of the mean all increased substantially. Perhaps most important of all, the skewness and kurtosis values for the mineralized populations dramatically shifted to a more normal range. Anomalous groups only approach normal distributions, but they do not actually attain normalcy. The background population, as expected, shows a consistently lower mean concentration for copper, zinc, and lead. Furthermore, as a result of limited ranges of variation (between zero and the threshold value for the particular element) there were significant decreases in the standard deviation, variance, and the standard error of the mean. The skewness and kurtosis for the background populations have decreased so much that they appear to be near normally distributed.

Copper Distribution in Stratigraphic-Geochemical

Cross Sections

From the inspection of Plates 1, 2, 3, and 4, it is evident that a significant copper mineralization zone is located in the Upper Shales Member of the Wellington Formation. Where it is best developed, as many as four distinct horizons may be encountered within a 250 to 320 foot interval. Excellent examples of this fully developed copper sequence

can be found in Wells 8 and 10 (Plate 2). Wells in Kay and eastern Grant Counties may not have this copper zone, either because well-cuttings were not recovered during the drilling or wells are to the east of the copper outcrop belt. From strong showings of copper in the easternmost wells, there is reason to suspect that these mineralized zones extend farther east into shallower depths. But how far east is uncertain and would require additional shallow wells to determine their extent. To the west this copper zone seems to contain fewer mineralized horizons and usually with reduced copper concentrations, suggesting the copper zone pinches out to the west. Figure 9 is a geochemical map of the copper zone for the study area and was prepared in the following manner: (1) each well was studied to determine the number of copper zones it contained and the maximum concentration for each zone; (2) an average copper value was determined for each well based on the number of copper zones in the Upper Shales Member of the Wellington Formation; and (3) areas of equal copper content were mapped (Table VI). The resulting geochemical map illustrates the variation of Upper Shales Member copper in the western two-thirds of Grant County. The most promising geochemical prospect area is outlined by the 1000 ppm and greater copper pattern.

Other copper anomalies are present elsewhere in the sections; however, they are not as large or as correlatable as those in the Upper Shales Member copper zone. Examples of these untraceable copper anomalies may be found in the Lower Evaporites Member of Wells 18 and 19 (Plate 4), which contains three or four low-level anomalies at various stratigraphic horizons. Copper anomalies of this sort are not associated with significant, observable mineralization in well-cuttings as are those of the Upper Shales Member.

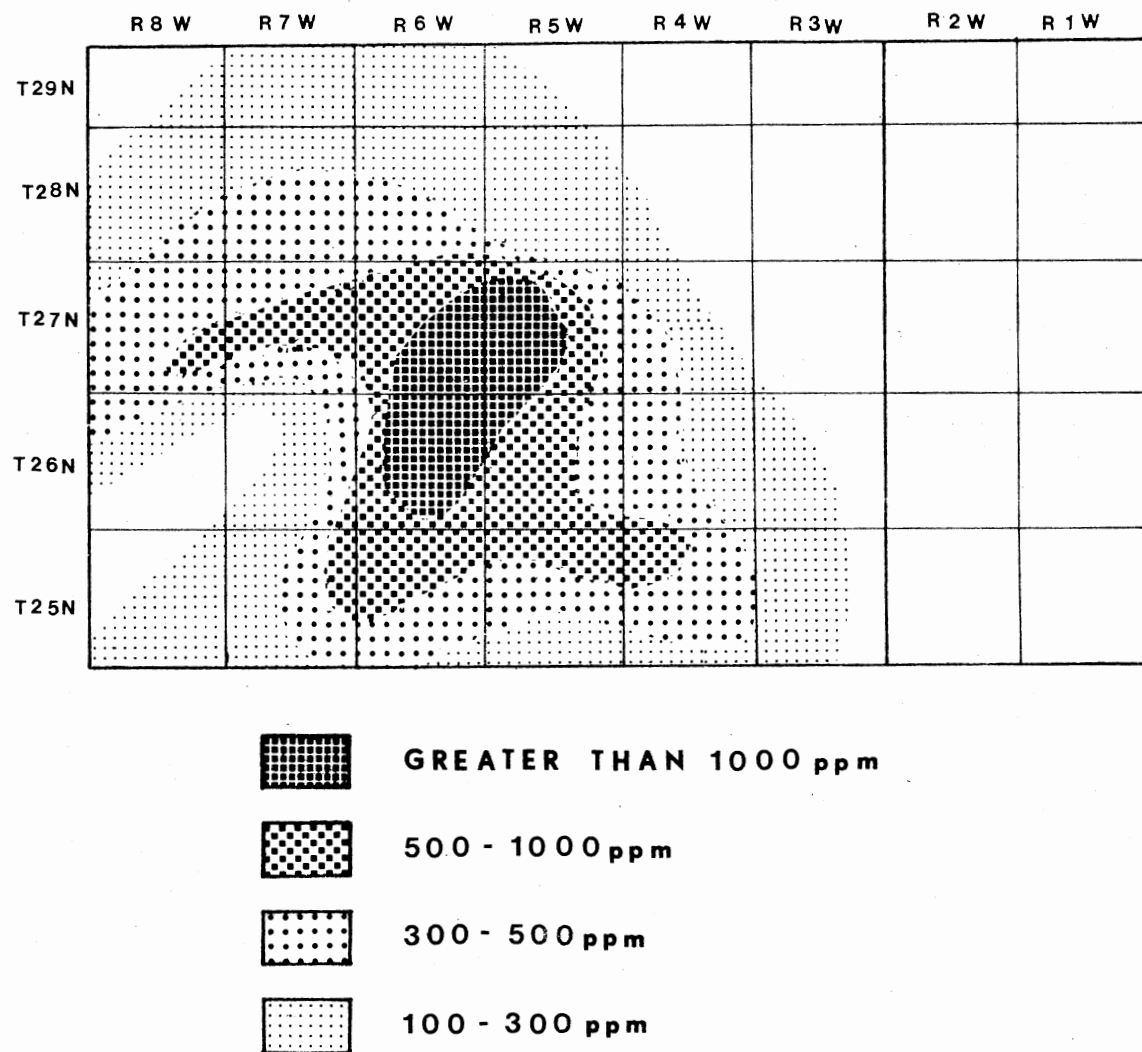


Figure 9. Copper Distribution in the Upper Wellington Formation in North-Central Oklahoma

TABLE VI
AVERAGED COPPER CONTENT OF THE MINERALIZED ZONES
IN THE UPPER WELLINGTON FORMATION

Well No.	Copper Content (PPM)
1	135
2	277
3	661
4	N.D.*
5	N.D.
6	N.D.
7	44
8	906
9	N.D.
10	438
11	N.D.
12	N.D.
13	463
14	3070
15	N.D.
16	N.D.
17	88
18	350
19	139
20	90
21	N.D.

* N.D. = no data.

Zinc Distribution in Stratigraphic-Geochemical

Cross Sections

Anomalous zinc concentrations in Plates 1, 2, 3, and 4 do not seem to be organized into distinct, correlatable zones as were the copper. There is, however, some indication of minor zinc zones in the Upper and Middle Shales Members in the eastern portions of Plates 2 and 4, but they are not clearly defined. The best example of this phenomenon is in Wells 9, 10, and 11 of Plate 2. In each well the zinc zone ranges in thickness from 200 to 250 feet with two or three discontinuous zinc horizons.

Lead Distribution in Stratigraphic-Geochemical

Cross Sections

Anomalous lead concentrations are extremely discontinuous and occur in what seems to be unrelated stratigraphic horizons. For example, Well 2 (Plate 1) has a mineralized lead horizon at the base of the Lower Evaporites Member, Well 7 (Plate 2) has lead zones at the base of the Garber Sandstone, the Upper Evaporites Member and the Lower Shales Member, and Well 21 (Plate 4) has three distinct lead zones in the Upper and Middle Shale Members. Lead anomalies, unlike zinc anomalies, are much more intense (similar to copper) but appear to have no correlatable trends.

Ore Petrology of the Upper Wellington Formation

Chalcocite seems to be responsible for copper anomalies in the upper Wellington Formation of the shallow subsurface of Grant County. The morphology of chalcocite observed in this area is quite varied, and

includes: (1) fine-grained disseminations, (2) veinlets, (3) irregular patches, (4) mineralization in carbonate vugs, and (5) pseudo-hexagonal and cubic forms.

Fine-grained disseminations of chalcocite are the most abundant forms of mineralization and may range in size from 200 microns down to the limit of resolution of the microscope (Figure 10). Smaller grains have irregular forms whereas some larger grains may have pseudo-hexagonal or cubic forms. These fine-grained disseminations are often bimodally distributed as suggested in Figure 10, and are the principal source of copper anomalies in the upper Wellington Formation.

Another less frequently encountered mineralization form are veinlets of chalcocite up to 500 microns in length. Chalcocite veinlets are not commonly observed, but occur mainly in gray shales (Figures 11 and 12), but may be found in fine-grained micritic carbonates (Figure 13). Of further interest is the shadow phenomenon associated with veinlets in gray shales (Figures 11 and 12) which suggests that the veinlet plane extends down below the surface of the thin section casting a shadow. These veinlets were perhaps compaction fractures that were later mineralized, and based on their scarcity, are not expected to contribute substantially to the overall copper content of the upper Wellington Formation.

Irregular patches of chalcocite are very common and are second only to fine-grained disseminations in abundance. This group consists of wide-ranging shapes generally larger than 100 microns and can be found in either shales or carbonates. Irregular patches of chalcocite within carbonates tend to be found where micrite recrystallization is slightly more intense (Figures 14 through 17). Figure 18 shows an irregular

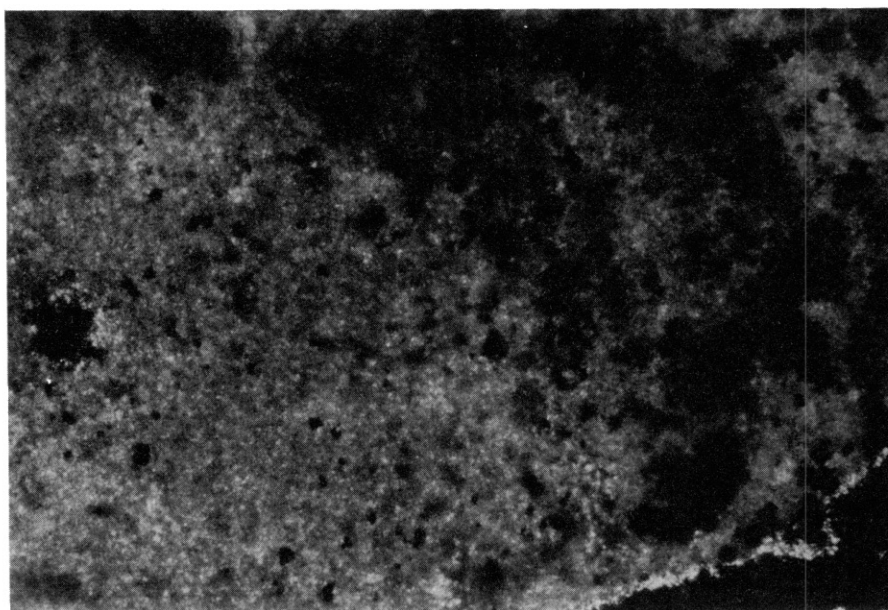


Figure 10. Fine-Grained Disseminated Chalcocite (Black)
in Fine-Grained Micritic Carbonate,
Transmitted Polarized Light (X10)

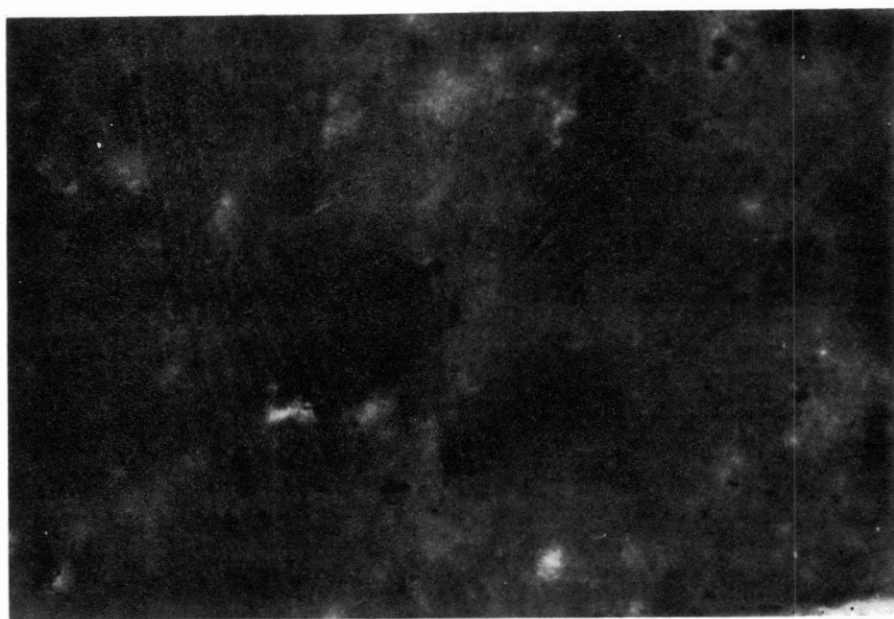


Figure 11. Chalcocite Veinlets (Black) in Gray Shale, Transmitted Polarized Light (X10)



Figure 12. Chalcocite Veinlets (Black) in Gray Shale, Transmitted Polarized Light (X11)

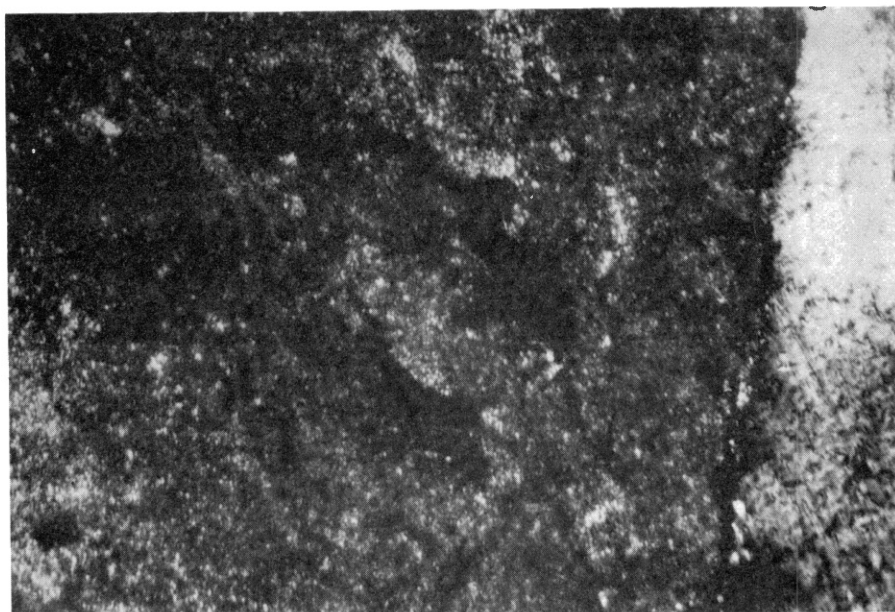


Figure 13. Chalcocite Veinlets (Black) in
Fine-Grained Micritic Carbon-
ate, Transmitted Light (X10)

