VIRGINIA DIVISION OF MINERAL RESOURCES PUBLICATION 29

GEOLOGIC INVESTIGATIONS IN THE WILLIS MOUNTAIN AND ANDERSONVILLE QUADRANGLES, VIRGINIA

COMMONWEALTH OF VIRGINIA

DEPARTMENT OF CONSERVATION AND ECONOMIC DEVELOPMENT
DIVISION OF MINERAL RESOURCES
Robert C. Milici, Commissioner of Mineral Resources and State Geologist

CHARLOTTESVILLE, VIRGINIA
1981

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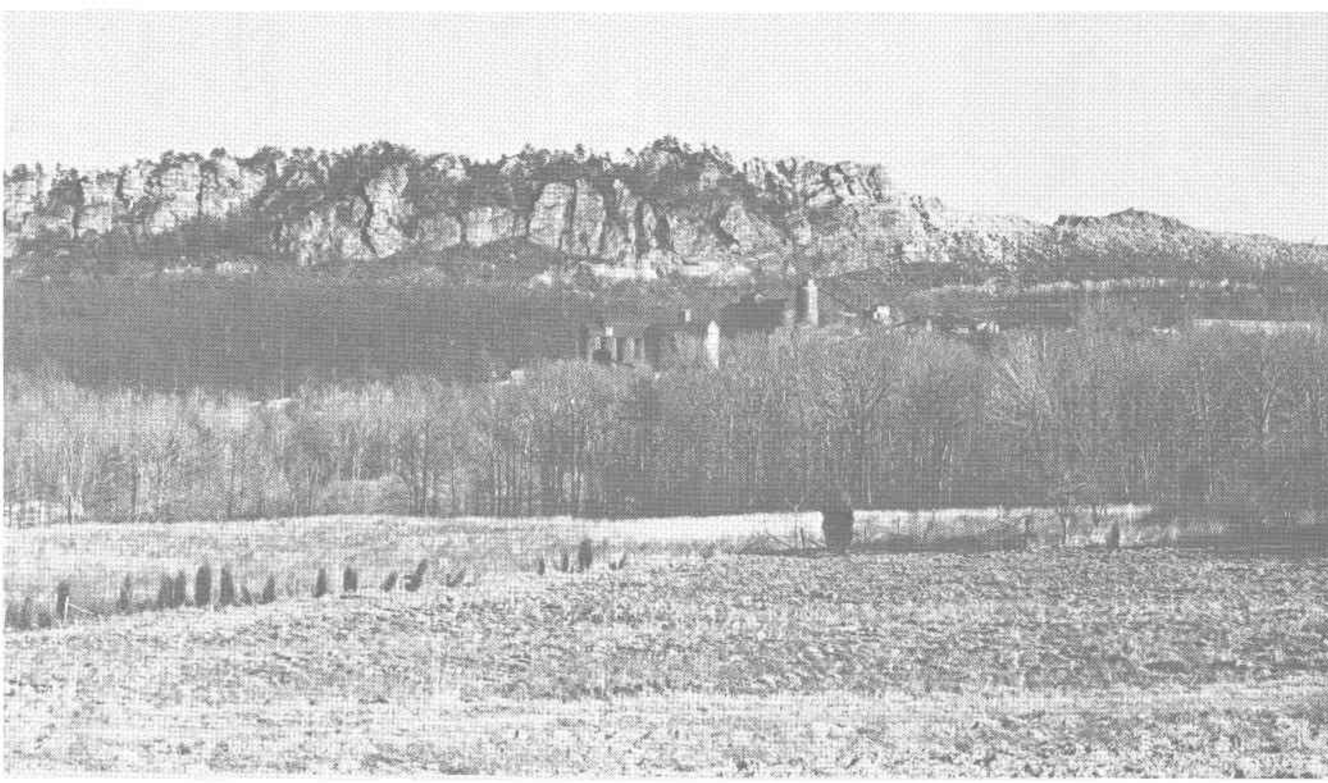

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FRONT COVER: Cliffs in kyanite quartzite of Arvonia Formation on west side of Willis Mountain (photo by R. S. Good).

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COMMONWEALTH OF VIRGINIA
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Richmond, 1981

FOREWORD

Publication of the following collection of reports is made possible through joint funding by the Virginia section of the American Institute of Mining, Metallurgical and Petroleum Engineers, Inc.; The Piedmont Planning District Commission; and the Division of Mineral Resources, Department of Conservation and Economic Development, Commonwealth of Virginia.

GEOLOGIC INVESTIGATIONS IN THE WILLIS MOUNTAIN AND ANDERSONVILLE QUADRANGLES, VIRGINIA

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INTRODUCTION

Based on a mineral resources development study completed in March 1977, the Piedmont Planning District Commission recognized the need to further evaluate potential mineral resources through detailed geologic mapping. Under contract with the Commission, the Division of Mineral Resources performed a geologic survey of the Andersonville and Willis Mountain quadrangles with an emphasis on potential economic mineral studies. Geologic map reports for these quadrangles are complete and were distributed December 1980. Additional information was developed during different phases of this work and the collection of reports contained herein is an outgrowth of these efforts.

The present volume includes summarys of these geologic map reports, the results of three other geologic studies carried out under the same program, and a field trip guide and road log prepared for the 1981 annual meeting of the Virginia section of the American Institute of Mining, Metallurgical, and Petroleum Engineers, Inc. The new results presented include those of: regional geophysical surveys (aeromagnetic, aeroradiometric, and ground-base gravity maps); reconnaissance geochemistry of stream sediments and selected water samples (computer-derived maps of base-metal and mineral concentrations); and geophysical data for 17 massive sulfide zones (location and electromagnetic anomaly map) and detailed geologic, geophysical and geochemical surveys (surface geologic maps, drill-hole logs and sections, electromagnetic and self-potential maps, and soil geochemistry maps).

STRATIGRAPHY AND STRUCTURE[1]

by
John D. Marr, Jr.
(Triassic System by Michael B. McCollum)

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ABSTRACT

Willis Mountain and Andersonville 7.5-minute quadrangles encompass approximately 112 square miles (290 square kilometers) in southern Buckingham, eastern Appomattox, northern Prince Edward and western Cumberland counties in the central Virginia Piedmont. The rocks within these quadrangles range in age from Precambrian or Lower Paleozoic to Triassic. These include, from oldest to youngest, the Candler Formation, the Chopawamsic Formation, the Arvonia Formation and Triassic-age arkosic sedimentary rocks within the Farmville basin. All rock types have been intruded by late Triassic-Jurassic diabase dikes. The Chopawamsic Formation contains ferruginous quartzites which are intimately associated with massive sulfide deposits which may have commercial value.

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[1] Portions of this report may be quoted if credit is given to the Virginia Division of Mineral Resources. It is recommended that reference to this report be made in the following form: Marr, J. D., Jr., 1981, Stratigraphy and structure (Triassic System by M. B. McCollum), *in* Geologic investigations in the Willis Mountain and Andersonville quadrangles, Virginia: Virginia Division of Mineral Resources Publication 29, p. 3-8.

All pre-Triassic age rocks within the area have a complex deformational history. The oldest rocks display four distinct fold systems whereas the younger Arvonia Formation rocks exhibit only three fold systems.

INTRODUCTION

Willis Mountain and Andersonville quadrangles are located in central Virginia. The total area of study comprises 112 square miles (290 square kilometers) bounded by latitudes 37°22′30″ and 37°30′ north and longitudes 78°22′30″ and 78°37′30″ west.

A network of primary and secondary highways, fire trails and logging roads provide access to most of the area. The principal routes of travel are U.S. highways 60 and 15, and State roads 640 and 636. The population is mainly rural. Lumbering, mining and farming are the principal occupations.

The area has a subdued rolling topography with the higher elevations being underlain by more resistant rocks. Willis and Woods mountains are prominent monadnocks standing above a rolling peneplain. Elevations range from 1128 feet (344 m) at the top of Willis Mountain to approximately 285 feet (87 m) in Fork Swamp. Both areas are in the Willis Mountain quadrangle. Principal drainages are the Willis, Little Willis, Appomattox and Slate rivers. These rivers along with their tributaries form a well-developeddendritic drainage pattern.

STRATIGRAPHY

The bulk of the rocks in the Willis Mountain and Andersonville quadrangles are mostly metasedimentary and metavolcanic rocks of Lower Paleozoic age (Plate 1). These rocks lie in northeast-trending fold belts. The strike direction of the penetrative foliation is also to the northeast; it dips southeast.

Sedimentary rocks of Mesozoic age are located in the southeastern part of Willis Mountain quadrangle where they occupy part of the Farmville basin, which extends beyond the quadrangle. These arkosic sediments were derived from metamorphic rocks lying northwest of the large normal fault which forms the northwest boundary of the basin. Diabase dikes of late Triassic-early Jurassic age intrude older rocks in the area.

Cenozoic alluvial sediments blanket areas along major streams. Older Cenozoic alluvial terrace deposits which represent erosional remnants of once more extensive deposits occur at higher elevations.

Modal analyses of a number of thin sections of the rocks of the area are shown in Table 1. These data represent typical mineral contents and textures of these rock.

Table 1. Modal analyses of Lower Paleozoic rocks in the Willis Mountain and Andersonville quadrangles.

	Stratigraphic Units and Rock Percent				
		Chopawamsic Formation			
Mineral	Candler Formation	Lower unit	Upper unit	Plagioclase granite	Arvonia Formation
Quartz	20-90	5-25	10-50	20-40	42-85
Muscovite	28-30	0-15	0- 5	0- 5	15-30
Biotite	—	10-15	10-17	0- 3	6-20
Chlorite	5-21	0-20	0- 5	—	—
Plagioclase Feldspar	—	2-15 (An_{15})	15-40 (An_{25})	15-45	—
Potassium Feldspar	—	0-12	0-18	5-15	—
Hornblende	—	0-45	0-50	—	—
Garnet	—	0. 5	0- 2	—	2- 8
Epidote	—	0- 5	5-15	—	—
Paragonite*	10-12	—	—	—	—
Kyanite	—	—	—	—	0-30
No. of rock samples	7	6	9	4	6

*Based on X-ray diffraction analyses.

PRECAMBRIAN OR LOWER PALEOZOIC ROCKS

Candler Formation

The oldest rocks exposed in the area belong to the Candler Formation. Brown (1951) named this unit the Candler phyllite and schist and later changed the name to the Candler Formation (Brown, 1953). The unit underlies the northwestern area of the Andersonville 7.5-minute quadrangle. The Candler consists predominantly of muscovite-paragonite-chlorite phyllites with interbedded quartz-biotite metagraywackes and quartzites; these lithologies are more common in the upper part of the unit.

In hand specimen the phyllite is dark gray to light green, fine grained and highly fissile. It typically contains a double cleavage. Primary bedding, defined by a light-medium-gray to reddish-orange banding, occurs at a slight angle to the foliation. Quartz interlayers are common and are generally about 1/16 inch (0.25 cm) thick. Vein quartz occurs as thin (one-inch) stringers and lenticular pods. The Candler typically weathers rapidly to a reddish-gray to medium-gray, impermeable saprolite which forms a slick, viscous mud when wet. Excellent exposures of this formation occur along State Road 746 near the Slate River. The contact between the upper Candler and the basal part of the Chopawamsic is placed where recognizable, conformable volcanic interlayers predominate over the pelitic rocks of the Candler Formation.

Chopawamsic Formation

The Chopawamsic Formation was named for exposures along Chopawamsic Creek in northern Virginia by Southwick, Reed and Mixon (1971). It was extended into north-central Virginia by Higgins and others (1973), Pavlides and others (1974) and Conley and Johnson (1975). It was recognized in central Virginia by Conley (1978), Conley and Marr (1979, 1980), and Marr (1980A and 1980B).

The Chopawamsic Formation in the present study area consists of two units. The lower unit consists of interlayered chlorite schists, biotite metagraywackes and metabasalts with thin interlayers of mica phyllites and quartzite. In hand specimen the schists are typically light grayish green to olive green, fine- to medium-grained, moderately foliated and break with a hackley fracture. The unit is moderately resistant to weathering and typically underlies areas of rolling topography. It generally weathers to a slightly acid, impermeable reddish-orange saprolite.