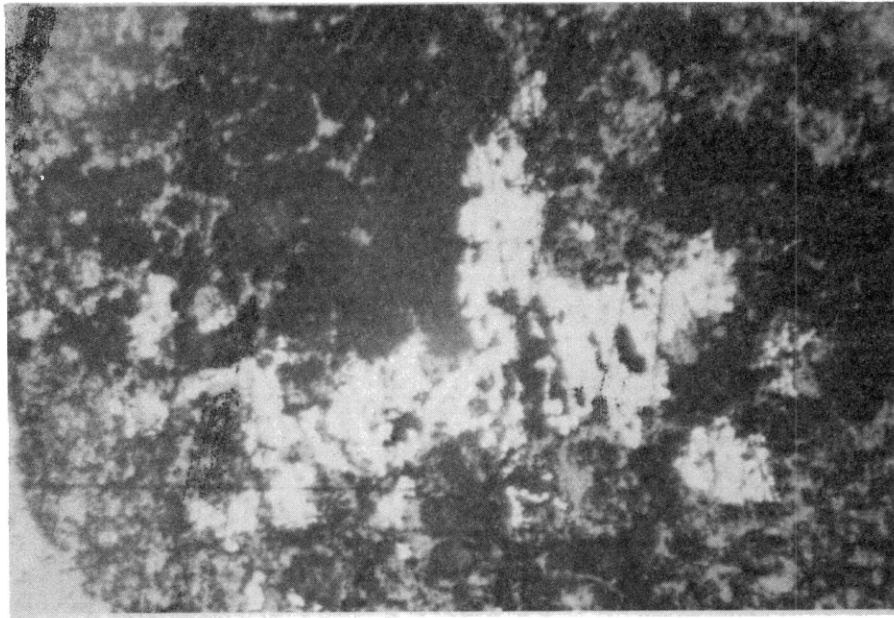


Figure 14. Irregular Chalcocite Patch (White) in
Medium-Grained Micritic Carbonate,
Polished Ore Section (X10)

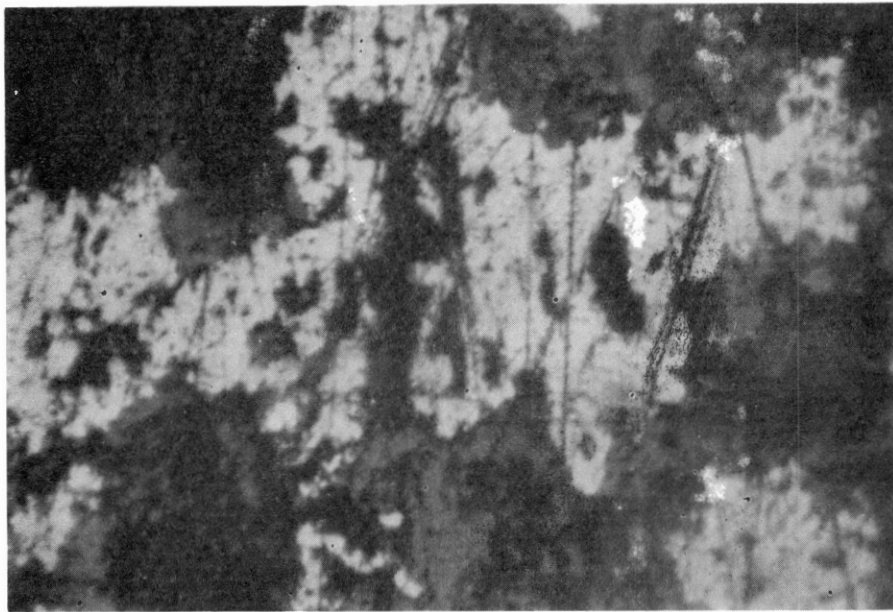


Figure 15. Irregular Chalcocite Patch (White),
Same as Figure 14 but Enlarged
(X20)

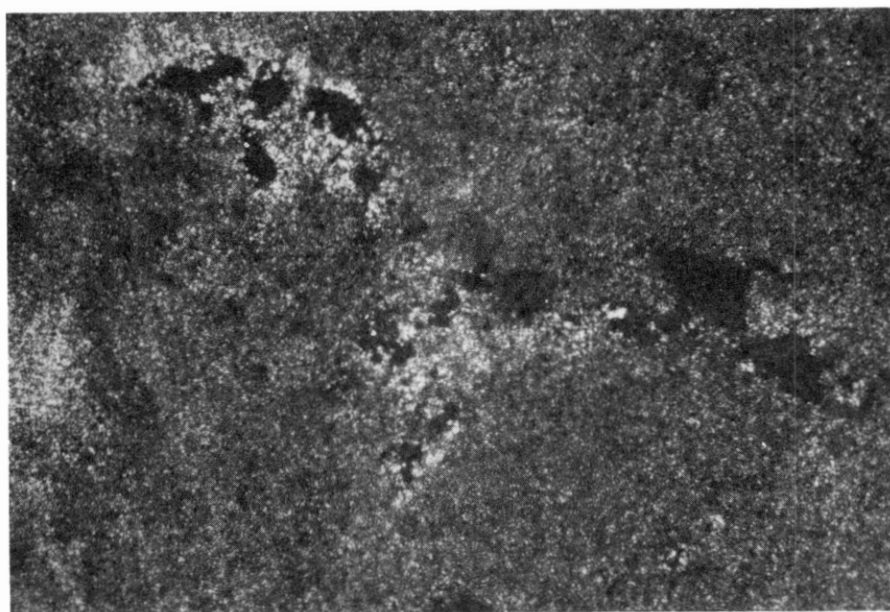


Figure 16. Irregular Chalcocite Patches (Black) in
Fine- to Medium-Grained Micrite,
Transmitted Polarized Light (X10)

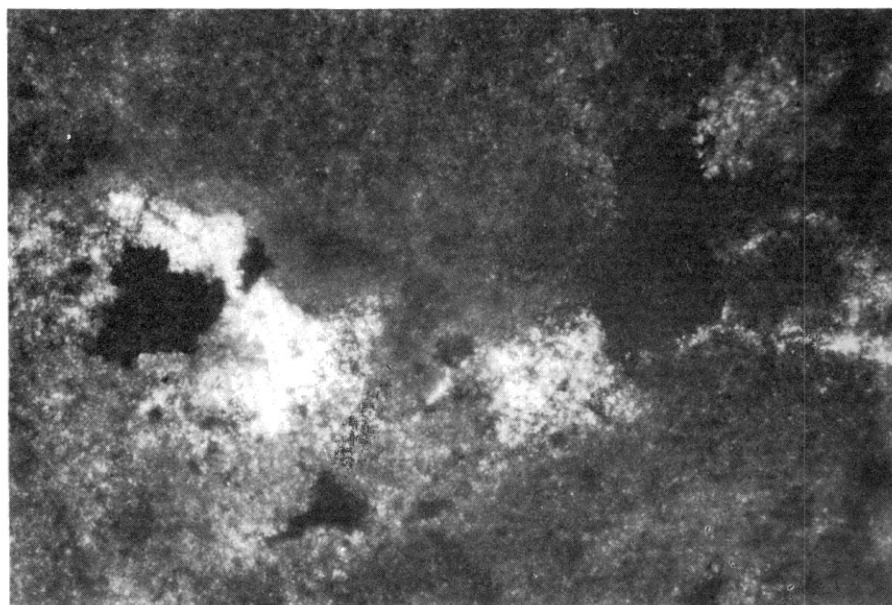


Figure 17. Irregular Chalcocite Patches (Black) in
Fine- to Medium-Grained Micrite,
Transmitted Polarized Light (X10)

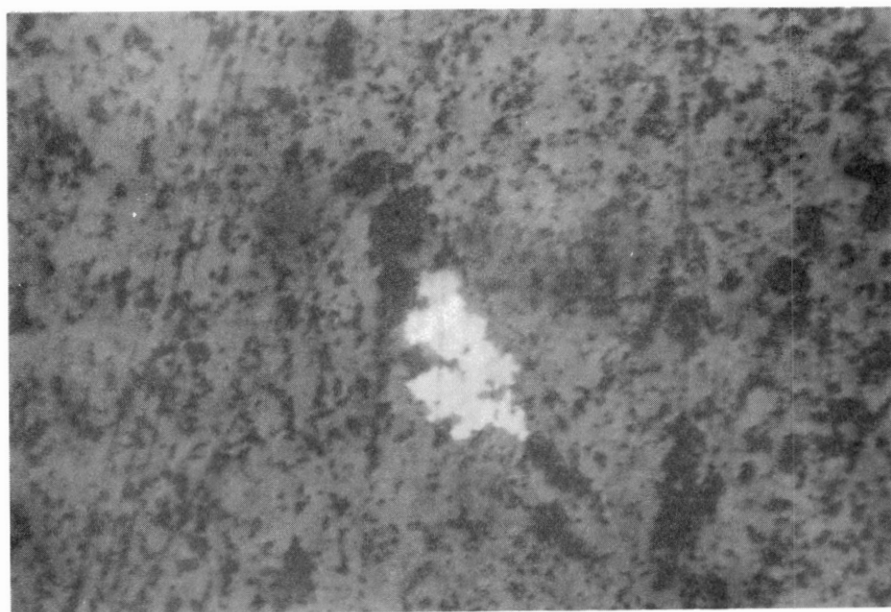


Figure 18. Irregular Patch of Chalcocite (White)
With Two Phases in Gray Shale,
Polished Ore Section (X20)

shaped grain with two phases of chalcocite in gray shale. Figure 19 is an irregular mineralization form that suggests that the digestive tract of burrowing organisms may have been replaced by chalcocite. Similar to veinlets, the shadow phenomenon permits tracing the burrow below the viewing surface of the thin section.

Chalcocite grains that have grown in carbonate vugs are another form of mineralization but are not a significant contributor of copper. Most chalcocite growths only partially fill vugs, which are later flooded by silica (Figures 20 through 23).

Pseudo-hexagonal and cubic forms of chalcocite are the least abundant habit in the upper Wellington (Figures 24 and 25). These forms are the result of either replacement of pyrite or the growth of primary chalcocite crystals.

Clay Minerals Distribution

Clays of the Wellington Formation consist principally of illite, kaolinite, and chlorite. Tables VII and VIII list the clay distribution from the upper and lower Wellington Formation in this study area. Table IX is a statistical summary of the Wellington clays where the mean, standard deviation, and variance were calculated. Based on this data, illite was found to be dominant with an average of 60.5 percent, whereas kaolinite was 22.4 percent, and chlorite was only 16.9 percent.

The upper and lower Wellington clays are quite similar; however, there are some interesting differences. The lower Wellington clays tend to be significantly richer in illite (55.5 percent for the upper and 62.0 percent for the lower), and kaolinite (22.9 percent for the lower and 21.4 percent for the upper). The upper Wellington clays, on the other

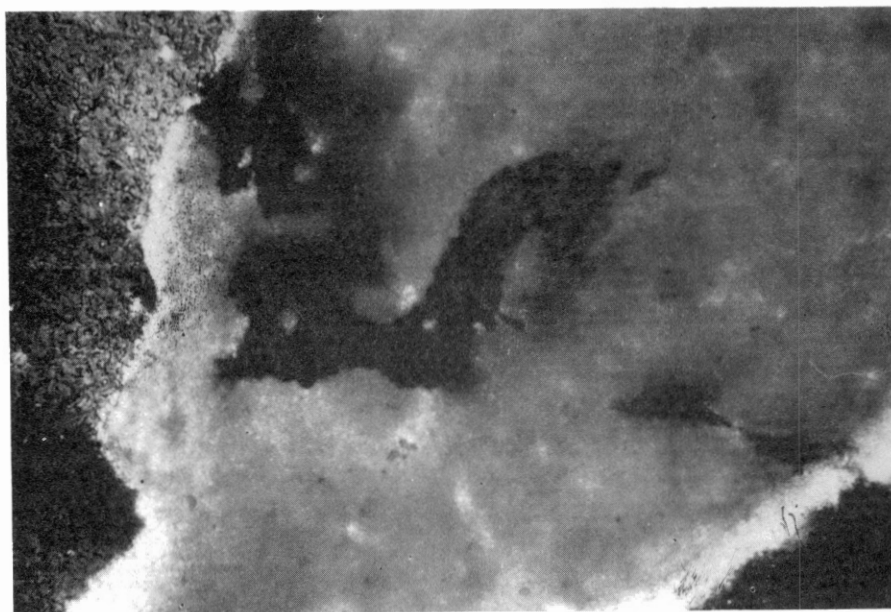


Figure 19. Irregular Patch of Chalcocite (Black)
in the Form of a Burrow in Gray
Shale, Transmitted Polarized Light
(X11)

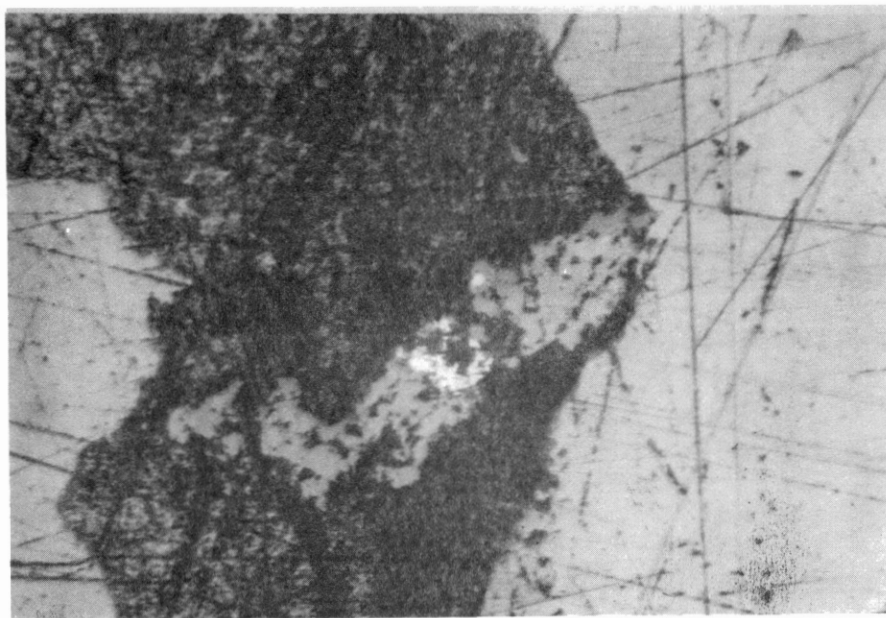


Figure 20. Chalcocite Grain (White) Partially Filling a Carbonate Vug, Polished Ore Section (X10)

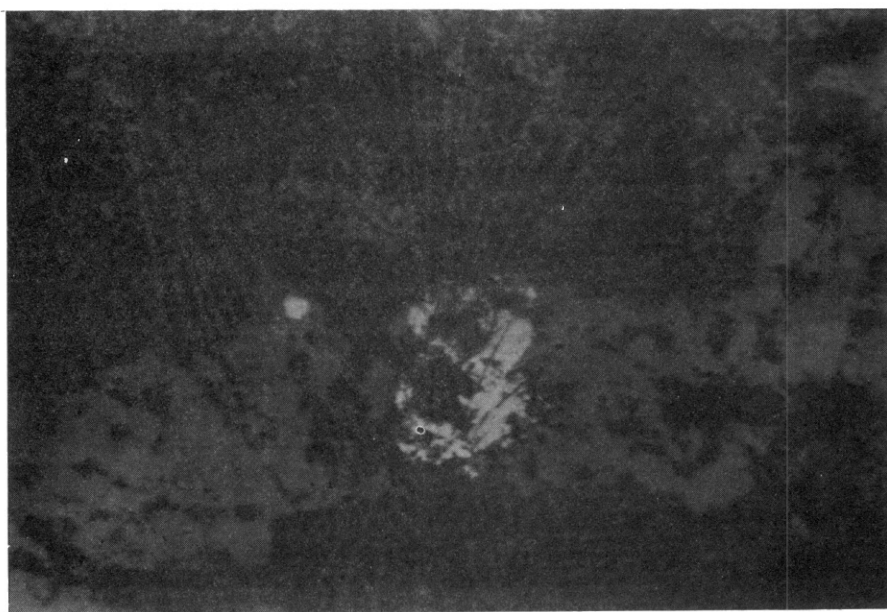


Figure 21. Chalcocite Grain (White) in Carbonate Vug, Same as Figure 20 but Enlarged, Polished Ore Section (X20)



Figure 22. Chalcocite Grain (Black) in a Carbonate Vug, Same as Figure 21, but in Transmitted Polarized Light (X20)

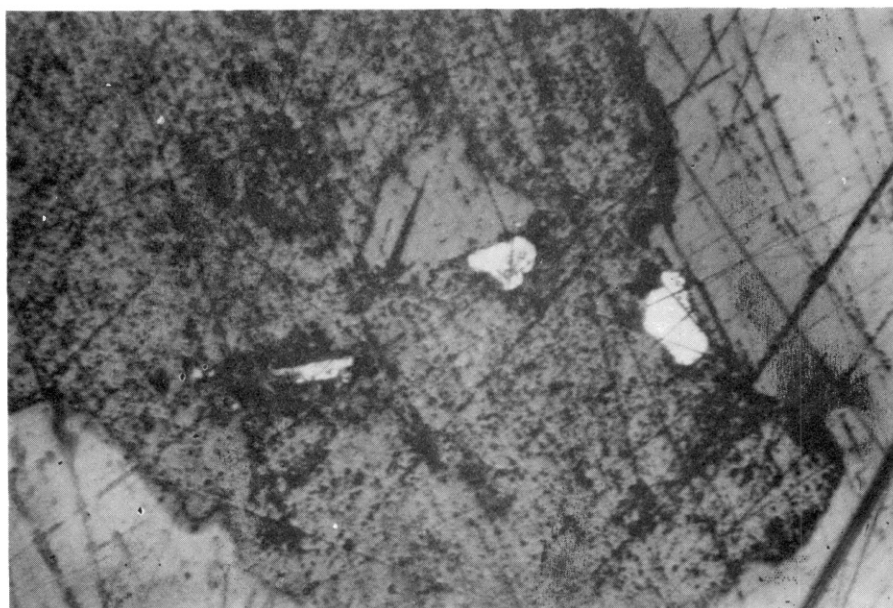


Figure 23. Chalcocite Grain (White) Partially Filling a Carbonate Vug, Polished Ore Section (X10)

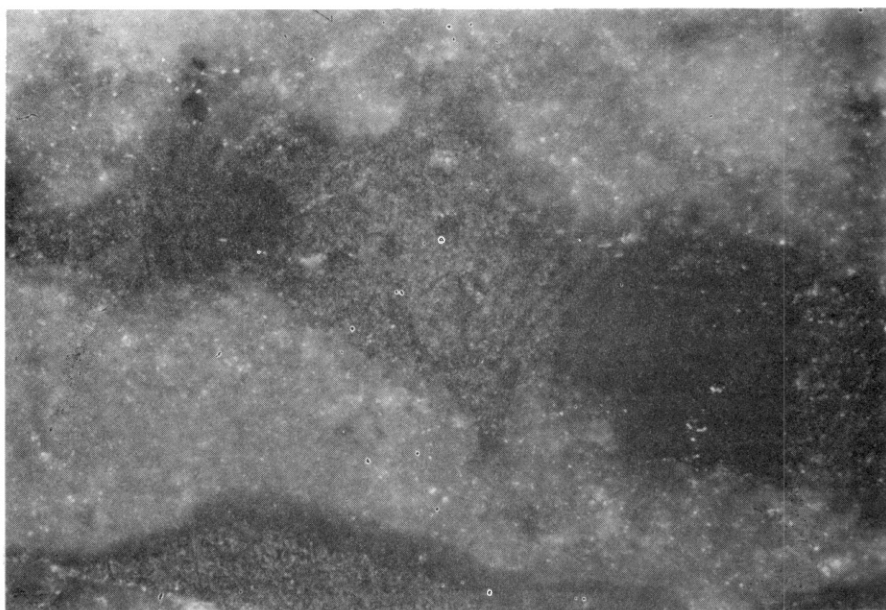


Figure 24. Cubic Chalcocite (Black) in Carbonate Vug, Transmitted Light (X10)

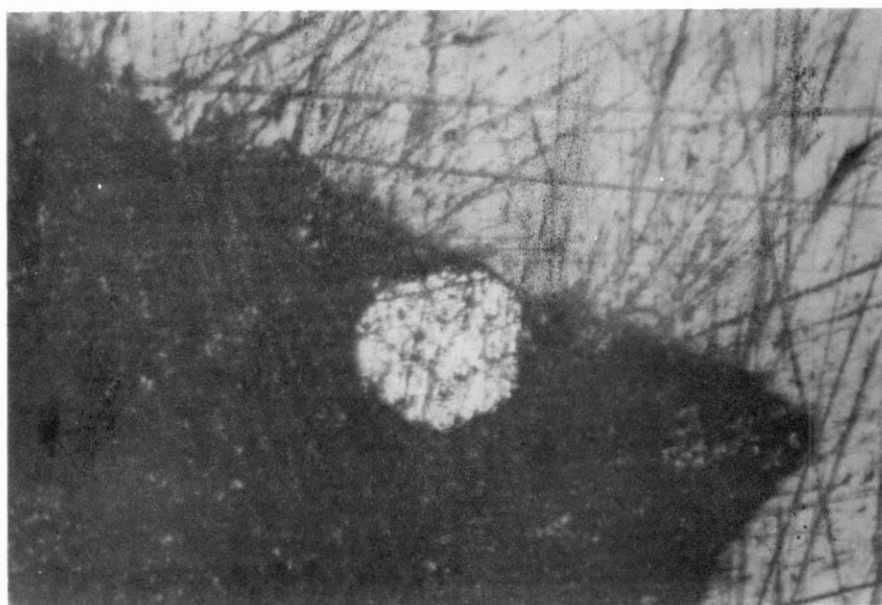


Figure 25. Pseudohexagonal Chalcocite (White) in Gray Shale, Polished Ore Section (X10)

TABLE VII
UPPER WELLINGTON FORMATION CLAYS IN PERCENT

Well No.	Kaolinite	Illite	Chlorite
1	17.3	65.7	16.9
2	21.1	66.2	12.6
3	26.5	63.3	10.2
7	24.1	68.9	6.9
8	9.2	34.3	56.5
9	17.6	76.5	5.9
10	22.2	51.9	25.9
11	6.4	58.2	35.5
13	26.1	63.0	10.9
14	42.3	38.5	18.2
17	21.1	52.6	26.3
18	15.3	76.3	8.5
19	19.5	56.1	24.4
20	31.3	50.0	18.8

TABLE VIII
LOWER WELLINGTON FORMATION CLAYS IN PERCENT

Well No.	Kaolinite	Illite	Chlorite
1	30.4	55.9	13.7
2	16.3	77.5	6.3
3	18.2	77.3	4.6
4	30.5	69.5	6.1
5	11.1	69.4	19.4
7	31.1	55.6	11.1
8	14.3	74.3	11.4
9	12.1	81.8	6.1
10	18.2	72.7	9.1
11	18.5	66.7	14.8
12	52.0	36.0	12.0
13	6.7	73.3	20.0
14	31.3	59.4	9.4
15	37.3	63.6	9.1
16	21.2	66.7	12.1
17	17.8	55.6	26.7
18	26.7	40.0	33.3
19	21.7	56.5	21.7
20	25.0	27.3	27.3
21	16.7	60.0	23.3

TABLE IX
STATISTICAL SUMMARY OF THE WELLINGTON FORMATION CLAYS

Factor	Total	Upper Wellington	Lower Wellington
Kaolinite			
N =	34.0	14.0	20.0
Mean =	22.4	21.4	22.9
S.D. =	9.8	8.9	10.5
Var. =	92.6	74.1	104.7
Illite			
N =	34.0	14.0	20.0
Mean =	60.5	55.5	62.0
S.D. =	13.4	19.0	14.4
Var. =	174.1	336.2	197.1
Chlorite			
N =	34.0	14.0	20.0
Mean =	16.9	19.8	14.9
S.D. =	10.9	13.6	8.2
Var. =	114.5	172.6	63.6

hand, are slightly richer in chlorite (19.9 percent for the upper and 14.9 percent for the lower). These relationships are best observed in statistical summary (Table IX), although the illite-kaolinite-chlorite tertiary diagram suggests similar relationships; however, it is not quite as clear (Figure 26).

The kaolinite-chlorite fields map of the lower Wellington reflects the dominance of illite (Figure 27). There is only one significant kaolinite trend that extends approximately from the northeast to the southwest, in a diagonal fashion across this area. Other kaolinite-chlorite fields show no trend, and are in comparison quite limited.

This clay distribution fits into the lower Wellington paleoenvironments when it is considered part of the transgressive phase, where the Permian seas expanded and flooded the Wellington lowlands. The clay distribution, as illustrated, is strongly influenced by marine illite. The composition of this portion of the Wellington clays is quite similar to the Permian Zechstein sequence of Germany, which was found to be also dominated by marine illite (Weaver and Pollard, 1973). The generally weak and few kaolinite-chlorite trends may be the result of limited distributary channel development and the influence of tidal and long-shore currents.

The kaolinite-chlorite fields map of the upper Wellington indicates that there are four major trends represented: two kaolinite and two chlorite, each of which is elongated in the east-west direction (Figure 28). The illite content of the upper Wellington is shown to be depleted by the large areas occupied by other fields.

The clay distribution of the upper Wellington may be related to the regressive phase of the Permian sea, where Wellington sediments were