The contact between the lower and upper units of the Chopawamsic Formation is gradational. The upper unit is composed of a sequence of felsic and mafic metavolcanic rocks. There is also a change in the calcium content of plagioclase feldspar across this contact. Plagioclase feldspars from the lower unit have anorthite contents of 0-15 percent whereas those from the upper unit range from 15 to 40 percent. The upper unit consists of biotite gneiss, amphibole gneiss, felsic (rhyodacitic) volcanic rocks, talc-tremolite schists and ferruginous quartzites.

In hand specimen the biotite gneiss is a light-gray, medium- to fine-grained, moderately foliated, banded rock composed of biotite layers and quartz-feldspar layers; some biotite layers contain amphibole. The biotite gneiss occurs as interlayers within amphibole gneiss ranging from one to hundreds of feet thick. The amphibole gneiss is greenish-black to black, medium- to coarse-grained, lineated, well-banded rock composed of one of two amphibole pairs, tremolite-cummingtonite or hornblende-cummingtonite, and quartz, calcic oligoclase (An_{25}), biotite, epidote, and garnet. Light-greenish-gray, quartz-epidote lenses are common. The felsic rocks are light-gray to white, equigranular and are composed of quartz and feldspar with minor amounts of muscovite. The ferruginous quartzites, which are unique to the Chopawamsic Formation, are in both the lower and upper units, and are associated with gossans (weathered sulfide zones). The ferruginous quartzites are dark-reddish-gray, fine- to medium-grained, banded, moderately persistent lenses composed of magnetite, specular hematite and quartz. Talc-tremolite bodies in the Chopawamsic range in composition from talc-tremolite schists to actinolite-chlorite schist.

Weathering products of the upper unit of the Chopawamsic depend upon lithology. Deep, loamy, porous saprolite overlies biotite gneiss, and thin, ocherous, impermeable saprolite overlies amphibole gneiss. The ferruginous quartzites are resistant to weathering and tend to underlie linear ridges. An excellent exposure of the amphibole gneiss is located ¾ mile (1.2 km) north of the intersection of State roads 609 and 633, where State Road 633 crosses the Willis River.

The Chopawamsic Formation is considered to be Early Cambrian in age based on discordant radiometric zircon dates (Higgins and others, 1971) and an age of 530 to 570 million years reported by Glover (1974).

Plagioclase Granite and Pegmatite

In the southwestern part of the Andersonville 7.5-minute quadrangle the Chopawamsic Formation is intruded by a plagioclase granite. This rock is a light-gray to white, medium- to coarse-grained, moderately foliated rock consisting of quartz, plagioclase feldspar (oligoclase, An_{25}), muscovite and biotite with potassium feldspar (microcline). The plagioclase granite does not intrude the overlying Arvonia Formation rocks. Good saprolite exposures of this unit occur along State Road 612 approximately 0.5 mile (0.8 km) south of its intersection with the Appomattox River.

Granitic pegmatites also intrude the Chopawamsic rocks. They occur throughout the upper unit and are particularly abundant along the northwestern edge of the fault bordering the Farmville basin (Willis Mountain 7.5-minute quadrangle). The pegmatites are composed primarily of quartz, potassium feldspar and muscovite with minor amounts of plagioclase feldspar.

Arvonia Formation

The Arvonia Formation was named by Watson and Powell (1911) for exposures in the slate quarries at Arvonia, Virginia in the Arvonia 7.5-minute quadrangle to the northeast of the study area. As recognized within the Andersonville and Willis Mountain quadrangles the formation consists of a basal locally discontinuous, quartz-mica schist with interlayered micaceous quartzite and quartz-mica conglomerate. This interbedded interval is overlain by a moderately persistent, banded quartzite which in turn is overlain by a thick interval of porphyroblastic, garnet-mica-graphite schist. The Arvonia Formation also includes the kyanite-mica quartzites and schists located on Willis and Woods mountains. These kyanite quartzites and schists are correlated with the basal units of the Arvonia (Conley and Marr, 1980).

In hand specimen the conglomeratic quartz-mica schist is a light-gray to gray, medium-grained, moderately foliated, moderately lineated schist which contains muscovite, quartz and minor amounts of biotite. Bluish quartz pebbles are in the conglomerate. The schist weathers to a light-yellowish-gray, sandy, micaceous saprolite. The quartzite is a light-yellowish-gray, fine- to medium-grained, banded or cross-bedded rock composed predominantly of quartz and muscovite. It weathers to a pale-orange, sandy, micaceous saprolite. The overlying porphyroblastic garnet-mica schist is light gray to dark grayish green, medium- to coarse-grained, crinkle-folded and well-foliated. It is composed of quartz, graphite, muscovite, biotite and garnet. The porphyroblastic schist is moderately resistant to weathering and underlies long, linear ridges. Upon weathering it forms a light-orange to light-red, impermeable thin saprolite littered with mica schist chips.

Excellent exposures of the porphyroblastic schist are in several northwest-trending drainages west of State Road 612, approximately 1 mile (1.6 km) southwest of its intersection with State Road 636.

Kyanite constitutes as much as 30 percent of the rock in some places. It occurs as stringers and lenses within quartzite beds at Willis and Woods mountains and as disseminated blades in the quartz-mica conglomerate of the basal Arvonia Formation. Sillimanite as fibrous prismatic crystals, also occurs in this conglomerate. At Willis and Woods mountains the kyanite quartzite contains primary sedimentary structures. These include: repeated pairs of wedge-shaped quartzite and metapelite interlayers, "jelly-bean" conglomerates, fining-upward sequences, channel-fillings and both large- and small-scale cross-beds (Conley and Marr, 1980).

MESOZOIC

Triassic System

Sedimentary rocks of Triassic age are in the Farmville basin, a basin with a total area of approximately 50 square miles (300 sq. km); nineteen square miles (49 sq. km) of the basin occupies the southeastern part of the Willis Mountain 7.5 -minute quadrangle. The average strike of rocks within this basin is approximately N25°E; dips range between 20° and 35° to the northwest. Two major depositional regimes are represented by sedimentary rocks in the basin. A gravity flow regime, in which metamorphic rocks northwest of the basin were eroded and transported to the southeast, is represented by rocks along the western margin of the basin. These sediments formed a fanglomerate sequence in which the average grain size decreases progressively to the southeast. These rocks are reddish brown to medium gray, and massive to thick-bedded. Metamorphic clasts range from pebble- to boulder-size and are in a reddish-brown, fine-grained, arkosic matrix. To the southeast running water played a more important role in the depositional process and the beds contain heavy-mineral-accentuated cross-beds and coarse pebbles in channel fill deposits.

Farther southeast, are beds formed under fluvial-lacustrine conditions. This facies, which is poorly exposed, is divided into a basal arkosic conglomerate and an overlying sequence of siltstone, shale and mudstone.

Diabase dikes intruded the area of the Farmville basin during late Triassic to early Jurassic time. The dikes trend approximately north 12° west. In hand specimen the diabase is dark gray to black, fine- to medium-grained and has an ophitic texture. Minerals present include plagioclase feldspar (labradorite-An_{67}), augite, antigorite, olivine and magnetite. The dikes weather to a dark-red, clay-rich saprolite which contains spheroidally weathered boulders in many places.

CENOZOIC

Colluvial Deposits

Several of the steeper slopes are blanketed with gravity-transported colluvial deposits. These consist of unsorted, angular, pebble- to boulder-sized rock fragments in an unsorted sand, silt and clay matrix.

Alluvium and Terrace Deposits

Floodplains of major streams are covered by alluvial deposits. These consist of poorly sorted rounded pebbles and cobbles in a crudely-stratified sand and silt matrix. Remnant fluvial terrace deposits persist on some areas of relatively high elevations.

STRUCTURE

The rocks in the area record four distinct periods of folding, one of which preceded the deposition of the rocks of the Arvonia Formation. Major structural features formed by these events include the Whispering Creek anticline, numerous synclinal infolds of Arvonia Formation rocks, the southern part of the Long Island syncline, several small-scale shear zones associated with tightly folded rocks, and the Farmville basin. The basin was formed by normal faulting after the folding events.

FOLDS

Isoclinal, intrafolial, F_1, folds can be observed on the limbs of larger, F_2, folds. The plunge of F_1 folds intersects the F_2 lineation (which is defined by the long axes of some minerals) at angles ranging from 17° to 43°. F_1 folds were observed only within the rocks of the Chopawamsic Formation. Pavlides (1973) described a similar relationship between folds in the rocks of the Chopawamsic Formation and those of the Quantico Formation in northern Virginia.

F_2 folds include tight, isoclinal synclines and broader, more open anticlines; the folds generally have a strike to the northeast and are overturned to the northwest. The penetrative foliation or schistosity in rocks of the area developed during this F_2 fold event. The foliation is seen in all Paleozoic rocks in the area and is best developed in the rocks of the Arvonia Formation, which occupies the cores of the tight synclinal F_2 folds.

F_3 folds are more open and upright than F_2 folds. They are readily recognized where the pervasive F_2 foliation is warped around noses of F_3 structures. F_3 folds generally trend northeast and constitute the largest folds in the study area, including the Whispering Creek anticline.

F_4 folds are broad, open northwest-trending structures in which the pervasive F_2 foliation and the axial planes of F_3 folds are gently warped. This F_4 fold event did not impose an observable foliation on the rocks.

Whispering Creek Anticline

Espenshade and Potter (1960) interpreted the Whispering Creek anticline in Willis Mountain quadrangle as a large open anticline in which the western limb folded back into a tight syncline. The eastern limb was interpreted as having a homoclinal dip to the southeast. Brown (1969) described the structure as a large, asymmetric anticline with the northwestern limb appreciably steeper than the southeastern one. The Whispering Creek anticline is actually a broad, asymmetric anticline flanked on either side by two tight isoclinal synclines. These synclines are cored by rocks of the basal Arvonia Formation.

Infolds of Arvonia Formation Rock

The Arvonia Formation occupies the cores of several elongate synclinal bands in the area, three of which form conspicuous structural features. The most eastern syncline is on strike with what was previously called the east limb of the Arvonia syncline (Brown, 1969). The central syncline is on strike with the western limb of the Arvonia syncline as mapped by Ern (1968) and Brown (1969) and the most westerly syncline is on strike with the Long Island syncline as mapped by Smith, Milici and Greenburg (1964), Ern (1968) and Brown (1969). The eastern and western most synclines are discontinuous due to changes in the plunge of these folds. Other synclinal infolds of Arvonia Formation rocks occur at Willis and Woods mountains and southeast of Willis Mountain.

Minor Shear Zones

There are several narrow and discontinuous shear zones developed in rocks of the Arvonia Formation along the flanks of some of the major synclinal folds. These zones are interpreted to be genetically related to the tight folding of the Arvonia rocks. If this is correct, the zones do not represent large displacements, however, because the area underlain by the Arvonia rocks coincides with a distinctive regional aeromagnetic anomaly, it is possible that it corresponds to a zone of crustal weakness.

FAULTS

The Farmville basin is bounded on its western side by a high-angle normal fault that strikes north-northeast and dips to the southeast. The fault zone contains fine-grained siliceous mylonite and extensively brecciated and silica-cemented cataclastic rocks. These features are found at the fault zone and extend westward into the Paleozoic metamorphic rocks.

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REGIONAL GEOPHYSICS[1]

By
Stanley S. Johnson

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ILLUSTRATIONS

Plate 1. Geologic and geophysical maps of Willis Mountain and Andersonville quadrangles ...... In pocket

ABSTRACT

Aeromagnetic, aeroradiometric and gravity data have been useful in aiding the local correlation of the many lithologies within the Andersonville and Willis Mountain quadrangles. Regionally, the geophysical data correlate with the lithologic and structural trends. Major trends are recognizable on small-scale regional aeromagnetic and aeroradiometric contour maps. The contour patterns indicated by the geophysical maps are those expected for an area of complex lithology and structure.