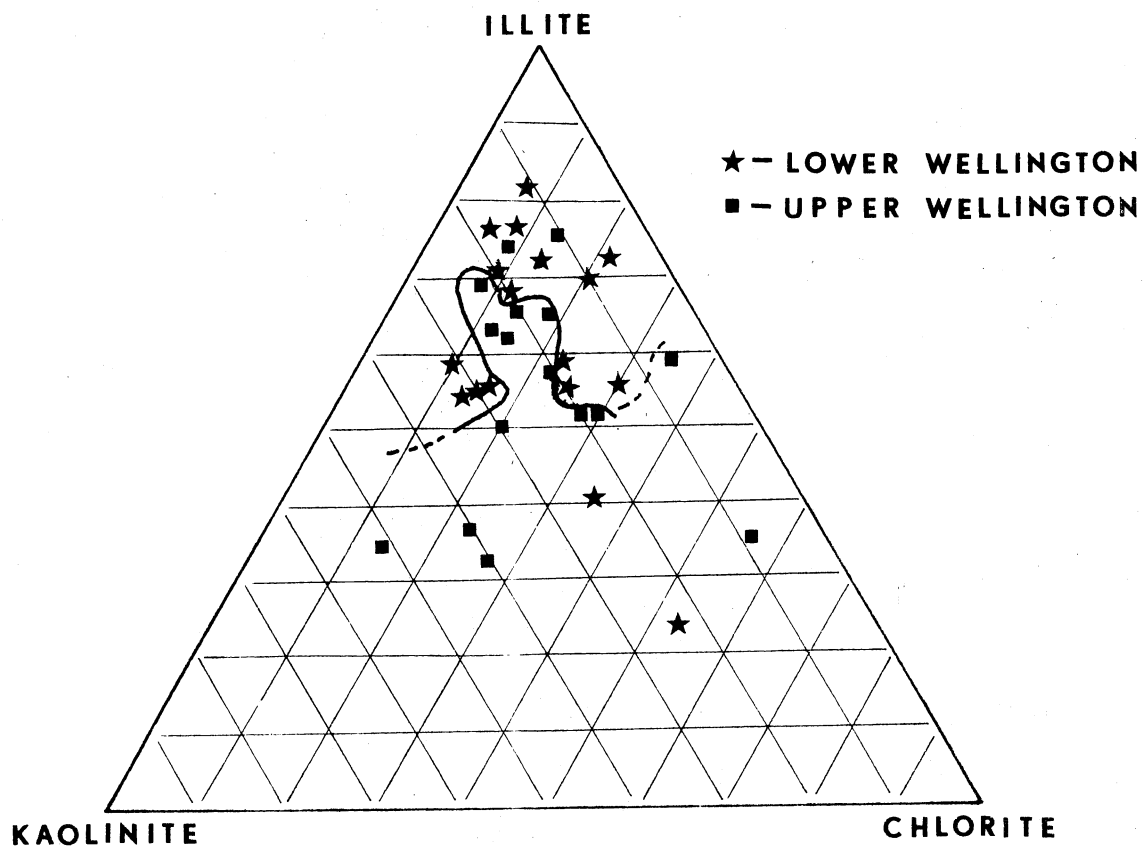


Figure 26. Tertiary Diagram of the Wellington Formation Clays

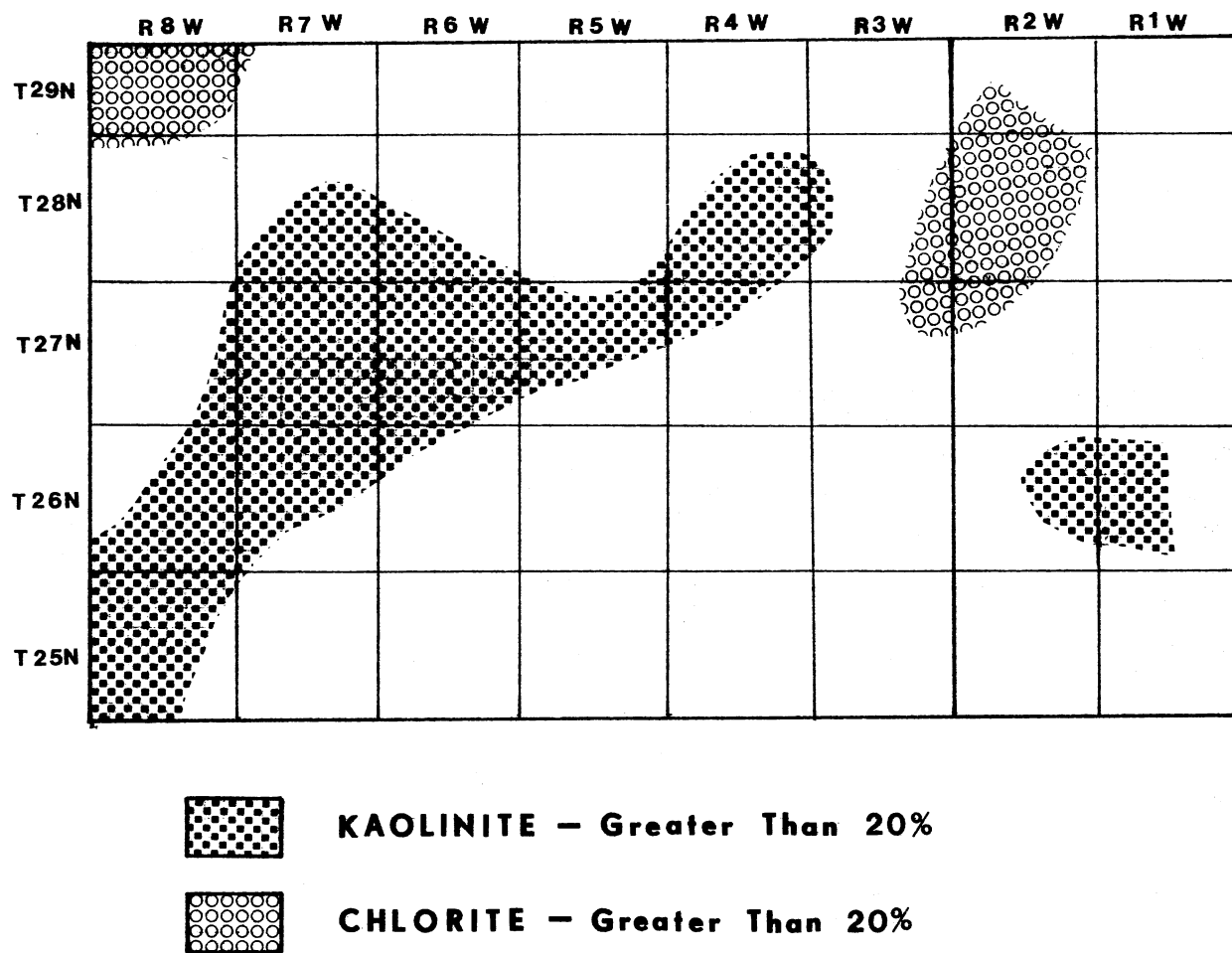


Figure 27. Lower Wellington Formation Kaolinite-Chlorite Facies Map

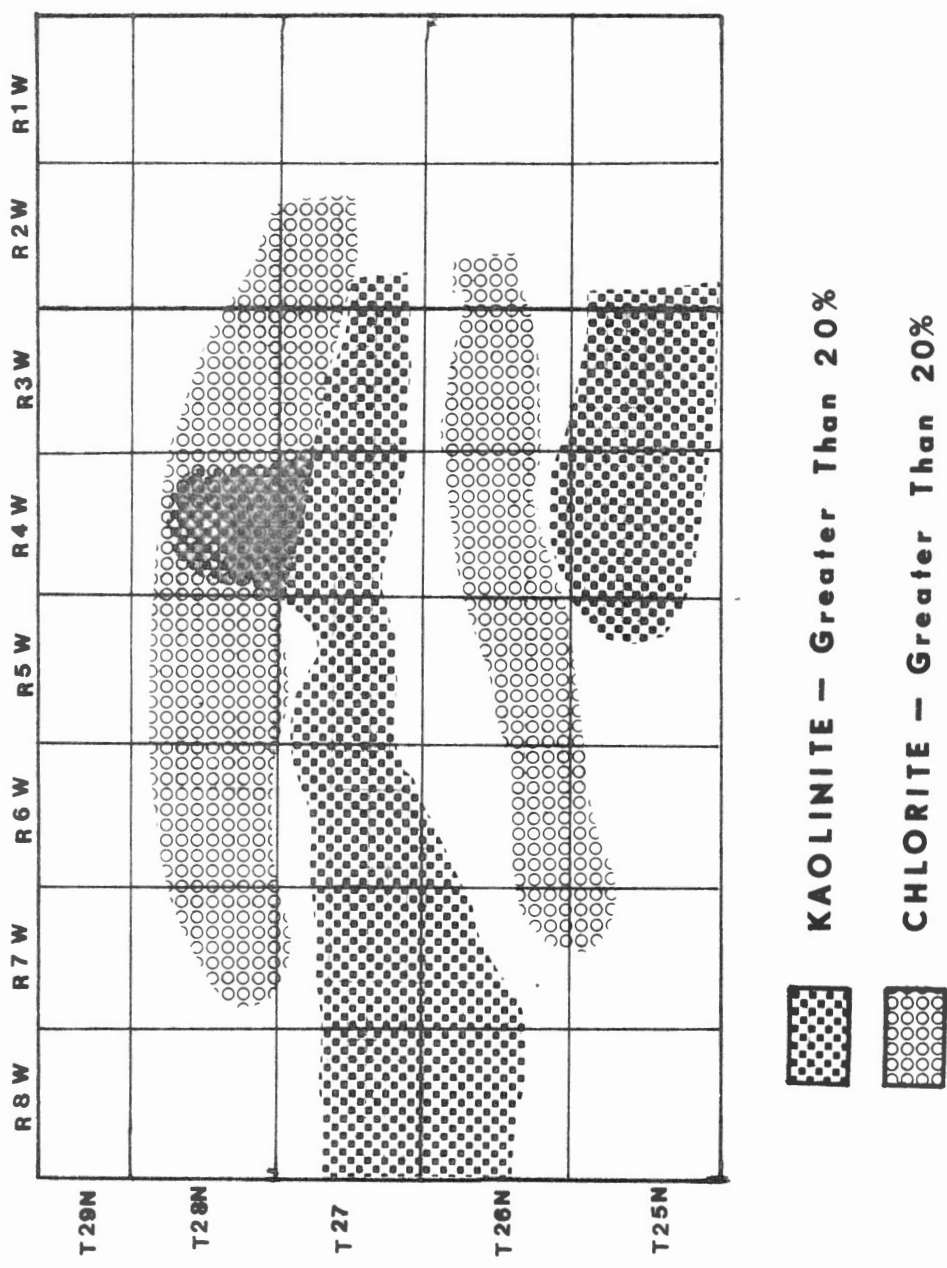


Figure 28. Upper Wellington Formation Kaolinite-Chlorite Facies Map

advancing into the Permian basin. The clay of this section should be expected to be more terrestrially influenced, which is perhaps reflected in the reduced amount of illite and the increased importance of kaolinite, which is probably detrital. The kaolinite-chlorite fields may be related to the activity of streams on minor shallow marine topography.

The stratabound copper of the upper Wellington Formation thus seems to be related to the major regression of the Permian sea. Furthermore, copper mineralization seems to be hosted by rocks influenced by the terrestrial phase of the Wellington as evidenced by detrital clay in the shales and the intertidal origin of the carbonates.

Comparison With Regional Occurrences

Permian redbed stratabound copper of the Midcontinent occurs over a wide geographic area, and within varied host lithologies. But with all these variables, each copper occurrence shares many common characteristics with Midcontinent copper as a whole, including age, mineralogy, paragenesis, and possibly origin. The detailed work done at the Creta and to a lesser extent at the Mangum District permits some speculation regarding similarities and differences between the Grant County occurrence and these Districts.

Mangum District, Greer County

The copper bearing-bed at the Mangum District is a medium gray, laminated silty shale called the Meadows Copper Shale, and is 30 to 35 feet from the top of the Flowerpot Shale. The Meadows Copper Shale varies in thickness between 4 and 18 inches with an average of 14 inches.

Copper mineralization is not uniform throughout the entire interval, but averages about 1.1 percent and ranges from 0.5 to more than 2.0 percent.

Since the Mangum deposit has not yet been mined and studied in as much detail as the Creta deposit, it is not as well understood. Nearly all testing has been at the outcrop or in shallow test pits. Disseminated malachite is reported to be the dominant copper-sulfide so far, but some test pits have recovered chalcocite under 10 to 15 feet of overburden, and it is likely to be the dominant ore mineral for the Meadows Copper Shale in the shallow subsurface (Johnson, 1976).

Creta District, Jackson County

The mineralized unit at this deposit is a medium gray, gypsiferous silty shale called the Prewitt Copper Shale and is 35 to 40 feet below the top of the Flowerpot Shale. The Prewitt Copper Shale ranges in thickness from 3 to 12 inches, but averages about 8.5 inches, with an average ore grade of about 2.0 percent copper, and ranges from 0.5 to 4.5 percent. The principal copper-sulfides at this deposit are chalcocite, malachite, and azurite, with minor quantities of botallackite and callaghanite. Chalcocite is the principal ore mineral mined at Creta, and occurs in various forms (Ham and Johnson, 1964).

1. Fine-grained disseminations of chalcocite 10 to 150 microns in diameter are most abundant, and whose shape varies from irregular to spherical. Spherical chalcocite disseminations are generally larger than irregular shaped grains and have been identified as replacements of spores. Nearly all the mineralization in the Prewitt Copper Shale is contained in spores replaced by chalcocite. There is an abrupt

contact between the mineralized zone and the barren rock above and below. Most of the spores exhibit only a minor degree of collapse and may appear slightly ellipsoidal; completely collapsed spores are uncommon at Creta. Spores of the Prewitt Shale have been identified as Triletes (Hagni and Gann, 1976).

2. Veinlets of chalcocite have also been reported in the Prewitt Copper Shale. These thin, flaky, irregular discontinuous veinlets are probably compaction fractures that may be as long as a few inches, but most are microscopic in size. These mineralized forms are of minor quantitative importance to the overall copper content of the Prewitt Shale, but suggest that copper-bearing solutions may have migrated through them during diagenesis. Veinlets have been reported along, as well as, across bedding planes, and appear to consist entirely of chalcocite without replacement remnants of other materials such as pyrite (Hagni and Gann, 1976).

3. Amoeboid patches and stringers of chalcocite are a conspicuous form of mineralization at Creta. Typically, they are elongated and meander randomly. These patches seem to be confined to non-laminated, bioturbated, blocky shale beds and thus they may have been formed in digestive tracts of burrowing organisms (Hagni and Gann, 1976).

4. Pyrite replacement by chalcocite occasionally indicates its origin when the process is not complete. In these cases, islands of pyrite (atoll structure) may be found where chalcocite completely surrounds pyrite. Chalcocite pseudomorphs of pyrite may occasionally be found (Hagni and Gann, 1976).

The origin of copper mineralization at Creta is told by the replacement of spores and pyrite, chalcocite veinlets, and some encroachment on

quartz grains, indicating that mineralization occurred after deposition with some diagenesis of the host sediments. Additional evidence from sulfur-isotope studies indicate that the sulfur was biogenically produced and probably diagenetic (Lockwood, 1972). The origin of the mineralizing solution is uncertain and is without any indications of faulting, folding, or hydrothermal activity (Lockwood, 1972; Dingess, 1976; Hagni and Gann, 1976; Kidwell and Bower, 1976).

Speculation on the Origin of Redbed Copper in Oklahoma

The literature on the subject of redbed copper genesis reflects wide ranging opinions. The principal modes of origin of Permian redbed stratabound copper of the Midcontinent can be grouped into four categories: (1) syngensis, (2) epigenesis, (3) complex mixture of syngensis followed by epigenetic processes, and (4) diagenesis. The following is a brief review of these models and their application in Oklahoma.

Fischer (1937) described the origin of copper-vanadium-uranium-silver associated deposits in southwestern United States. He presented a syngenetic mechanism to explain mineralization in redbeds and in order to satisfy certain geologic relationships: (1) lenticular nature of ore bodies, (2) the restriction of mineralization to limited lithologic horizons, and (3) the absence of any evidence of structural control over mineralization. Fay (1975) applied a similar syngenetic mechanism when he concluded that sedimentary chalcocite deposition occurred in environments beyond delta margins and a long basin margin. In these areas there was a mixing of fresh water from the land with near-shore marine water which resulted in the deposition of copper.

Rogers (1916) examined polished sections of redbed copper-sulfides to determine their origin through textures. From the study of several deposits in Oklahoma and New Mexico, he noted that there were remarkable petrographic similarities and suggested that their origins are also similar. Based on textural relationships, he strongly emphasized an epigenetic argument.

Tarr's (1910) study of redbed copper in northeastern Payne County suggested a complex origin for this occurrence. He constructed a model where Permian streams flowed into an inland bay of the Permian sea, and brought both metallic salts and fragments of wood together. Organic matter produced locally reduced conditions where copper-sulfides precipitated during sedimentation. A second mineralization event occurred after these sediments were deeply buried, lithified, and brought back to near the surface where remobilization of copper enriched pre-existing copper forms and the remaining unmineralized organic debris.

Lockwood (1972) compared the Creta and Mangum deposits and concluded that a diagenetic origin for both these occurrences seemed to fit observations regarding: (1) paragenesis of ore minerals, (2) presence of diagenetic sulfur, (3) geometry of the ore bodies, and (4) relationships to organic content.