The lithologies in the Chopawamsic Formation, such as metamorphosed volcanic rocks of felsic and intermediate compositions (lower member), and biotite and amphibole gneisses, and interlayed mafic, intermediate, and felsic volcanic rocks (upper member), are recognizable on the geophysical maps of the area. The porphyroblastic garnet-mica schist, metasiltstone, and metaclaystone units that make up the upper part of the Arvonia Formation display a different geophysical pattern than that of the lower part of the formation, which is composed of quartz-mica schist containing interlayers of micaceous quartzite and quartz-mica conglomerate. Several aeroradiometric highs over the Farmville basin are attributed to two possible origins—deposition of sediments derived from rocks bearing radioactive elements or precipitation and concentration of such elements in these sediments by groundwater.

The Spotsylvania lineament (Pavlides, 1980) is recognized mainly as aeromagnetic and aeroradiometric anomalies that lie along a zone separating two rock units of unlike compositions. Northwest of this lineament, the rocks are chiefly amphibole gneiss (Ta River metamorphic suite of Pavlides, 1980); southeast of it, they are predominantly biotite gneiss (Po River metamorphic suite of Pavlides, 1980). Magnetic and radiometric contour patterns are different for these two areas. The lineament-trend appears to be slightly off-set near the northern part of the Farmville basin. The lineament is not readily discernible on

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large-scale aeromagnetic and aeroradiometric maps because of the scatter of magnetic and radioactivity values on such maps.

INTRODUCTION

The geophysical surveys presented in this study consist of physical measurements of local variations in the earth's naturally occurring magnetic, radiometric, and gravity fields. Variations in such parameters are determined by the composition and structure of the rock on and below the surface. Because rocks vary widely in such parameters as density, magnetism, and radioactive element concentrations, the physical fields generally differ from area to area in accordance with variations in rock type. The changes detected from area to area may correlate with geologic boundaries. The ease of recognition of the change depends on the degree of contrast of the physical properties of the rocks being investigated, and the data obtained from a particular geophysical method will be influenced by the degree to which a specific property varies among rock units. In general, a combination of geophysical methods or techniques allows for a better intrepretation of the survey results than the data received from a single technique because the range of possible interpretations is thereby reduced. Naturally, the technique or techniques utilized to locate certain types of rocks and minerals will depend upon the nature of the rock and its contrast with the enclosing rock. Radioactivity surveys generally yield information about the upper three feet of the surface, whereas data received from magnetic and gravity surveys measure rock properties that can reflect geological and/or geophysical features at depth.

The geomagnetic field of the earth is a complex and complicated field, especially at the earth's surface where the internal field interacts with the external and interplanetary magnetic fields. The earth's internal geomagnetic field is caused by some mechanism in the core of the earth, possibly a type of dynamo-like action. This internal magnetic field can be thought of as a dipole field (similar to a bar magnet) in its simplest terms, but in reality it is much more complicated.

The earth is in a steady, but variable, interplanetary magnetic field (produced primarily by the sun) that distorts the ideal dipole lines of force of the earth's internal magnetic field. In addition, flare activity on the sun causes magnetic storms that increase and distort the interplanetary field for time periods up to several days. After these periods of flare activity, the distorted magnetic field settles back to its previous state. Generally, magnetic surveys are not carried out during these periods. In addition, the sun interacts with the ionosphere to cause a complex external magnetic field. This field undergoes diurnal changes which are dependent on local time. Magnetic surveys are corrected for these daily changes in the magnetic field. The normal internal magnetic field of the earth, like the external field, varies in intensity and direction. These changes take place over relatively long time periods and are therefore secular variations.

Superimposed on the geomagnetic field are minor irregularities caused by inhomogeneities in the outer layer of the earth. These irregularities in the earth's crust cause anomalies in the magnetic field, and are expressions of local magnetic fields induced by the general field in certain types of rocks. Magnetic surveys are mainly concerned with these irregular fields; that is, the difference between the measured field and the mathematically derived planetary field.

The magnetic properties of the rocks causing the local variations depend on their mineral content and geologic history of their formation. All rocks in the earth's crust contain some magnetic minerals. The content of these minerals in rocks can range from a very small fraction of a percent to several tens of percent. The magnetic minerals of any importance are few in number and those most commonly found are oxides of iron and titanium. The most important magnetic minerals are magnetite, pyrrhotite, and ilmenite. Almost all magnetic anomalies result from an uneven distribution of these three minerals. As a general rule, dark, mafic igneous and metamorphic rocks possess higher magnetic susceptibility than light, felsic igneous and metamorphic rocks. Most sedimentary rocks have a low magnetic susceptibility.

Natural radioactivity in rocks is produced largely by uranium and thorium, and a radioactive isotope of potassium. The most abundant rock-forming minerals that contain radioactive isotopes are potassium-bearing feldspars and micas, minerals generally abundant in granitic and pegmatitic rocks. Thus relatively high levels of radioactivity are normally found over these rock types. As a general rule, potassium, uranium and thorium content decreases in igneous rocks as they become less felsic in composition. Mafic rocks, such as basalt, normally lack potassium-bearing minerals and exhibit low radioactivity. Radioactivity surveys assist geologic mapping by delineating rock units having characteristic radiometric properties and aid in detecting radioactive mineral deposits and mineral deposits known to be associated with radioactive minerals.

Metamorphic rocks may display the same degree of radioactivity as the sedimentary, igneous, or other metamorphic rock from which they were derived, except where radionuclides have been introduced, dispersed, or removed during metamorphism.

Gravity surveys are dependent on rock density. Variations in the density of rocks and geological structures near the surface cause very slight changes in the regional gravity field. Regional gravity surveys provide basic data pertaining to the nature, composition, and structure of the earth's crust. Such data may be an aid in the search for mineral deposits, but normally such exploration requires many more gravity measurements than are used in a regional survey.

The variations in the earth's gravity field are caused by the latitude of the area, elevation, local terrain and earth tides, in addition to rock density and geologic structure. Gravity surveys are tedious, time-consuming, generally ground-based operations that are performed at accurately known elevations. Most modern gravity meters have a sensitivity of 0.01 milligal, which means that the instrument can detect a change in latitude of 40 feet (12 m) and a change in elevation of two inches (5 cm).

PREVIOUS INVESTIGATIONS

An aeromagnetic survey of the Andersonville and Willis Mountain 7.5-minute quadrangles was made as part of a survey of a larger area by the Virginia Division of Minerals Resources (1970A, 1970B). The area was also included in regional and state-wide gravity surveys (Johnson 1971; 1977) and in a statewide aeromagnetic survey (Zietz and others, 1977A and 1977B). The regional gravity and aeromagnetic surveys were done to provide data for future detailed geologic mapping and mineral exploration, and to aid in the interpretation of regional geology.

Other regional geophysical studies which include the Andersonville and Willis Mountain quadrangles are: an aeromagnetic survey by Zietz and others (1968); an aeromagnetic and aeroradioactivity survey funded by the Regional Coastal Plains Commission, (U.S. Geological Survey open-file reports 1978A, 1978B); and magnetic and radioactivity surveys carried out by the U.S. Department of Energy (1980).

Several private exploration companies have also performed airborne and ground geophysical surveys throughout the "gold-pyrite belt" that includes the Willis Mountain and Andersonville 7.5-minute quadrangles. These data have not been made available to the public.

PRESENT INVESTIGATION AND PROCEDURES

Gravity and radiometric data in addition to those gathered in previous surveys were required for the present study. The detailed regional gravity survey of the area was completed in January, 1979, and the detailed aeroradioactivity survey was flown by LKB Resources, Inc. under contract to the Division of Mineral Resources in the Winter of 1978. The gamma-ray spectrometer aboard the aircraft measured the total-count radioactivity as well as the individual responses of bismuth-214 (uranium), thallium-208 (thorium) and potassium-40 (potassium). In addition to the aeroradioactivity total-count contour maps, data included "stacked" flight-line profiles. These profiles, which are available for study at the Division of Mineral Resources, show adjusted total-count data, adjusted thorium, uranium, and potassium data, the ratio of Bi/K, Bi/Tl, and Tl/K, radar altimetry, and "raw" total-field aeromagnetic data along identical flight lines. Aeromagnetic surveys performed during earlier work was considered sufficient for the present study. Contour maps for these surveys are in Plate 1.

AEROMAGNETIC SURVEY

The 1970 regional aeromagnetic survey was performed by Lockwood, Kessler and Bartlett, Inc. under contract to the Virginia Division of Mineral Resources. The magnetometer used for the survey was a "saturable core" flux gate Air Mag III (Gulf Research and Development Company). The magnetometer (stinger assembly) and ancillary equipment was installed in a modified twin-engine Aero Commander 680E. The magnetometer had a "noise envelope" of less than two gammas and was compensated for the effects of permanent and induced magnetism produced by the aircraft. A ground monitor was utilized to collect data on diurnal changes and magnetic storms for adjusting and correcting final results.

A 35mm continuous strip camera was used to record the flight path of the aircraft. The aircraft-to-ground distance was continuously recorded by a Honeywell radar altimeter. In addition to the radar altimeter, a differential pressure altimeter was also used to continuously record the barometric altitude.

The survey was flown in an east-west direction at a flight altitude of 500 feet (152 m) above ground. The flight lines were spaced at 0.5 mile (0.8 km). Sufficient control lines were flown to adequately cover the survey area. The survey was flown with an analog acquisition system.

The flight path of the aircraft was determined by using the 35mm tracking camera film and matching the film images to features on U.S. Geological Survey topographic maps. Fiducials on the film were correlated with all analog records. The data were manually reduced, corrected, and contoured. The regional gradient of the magnetic field was removed during the compilation process.

AERORADIOACTIVITY SURVEY

The 1978 aeroradioactivity survey flown by LKB Resources, Inc. under contract to the Division of Mineral Resources utilized a GAD 5, four-channel, gamma-ray spectrum analyzer installed in a modified twin-engine Aero Commander 680E. The airborne detector package used in this survey consisted of a thermally packaged Bicron/Scintrex sensor containing a crystal volume of 500 cubic inches. The crystals were thallium-activated sodium iodide; these were coupled to selected photomultiplier tubes.

A 35mm continuous strip camera was used to record the flight path (east-west) of the aircraft. The distance from aircraft to ground was continuously recorded by a Honeywell radar altimeter. In addition to the radar altimeter, a Rosemont 804 differential pressure altimeter was used to continuously record the barometric altitude.

A geoMetrics Model G-803 airborne proton magnetometer was also utilized aboard the aircraft. The detector was housed in a tail "stinger" assembly. The observed total field data from this instrument was displayed on a 7100 B dual channel, Hewlett-Packard strip chart recorder.

The survey was flown in an east-west direction at a flight altitude of 500 feet (152 m) above ground. The flight lines were spaced at 0.5 mile (0.8 km). Sufficient control lines were flown to cover the survey area. The survey was flown with simultaneously operating analog and digital acquisition systems.

Cosmic and aircraft radioactivity (background) were monitored by twice-a-day measurements (before and after production flights) at an altitude of 5000 feet (1, 524 m) above the ground. Check flights were made over a test line each day. A second test line was flown over water at the start of production flying and at the end of the survey to further establish the atmospheric and aircraft backgrounds.

The window settings for the spectrometer were established in accordance with the manufacturer's recommendations. The integrating time constant was 1.0 second. The live time for the digital data was 0.95 seconds, and counts read into the system during the live time were averaged automatically. This average was then output to the digital magnetic tape at each 1.0 second interval. The values recorded on the digital magnetic tape lag behind the ground position by 115 to 148 feet (35 to 45 m). No compensations were made in the compilation for this lag in positioning.

The flight path was recovered (accurately located) using the 35mm tracking camera film and matching its images on 1:24,000-scale, U.S. Geological Survey topographic maps. Fiducial numbers on the film were correlated with all analog and digital records by means of automatically placed fiducial marks. UTM coordinates for all plotted points were read from the maps and then input to a computer for analysis, evaluation and plotting.

The airborne radiometric background levels were tabulated and listed for each line flown. Additional checks were made on those lines flown over water at the survey altitude and these control data were compared to the daily test lines. At the completion of this evaluation, a set of background levels were input to the computer for correcting and leveling the radiometric data. The data were further corrected for Compton scattering effects by employing scatter coefficients which were determined by calibrations at the Geological Survey of Canada Test Pads in Ottawa, Canada. All data were normalized to 500 feet (152 m) employing the theoretical values for the atmospheric attenuation coefficients for thorium, uranium, and potassium. At the completion of the leveling process, the radiometric data were input to a computer contouring-program. Total-count contour maps were prepared. The associated uranium, potassium, or thorium highs were labeled on the contour maps as determined from a computer printer listing. The contour maps were reviewed and revised manually as required.

GRAVITY SURVEY

Field observations in the Andersonville and Willis Mountain quadrangles were made utilizing a LaCoste and Romberg Model G geodetic gravity meter (number 77). This meter has a range of over 7000 milligals and a reading accuracy of ± 0.01 milligal. All observations were made utilizing a modified ladder-sequence loop technique. Each loop started and ended the same day from the established base station. Field observations were made on U.S. Geological Survey and U.S. Coast and Geodetic Survey bench marks that had been established by first- through third-order leveling. Observations were also made at sites for which useful, checked spot, and bridge elevations had been determined by the U.S. Geological Survey. A valid observation consisted of the average field value that was obtained from two consecutive readings; these observations had a maximum spread no greater than 0.01 milligal. Previously occupied stations in a loop were generally reoccupied every three hours during the survey. Stations were plotted on 7.5-minute series topographic maps. Established horizontal control was used for station coordinates where available; for all other stations, latitude and longitude were scaled from the topographic maps. No terrain corrections were made.

The Charlottesville base station (174-D-1) located at the Natural Resources Building, Virginia Division of Mineral Resources, was used for the survey (Johnson and Ziegler, 1972).

The computation and reduction of field data was done on a CDC 6400 and on a Burroughs 5500 computer at the Division of Academic Computing, University of Virginia, Charlottesville, utilizing a modified GRAVAS program. The GRAVAS program is designed to reduce and correct field observations obtained with LaCoste and Romberg gravity meters and includes corrections for solar and lunar tides and instrument drift. A density of 2.67 gm/cc was used for computing the Bouguer values. The simple Bouguer contour map was initially drawn by computer and then manually reviewed and smoothed as needed.

RELATIONSHIPS OF GEOPHYSICAL DATA TO STRATIGRAPHIC UNITS

Aeromagnetic, aeroradiometric and gravity data correlate rather well with the regional lithologic and structural trends of the rocks in the Andersonville and Willis Mountain quadrangles as mapped by Marr (Plate 1). Major trends of the rock units are recognizable on small-scale, regional geophysical contour maps. The contour patterns indicated by the various geophysical contour maps of the study area are those that would be expected when considering the complexities between lithologies and structure. Isolated magnetic highs and areally high magnetic values are over the intermediate to mafic lithologies; low magnetic values are over the more felsic units. The aeroradiometric data is indicative of complex geologic structure and heterogeneous units. In general the radiometric highs occur over lithologies with abundant potassium micas and potassium feldspars and radiometric lows are over those lithologies low in these minerals.

PRECAMBRIAN OR LOWER PALEOZOIC ROCKS

Candler Formation

Rocks of the Candler Formation underlie the northwestern part of the Andersonville quadrangle, and although they occupy only a small area, these rocks display the northeast-trending aeromagnetic pattern generally found over the formation in central Virginia (Plate 1). In the study area, the magnetic field over the Candler decreases to the southeast. Profiles over the Candler indicate a steep magnetic gradient from the northwest to the southeast. A closed low (less than 3700 gammas) shows that the lowest magnetic values are at and just northwest of its contact with the lower member of the Chopawamsic Formation. The low probably reflects the change in composition from the quartz-mica phyllite and schist of the Candler to the intermediate metavolcanic and metagraywacke rocks of the lower Chopawamsic, rather than a change in geologic structure.

Aeroradiometric values over the Candler Formation do not generally exceed 325 counts per second. The radiometric contour map contains several north-trending patterns over the Candler; these trends may reflect fracture patterns. The possibility of fractures is discussed in the section on the Arvonia Formation.

Chopawamsic Formation

The Chopawamsic Formation as mapped by Marr (1980B) in the Andersonville quadrangle is divided into a lower and an upper member. The geophysical patterns developed over these two members are quite different owing to differences in their compositions. The lower member, consisting predominantly of metamorphosed volcanic rocks of felsic and intermediate composition, displays the normal northeast-trending pattern observed on regional aeromagnetic contour maps of central Virginia. Magnetic values are generally higher for the lower than for the upper member. Steep magnetic gradients are over the lower member at its contact with the Candler Formation and at its contact with the Arvonia Formation (Plate 1). Aeroradiometric contours over the lower member do not show a strong northeast trend, but values are generally lower (less than 250 cps) than those of the Candler and Arvonia formations.

The lack of strong regional trends in the magnetic and radiometric data over the upper part of the Chopawamsic Formation is apparently due to its heterogeneous composition. The unit consists of interlayers of several mafic, intermediate and felsic lithologies in biotite gneiss and amphibole gneiss. The aeromagnetic, aeroradiometric and gravity values are also influenced by the complex fold systems developed in most of the area. A typical example of the geophysical response to these factors is observed in the southeastern part of the Andersonville quadrangle. In this area, a generally broad magnetic low is over the core of a large northwest-trending fold. This fold core is mainly biotite gneiss interlayered with amphibole gneiss of the upper part of the Chopawamsic. Over this same area, a general low- to intermediate-valued radiometric field occurs. The gravity field contains generally low values that do not vary by more than one milligal over the area of the fold core. It is also apparent from the three geophysical contour maps in Plate 1 that there is a large north-northwest-trending feature in the southern part of the Andersonville quadrangle. The anomaly corresponds to an area of folded biotite gneiss which yields low magnetic, intermediate radiometric and low gravity values in comparison to those of the surrounding area. The magnetic pattern in the biotite gneiss displays similar characteristics in the northeast and southwest quadrants of the Willis Mountain quadrangle (note the 3900 gamma, northeast-trending features defined by linear contours, and the 3900 gamma, north-trending feature in the northeast quadrant; and the 3800-3900 gamma, northwest- and north-trending features in the southwest quadrant). All of these areas are underlain mainly by biotite gneiss.

The area in the west-central part of the Willis Mountain quadrangle and the east-central part of the Andersonville quadrangle has generally high magnetic, low radiometric, and high gravity values corresponding to an area of amphibole gneiss lying in a northeast-trending fold. Amphibole gneiss is a more mafic rock than the biotite gneiss, the rock at the core of the fold mentioned earlier, and the changes on the contour maps reflect the differences.

Arvonia Formation

A high magnetic field lies over porphyroblastic garnet-mica schist, metasiltstone and metaclaystone forming the uppermost part of the Arvonia Formation in the Andersonville quadrangle. A lower-valued magnetic field is observed over the quartz-mica schist containing interlayers of micaceous quartzite and quartz-mica conglomerate forming the lowest of the three units of the formation. The radiometric values are high over all units of the formation. The northeast-trending feature that is indicated by relative highs on both the magnetic and radiometric contour maps in the central part of the Andersonville quadrangle lies over the Arvonia Formation.

The trend of the maximum magnetic high on the Arvonia Formation is to the northwest in the southwestern part of the Andersonville quadrangle. Analysis of stacked-profiles indicates that a magnetic high correlates directly with a radiometric low on an anticlinal axis in the Arvonia Formation. These data indicate that the Arvonia is thin in this anticlinal axis and that the relatively high magnetic and low radiometric values on the axis are due to the underlying Chopawamsic Formation being relatively near the surface along it. The magnetic high over the Arvonia, as seen in the stacked profiles, lies progressively farther west as it is traced to the northeast along the Arvonia Formation. The trace of this magnetic high probably reflects the position of the anticlinal axis along this distance; the trend is not evident on the magnetic contour map.

The northeast trend of the Arvonia Formation as shown by contour patterns on the radiometric contour map is interrupted in the area around Andersonville where the contours are oriented north. This north trend may reflect weathering and leaching due to groundwater flow in a northwest-trending fracture system. Many diabase dikes in the area are oriented northwest and this observation lends support to a hypothesis of the presence of a northwest-trending fracture system. This fracture system, if present, could have promoted groundwater leaching of radioactive elements in the area, thus producing a radiometric field of relatively low values. The regional magnetic pattern is not interrupted in this area.

Several of the higher isolated radiometric anomalies in the Willis Mountain quadrangle are over the Arvonia Formation. The anomaly in the northwestern part of the quadrangle (values greater than 375 cps), the anomaly at the southern end of Willis Mountain (values greater than 425 cps), and the one trending northeast (values greater than 350 cps) to the southeast are all related to the Arvonia Formation. These areas, which have a low-valued magnetic field over them, are areas underlain by quartz-mica schist with interlayers of micaceous quartzite and quartz-mica conglomerate. This is the relationship noted between magnetic and radiometric values over the Arvonia rocks in the Andersonville quadrangle.

MESOZOIC ROCKS

The sedimentary rocks of Triassic age in the Willis Mountain quadrangle define a part of the Farmville basin. These rocks generally display a random magnetic pattern except where they are intruded by diabase dikes, which produce northwest trends in keeping with the orientation of these igneous bodies. There are several aeroradiometric highs over the basin. Most of these anomalies occur just southeast of the border fault. These anomalies may be due to one of two possible origins—radioactive elements were in the rocks forming the sediments or the elements were precipitated and concentrated in the sediments by groundwater. The anomalies are mainly due to the presence of potassium with thorium and/or uranium occurring to a lesser degree. The anomalies parallel the distribution of the fanglomerates and siltstones lying southwest of the Triassic border fault. These rocks are derived from areas to the northwest of the border fault which contain granite pegmatites lying within the Chopawamsic Formation. In addition, most of the anomalies are along and parallel to major streams.

Other isolated radiometric highs occur in the basin. Some of these appear to have a relationship with intrusive diabase and some occur over terrace and alluvial deposits, but many of the anomalies in the basin, especially those along the border fault, might be explained by a hypothesis suggested by Dribus (1978). The possibility exists that fault zones and intrusive bodies in the Triassic rocks might have impeded the flow of groundwater through the rocks long enough to produce local mineralization. Because uranium is soluble in oxygenated waters and can be mobilized and transported in these waters, the coarse-grained, porous rocks or sediments in the basin could have allowed groundwater and surface water flowing from the west (through the Chopawamsic Formation and granite pegmatites) to enter them. Local groundwater could also contribute to the deposition model. The groundwater could have reacted with reductants in the sediments, such as hydrogen sulfide emitted from diabase intrusives (Drez, 1977, p. 134) and from the breakdown of pyrite in the sediments. These reductants could have aided precipitation and concentration of uranium because of the reducing environment created by them. The source of the uranium would have been from rocks in the vicinity of the basin. This hypothesis is made plausible by the work of Brown and Silver (1956, p. 92-93). They have indicated that uranium and thorium do not fit very well into the lattices of any of the common major minerals that make up granites, but do fit the lattices of some of the accessory minerals such as zircon, sphene, apatite and allanite. The uranium and thorium are generally localized in minerals comprising only a small fraction of the weight of the entire rock. In their analyses of granites from several localities, Brown and Silver found that in leachates derived from pulverized granites, as much as 38 percent of the dissolved material is radioactive. The trace elements extracted in these leachates were uranium, thorium, cerium, lanthanium, neodyminum and yttrium. It is not known whether uranium or thorium occur in any concentrated amounts in the area.

Magnetic values over the diabase dikes appear to be related to size, location (in relation with other high magnetic rocks) and orientation of the dike. The northwest-trending magnetic highs on the aeromagnetic contour maps of the Farmville basin are due to diabase dikes. The influence of large regional dikes on magnetic contour patterns can readily be seen in the Willis Mountain quadrangle where high magnetic values define a north-trending linear feature in the center of the map. The northwest-trending features in the Chopawamsic Formation in the southern and southeastern parts of the Andersonville quadrangle are also due to diabase (Plate 1).

The diabase dikes normally have a low-value radiometric field over them. Stacked profiles, and, generally, contour maps show this relationship between magnetic and radiometric data and rock type.