Genesis of Copper Mineralization in North-Central Oklahoma

Host lithologies for chalcocite mineralization in Grant County are carbonates and gray shales. The carbonate hosts are thin, vuggy, fine- to medium-grained micrites, with some minor recrystallization. Some vugs record a sequence of events where minor fine calcite grew around

the rim, followed by a chalcocite mineralization event and finally a silica flood which filled the rest of the vug space. Mineralization in gray shales and carbonates occurred in various forms: (1) fine-grained dissemination, (2) veinlets, (3) irregular patches, (4) mineralization in vugs, and (5) cubic or hexagonal pseudomorphs.

The first estimation of the geometry of this copper deposit would be an irregular blanket, paralleling a portion of the ancient Permian shoreline (Figure 9). Since the margins of this deposit apparently exceed the confines of the study area, the ultimate geometry of this body is not certain.

All significant copper-sulfide mineralization is confined to the Upper Shales Member of the Wellington Formation. In fact, where mineralization is most intense, four distinct zones may be observed in various stratigraphic positions that do not seem to fluctuate substantially in this area. The restriction of the copper to these horizons, without any evidence of structural or hydrothermal activity, suggests to this writer a strong lithologic control.

The Grant County occurrence has some apparent vertical and horizontal zonations with respect to copper and zinc. The copper zone is found stratigraphically higher in the section and possibly extending farther into the basin than the zinc.

The genesis of the Grant County deposit, in this writer's opinion, is probably related to diagenetic processes, which would explain the geologic relationships discussed earlier. The mechanism that caused the mineralizing solution to pass through these favorable lithologies is uncertain. The sabkha process described by Renfro (1974) is indeed plausible, and has already been applied to the Midcontinent by Smith (1975).

An alternative to the sabkha model is Rose's (1976) suggestion that cuprous chloride complexes are important in understanding the origin of redbed copper. He recognized that normal oxidized ground and surface waters, at reasonable pH values had negligible copper solubilities, and thus could not be mineralizing agents. However, copper, as CuCl_2^- and CuCl_3^{2-} with 0.5m Cl^- at intermediate Eh and pH, will have solubilities of about 100 ppm copper, and contains enough copper in solution to be an effective transporter of copper and possibly a mineralizing agent. Rose (1976) points to two geological situations likely to have high-chloride water associated with them: basins with evaporites and where connate waters are moving out of marine sediments. These oxidized connate brines escape from the underlying sediments during compaction and migrate upward where they may encounter organically-reduced conditions which will precipitate copper.

Copper mineralization characteristics in north-central Oklahoma seems to favor Rose's (1976) hypothesis. The chalcocite mineralization zone of the upper Wellington Formation is part of a major regressive sequence and is underlain by a thick wedge of evaporites and marine shales. During the compaction, connate water rich in chlorides complexed with copper migrates upward through the upper Wellington which contains terrestrially-related sediments and organic matter. This reduced environment causes the copper to precipitate in compaction fractions, as fine-grained disseminations, in carbonate vugs and as irregular patches. In general, the following relationships seem to be important in copper mineralization in the Midcontinent: (1) regressive sequences containing organic matter underlain by a thick marine transgressive wedge, (2) the transgressive wedge contains evaporites or marine shales

with saline connate waters rich in chlorides, (3) cuprous chloride complexes form in the connate water, and (4) compaction of these thick, marine sequences causes this solution to move upward through the reduced regressive sequences above, causing low temperature chalcocite to precipitate.

Source of Copper

The source of copper is perhaps the least problematic in the understanding of redbed copper genesis. The Wichita Mountains that were flanking the Permian sea to the south was an excellent source of Permian copper. Important contributors of copper were the gabbroic and anorthosite groups, which contained on the average 140 ppm and 20 ppm copper, respectively. Granites and rhyolites were less important, as they averaged only 11.0 copper. Following the late Pennsylvanian uplift, vast quantities of granite and gabbro were eroded and leached, as evidenced by local accumulations of more than 5,000 feet of granite wash (Al-Shaieb and others, 1976).

Fay (1975) proposed that the weathering and erosion of chalcopyrite deposits of the Ouachitas would release copper to streams under oxidizing conditions. These mineralized areas of the Ouachitas were emplaced by Virgilian time and are suggested to be an important source of Permian copper. Late Pennsylvanian and early Permian streams transported copper in solution to the Permian sea and seems to be a closer source of copper for the Grant deposit than the Wichitas, and may have had greater influence.

CHAPTER IV

SUMMARY

Geochemical exploration of the shallow subsurface of Grant and Kay Counties, Oklahoma has revealed several interesting ideas which can be summarized in the following:

1. The Upper Shales Member of the Wellington Formation contains anomalous copper mineralization trends which, when fully developed, may contain up to four distinct copper zones within 250 to 320 foot intervals. Chalcocite is the principal copper-sulfide phase of these trends which have an irregular blanket geometry. The eastern limit of the chalcocite zone remains to be tested to determine its concentration and extent near the surface.

2. Copper, zinc, and lead zonations are not very distinct; however, copper and zinc horizons do suggest some zoning patterns:

- a. a weak zinc zone appears to be stratigraphically lower than the copper zone;
- b. furthermore, the copper zone extends more basinward than the zinc zone. Lead anomalies are intense but do not appear to be organized into a definable trend.

3. Geochemical distribution of copper, zinc, and lead for this red-bed stratabound body is bi-modal.

4. The principal reason behind the skewed distribution of copper, zinc, and lead is that they consist of two distinct populations: a

background and a mineralized population.

5. Background and anomalous (mineralized) populations have been statistically separated by the determination of a threshold value for each element.

6. Petrographic studies of well-cuttings in polished thin sections indicate clearly that the mineralization occurred after the deposition of the host rocks and is probably of diagenetic origin.

7. Host rocks consist of gray shales and carbonates.

8. Clay studies of the Wellington Formation suggest that mineralization is related to terrestrially influenced, regressive portion of the Wellington Formation.

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APPENDIX A

CHEMICAL ANALYSIS OF WELL-CUTTINGS

TABLE X
CHEMICAL ANALYSIS OF WELL-CUTTINGS

Depth Interval	Copper (PPM)	Zinc (PPM)	Lead (PPM)	Depth Interval	Copper (PPM)	Zinc (PPM)	Lead (PPM)
Well No. 1 Sec. 29, T.25N., R.8W.							
220-240	141	249	108	1130-1150	25	47	25
240-260	72	45	36	1150-1170	53	52	30
260-280	10	55	33	1170-1190	30	44	25
280-300	8	44	28	1190-1210	16	43	30
300-320	7	46	32	1210-1230	40	47	25
360-380	6	60	31	1230-1250	22	50	28
420-440	9	67	16	1250-1270	19	51	30
440-460	11	73	46	1270-1290	25	50	33
460-480	10	47	25	1290-1310	40	46	30
480-500	7	52	18	1310-1330	69	61	23
500-520	6	53	13	1330-1350	18	47	25
520-540	8	67	28	1350-1370	93	111	40
540-560	9	57	29	1370-1390	72	93	55
560-580	5	84	51	1390-1410	28	48	25
580-600	9	46	20	1410-1430	34	69	43
610-630	5	35	35	1430-1450	27	94	45
630-650	4	33	15	1450-1470	21	144	30
650-670	4	71	25	1470-1490	17	109	25
670-690	20	33	30	1510-1520	41	64	25
690-710	5	58	25	1520-1530	24	183	25
710-730	7	47	20	1530-1540	85	51	20
730-750	25	73	15	1540-1550	80	104	25
750-770	9	49	20	1550-1560	56	151	50
770-790	8	46	15	1560-1570	25	108	27
790-810	7	42	15	1570-1580	47	147	26
810-830	8	41	13	1580-1590	77	69	25
830-850	10	37	15	1590-1600	47	186	28
850-870	19	47	15	1600-1610	24	182	70
870-890	41	48	18	1610-1620	35	69	25
890-910	158	45	15	1620-1630	37	92	35
910-930	34	47	13	1630-1640	15	76	20
930-950	47	50	15	1640-1650	43	47	50
950-970	51	40	15	1650-1660	21	135	20
970-990	106	49	15	1660-1670	20	71	20
990-1010	86	95	15	1670-1680	14	71	20
1010-1030	142	85	70	1680-1690	55	40	20
1030-1050	29	47	35	1690-1700	27	43	25
1050-1070	99	56	23	1700-1710	21	48	25
1070-1090	35	79	23	1710-1720	15	33	20
1090-1110	72	48	20				
1110-1130	17	49	25				

TABLE X. (Continued)

Depth Interval	Copper (PPM)	Zinc (PPM)	Lead (PPM)	Depth Interval	Copper (PPM)	Zinc (PPM)	Lead (PPM)
Well No. 2 Sec. 36, T.25N., R.6W.							
130-140	7	21	15	590-600	13	36	20
140-150	8	23	10	600-610	6	33	8
160-170	7	26	15	610-620	6	35	15
170-180	7	24	15	620-630	9	37	10
180-190	7	22	15	630-640	155	36	8
190-200	7	24	10	640-650	9	37	8
200-210	3	19	20	650-660	11	33	10
210-220	3	22	10	660-670	13	35	20
220-230	6	27	15	670-680	9	34	15
230-240	6	33	20	680-690	14	35	20
250-260	10	36	30	690-700	13	35	17
260-270	7	35	15	700-710	18	37	20
270-280	6	26	15	710-720	28	37	20
280-290	9	28	15	720-730	122	43	20
290-300	8	26	15	730-740	62	36	15
300-310	10	30	20	740-750	12	35	30
310-320	14	24	20	750-760	8	35	15
320-330	16	30	20	760-770	31	36	25
330-340	6	28	15	780-790	19	39	35
340-350	8	27	15	790-800	14	37	25
350-360	5	27	13	800-810	12	33	30
360-370	5	27	10	810-820	14	36	25
370-380	4	22	18	820-830	14	95	30
380-390	6	26	15	830-840	12	34	25
390-400	6	23	15	840-850	14	33	30
400-410	8	22	15	850-860	13	34	40
410-420	10	22	18	860-870	21	35	35
420-430	5	22	15	870-880	20	33	25
430-440	7	27	13	880-890	46	32	25
440-450	6	25	15	890-900	13	34	30
450-460	7	30	15	900-910	20	95	35
460-470	7	37	20	910-920	15	35	35
470-480	8	40	15	920-930	15	34	35
480-490	8	27	15	930-940	16	445	30
490-500	7	30	15	940-950	21	44	35
500-510	10	30	18	950-960	15	36	35
510-520	14	34	20	960-970	17	41	30
530-540	32	26	20	970-980	17	87	30
540-550	10	36	15	980-990	17	233	30
550-560	553	44	25	990-1000	14	38	35
560-570	80	35	20	1000-1010	44	49	30
570-580	19	35	20	1010-1020	23	48	46
580-590	13	33	15	1020-1030	60	38	25

TABLE X. (Continued)

Depth Interval	Copper (PPM)	Zinc (PPM)	Lead (PPM)	Depth Interval	Copper (PPM)	Zinc (PPM)	Lead (PPM)
1030-1040	18	40	30	1370-1380	12	29	20
1040-1050	28	65	30	1380-1390	9	26	20
1050-1060	25	68	35	1390-1400	17	51	25
1060-1070	46	49	500	1400-1410	10	425	15
1070-1080	15	34	25	1410-1420	22	41	20
1080-1090	12	35	25	1420-1430	11	34	20
1090-1100	30	37	25	1430-1440	13	48	20
1100-1110	25	42	25	1440-1450	16	42	20
1110-1120	12	34	25	1450-1460	18	37	35
1120-1130	23	58	35	1460-1470	220	58	20
1130-1140	69	45	35	1480-1490	31	36	40
1140-1150	103	40	30	1490-1500	102	57	35
1150-1160	12	37	25	1500-1510	12	30	20
1160-1170	18	45	30	1510-1520	24	37	30
1180-1190	25	40	35	1520-1530	18	35	35
1190-1200	26	61	30	1530-1540	15	23	30
1200-1210	15	41	30	1540-1550	26	29	50
1210-1220	14	35	35	1550-1560	12	22	20
1220-1230	20	32	25	1560-1570	12	84	30
1230-1240	15	35	30	1570-1580	15	65	30
1240-1250	15	57	25	1580-1590	17	42	25
1250-1260	13	36	35	1590-1600	32	165	30
1260-1270	16	41	30	1600-1610	15	80	30
1270-1280	12	29	20	1610-1620	66	38	35
1280-1290	13	38	15	1620-1630	18	32	25
1290-1300	16	38	15	1630-1640	15	32	24
1300-1310	13	35	15	1640-1650	29	31	30
1310-1320	11	25	20	1650-1660	15	120	25
1320-1330	20	42	20	1660-1670	16	31	20
1330-1340	39	41	15	1670-1680	16	30	20
1340-1350	15	30	25	1680-1690	15	41	20
1350-1360	17	26	25	1690-1700	15	35	30
1360-1370	16	33	20				

Well No. 3
Sec. 6, T.25N., R.4W.