RELATIONSHIP OF GEOPHYSICAL DATA TO THE SPOTSYLVANIA LINEAMENT

The Spotsylvania lineament (Pavlides, 1980), earlier known informally as "Neuschel's lineament," is a regional feature extending into the study area. It was postulated to be a fault by Neuschel (1970) and was tentatively called the Fredericksburg fault zone by Higgins and others (1973). The lineament is recognized mainly as an aeromagnetic and aeroradiometric anomaly, and it lies along a zone separating two rock types of unlike compositions. Northwest of this lineament, the rocks are chiefly amphibole gneiss (Ta River metamorphic suite of Pavlides, 1980); southeast of it, predominantly biotite gneiss (Po River metamorphic suite of Pavlides, 1980). Over the amphibole gneiss, northeast-trending magnetic highs and low-valued, irregular radiometric anomalies lie parallel to the strike of the rocks. The biotite gneiss of the Po River metamorphic suite is indicated on the geophysical maps by magnetic values lower than and radiometric values higher than those in the Ta River metamorphic suite. The general trend of the magnetic contours over the Po River metamorphic suite is more northwesterly than the trend of contours over the Ta River metamorphic suite. The juxtaposition of these unlike aeromagnetic and aeroradioactivity values and trends define the lineament. The lineament trend appears to be slightly offset near the northern part of the Farmville basin; it appears to lie just northwest of the border fault of the basin. A more detailed airborne or ground survey may indicate that this lineament coincides with the border fault.

The lineament is not readily discernible on large-scale, aeromagnetic and aeroradiometric maps such as those at a scale 1:24,000. The geophysical aspects of the lineament become much more apparent on small-scale maps. Small-scale, regional aeroradioactivity contour maps indicate that the pattern described continues to the south beyond 37°15′ north latitude. In this area, the contour data suggest that the lineament may end or be farther west and continue southwest to at least 37° north latitude.

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SULFIDE ZONES[1]

By
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ABSTRACT

The Andersonville, Virginia sulfide district, discovered in the mid-1950's, was the subject of two intensive exploration programs. The first was carried out in the late 1950's by Virginia Mining Corporation of Montreal, Quebec. The second was performed in the late 1960's by Dominion Explorers, Limited of Toronto, Ontario. An airborne geophysical survey was completed in 1968. Six sulfide bodies of significant size were discovered and evaluated through modern exploration techniques. Two sulfide bodies, Zones 18 and 24, contain significant amounts of zinc and copper along with minor amounts of silver. Gold occurs in trace amounts only. Zone 18 is estimated to have reserves of 794,000 tons with an average of 4.68 percent zinc and 0.60 percent copper. Zone 24 is estimated to contain 550,000 tons with an overall grade of 4.87 percent zinc and 0.98 percent copper. The Zone 18 sulfide body appears to have been localized in a shear zone, whereas the Zone 24 sulfide mass is stratabound. Some workers postulate a volcanogenic origin for all of the sulfide deposits.

INTRODUCTION

This report is a summary of some results of two exploration programs, one by the Virginia Mining Corporation (VIMCO) of Montreal, Quebec, and the other by Dominion Explorers, Limited (DOMEX) of Toronto, Ontario, carried out in the area of the Willis Mountain and Andersonville 7.5-minute quadrangles during the period 1956-1971. Both programs involved exploration for base-metal sulfides. Representatives of Virginia Mining Corporation were responsible for discovery of the district and carried out a drilling program of significant propor-

[1] Portions of this report may be quoted if credit is given to the Virginia Division of Mineral Resources. It is recommended that reference to this report be made in the following form: Young, R.S., 1981, Sulfide zones, *in* Geologic investigations in the Willis Mountain and Andersonville quadrangles, Virginia: Virginia Division of Mineral Resources Publication 29, p. 17-47.

[2] North American Exploration, Inc. Charlottesville, Va.

tions from 1956 to 1958. Data from the VIMCO project were supplied by John D. Hagan of the VIMCO staff. In the period 1968-1971, DOMEX sponsored an exploration program under the direction of staff geologists of North American Exploration, Incorporated of Charlottesville, Virginia. The project geologist was Donald J. Hathaway, who was assisted by Ralph D. Mulholland, D. Allen Penick, and William E. Scherffius. None of the persons listed above has been involved in exploration in the area since 1971, though exploration has continued.

Four sizeable sulfide bodies have been recognized; the areas containing these bodies are designated in this report as Zones 3, 9, 18 and 24. Several additional areas showing conductivity anomalies were identified (Plate 2). The numbers do not reflect a ranking of the deposits. Data given for the sulfide deposits include: size, orientation, and base-metal and mineral content of each body as well as the results of geophysical surveys and detailed mapping at each site. Graphic data on the bodies and sites are presented in Plates 2-6. The appendix to this report contains descriptive logs and assays for many drill holes. Those drill holes designated by letters and numbers (for example, DM-20) were part of the Dominion Explorers, Limited, program. Those drill holes identified by numbers only (for example, 18-12) were sponsored by the Virginia Mining Corporation. The DOMEX drill cores were logged by various staff geologists of North American Exploration, Incorporated; the VIMCO cores were logged by John D. Hagan. In the assay data, the values for the base metals (zinc, copper, lead) are weight percents, and the values for the precious metals (gold and silver) are in troy ounces per ton. Analyses were made by personnel of Union Assay Office, Incorporated (Denver, Colorado.)

The sulfides are associated with ferruginous quartzites of the Cambrian Chopawamsic Formation (Plate 1), which consists chiefly of biotite and amphibole gneiss with interbedded volcanic rocks. Rocks in drill cores that accompany the sulfides include quartz-hornblende and quartz-chlorite gneiss and schist. The occurrences of some of the sulfide bodies, at least, are related to the polyphase folds of the area.

HISTORY OF SULFIDE EXPLORATIONS

Exploration for and development of metal deposits in the Andersonville area dates to the early 1800's for gold, but only to 1956 for base metals. Six of the eight gold mines and prospects in the area were reported by Luttrell (1966); two others were reported by Sweet (1980). Only one of the mines, the Morrow mine, is reported to have contained sulfide mineralization. The quartz veins carried pyrite, pyrrhotite and chalcopyrite as well as gold.

Although there is no recorded history of exploration for base metals prior to the mid-1950's, there are shallow pits of considerable antiquity in the gossan of Zone 24 (Claude Morris property). Virginia Mining Corporation explored the Andersonville and Willis Mountain quadrangle areas during the period 1956-1958. Earlier, VIMCO personnel used airborne geophysical surveys to explore parts of the area between New Canton and Dillwyn but used a ground search for gossans in most of the area explored. VIMCO drilled at least four gossan areas, and put in a strong exploration effort on Zones 18 and 24.

Dominion Explorers, Limited sponsored exploration for base-metal sulfides during the period 1968-1971, beginning with an airborne geophysical survey in November of 1968. Although a number of geophysical anomalies and gossan occurrences were explored, the majority of drilling footage was expended on Zones 18 and 24. All work sponsored by DOMEX was carried out by the staff of North American Exploration, Incorporated.

EXPLORATION PROCEDURES

In 1968, DOMEX sponsored an airborne geophysical survey of 821 line miles. Plates 2 through 6 show the results of this survey for the Willis Mountain and Andersonville 7.5-minute quadrangles. The survey flight line spacing was one-eighth mile (0.2 km) and the ideal terrain clearance was 150-200 feet (46-61 m). A single-engine, slow-speed, high-performance aircraft, a DeHaviland "Otter," was used. The geophysical equipment employed consisted of: (1) a Rio-Tinto-type electromagnetic unit, which was used to measure the in-phase and out-of-phase components of the secondary electromagnetic field at a frequency of 320 hertz; (2) a Barringer nuclear precession magnetometer; and (3) a Sharpe Model SC-1 threshold-type spectrometer.

After a target such as an airborne electromagnetic anomaly or gossan occurrence was selected, a map grid was established to provide location control for plotting the results from geologic mapping and from soil geochemistry and geophysical surveying. All grid-formed rectangles were mapped geologically at a scale of 1″ = 100′. In most areas, "B"-horizon soil samples were collected on all grid lines at 100-foot intervals. Soil samples were routinely analyzed by atomic absorption spectrophotometry for copper, zinc, lead, nickel, and cobalt; some samples were analyzed for silver and cadmium. All grid areas were surveyed with magnetometer, self-potential and very low frequency electromagnetic units. Many areas that displayed positive geophysical and geochemical response were core drilled. Four prospects, Zones 3, 9, 18, 24, have significant or potentially significant sulfide occurrences. A discussion of these zones is presented below. The prospect number in no way constitutes a ranking.

DESCRIPTIONS OF ZONES

ZONE 3

This prospect (Plates 2 and 3) was apparently discovered by VIMCO personnel in 1956 as the result of a search for gossans. It is represented by a sulfide body which is at least 1200 feet (366 m) long and at least 15 feet (5 m) thick. The mass extends an unknown distance beyond its mapped limits, and its maximum depth is likewise unknown. As currently known, the low copper and zinc values in the sulfide mass do not make it an attractive exploration target. On the bases of gossan distribution and self-potential anomaly, VIMCO completed five core holes totaling 1,541.5 feet (470 m) in the zone. The locations of the VIMCO holes (26-01 through 26-05) are shown on Plate 3. Semi-massive to massive sulfide zones (ones in which the rock is largely or totally made up of sulfides) principally composed of pyrite and pyrrhotite were intersected in all five holes. Copper and zinc values were very low. The 1968 airborne electromagnetic survey showed the sulfide zone to be a two-line anomaly of the class 2A type (strong conductivity with direct magnetic confirmation). A survey grid was established for the total extent of the anomaly. Geologic mapping disclosed a principal gossan trend about 1400 feet (427 m) long, and additional small, scattered gossans. The foliation attitudes of the rocks in Zone 3 indicate a complex structural pattern, possibly that of an antiform. The pattern of copper- and zinc-in-soil values closely reflects the gossan distribution. The relatively high level of copper concentrations with regard to zinc concentrations indicate that chalcopyrite predominates over sphalerite in the sulfide zones. There are high zinc values in the southeastern part of the area of Zone 3. The self-potential data clearly defines a polarization anomaly which is almost perfectly coincident with the main gossan zone. The very low frequency electromagnetic data delineates several areas of moderate conductivity, in which the highest values correspond to well-defined self-potential and metal-in-soil anomalies. An arcuate trend of the sulfide zone is apparent from each of the surveys. The pattern of magnetic variations suggests that the mineralized zone would be richer in magnetite than the enclosing rocks, an observation that enhances exploration interest in one sulfide body that is a relatively weak conductor. Five core holes, totaling 1,460.5 feet (445.3 m), were drilled by DOMEX in Zone 3. The locations of the holes are shown on Plate 3, and the logs and assays for three of the holes are in the appendix. The rock section established by holes DR-1 and DR-2 is shown on Plate 3. The sulfide zone, which dips approximately 35° NW, was intersected in DR-1, DR-2 and DR-3. The only sulfides encountered in the other two holes, DR-4, DR-5, were traces of pyrrhotite and chalcopyrite. Between holes DR-1 and DR-2, the strike of the sulfide zone appears to lie at a high angle to the general strike of the deposit. In DR-1, the two sulfide zones are in a hornblende-quartz-chlorite gneiss containing disseminated pyrite. In DR-2, the 6.4-foot-thick (2.0 m) sulfide zone is in a quartz-chlorite-garnet schist with disseminated pyrite. The sulfide zones are rather variable in mineral content over relatively short distances. In DR-1, for example, the upper sulfide zone (core depth 257.1′-260.2′) is predominantly pyrite and pyrrhotite and contains chalcopyrite. The lower zone of massive sulfides (282.5′-298.2′) is mostly pyrrhotite and chalcopyrite, with some pyrite and magnetite. This sulfide zone is characterized by large, fractured pyrite cubes. In DR-3, there is a semi-massive sulfide zone which contains residual schist or gneiss. Pyrite predominates, and there are scattered specks and stringers of chalcopyrite, sphalerite and magnetite.

ZONE 9

This prospect (Plates 2 and 4) was discovered and drilled by VIMCO in 1956. Electromagnetic surveys, coupled with drilling data, indicate a sulfide body at least 4,000 feet (1,220 m) long and having a true thickness of at least 9 feet (2.7 m). The mass extends an unknown distance beyond its mapped limits, and its maximum depth is likewise unknown. Base-metal values are low. Six core holes were completed; four intersected sulfide zones. The drill hole locations were apparently selected on the pattern of gossan float and a linear self-potential anomaly. The locations of the VIMCO drill holes could not be accurately established in later exploration, and no specific data on thee core holes are included in the present report. In general, the VIMCO drilling showed that copper and zinc concentrations were too low to be economic. The apparent thickness of the sulfide zone as established by drilling was nine feet. The sulfide was described as "90 percent pyrrhotite and pyrite, about 2 percent chalcopyrite."

On the map produced from the 1968 DOMEX airborne electromagnetic survey, Zone 9 was depicted as a seven-line anomaly; the highest conductivity recorded is at the northern end of the anomaly (Plate 4). Geologic mapping located three relatively small areas of gossan concentration. The very low frequency electromagnetic survey conducted by DOMEX in 1969 confirmed the minimum length of the conducting zone as earlier mapped (4, 000 feet) (1,220 m), and the relatively high conductivity at the northern end of the zone. The self-potential values were so strongly influenced by an underground cable on the extreme northern end of the area that the sulfide zone shows only as deflections in three contour lines. The geochemical survey showed that copper- and zinc-bearing minerals make up part of the sulfide zone, although total concentrations of these metals were relatively low.

Three DOMEX core holes were completed in Zone 9; the total footage was 891 feet (272 m). The host rock for the sulfide zone in all three holes is quartz-biotite gneiss; the rock is variably pyritiferous and garnet-bearing. The sulfide zone, as identified in holes DD-1 and DD-2, has a true thickness of about 9 feet (2.7 m) and dips approximately 70° SE. The mineralized zone is composed almost entirely of iron sulfides, predominantly pyrrhotite, with scattered chalcopyrite grains. There was no visible sphalerite in the core.

ZONE 18

The sulfide body, which has a minimum length of 1,000 feet (305 m) and a true thickness up to 50 feet (15 m), is the largest known to exist in the area. It was discovered by chance when a VIMCO engineer observed a gossan outcrop in a road cut. It was this discovery which led to exploration in Zone 18. VIMCO's drilling program in Zone 18 extended through 1956 and 1957; drill hole length reached a total of 11,283 feet (3,440 m). Upon conclusion of the drilling program, VIMCO management reported reserves of 442,800 tons of ore averaging 6.01 percent zinc and 0.77 percent copper. The ore was estimated to contain 60 percent pyrite.

The Zone 18 sulfide body, which was known prior to the 1968 DOMEX airborne electromagnetic survey, could not be recognized from the air by the Rio Tinto-type electromagnetic system during the present study. There is no ready explanation for the lack of airborne response using this system. The zone is strongly conductive when measured from ground level.

The very low frequency electromagnetic ground survey revealed a moderate to strong zone of conductivity extending the length of the grid area, and a second, weaker zone lying at the east side of the area. Areas of high conductivity are accompanied by high magnetic readings. The self-potential survey indicates the possibility of two, overlapping sulfide bodies which outcrop in the areas between 0-4E and 24E-32E (Plate 5). This interpretation is distinctly reinforced by the pattern of copper-in-soil values. The zinc soil geochemistry suggests that sphalerite may have a wider distribution than chalcopyrite in the zone.

Under the DOMEX program, 34 holes were drilled in the area; total drill hole length was 13,066.0 feet (3,983.5 m). The net result of the DOMEX drilling program was to increase the estimated reserves to 794,000 tons. The average grades for the larger body were estimated to be 4.68 percent zinc and 0.60 percent copper; both values are lower than the earlier values determined by VIMCO's work.

Six generalized drill hole sections (Plate 5) are included with this report to illustrate the basic characteristics of the sulfide body. The form of the sulfide mass is that of an elongate lens; the top is truncated by erosion. The body pinches out updip, downdip and down plunge. The maximum thickness encountered was approximately 50 feet (15 m). The sulfide zone strikes about N 55° E and dips 50°-55° NW. In those areas where the sulfides approach semi-massive to massive concentrations, pyrite is the predominate mineral; sphalerite or pyrrhotite and chalcopyrite are next in abundance. The ore body is fine- to medium-grained and generally equigranular, but large pyrite cubes are not uncommon. There are relatively thin zones of high copper concentration and in these, almost without exception, the chalcopyrite is accompanied only by pyrrhotite.

The mineralization is in what is interpreted as a major shear zone. The host rock is a brecciated chlorite schist and quartz-chlorite schist. Small- and large-scale folds are common. In some places, silicification was a component of the mineralizing process.

ZONE 24

Information on this deposit is shown in Plates 2, 6A and 6B. The extensive gossan cap overlying the Zone 24 sulfide body was discovered by VIMCO personnel early in 1956. The gossan is more than 1,600 feet (489 m) long and is up to 800 feet (244 m) wide. During the period September-November 1956, VIMCO staff drilled 18 core holes into the zone; the total length of the drill holes was 5,049.0 feet (1,539.3 m).

On the basis of this work, a tonnage reserve of 368,000 tons, averaging 5.05 percent zinc and 0.65 percent copper, was estimated by VIMCO personnel.

The 1968 airborne EM survey, sponsored by DOMEX, showed Zone 24 as a 1B-type anomaly, i.e., one in which strong conductivity is without direct magnetic correlation (Plate 2). Geological mapping disclosed an unusually large area (1,800 feet by 900 feet (549 m by 274 m) of gossan float. Bedrock foliations in the area of the gossan dips mostly 20°-30° to the northwest. Soil geochemical data, especially in the case of copper, indicates an anomaly area somewhat larger than the area of gossan float. The very low frequency electromagnetic survey does show a discrete zone of conductivity along the north edge of the gossan area, but conductivity is relatively low in that area. Although the self-potential survey shows anomalous values, the pattern was so strongly influenced by the polarization effect of an underground cable along the south side of the grid that a definitive interpretation is not possible. Magnetic variations in and around the gossan area were also nondefinitive. The horizontal-loop electromagnetic survey, run at a 200-foot (61 m) coil separation, provided the most useful geophysical information. A conducting zone some 2,000 feet (610 m) long and up to 700 feet (213 m) wide, dipping gently to the north-northwest, was indicated by the results.

Upon completion of all surface mapping and surveying, 32 drill holes totaling 11,184.0 feet (3,409.8 m) were completed in Zone 24 under DOMEX sponsorship. On the basis of data acquired through the DOMEX drilling program, the reserves at Zone 24 are projected to be 550,500 tons with an average grade of 4.87 percent zinc and 0.98 percent copper. Most of these reserves could be recovered through open-pit mining.

Four generalized drill hole sections are included with this report, and logs and assays for the holes are in the appendix. In the mineralized zones, the ore is medium grained and pyrite generally predominates, but pyrrhotite predominates where concentrations of chalcopyrite are high. Hornblende gneiss or schist is the dominant lithology among the host rocks. As best shown on Section 7.50E, there are three semi-parallel sulfide bodies which dip about 20° NW. The upper body is referred to as the "ore zone," because it alone consistently showed significant zinc and copper values. The middle and lower bodies, which are very high in pyrite, contain local, high-grade concentrations of sphalerite as is true in hole DM-25 on Section 10.88 E. Local, high-grade ore concentrations also occur in the upper zone, such as in hole DM-9 (Section 4.15 E) where 2.9 feet (0.9 m) of core (106.5′-109.4′) assayed 18.47 percent copper, 8.2 percent zinc and 7.2 oz. silver per ton.

SUMMARY

Despite the fact that the two principal sulfide zones in the area, Zones 18 and 24, are only a few miles apart, their physical characteristics are quite different. Zone 18 consists of two plunging, apparently *en echelon* lenses, lying in a large shear (breccia) zone. The principal sulfide is pyrite, through which is disseminated sphalerite and minor amounts of chalcopyrite. Zone 24 consists of several sulfide zones lying one above the other in a fairly constant "stratigraphy" throughout the drilled area. There are strong indications that the sulfide bodies in Zone 24 are near the crestal portion of a partially eroded anticline. The principal sulfides are pyrite and pyrrhotite with sphalerite and chalcopyrite.

Both sphalerite and chalcopyrite occur locally as high-grade zones. The ores from both Zone 18 and Zone 24 show evidences of remobilization.

Tonnage and grade estimates are as follows:

Zone 18: 794,000 tons: 4.68%Zn, 0.60%Cu

Zone 24: 555,500 tons: 4.87%Zn, 0.98%Cu

Three other sulfide occurrences (Zones 3, 5 and 9) are near Zone 24.

APPENDIX
DRILL CORE LOGS AND ASSAYS[1]

ZONE 3

DRILL HOLE LOG FOR DR-1

LOCATION: Zone 3; 21.0E, 5.15N. ELEVATION: 482′ BEARING & INCLINATION: S 50°E, 45°

0-15′:	Soil and saprolite; no core recovery.
15′-40′:	Quartz-hornblende gneiss; core weathered and iron-stained at 98′.
40′-75′:	Quartz-chlorite schist.
75′-82′:	Hornblende-quartz schist/gneiss.
82′-97′:	Quartz-chlorite schist.
97′-126′:	Quartz-hornblende gneiss; garnetiferous; banded appearance; minor fault 124′.
126′-146′:	Hornblende-quartz gneiss; garnet-bearing.
146′-165′:	Quartz-chlorite schist; high in biotite 147.5′-166′.
165′-184′:	Quartz-hornblende gneiss; high in biotite and chlorite; garnet-bearing; drag and microfolding in foliation 177′-179′.
184′-242′:	Hornblende-quartz gneiss; high in chlorite 184′-192′; very high in biotite 217′-222′; scattered garnet zones; 0.5′ vein quartz at base.
242′-255′:	Quartz-chlorite schist; high in biotite 247′-254′; disseminated pyrite and trace chalcopyrite; garnetiferous.
255′-257.1′:	Hornblende-quartz gneiss; disseminated pyrite and trace chalcopyrite.
257.1′-260.2′:	Pyrite and pyrrhotite, variable amounts of chalcopyrite; no visible sphalerite; magnetite mixed with sulfides 254.5′-263′.
260.2′-282.5′:	Hornblende-quartz gneiss; disseminated pyrite throughout; trace chalcopyrite 260.2′-263′, 279′-281′; 0.3′ massive sulfides 271′.
282.5′-298.2′:	Pyrrhotite with subordinate pyrite and variable amounts of chalcopyrite; no visible sphalerite; magnetite present.
298.2′-307′:	Hornblende-quartz gneiss; sphalerite specks at 299.5′.
307′-319′:	Quartz-chlorite schist; disseminated pyrite 307′-312′; 1′ vein quartz 311′.
319′-331′:	Quartz-hornblende gneiss; minor fault 323′ with pyrite; quartz veins 328′, 330′; section high in chlorite 306′-326′.

TOTAL DEPTH: 331′

DR-1 ASSAYS:

No.	INTERVAL	Au	Ag	Cu	Zn
1	251.5′-253.5′	Tr	0.1	0.018	None
2	253.5′-255.5′	Tr	0.1	0.056	None
3	255.5′-257.1′	None	None	0.075	None
{ 4	257.1′-260.2′	Tr	None	2.671	None
{ 5	260.2′-263.5′	None	None	0.340	None
6	263.5′-268.5′	—	—	None	None
7	268.5′-273.5′	—	—	0.100	None
8	273.5′-278.5′	—	—	0.018	None
9	278.5′-280.3′	—	—	0.050	None
10	280.3′-282.5′	Tr	None	0.176	None
{ 11	282.5′-287.5′	Tr	0.8	0.617	None
{ 12	287.5′-292.5′	Tr	0.9	0.541	0.3
{ 13	292.5′-297.5′	Tr	1.0	0.680	Tr
14	297.5′-298.2′	Tr	0.4	0.352	None
15	298.2′-300.2′	Tr	0.4	0.081	None
16	300.2′-302.2′	None	0.4	0.025	None

[1] Braces denote assay interval depicted in drill hole sections in Plates 3-6 in back pocket. Dash indicates no analysis made.