100-110	8	21	20	280-290	8	24	25
120-130	33	24	20	300-310	6	23	25
140-150	10	24	30	320-330	10	27	30
160-170	9	23	20	340-350	16	26	40
180-190	9	23	35	350-360	6	27	20
200-210	8	25	20	360-370	675	32	20
220-230	0.5	21	25	370-380	106	36	25
240-250	24	23	30	380-390	23	35	20
260-270	13	28	25	390-400	55	32	20

TABLE X. (Continued)

Depth Interval	Copper (PPM)	Zinc (PPM)	Lead (PPM)	Depth Interval	Copper (PPM)	Zinc (PPM)	Lead (PPM)
400-410	1023	44	20	810-820	23	34	20
410-420	407	29	15	820-830	20	46	20
420-430	28	44	20	830-840	20	75	15
430-440	388	27	20	840-850	28	60	20
440-450	805	29	20	850-860	25	31	20
450-460	43	33	20	860-870	19	40	25
460-470	33	48	30	870-880	38	71	25
470-480	16	40	30	880-890	29	60	15
480-490	10	44	25	890-900	18	34	20
490-500	80	40	30	900-910	15	25	20
500-510	20	45	40	910-920	15	31	20
510-520	27	44	30	920-930	23	28	30
520-530	12	41	30	930-940	20	35	20
530-540	20	38	35	940-950	19	29	30
540-550	18	43	35	950-960	19	40	25
550-560	34	39	35	960-970	17	34	25
560-570	40	42	35	970-980	18	33	20
570-580	46	38	45	980-990	24	77	15
580-590	19	40	45	990-1000	25	26	30
590-600	20	40	50	1000-1010	11	23	25
600-610	13	39	40	1010-1020	23	28	35
610-620	24	40	40	1020-1030	14	26	20
620-630	17	39	35	1030-1040	19	28	30
630-640	21	40	35	1040-1050	11	17	10
640-650	13	34	35	1050-1060	18	25	20
650-660	18	39	35	1060-1070	15	17	20
660-670	16	39	30	1070-1080	10	27	15
670-680	18	37	30	1080-1090	9	22	25
680-690	16	35	25	1090-1100	24	30	20
690-700	17	41	35	1100-1110	17	19	20
700-710	24	33	20	1110-1120	10	15	20
710-720	21	35	25	1130-1140	10	17	20
720-730	21	30	30	1140-1150	8	30	10
730-740	17	44	20	1150-1160	16	39	25
740-750	19	37	25	1160-1170	23	29	20
750-760	18	39	30	1170-1180	17	28	20
760-770	22	34	35	1180-1190	14	22	25
770-780	19	29	20	1190-1200	30	35	25
780-790	16	34	20	1200-1210	14	25	20
790-800	20	40	30	1210-1220	20	35	30
800-810	46	34	35				

TABLE X. (Continued)

Depth Interval	Copper (PPM)	Zinc (PPM)	Lead (PPM)	Depth Interval	Copper (PPM)	Zinc (PPM)	Lead (PPM)
Well No. 4 Sec. 16, T.25N., R.3W.							
360-370	16	93	30	650-660	15	32	10
370-380	14	30	50	660-670	13	82	20
380-390	16	36	30	670-680	43	123	25
390-400	15	30	35	680-690	12	26	15
400-410	19	82	25	690-700	9	25	20
410-420	16	90	30	700-710	19	37	25
420-430	16	35	25	710-720	15	33	35
430-440	16	39	30	720-730	14	39	25
440-450	17	36	20	730-740	12	36	30
450-460	19	36	25	740-750	9	26	15
460-470	21	34	25	750-760	10	18	20
470-480	33	30	30	760-770	13	23	15
480-490	17	35	25	770-780	82	120	20
490-500	19	34	20	780-790	11	24	20
500-510	17	38	20	790-800	67	21	15
510-520	15	35	15	800-810	7	23	20
520-530	16	35	15	810-820	10	20	15
530-540	9	30	5	820-830	26	32	15
540-550	33	30	5	830-840	12	21	20
550-560	35	33	5	840-850	10	26	15
560-570	14	31	5	850-860	10	23	15
570-580	17	37	15	860-870	11	22	15
580-590	33	38	10	870-880	13	31	15
590-600	10	29	10	880-890	37	26	15
600-610	23	33	20	890-900	26	30	20
610-620	33	31	25	900-910	10	25	10
620-630	17	31	25	910-920	12	27	10
640-650	16	58	25				
Well No. 5 Sec. 4, T.25N., R.2W.							
150-160	26	40	25	330-340	12	68	20
160-170	34	40	25	340-350	35	35	20
170-180	23	47	25	350-360	14	33	20
180-190	20	33	25	360-370	19	17	20
190-200	20	29	20	370-380	21	33	25
210-220	17	42	15	380-390	12	47	20
280-290	17	30	20	390-400	50	31	20
290-300	48	58	30	400-410	21	55	25
300-310	17	35	25	410-420	30	51	25
310-320	25	35	40	420-430	40	55	25
320-330	19	35	25	430-440	56	50	15

TABLE X. (Continued)

Depth Interval	Copper (PPM)	Zinc (PPM)	Lead (PPM)	Depth Interval	Copper (PPM)	Zinc (PPM)	Lead (PPM)
440-450	13	28	20	540-550	12	22	20
460-470	14	36	20	550-560	11	20	20
470-480	8	23	15	560-570	8	16	20
490-500	17	36	15	570-580	9	26	20
500-510	12	30	20	580-590	14	230	20
510-520	11	31	15	590-600	39	21	20
520-530	8	38	20	600-610	64	25	20
530-540	11	25	20	610-620	17	28	15

Well No. 6
Sec. 27, T.25N., R.1W.

100-110	2	25	15	270-280	8	25	15
110-120	32	27	15	280-290	8	18	20
120-130	7	30	10	290-300	15	19	30
130-140	36	57	10	300-310	13	42	30
140-150	17	50	10	310-320	10	103	35
150-160	17	62	15	320-330	22	17	25
160-170	9	33	15	330-340	10	21	25
170-180	15	30	10	340-350	7	62	25
180-190	10	30	15	350-360	13	48	50
190-200	12	27	20	360-370	12	19	30
200-210	9	17	25	380-390	12	21	15
210-220	15	23	15	390-400	19	21	20
220-230	10	24	15	400-410	16	22	20
230-240	9	24	15	410-420	6	21	15
240-250	7	18	20	420-430	9	21	20
250-260	13	51	35	430-440	15	24	25
260-270	16	22	20	440-460	11	39	25

Well No. 7
Sec. 7, T.26N., R.7W.

350-360	3	23	12	480-490	3	22	15
360-370	6	21	13	490-500	3	19	10
370-380	3	19	10	500-510	5	20	15
380-390	2	18	8	510-520	2	18	13
390-400	3	18	10	520-530	26	22	13
400-410	5	16	13	530-540	3	24	13
410-420	2	17	13	540-550	4	21	13
420-430	10	21	15	550-560	6	32	18
430-440	10	22	18	560-570	17	41	18
440-450	7	21	18	570-580	3	32	15
450-460	10	39	345	580-590	4	35	10
460-470	3	17	10	590-600	4	34	13
470-480	3	21	15	600-610	9	35	15

TABLE X. (Continued)

Depth Interval	Copper (PPM)	Zinc (PPM)	Lead (PPM)	Depth Interval	Copper (PPM)	Zinc (PPM)	Lead (PPM)
610-620	24	30	15	1070-1080	8	29	20
620-630	89	79	20	1080-1090	116	25	15
630-640	60	110	85	1090-1100	8	29	15
640-650	21	30	30	1110-1120	15	24	20
650-660	19	32	30	1120-1130	12	29	25
660-670	13	34	20	1130-1140	14	26	30
670-680	43	33	20	1140-1150	14	25	25
680-690	24	35	25	1150-1160	18	30	90
690-700	25	33	30	1180-1190	17	29	35
700-710	19	32	25	1190-1200	13	56	1300
710-720	16	34	30	1200-1210	11	22	20
720-730	20	42	30	1210-1220	14	30	25
730-740	49	38	30	1220-1230	14	36	30
740-750	25	42	28	1230-1240	16	27	30
750-760	13	34	20	1240-1250	13	26	30
760-770	17	40	25	1250-1260	14	24	25
770-780	13	33	20	1260-1270	8	14	20
780-790	20	43	33	1270-1280	8	16	20
790-800	25	44	45	1280-1290	9	22	35
800-810	16	53	20	1290-1300	6	317	10
810-820	15	44	20	1300-1310	6	22	10
820-830	16	91	35	1310-1320	9	21	8
830-840	17	66	80	1320-1330	8	64	8
840-850	17	44	35	1330-1340	8	15	10
850-860	24	26	25	1340-1350	6	13	10
860-870	21	26	25	1350-1360	6	25	8
870-880	11	22	30	1360-1370	8	22	10
880-890	19	27	30	1370-1380	11	26	15
890-900	20	27	25	1380-1390	10	25	20
900-910	23	26	35	1390-1400	12	20	15
910-920	19	153	25	1400-1410	13	32	30
920-930	16	30	35	1410-1420	8	12	13
930-940	14	22	25	1420-1430	15	17	30
940-950	19	27	25	1430-1440	9	9	30
950-960	20	29	20	1440-1450	11	17	13
960-970	12	28	43	1450-1460	10	17	35
970-980	10	49	18	1460-1470	12	18	25
980-990	13	31	25	1470-1480	11	23	20
990-1000	12	28	30	1480-1490	12	21	25
1000-1010	12	29	30	1490-1500	10	14	15
1010-1020	19	22	25	1500-1510	17	23	30
1020-1030	25	37	28	1510-1520	17	29	30
1030-1040	18	324	4725	1520-1530	10	13	25
1040-1050	13	33	30	1530-1540	9	12	20
1050-1060	14	34	25	1540-1550	10	16	20
1060-1070	14	595	6525	1550-1560	19	28	195

TABLE X. (Continued)

Depth Interval	Copper (PPM)	Zinc (PPM)	Lead (PPM)	Depth Interval	Copper (PPM)	Zinc (PPM)	Lead (PPM)
Well No. 8 Sec. 31, T.26N., R.6W.							
300-310	24	28	15	800-810	21	48	40
320-330	7	30	10	810-820	19	44	30
330-340	15	29	15	890-900	18	37	25
340-350	11	32	15	900-910	15	177	25
350-360	7	38	10	910-920	19	47	35
370-380	37	24	15	920-930	19	44	20
380-390	9	25	10	930-940	13	36	25
400-410	7	31	20	940-950	14	40	20
410-420	8	25	15	950-960	16	31	25
450-460	5	24	15	960-970	45	57	25
460-470	4	25	15	970-980	21	54	25
470-480	107	34	105	980-990	15	42	15
480-490	8	32	15	990-1000	14	36	30
490-500	5	24	20	1000-1010	15	37	30
500-510	925	29	30	1020-1030	8	42	15
510-520	10	38	20	1030-1040	15	41	25
520-530	5	38	20	1040-1050	11	43	20
530-540	4	32	15	1050-1060	7	40	20
540-550	6	37	10	1060-1070	21	59	20
550-560	31	41	15	1070-1080	15	44	20
560-570	6	35	15	1080-1090	14	35	30
570-580	95	37	45	1090-1100	22	58	30
580-590	1685	37	30	1100-1110	38	73	25
590-600	55	29	15	1120-1130	20	45	20
600-610	18	41	20	1130-1140	14	41	25
610-620	12	43	20	1140-1150	17	38	15
620-630	9	35	15	1150-1160	12	52	20
630-640	6	40	15	1160-1170	21	49	25
640-650	10	45	20	1170-1180	12	60	20
650-660	21	45	30	1180-1190	5	31	10
660-670	16	58	15	1190-1200	9	32	20
670-680	44	61	50	1200-1210	14	38	25
680-690	98	50	25	1210-1220	8	27	15
690-700	18	42	25	1220-1230	23	37	25
700-710	21	56	10	1230-1240	9	38	15
710-720	12	51	25	1240-1250	17	46	25
720-730	11	44	15	1250-1260	17	51	15
730-740	8	59	20	1260-1270	16	452	25
740-750	30	56	25	1270-1280	23	33	50
750-760	30	45	70	1280-1290	6	16	20
760-770	13	41	25	1290-1300	9	28	15
780-790	19	48	35	1310-1320	19	27	20
790-800	17	46	40	1320-1330	15	43	20

TABLE X. (Continued)

Depth Interval	Copper (PPM)	Zinc (PPM)	Lead (PPM)	Depth Interval	Copper (PPM)	Zinc (PPM)	Lead (PPM)
1330-1340	26	34	25	1420-1430	15	29	20
1340-1350	15	31	20	1440-1450	15	31	20
1350-1360	9	24	15	1450-1460	21	38	20
1360-1370	11	31	10	1460-1470	24	35	30
1370-1380	10	30	20	1470-1480	15	35	25
1380-1390	11	39	15	1480-1490	19	39	15
1390-1400	11	31	20	1490-1500	16	50	20
1400-1410	14	34	15	1500-1510	16	47	20
1410-1420	15	35	20	1510-1520	26	44	20

Well No. 9
Sec. 4, T.26N., R.5W.

460-470	17	80	25	810-820	21	38	25
470-480	14	41	20	820-830	17	36	30
480-490	19	38	20	830-840	18	38	30
490-500	13	38	30	840-850	16	38	20
500-510	21	41	20	850-860	80	79	25
510-520	12	41	20	860-870	18	43	25
520-530	36	57	25	870-880	21	37	25
530-540	17	58	45	880-890	41	60	30
540-550	15	41	25	890-900	23	38	20
560-570	16	40	40	900-910	26	46	25
570-580	16	41	45	910-920	24	36	30
580-590	15	43	30	920-930	20	37	25
590-600	16	45	20	930-940	16	28	25
600-610	16	125	25	940-950	15	44	30
610-620	16	32	20	950-960	15	32	35
620-630	15	30	25	960-970	15	36	25
640-650	16	32	35	970-980	13	21	35
650-660	16	104	30	980-990	19	35	25
660-670	17	55	35	990-1000	41	36	30
670-680	17	37	15	1000-1010	16	30	25
680-690	18	18	20	1010-1020	14	27	20
690-700	20	38	25	1020-1030	18	25	20
700-710	18	182	25	1030-1040	12	20	30
710-720	16	39	20	1040-1050	11	384	25
720-730	16	60	35	1050-1060	9	33	30
730-740	18	57	30	1060-1070	14	30	25
740-750	17	49	25	1070-1080	19	30	20
750-760	21	41	25	1080-1090	16	22	15
760-770	62	50	20	1090-1100	14	25	20
770-780	16	46	20	1100-1110	14	30	20
780-790	17	51	35	1110-1120	15	50	30
790-800	117	58	30	1120-1130	29	14	25
800-810	18	35	20	1130-1140	14	32	20

TABLE X. (Continued)

Depth Interval	Copper (PPM)	Zinc (PPM)	Lead (PPM)	Depth Interval	Copper (PPM)	Zinc (PPM)	Lead (PPM)
1140-1150	14	33	25	1270-1280	9	23	10
1150-1160	12	25	20	1280-1290	13	24	15
1160-1170	17	35	15	1290-1300	12	34	30
1170-1180	14	28	20	1300-1310	14	43	25
1180-1190	13	188	20	1310-1320	12	35	25
1190-1200	18	33	15	1320-1330	12	34	25
1200-1210	15	62	20	1330-1340	16	28	30
1210-1220	13	25	20	1340-1350	12	23	25
1220-1230	16	26	25	1350-1360	14	32	25
1230-1240	14	28	15	1370-1380	11	24	20
1240-1250	13	34	18	1380-1390	12	70	30
1250-1260	13	32	20	1390-1400	10	145	25
1260-1270	12	32	20	1410-1420	13	25	20

Well No. 10
Sec. 25, T.26N., R.5W.