DRILL HOLE LOG FOR DR-2

LOCATION: Zone 3; 21.0E, 5.15N. ELEVATION: 482′ BEARING & INCLINATION: S 50°E, 60°

0-20′: Overburden, soil and saprolite; no core recovery.
20′-35′: Quartz-hornblende gneiss; weathered and saprolitic.
35′-41′: No core recovery.
41′-45′: Quartz-hornblende gneiss.
45′-80′: Quartz-chlorite gneiss, saprolitic in places to 67′.
80′-86′: Quartz-hornblende-chloritic-biotite-garnet schist.
86′-103′: Quartz-chlorite-muscovite schist; limonite stained fractures; garnet-bearing.
103′-105′: Quartz-hornblende gneiss.
105′-111′: Quartz-chlorite schist, garnetiferous.
111′-113′: Chlorite-quartz schist, garnetiferous.
113′-131′: Quartz-chlorite-biotite schist, garnetiferous.
131′-157′: Quartz-hornblende gneiss, scattered garnets.
157′-160′: Chlorite-biotite schist, garnetiferous.
160′-163′: Quartz-chlorite gneiss, garnetiferous.
163′-166′: Hornblende-quartz gneiss, garnetiferous.
166′-167′: Quartz vein.
167′-196′: Quartz-chlorite gneiss; high in biotite in places; garnet-bearing.
196′-223′: Hornblende-quartz gneiss; foliation contorted in places, garnetiferous.
223′-227′: Quartz-chlorite gneiss, garnetiferous.
227′-236′: Hornblende-quartz gneiss.
236′-243′: Quartz-chlorite gneiss, high in biotite.
243′-255′: Hornblende-quartz gneiss; garnet-bearing 245′-250′.
255′-263′: Quartz-chlorite gneiss, garnetiferous 255′-260′; disseminated pyrite at base.
263′-265′: Hornblende-quartz gneiss.
265′-266′: Quartz vein.
266′-269′: Quartz-chlorite gneiss, garnetiferous.
269′-271′: Quartz-feldspar vein.
271′-283′: Quartz-chlorite-garnet schist; unusually high garnet content.
283′-289.5′: Massive to semi-massive sulfides, pyrite and pyrrhotite with visible chalcopyrite and magnetite; large pyrite crystals throughout ore zone.
289.5′-296′: Quartz-chlorite gneiss with disseminated pyrite at top.
296′-319′: Hornblende-quartz gneiss with scattered garnets and pyrite grains.
319′-365′: Quartz-chlorite gneiss; scattered garnets and magnetite grains; considerable biotite.
365′-375′: Quartz-hornblende gneiss with disseminated pyrite and scattered garnets.
375′-401′: Quartz-chlorite-garnet gneiss; very high garnet concentration; traces of chalcopyrite; high biotite content 396′-401′.

TOTAL DEPTH: 401′

DR-2 ASSAYS:

No.	INTERVAL	Au	Ag	Cu	Zn
1	281.0′-283.1′	Tr	None	0.037	None
{2	283.1′-289.5′	Tr	None	0.510	Trace
3	289.5′-291.5′	Tr	0.1	0.081	0.2

DRILL HOLE LOG FOR DR-3

LOCATION: Zone 3; 24.0E, 6.0N. ELEVATION: 476′ BEARING & INCLINATION: S 74°E, 45°

0-92′:	Overburden, soil and saprolite; no core recovery.
92′-111′:	Quartz-hornblende gneiss; minor faults at 105′ and 109′.
111′-121.5′:	Chlorite-quartz schist; strongly garnetiferous; disseminated pyrite.
121.5′-145.5′:	Quartz-chlorite schist/gneiss; garnetiferous; some disseminated pyrite; fault at 140′ with footwall foliation highly contorted.
145.5′-148′:	Chlorite-quartz schist; garnet-bearing.
148′-150′:	Mostly pyrite with considerable magnetite; traces of sphalerite and chalcopyrite.
150′-152.5′:	Quartz-chlorite schist with pyrite disseminated on folia.
152.5′-157′:	Mostly pyrite; scattered specks and stringers of sphalerite and chalcopyrite; some magnetite.
157′-157.8′:	Quartz-garnet-sericite gneiss.
157.8′-176′:	Massive to semimassive iron sulfide with visible magnetite and scattered specks of sphalerite and chalcopyrite; 161′-162′ is high in chlorite and large garnets.
176′-200′:	Hornblende-quartz gneiss; garnetiferous to 191′; 180′-193′ high in chlorite; 193′-197′ high in biotite; sphalerite specks at 198′.
200′-209′:	Quartz-chlorite gneiss.
209′-224′:	Hornblende-quartz schist/gneiss; garnet-bearing; foliation contorted and parallel to core axis.

TOTAL DEPTH: 224′

DR-3 ASSAYS:

No.	INTERVAL	Au	Ag	Cu	Zn
1	146.0′-148.0′	Tr	None	0.037	0.15
2	148.0′-152.5′	Tr	None	0.226	Tr
3	152.5′-157.5′	Tr	0.1	0.289	1.10
4	157.5′-162.5′	Tr	None	0.340	None
5	162.5′-167.5′	Tr	None	0.352	1.30
6	167.5′-172.5′	Tr	0.4	0.226	2.50
7	172.5′-177.0′	Tr	None	0.302	1.05
8	177.0′-179.0′	Tr	None	0.126	0.25

ZONE 9

DRILL HOLE LOG FOR DD-1

LOCATION: Zone 9; 38.47N, 2.72E ELEVATION: Not available BEARING & INCLINATION: N 60°W, 60°

0-35′:	Soil and saprolite; no core recovery.
35′-70′:	Quartz-hornblende gneiss.
70′-196′:	Hornblende-quartz gneiss; variably garnetiferous; generally massive.
	141′: 1′ vein quartz with pyrite
	163′-196′: pyritic
	170′-196′: brecciated
	190′-196′: high biotite content
196′-205′:	Semi-massive pyrrhotite and pyrite with scattered chalcopyrite; no visible sphalerite.
205′-319′:	Hornblende-quartz gneiss; brecciated 205′-216′, 221′-223′, 240′-267′; garnetiferous; minor fault 261′-262′; pyritic 250′-265′.
319′-331′:	Quartz-hornblende gneiss; lightly fractured 324′-327′; garnetiferous.
331′-404′:	Hornblende-quartz gneiss; garnet-bearing zones; vein quartz 382′-383′.

TOTAL DEPTH: 404′

DD-1 ASSAYS:

No.	INTERVAL	Au	Ag	Pb	Cu	Zn
1	192′-194′	Tr	0.6	None	0.050	None
{ 2	194′-199.5′	Tr	0.3	None	0.189	None
{ 3	199.5′-205′	Tr	0.5	None	0.157	Tr
4	205′-207′	Tr	0.6	None	0.012	Tr

DRILL HOLE LOG FOR DD-2

LOCATION: Zone 9; 38.47N, 2.72E ELEVATION: Not available BEARING & INCLINATION: N 60°W, 75°

0-30′: Soil and saprolite; no core recovery.
30′-260′: Hornblende-quartz gneiss; garnetiferous 128′-195′, 220′-255′, 279′-315′; garnets large and numerous 220′-255′; high biotite concentration 240′-260′; disseminated pyrite and pyrrhotite 176′-260′; traces of chalcopyrite 225′-240′, 253′-259.5′; brecciated 194′-260′.
260′-279′: Predominantly pyrrhotite and pyrite; traces of chalcopyrite; no visible sphalerite; brecciated 260′-263′.
279′-315′: Hornblende-quartz gneiss; brecciated 279′-287′, 297′-315′; lightly garnet-bearing; disseminated iron sulfides; 1′ massive sulfides 284′ with trace chalcopyrite

TOTAL DEPTH: 315′

DD-2 ASSAYS:

No.	INTERVAL	Au	Ag	Pb	Cu	Zn
1	252′-253′	Tr	0.3	None	0.012	None
2	253′-258′	Tr	None	None	0.119	None
3	258′-263′	Tr	None	None	0.252	None
4	263′-268′	Tr	None	None	0.170	0.1
5	268′-273′	Tr	None	None	0.182	0.2
6	273′-279′	Tr	None	None	0.189	Tr
7	279′-284′	None	None	None	0.012	None
8	284′-285′	Tr	None	None	0.126	None
9	285′-287′	None	None	None	0.012	None

ZONE 18

DRILL HOLE LOG FOR DX-1

LOCATION: Zone 18; 4.0E, 2.40N ELEVATION: 517′ BEARING & INCLINATION: S 33°E, 45°

0-58′: Overburden, soil and saprolite; no core recovery.
58′-244′: Chlorite schist and quartz chlorite gneiss; red-brown garnets nearly throughout; disseminated pyrite common; sugary quartz with brown garnets 71′-72′; milky white quartz with chlorite stringers 191.5′-196′; disseminated pyrite concentration increases below 235′.
244′-260.5′: Massive sulfide zones and stringers in a chlorite-quartz schist breccia; chlorite interstitial to small breccia blocks; pyrite is dominant sulfide with sphalerite and traces of chalcopyrite.
260.5′-285′: Chlorite-quartz schist breccia; strongly contorted or brecciated.
285′-380′: Chlorite schist and quartz-chlorite gneiss; scattered garnetiferous zones and disseminated pyrite; sparse calcite- and siderite-filled fractures; zones of local folding.

TOTAL DEPTH: 380.0′

DX-1 ASSAYS:

No.	INTERVAL	Au	Ag	Pb	Cu	Zn
1	244.0′-249.0′	Tr	None	None	0.239	1.0
2	249.0′-254.0′	Tr	0.1	None	0.378	6.6
3	254.0′-259.0′	Tr	None	None	0.617	4.5
4	259.0′-262.0′	Tr	0.1	None	0.579	3.4
5	262.0′-267.0′	None	None	None	0.075	None

DRILL HOLE LOG FOR DX-2

LOCATION: Zone 18; 4.0E, 2.40N ELEVATION: 517′ BEARING & INCLINATION: S 33°E, 60°

0-51′: Overburden, soil and saprolite; no core recovery.
51′-249′: Chlorite schist and quartz-chlorite gneiss in alternating sequence; red-brown garnets nearly throughout; local and common zones of disseminated pyrite; brecciated quartz 151′-152.5′; concentration of disseminated pyrite increases below 235′.
249′-261.5′: Chlorite-quartz gneiss/schist breccia; traces of pyrrhotite, sphalerite and chalcopyrite with dominant disseminated pyrite.
261.5′-274.0′: Chlorite-quartz schist/gneiss breccia; dominantly pyrite with sphalerite and trace chalcopyrite as semi-massive zones and stringers.
274′-294′: Chlorite-quartz schist/gneiss; brecciated or intensely folded; sparse calcite-filled fractures.
294′-316′: Chlorite-quartz gneiss/schist; sparse garnets and disseminated pyrite.

TOTAL DEPTH: 316.0′

DX-2 ASSAYS:

No.	INTERVAL	Au	Ag	Pb	Cu	Zn
1	251.0′-256.0′	Tr	None	None	0.126	1.4
2	256.0′-261.0′	Tr	None	None	0.163	0.3
3	261.0′-266.0′	Tr	0.1	None	0.441	4.3
4	266.0′-269.3′	Tr	0.1	None	0.050	1.0
5	269.3′-274.0′	Tr	0.4	None	0.327	5.2

DRILL HOLE LOG FOR DX-3

LOCATION: Zone 18; 4.0E, 2.40N | ELEVATION: 517′ | BEARING & INCLINATION: S 33°E, 81°

0-49′: Overburden, soil and saprolite; no core recovery.
49′-237.5′: Chlorite schist and quartz-chlorite gneiss in alternating sequence; local zones of brecciation or folding; variably garnet-bearing; zones of disseminated pyrite common; garnets in quartz-chlorite gneiss noticeably smaller; calcite blebs and fracture fillings 223′-237.5′.
237.5′-297′: Quartz-chlorite gneiss; chlorite locally altered to biotite and muscovite; calcite blebs common in top 10′; locally garnetiferous.
297′-376′: Chlorite schist; calcite blebs common in top 20′; strongly pyritic, with some large crystals, 310′-323′; local zones of drag folding common below 332′, sparsely garnet-bearing.