90-100	11	62	25	450-460	18	36	20
100-110	10	63	35	460-470	140	34	25
110-120	11	57	35	470-480	30	42	35
120-130	6	35	25	480-490	150	42	30
140-150	3	19	5	490-500	14	42	25
160-170	12	43	25	500-510	7	31	15
170-180	510	34	25	510-520	10	31	20
190-200	22	20	15	520-530	10	39	20
210-220	30	45	20	530-540	13	38	25
230-240	6	23	25	540-550	14	36	25
240-250	79	22	20	550-560	17	41	35
250-260	23	20	15	560-570	19	47	35
260-270	7	29	25	570-580	16	38	30
280-290	7	15	20	580-590	18	67	35
300-310	4	31	20	590-600	17	65	40
310-320	4	27	20	600-610	17	258	50
320-330	6	28	20	610-620	16	49	25
330-340	6	31	20	620-630	24	31	25
340-350	6	31	25	630-640	17	42	35
350-360	326	36	25	640-650	21	48	35
360-370	355	36	25	650-660	13	51	15
370-380	540	35	20	660-670	13	31	35
380-390	815	22	35	670-680	13	36	25
390-400	71	32	15	680-690	18	35	25
400-410	5	35	15	690-700	16	53	25
410-420	13	28	15	700-710	17	36	15
420-430	18	33	25	710-720	15	41	15
430-440	6	29	25	720-730	22	48	20
440-450	36	37	20	730-740	15	35	25

TABLE X. (Continued)

Depth Interval	Copper (PPM)	Zinc (PPM)	Lead (PPM)	Depth Interval	Copper (PPM)	Zinc (PPM)	Lead (PPM)
740-750	18	54	30	990-1000	14	37	10
750-760	18	345	35	1000-1010	14	57	5
760-770	20	91	25	1010-1020	33	33	10
770-780	17	35	30	1020-1030	14	36	5
780-790	18	35	25	1030-1040	14	39	10
790-800	19	67	25	1040-1050	14	73	10
800-810	21	49	30	1050-1060	17	38	10
810-820	19	54	50	1060-1070	15	33	10
820-830	20	39	40	1070-1080	13	33	15
830-840	22	189	30	1080-1090	15	34	20
840-850	30	38	30	1090-1100	10	33	5
850-860	23	42	25	1100-1110	28	27	10
860-870	19	40	40	1120-1130	64	28	15
870-880	19	36	20	1130-1140	15	32	15
880-890	19	39	25	1140-1150	15	27	15
890-900	16	35	25	1150-1160	16	31	20
900-910	16	62	20	1160-1170	14	25	20
910-920	16	32	20	1170-1180	16	33	15
920-930	15	31	20	1180-1190	15	29	20
930-940	17	63	20	1190-1200	12	25	20
940-950	20	33	25	1200-1210	14	46	20
950-960	14	31	30	1210-1220	20	41	25
960-970	31	41	20	1220-1230	45	42	20
970-980	17	39	25	1230-1240	31	38	20
980-990	15	36	25				

Well No. 11
Sec. 13, T.26N., R.3W.

180-190	65	46	25	350-360	23	45	20
190-200	24	45	25	360-370	47	45	15
200-210	20	38	35	370-380	28	45	20
210-220	44	42	25	380-390	51	44	20
220-230	119	35	30	390-400	33	40	20
230-240	112	49	20	400-410	18	63	15
240-250	16	47	25	410-420	21	53	25
250-260	13	43	15	420-430	15	44	30
260-270	19	34	20	430-440	38	63	20
270-280	17	39	20	440-450	22	59	40
280-290	12	45	20	450-460	32	51	35
290-300	15	52	15	460-470	14	35	20
300-310	12	46	10	470-480	16	38	15
310-320	19	46	20	480-490	18	205	50
320-330	44	56	15	490-500	21	105	40
330-340	36	45	20	500-510	21	38	20
340-350	15	49	10	510-520	20	36	20

TABLE X. (Continued)

Depth Interval	Copper (PPM)	Zinc (PPM)	Lead (PPM)	Depth Interval	Copper (PPM)	Zinc (PPM)	Lead (PPM)
520-530	19	63	20	780-790	18	40	25
530-540	17	40	15	790-800	20	37	30
540-550	21	66	25	800-810	18	40	25
550-560	10	36	15	810-820	16	33	15
560-570	24	35	25	820-830	20	31	20
570-580	16	36	25	830-840	16	32	20
600-610	12	43	15	840-850	15	31	20
610-620	12	40	20	850-860	12	56	20
620-630	15	46	15	860-870	13	29	25
630-640	18	55	20	870-880	12	29	20
640-650	16	58	25	880-890	11	37	20
650-660	23	69	30	890-900	9	29	15
660-670	17	40	25	900-910	14	30	15
670-680	20	187	25	910-920	13	35	15
680-690	22	118	20	920-930	10	30	15
690-700	8	26	15	930-940	15	28	20
700-710	9	21	9	940-950	20	29	25
710-720	23	40	35	950-960	14	26	25
720-730	21	35	25	960-970	16	32	15
730-740	17	35	25	970-980	17	30	20
740-750	15	34	20	980-990	14	31	20
750-760	21	42	20	990-1000	20	32	20
760-770	21	43	20	1000-1010	15	30	20
770-780	15	60	25				

Well No. 12
Sec. 13, T.26N., R.2W.

180-190	22	28	65	320-330	20	19	20
190-200	22	33	30	340-350	14	27	25
200-210	12	33	25	350-360	15	30	25
210-220	18	27	25	370-380	35	25	20
220-230	19	27	30	390-400	15	25	20
230-240	11	31	15	400-410	23	34	15
240-250	16	54	25	410-420	33	23	25
250-260	14	29	30	420-430	15	22	25
260-270	14	27	25	430-440	21	29	30
270-280	28	24	25	440-450	17	32	25
280-290	52	25	25	450-460	18	61	15
290-300	26	22	140	460-470	17	26	20
300-310	31	24	25	470-480	19	25	25
310-320	9	18	20	480-490	12	34	25

TABLE X. (Continued)

Depth Interval	Copper (PPM)	Zinc (PPM)	Lead (PPM)	Depth Interval	Copper (PPM)	Zinc (PPM)	Lead (PPM)
Well No. 13 Sec. 30, T.27N., R.8W.							
350-360	9	40	20	810-820	11	36	20
360-370	11	64	30	820-830	16	41	20
370-380	14	32	23	830-840	500	28	33
380-390	11	57	33	840-850	16	41	35
390-400	4	27	10	850-860	11	35	23
400-410	6	40	15	860-870	15	44	25
410-420	8	34	15	880-890	13	41	23
420-430	7	32	20	890-900	22	39	30
430-440	6	34	20	900-910	22	50	25
440-450	11	38	23	910-920	12	38	28
450-460	4	34	10	920-930	16	35	20
460-470	2	25	15	930-940	37	36	15
470-480	7	32	25	940-950	15	34	15
480-490	6	55	36	950-960	16	36	15
490-500	6	57	25	960-970	17	40	45
500-510	4	30	25	970-980	13	35	18
510-520	4	33	28	980-990	16	76	20
530-540	4	32	15	990-1000	15	56	20
540-550	4	43	15	1000-1010	15	39	22
570-580	4	35	15	1010-1020	13	46	16
580-590	8	41	20	1020-1030	12	80	18
590-600	5	34	15	1030-1040	10	17	33
600-610	36	34	18	1040-1050	16	26	25
610-620	5	31	15	1050-1060	16	29	25
620-630	4	36	18	1060-1070	19	29	25
630-640	20	28	20	1070-1080	14	28	21
640-650	6	42	18	1080-1090	15	26	20
650-660	7	50	18	1100-1110	13	34	15
660-670	6	42	15	1110-1120	16	27	18
670-680	7	43	30	1120-1130	16	32	18
680-690	7	46	18	1130-1140	14	26	23
690-700	5	45	15	1140-1150	13	30	25
700-710	4	45	15	1150-1160	19	34	20
710-720	4	36	15	1160-1170	12	82	20
720-730	425	40	15	1170-1180	37	38	23
730-740	33	44	18	1180-1190	17	27	20
740-750	6	36	15	1190-1200	16	35	18
750-760	5	40	18	1200-1210	16	34	20
760-770	8	53	18	1210-1220	26	37	23
770-780	22	43	18	1220-1230	19	152	23
780-790	37	36	20	1230-1240	16	34	25
790-800	11	40	25	1240-1250	18	41	23
800-810	11	46	13	1250-1260	51	37	20

TABLE X. (Continued)

Depth Interval	Copper (PPM)	Zinc (PPM)	Lead (PPM)	Depth Interval	Copper (PPM)	Zinc (PPM)	Lead (PPM)
1260-1270	14	41	15	1510-1520	17	42	13
1270-1280	12	41	15	1520-1530	34	89	18
1280-1290	15	40	18	1530-1540	20	67	10
1290-1300	13	52	18	1540-1550	18	37	18
1300-1310	16	74	18	1550-1560	17	112	10
1310-1320	23	29	25	1560-1570	19	72	13
1320-1330	14	51	18	1570-1580	16	31	15
1330-1340	65	48	18	1580-1590	31	54	15
1340-1350	18	43	23	1590-1600	17	37	10
1350-1360	71	68	20	1600-1610	16	23	10
1360-1370	13	34	15	1610-1620	17	29	13
1370-1380	37	41	23	1620-1630	17	32	13
1380-1390	16	40	18	1630-1640	17	38	18
1390-1400	20	48	20	1640-1650	16	25	18
1400-1410	17	62	20	1560-1660	14	18	20
1410-1420	18	43	15	1660-1670	22	23	15
1420-1430	31	49	20	1670-1680	15	51	18
1430-1440	22	47	20	1680-1690	25	27	20
1440-1450	18	32	18	1690-1700	15	20	15
1460-1470	19	52	15	1700-1710	56	25	15
1470-1480	22	55	18	1710-1720	20	80	20
1480-1490	23	35	18	1720-1730	13	66	20
1490-1500	46	43	15	1730-1740	12	40	25
1500-1510	22	51	20	1740-1750	15	24	30

Well No. 14
Sec. 18, T.27N., R.8W.

280-290	2550	46	25	450-460	24	40	15
290-300	5800	28	30	470-480	10	46	15
300-310	11	50	10	480-490	27	29	25
310-320	14	45	15	490-500	20	27	35
320-330	26	57	10	500-510	12	200	25
330-340	7	29	15	510-520	17	98	25
340-350	10	31	15	520-530	18	47	30
350-360	14	31	25	530-540	20	52	30
360-370	35	23	20	550-560	16	31	20
370-380	11	27	20	570-580	16	36	25
380-390	339	19	30	580-590	13	34	15
390-400	37	23	30	590-600	14	32	25
400-410	7	26	20	600-610	18	34	20
410-420	39	23	25	610-620	16	32	25
420-430	20	33	15	620-630	15	34	15
430-440	35	29	20	650-660	17	38	15
440-450	17	27	20	660-670	15	34	20

TABLE X. (Continued)

Depth Interval	Copper (PPM)	Zinc (PPM)	Lead (PPM)	Depth Interval	Copper (PPM)	Zinc (PPM)	Lead (PPM)
670-680	16	37	10	960-970	10	28	30
680-690	16	47	15	970-980	12	25	20
690-700	14	51	20	980-990	18	27	25
710-720	15	36	20	990-1000	12	42	20
720-730	18	70	20	1000-1010	10	33	20
730-740	15	64	15	1010-1020	11	32	25
740-750	17	101	20	1020-1030	11	28	20
750-760	14	39	10	1030-1040	13	68	20
760-770	12	36	15	1040-1050	12	28	25
770-780	12	40	10	1050-1060	13	40	25
780-790	14	34	20	1060-1070	12	27	20
790-800	22	42	25	1070-1080	11	39	30
820-830	22	34	20	1080-1090	37	28	25
830-840	32	40	30	1100-1110	20	27	30
840-850	27	35	30	1110-1120	11	30	25
860-870	19	42	20	1120-1130	12	32	20
870-880	19	34	25	1130-1140	14	29	35
880-890	21	35	20	1140-1150	14	34	20
890-900	21	79	15	1150-1160	13	34	25
900-910	16	28	20	1160-1170	16	32	25
910-920	25	31	20	1170-1180	13	30	25
920-930	8	20	15	1180-1190	15	142	30
930-940	18	28	20	1190-1200	13	45	25
940-950	15	30	20	1200-1210	18	50	20
950-960	10	29	20	1210-1220	19	53	20

Well No. 15
Sec. 23, T.27N., R.3W.

170-180	15	30	25	370-380	16	40	25
180-190	17	30	40	380-390	20	37	20
190-200	15	27	35	390-400	15	36	20
200-210	13	35	20	400-410	16	39	15
220-230	24	35	40	410-420	18	34	20
230-240	38	35	35	420-430	23	36	15
250-260	20	36	25	430-440	17	35	15
270-280	16	40	20	440-450	18	34	15
290-300	16	30	40	450-460	18	36	20
300-310	18	36	25	460-470	16	37	15
310-320	15	54	30	470-480	23	40	25
320-330	19	44	25	480-490	19	37	15
330-340	18	38	25	490-500	21	36	20
340-350	21	40	25	500-510	12	31	10
350-360	17	36	15	520-530	9	26	20
360-370	20	36	20	540-550	11	27	20

TABLE X. (Continued)

Depth Interval	Copper (PPM)	Zinc (PPM)	Lead (PPM)	Depth Interval	Copper (PPM)	Zinc (PPM)	Lead (PPM)
550-560	12	20	15	630-640	9	124	20
560-570	24	24	25	640-650	9	30	20
570-580	7	18	14	650-660	13	22	15
580-590	7	63	25	660-670	19	52	35
590-600	7	19	15	670-680	13	28	15
600-610	10	125	30	680-690	40	39	15
620-630	12	50	25	690-700	22	22	30

Well No. 16
Sec. 1, T.27N., R.3W.

30-40	14	31	15	410-420	18	42	15
50-60	18	33	20	420-430	15	50	20
60-70	14	38	20	430-440	19	42	15
70-80	14	40	25	440-450	18	43	15
80-90	13	49	20	450-460	26	44	20
90-100	15	38	20	460-470	18	113	20
110-120	13	59	30	480-490	16	37	20
130-140	18	43	20	500-510	15	60	20
140-150	10	43	15	510-520	21	40	25
160-170	13	64	30	520-530	11	31	20
170-180	17	35	20	540-550	8	31	20
190-200	11	255	25	550-560	7	17	15
230-240	15	201	30	560-570	12	67	20
250-260	15	36	20	620-630	14	29	15
260-270	12	56	15	640-650	11	30	15
270-280	16	30	15	660-670	6	18	15
280-290	17	34	25	670-680	6	19	15
310-320	13	39	20	700-710	12	26	20
320-330	10	156	20	710-720	8	23	20
330-340	15	37	20	730-740	22	41	30
350-360	13	43	20	740-750	19	170	25
370-380	38	48	65	750-760	8	48	15
380-390	40	41	70	760-770	10	22	20

Well No. 17
Sec. 17, T.17 to 29N., R.8W.

400-410	9	45	10	480-490	14	43	25
410-420	12	45	15	490-500	13	42	20
420-430	19	51	20	500-510	12	43	10
430-440	15	44	20	510-520	35	44	15
440-450	12	48	13	520-530	18	45	15
450-560	15	42	15	530-540	20	44	10
460-470	12	40	25	540-550	15	40	15
470-480	85	42	15	550-560	15	39	15

TABLE X. (Continued)

Depth Interval	Copper (PPM)	Zinc (PPM)	Lead (PPM)	Depth Interval	Copper (PPM)	Zinc (PPM)	Lead (PPM)
560-570	35	38	10	1060-1070	16	40	20
560-580	29	88	10	1070-1080	18	33	30
580-590	25	41	15	1080-1090	12	32	25
590-600	55	42	15	1090-1100	17	40	25
600-610	5	39	20	1100-1110	14	35	25
610-620	25	41	10	1120-1130	23	44	35
620-630	12	40	5	1160-1170	13	41	20
630-640	10	34	5	1170-1180	18	35	15
640-650	8	40	15	1180-1190	10	31	15
650-660	55	29	5	1190-1200	12	45	30
660-670	35	43	5	1200-1210	13	49	25
670-680	10	35	5	1210-1220	10	32	30
680-690	44	37	10	1220-1230	9	32	20
710-720	46	40	5	1230-1240	8	28	30
720-730	7	44	5	1240-1250	14	33	25
730-740	20	45	15	1270-1280	7	23	15
740-750	155	50	10	1280-1290	6	25	20
750-760	14	47	15	1290-1300	11	29	15
760-770	16	45	20	1300-1310	19	34	30
770-780	14	47	30	1310-1320	38	39	35
780-790	8	44	25	1320-1330	15	45	15
790-800	10	50	20	1330-1340	10	35	20
800-810	24	48	25	1340-1350	15	39	15
810-820	10	47	25	1350-1360	8	36	20
820-830	17	48	30	1360-1370		72	50
830-840	40	48	25	1370-1380	39	39	20
840-850	21	45	30	1380-1390	12	33	15
850-860	16	45	20	1390-1400	22	25	20
860-870	27	41	30	1400-1410	13	26	20
870-880	14	45	25	1420-1430	11	24	25
880-890	67	50	25	1430-1440	8	18	20
890-900	27	46	20	1440-1450	4	8	15
900-910	14	42	25	1450-1460	6	18	20
910-920	18	50	25	1460-1470	10	24	20
920-930	14	41	35	1470-1480	9	24	15
930-940	10	42	25	1480-1490	13	27	30
940-950	35	42	30	1490-1500	14	25	25
950-960	21	45	25	1500-1510	10	24	25
970-980	10	35	20	1510-1520	13	28	20
980-990	17	39	25	1520-1530	12	36	30
990-1000	21	38	25	1530-1540	120	37	20
1000-1010	9	44	25	1540-1550	24	37	25
1010-1020	78	39	25	1550-1560	14	33	30
1030-1040	20	37	20	1560-1570	21	49	30
1040-1050	12	30	35	1570-1580	13	39	30
1050-1060	13	36	30				

TABLE X. (Continued)

Depth Interval	Copper (PPM)	Zinc (PPM)	Lead (PPM)	Depth Interval	Copper (PPM)	Zinc (PPM)	Lead (PPM)
Well No. 18 Sec. 27, T.28N., R.7W.							
90-100	14	37	35	550-560	68	34	25
100-110	13	44	30	560-570	18	33	30
110-120	11	37	40	570-580	4	36	15
120-130	21	32	35	580-590	38	41	10
130-140	7	33	35	590-600	8	38	10
140-150	8	33	35	600-610	44	37	10
150-160	6	32	20	610-620	14	41	15
160-170	5	32	15	620-630	28	45	20
180-190	11	25	25	630-640	10	42	15
190-200	9	31	25	640-650	16	40	25
200-210	6	40	15	650-660	27	38	25
220-230	6	32	20	660-670	9	34	20
230-240	7	29	25	670-680	10	35	25
240-250	5	35	25	680-690	13	36	20
250-260	10	27	35	690-700	11	31	20
260-270	10	32	35	700-710	16	34	30
280-290	5	31	25	710-720	14	34	25
290-300	8	31	25	720-730	9	30	30
300-310	8	29	20	730-740	15	40	35
310-320	11	31	20	740-750	11	30	20
320-330	6	35	25	750-760	14	25	25
330-340	14	25	20	760-770	11	29	20
340-350	7	29	20	770-780	11	22	25
350-360	6	32	20	780-790	11	23	30
360-370	7	28	15	790-800	13	30	25
370-380	6	27	20	800-810	12	27	20
380-390	7	29	20	810-820	11	27	15
390-400	7	42	25	820-830	11	23	25
400-410	10	26	15	830-840	15	29	30
410-420	5	34	25	840-850	14	29	30
420-430	5	36	10	850-860	10	27	25
430-440	13	37	25	860-870	15	43	30
440-450	5	34	15	870-880	10	33	15
450-460	5	29	10	880-890	12	46	20
460-470	19	26	20	890-900	6	21	15
470-480	6	24	20	900-910	19	23	15
480-490	14	36	25	910-920	13	25	20
490-500	5	25	20	920-930	9	38	15
500-510	4	31	15	930-940	8	31	20
510-520	216	26	40	940-950	5	42	10
520-530	505	27	30	950-960	9	22	20
530-540	550	23	25	960-970	9	480	20
540-550	128	24	35	970-980	58	25	20

TABLE X. (Continued)

Depth Interval	Copper (PPM)	Zinc (PPM)	Lead (PPM)	Depth Interval	Copper (PPM)	Zinc (PPM)	Lead (PPM)
980-990	12	30	30	1310-1320	77	98	35
990-1000	13	31	30	1320-1330	37	54	25
1000-1010	10	33	10	1330-1340	22	39	20
1010-1020	12	33	25	1340-1350	18	32	25
1020-1030	11	26	30	1350-1360	81	34	20
1030-1040	12	35	15	1360-1370	17	41	20
1040-1050	9	32	15	1370-1380	65	64	15
1050-1060	12	35	20	1380-1390	80	57	20
1060-1070	16	45	20	1390-1400	16	93	15
1070-1080	13	36	15	1400-1410	13	25	25
1080-1090	12	29	25	1410-1420	23	40	20
1090-1100	21	33	15	1420-1430	29	33	20
1100-1110	22	36	10	1430-1440	52	53	20
1110-1120	16	30	15	1440-1450	41	108	15
1120-1130	19	33	25	1450-1460	14	25	15
1130-1140	15	33	25	1460-1470	11	21	15
1140-1150	47	31	20	1470-1480	13	29	10
1150-1160	25	39	15	1480-1490	13	97	10
1160-1170	12	86	30	1490-1500	27	24	15
1170-1180	23	46	25	1500-1510	27	23	20
1180-1190	14	34	15	1510-1520	27	114	20
1190-1200	11	30	5	1520-1530	11	55	15
1200-1210	16	28	10	1530-1540	17	43	10
1210-1220	15	48	15	1540-1550	19	94	20
1220-1230	17	34	15	1550-1560	13	27	20
1230-1240	14	32	10	1560-1570	14	41	10
1240-1250	14	32	15	1570-1580	27	27	25
1250-1260	11	31	10	1580-1590	13	61	15
1260-1270	22	47	10	1590-1600	15	253	15
1270-1280	19	41	20	1600-1610	34	34	15
1280-1290	16	44	20	1610-1620	29	57	15
1290-1300	24	43	25	1620-1630	13	23	25
1300-1310	20	68	30				

Well No. 19
Sec. 28, T.28N., R.5W.

330-340	139	45	10	420-430	30	40	5
340-350	47	33	10	430-440	18	42	15
350-360	6	35	10	440-450	11	46	10
360-370	3	41	10	450-460	10	41	15
370-380	20	34	5	460-470	17	39	10
380-390	28	35	5	470-480	27	38	15
390-400	66	41	15	480-490	16	37	15
400-410	14	39	10	490-500	16	49	25
410-420	32	54	60	500-510	18	46	35

TABLE X. (Continued)

Depth Interval	Copper (PPM)	Zinc (PPM)	Lead (PPM)	Depth Interval	Copper (PPM)	Zinc (PPM)	Lead (PPM)
510-520	15	41	30	910-920	14	43	15
520-530	16	37	35	920-930	11	28	20
530-540	19	43	25	930-940	8	21	15
540-550	16	36	25	940-950	8	25	15
550-560	18	35	15	950-960	113	29	10
560-570	15	33	20	960-970	17	33	15
570-580	16	26	20	970-980	12	56	20
580-590	13	48	20	980-990	8	18	5
600-610	14	32	20	990-1000	14	39	10
610-620	17	80	15	1000-1010	13	313	20
620-630	17	54	15	1010-1020	15	34	15
630-640	16	39	15	1020-1030	13	34	15
640-650	18	49	15	1030-1040	15	34	10
650-660	18	43	20	1040-1050	13	33	10
660-670	18	46	15	1050-1060	36	30	15
670-680	16	45	15	1060-1070	16	31	20
680-690	20	59	15	1070-1080	15	42	15
690-700	17	180	20	1080-1090	14	31	15
700-710	16	35	10	1090-1100	15	23	15
710-720	18	42	15	1100-1110	10	25	10
720-730	16	38	10	1110-1120	11	42	15
730-740	15	37	20	1120-1130	13	42	10
740-750	17	138	20	1130-1140	9	26	15
750-760	16	88	20	1140-1150	28	40	20
760-770	17	52	15	1150-1160	135	130	10
770-780	15	38	20	1160-1170	17	27	15
780-790	31	33	10	1170-1180	11	89	20
790-800	15	32	10	1260-1270	11	37	20
800-810	13	37	15	1270-1280	32	23	25
810-820	9	35	15	1280-1290	10	25	25
820-830	10	33	10	1290-1300	10	51	20
830-840	44	40	15	1300-1310	13	38	20
840-850	18	33	20	1310-1320	9	23	20
850-860	15	34	10	1320-1330	11	25	25
860-870	15	34	20	1330-1340	9	24	20
870-880	7	202	0	1340-1350	9	24	20
880-890	8	28	10	1350-1360	10	102	20
890-900	10	29	15	1360-1370	10	27	25
900-910	11	27	15	1370-1380	11	27	25

Well No. 20
Sec. 22, T.28N., R.5W.

100-110	4	26	15	130-140	5	25	10
110-120	6	30	20	140-150	7	27	15
120-130	7	29	15	150-160	7	27	15

TABLE X. (Continued)

Depth Interval	Copper (PPM)	Zinc (PPM)	Lead (PPM)	Depth Interval	Copper (PPM)	Zinc (PPM)	Lead (PPM)
160-170	6	24	15	620-630	16	33	20
170-180	16	23	20	630-640	15	37	20
180-190	6	25	15	640-650	16	37	15
190-200	15	24	15	650-660	18	34	20
200-210	9	37	10	660-670	17	100	25
210-220	7	40	15	670-680	17	40	25
220-230	56	32	10	680-690	19	39	30
230-240	76	38	15	690-700	19	37	25
240-250	29	37	10	700-710	23	725	25
250-260	13	27	20	710-720	17	41	25
260-270	31	30	10	720-730	19	41	35
270-280	3	36	10	730-740	16	31	25
280-290	15	35	15	740-750	20	44	30
290-300	6	34	10	750-760	10	28	25
300-310	5	42	20	760-770	19	40	25
310-320	103	32	15	770-780	17	32	25
320-330	36	41	20	780-790	16	30	25
330-340	13	43	15	790-800	15	34	20
340-350	8	41	20	800-810	15	46	20
350-360	25	42	15	810-820	14	29	20
360-370	13	38	15	820-830	7	20	15
370-380	7	41	20	830-840	13	25	20
380-390	18	38	20	840-850	6	24	20
390-400	17	30	20	850-860	6	15	15
400-410	12	33	15	860-870	5	14	20
410-420	12	38	20	870-880	10	21	25
420-430	11	38	20	880-890	9	19	20
430-440	17	46	30	890-900	9	42	35
440-450	17	41	35	900-910	9	22	25
450-460	20	33	40	910-920	6	23	10
460-470	12	43	15	920-930	7	28	5
470-480	13	27	20	930-940	8	20	20
480-490	13	34	25	940-950	9	19	15
490-500	15	31	30	950-960	9	21	10
500-510	12	28	25	960-970	9	24	15
510-520	18	28	30	970-980	11	26	15
520-530	12	24	25	980-990	12	25	10
530-540	15	74	20	990-1000	12	25	15
540-550	13	28	20	1000-1010	13	34	15
550-560	15	850	30	1010-1020	51	28	20
560-570	13	34	20	1020-1030	11	27	25
570-580	18	52	20	1030-1040	16	25	20
580-590	16	47	20	1040-1050	8	16	10
590-600	19	45	55	1050-1060	10	20	15
600-610	15	33	30	1060-1070	8	19	20
610-620	16	33	25	1070-1080	10	22	15

TABLE X. (Continued)

Depth Interval	Copper (PPM)	Zinc (PPM)	Lead (PPM)	Depth Interval	Copper (PPM)	Zinc (PPM)	Lead (PPM)
1080-1090	11	23	20	1110-1120	15	19	25
1090-1100	8	18	15	1120-1130	10	24	20
1100-1110	10	20	20	1130-1140	9	20	20
Well No. 21 Sec. 8, T.28N., R.2W.							
80-90	42	33	15	350-360	17	37	25
90-100	30	42	15	360-370	44	55	30
100-110	16	31	20	370-380	38	41	25
110-120	41	38	20	380-390	30	40	20
120-130	24	37	15	390-400	25	41	1220
140-150	13	33	15	400-410	20	34	20
150-160	23	45	15	410-420	22	36	25
160-170	20	46	20	420-430	20	41	30
170-180	21	44	15	430-440	17	46	20
180-190	25	47	15	440-450	22	33	25
190-200	20	49	20	450-460	15	39	30
200-210	19	53	15	460-470	19	40	15
210-220	21	52	15	470-480	28	41	25
220-230	22	73	45	480-490	18	67	10
230-240	14	33	15	490-500	16	20	25
240-250	17	39	10	500-510	25	46	25
250-260	14	44	20	510-520	19	56	15
260-270	16	39	15	520-530	10	112	30
270-280	16	36	15	530-540	19	73	20
280-290	18	113	25	540-550	11	28	30
290-300	16	34	25	550-560	12	52	20
300-310	24	40	20	560-570	55	52	35
310-320	17	39	15	570-580	20	163	30
320-330	18	38	575	580-590	15	44	20
330-340	16	39	25	590-600	13	41	30
340-350	18	39	1150	600-610	15	40	30

VITA²

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