TOTAL DEPTH: 376′

DRILL HOLE LOG FOR DX-4

LOCATION: Zone 18; 4.0E, 1.0N | ELEVATION: 511′ | BEARING & INCLINATION: S 37°E, 45°

0-28′: Overburden, soil and saprolite; no core recovery.
28′-35′: Vein quartz, limonite staining on broken surfaces.
35′-52′: Core loss.
52′-150′: Chlorite schist and quartz-chlorite gneiss; zones of disseminated pyrite and garnets; minor breccia 75′-80′; considerable fracturing and local drag folds; vein quartz 143′-145′.
150′-162.7′: Chlorite-quartz schist breccia; pyrite-sphalerite-chalcopyrite in semi-massive beds.
162.7′-191′: Chlorite schist; brecciated and folded in top 3′; local folding 174′-179′; disseminated pyrite below 180′.

TOTAL DEPTH: 191′

DX-4 ASSAYS:

No.	INTERVAL	Au	Ag	Pb	Cu	Zn
1	146.9′-150.5′	Tr	0.1	None	0.308	0.9
⎧ 2	150.5′-155.0′	0.005	None	None	0.516	3.7
⎨ 3	155.0′-160.0′	Tr	0.2	None	0.636	2.0
⎩ 4	160.0′-162.7′	0.010	0.2	None	0.270	5.2

DRILL HOLE LOG FOR DX-5

LOCATION: Zone 18; 6.84E, 2.69N | ELEVATION: 490′ | BEARING & INCLINATION: S 33°E, 45°

0-48′: Overburden, soil and saprolite.
48′-59′: Quartz-chlorite schist.
59′-68′: Core loss.
68′-360′: Interlayered quartz-chlorite schist/gneiss and chlorite schist; scattered calcite veins and garnet zones; unusual absence of pyrite to 210′.
360′-380′: Chlorite schist breccia with strong, local folding; disseminated pyrite.
380′-397.5′: Massive to near-massive pyrite, pyrrhotite, sphalerite, and chalcopyrite.
397.5′-410′: Chlorite schist breccia with local folding.

TOTAL DEPTH: 410′

DX-5 ASSAYS:

No.	INTERVAL	Au	Ag	Pb	Cu	Zn
1	366′-371′	None	None	None	0.081	1.0
2	371′-376′	None	None	None	0.182	0.7
3	376′-380′	None	None	None	0.472	0.3
⎧ 4	380′-385′	Tr	None	None	0.529	5.9
⎨ 5	385′-390′	0.010	0.4	None	0.686	7.2
⎨ 6	390′-395′	0.005	0.4	None	1.290	1.0
⎩ 7	395′-398.5′	0.005	0.2	None	1.113	4.9

DRILL HOLE LOG FOR DX-6

LOCATION: Zone 18; 6.84E, 2.69N   ELEVATION: 490′   BEARING & INCLINATION: S 33°E, 60°

0-39′: Overburden, soil and saprolite.
39′-160′: Quartz-chlorite gneiss/schist; minor chlorite schist zones; scattered disseminated pyrite zones; variably garnet-bearing; minor calcite veins.
160′-364′: Interlayered quartz-chlorite gneiss/schist and chlorite schist; garnet-bearing nearly throughout; disseminated pyrite common; quartz veins 344′-345′, 349′-350′, 356.5′-361′.
364′-371.5′: Chlorite schist breccia; pyritic with traces of sphalerite and chalcopyrite.
371.5′-375.5′: Quartz-chlorite schist.
375.5′-427′: Semi-massive to massive pyrite, pyrrhotite, sphalerite, and chalcopyrite; traces of calcite throughout.
427′-458′: Chlorite schist with minor quartz-chlorite gneiss; minor garnet zones and disseminated pyrite; fault 454′-457′.

TOTAL DEPTH: 458′

DX-6 ASSAYS:

No.	INTERVAL	Au	Ag	Pb	Cu	Zn
1	375.5′-380′	Tr	0.2	None	0.529	1.4
2	380′-385′	Tr	0.3	None	0.607	5.8
3	385′-390′	0.010	0.3	None	1.189	2.6
4	390′-395′	0.020	0.4	None	1.771	2.1
5	395′-400′	0.020	0.3	None	0.258	5.1
6	400′-405′	0.015	0.5	None	1.012	7.8
7	405′-410′	Tr	0.3	None	0.126	5.0
8	410′-415′	Tr	0.2	None	0.144	7.9
9	415′-420′	Tr	0.3	None	0.359	8.9
10	420′-427′	Tr	0.4	None	0.611	6.4
11	367′-372′	Tr	None	None	0.333	1.7
12	372′-375.4′	Tr	None	None	0.050	0.5

DRILL HOLE LOG FOR DX-7

LOCATION: Zone 18; 6.84E, 2.69N   ELEVATION: 490′   BEARING & INCLINATION: S 33°E, 75°

0-41′: Overburden, soil and saprolite.
41′-101′: Chlorite schist with minor beds of quartz-chlorite gneiss; quartz vein 41.5′-43′ with pyrite in fractures; scattered calcite veins and garnet zones.
101′-297′: Quartz-chlorite gneiss with chlorite schist zones; abundant garnets; some chlorite schist beds pyritic.
297′-382′: Chlorite schist and quartz-chlorite gneiss in alternating beds; most chlorite schist beds pyritic; garnets common; quartz veins 315′-317′, 336′-340′, 348′-356′, 378′-382′.
382′-410′: Chlorite schist; microfolding common; brecciated 392′-410′, with pyrite; 0.3′ massive pyrite at 404′.
410′-412′: Semi-massive pyrite and pyrrhotite with sphalerite and galena.
412′-467′: Chlorite schist; brecciated 415′-426′ with microfolding; variably pyrite-bearing; quartz veins 448′-449′, 450′-450.5′, 458′-459.5′.

TOTAL DEPTH: 467′

DX-7 ASSAYS:

No.	INTERVAL	Cu	Zn
{1	409′-413′	0.34	7.40

DRILL HOLE LOG FOR DX-8

LOCATION: Zone 18; 6.84E, 1.45N   ELEVATION: 486′   BEARING & INCLINATION: S 33°E, 45°

0-69′: Overburden, soil and saprolite.
69′-190′: Quartz-chlorite gneiss and chlorite schist in alternating sequence; scattered disseminated pyrite zones; minor brecciation in chlorite schist beds; abundant garnets; fault zone 180′-182′ with footwall brecciation and large calcite crystals.
190′-228′: Quartz-chlorite gneiss with subordinate chlorite schist beds; vein quartz 207′-212′; pyritic and garnetiferous.
228′-285′: Chlorite schist; brecciated, with numerous faults; pyritic; garnetiferous 275′-285′; traces of pyrrhotite and chalcopyrite 272′-285′.
285′-292′: Semi-massive pyrite and pyrrhotite with sphalerite and chalcopyrite; thin chlorite schist beds at 286′ and 290′.
292′-356′: Chlorite schist; sparsely pyritic; numerous minor faults and veins; core highly faulted and jointed 332′-338′, vein quartz 325′-328′.

TOTAL DEPTH: 356′

DX-8 ASSAYS:

No.	INTERVAL	Au	Ag	Pb	Cu	Zn
{1	285′-290′	Tr	0.6	None	1.492	6.4
2	290′-293.3′	Tr	0.7	None	0.885	0.5

DRILL HOLE LOG FOR DX-9

LOCATION: Zone 18; 7.80E, 2.00N — ELEVATION: 473′ — BEARING & INCLINATION: S 33°E, 60°

0-36′:	Overburden, soil and saprolite.
36′-91′:	Quartz-chlorite gneiss; thin chlorite schist interbeds; variably pyrite- and garnet-bearing.
91′-120′:	Milky quartz, with thin chlorite schist or gneiss beds; fault 104′-106′.
120′-333′:	Quartz-chlorite gneiss and chlorite schist in alternating sequence; milky quartz 127′-132′, 141′-142′, 195′-202.5′, 245′-246′, 300′-305.5′, 308′-309′, 327.5′-329.5′; faults 139′-140′, 186′-188′; variably pyritiferous and garnetiferous; microfolding common.
333′-351′:	Chlorite schist; brecciated 341′-350′; disseminated pyrite, with traces of sphalerite and chalcopyrite below 347′; fault 335′-340′.
351′-354.5′:	Semi-massive pyrite, sphalerite and chalcopyrite.
354.5′-393′:	Chlorite schist; massive sulfides 361′-362′ and in thin layers 363′-367′; brecciated 367′-368′, 380′-382′; pyritiferous 354.5′-368′; faults 375′-380′.
393′-441′:	Chlorite schist and quartz-chlorite gneiss in alternating sequence; numerous calcite-filled fractures; fault 400′-401′; minor garnet zones.

TOTAL DEPTH: 441′

DX-9 ASSAYS:

No.	INTERVAL	Au	Ag	Pb	Cu	Zn
1	347′-349′	Tr	0.1	None	0.812	1.0
{ 2	349′-351′	0.005	0.1	None	0.926	1.5
{ 3	351′-355′	0.005	None	None	0.258	4.8
4	355′-360′	Tr	None	None	0.132	0.9
{ 5	360′-365′	Tr	None	None	0.132	4.6
{ 6	365′-367′	None	None	None	0.056	1.9

DRILL HOLE LOG FOR DX-10

LOCATION: Zone 18; 7.80E, 2.00N — ELEVATION: 473′ — BEARING & INCLINATION: S 33°E, 45°

0-34′:	Overburden, soil and saprolite.
34′-65′:	Quartz-chlorite gneiss; oxidized; garnets sparse.
65′-109′:	Chlorite schist with thin gneiss zones; faults 85′-94′; 99′-100′.
109′-178′:	Quartz-chlorite gneiss with chlorite schist interbeds; generally pyritic; abundant calcite-filled fractures; fault 160′-161′.
178′-300′:	Quartz-chlorite gneiss and chlorite schist in alternating sequence; abundant calcite-filled fractures; variably pyritic and garnet-bearing; faults 209′-210′, 220′-221′, 234′-236′, 249′-250′, 257′-258′, 276′-278′, 299′-300′.
300′-327.5′:	Chlorite schist; brecciated below 314′; disseminated pyrite throughout; traces of chalcopyrite and pyrrhotite below 315′.
327.5′-331′:	Massive pyrite and sphalerite, traces of chalcopyrite.
331′-361′:	Chlorite schist, with gneissic zones 346′-348′, 354′-359′; fault 348′-350′; pyritic below 345′.

TOTAL DEPTH: 361′

DX-10 ASSAYS:

No.	INTERVAL	Au	Ag	Pb	Cu	Zn
1	314′-319′	Tr	None	None	0.037	0.3
2	319′-324′	None	None	None	0.189	0.2
{ 3	324′-327.4′	None	None	None	0.327	1.7
{ 4	327.4′-331.2′	None	None	None	0.245	7.9

DRILL HOLE LOG FOR DX-11

LOCATION: Zone 18; 7.80E, 2.00N — ELEVATION: 473′ — BEARING & INCLINATION: S 33°E, 75°

0-26′:	Overburden, soil and saprolite.
26′-333′:	Quartz-chlorite gneiss with subordinate beds of chlorite schist; milky vein quartz 113′-122′, 285′-287′, 323′-324′, 326′-328′, 329′-333′; disseminated pyrite common; faults 133′, 135′, 150′-152′, 173′, 192′-194′, 218′-219′, 248′-249′, 281′-282′, 300′-302′, 330′-331′; abundant calcite-filled fractures; garnetiferous.
333′-371′:	Chlorite schist and quartz-chlorite gneiss in alternating sequence; chlorite schist beds brecciated; pyritic; pyrrhotite and chalcopyrite traces 360′-368′ with a thin massive sulfide bed at 368.5′.
371′-374.5′:	Quartz-chlorite gneiss; pyritic.
374.5′-375.5′:	Massive pyrite and pyrrhotite with sphalerite and chalcopyrite.
375.5′-380′:	Chlorite schist; brecciated and pyritic.
380′-390′:	Quartz-chlorite gneiss; pyritic.
390′-396′:	Semi-massive pyrite, pyrrhotite, sphalerite, and chalcopyrite; includes thin chlorite schist layers.
396′-419′:	Chlorite schist; brecciated and pyritic; scattered magnetite 405′-417′; microfolding common.
419′-431′:	Quartz-chlorite gneiss; calcite-filled fractures common.

TOTAL DEPTH: 431′

DX-11 ASSAYS:

No.	INTERVAL	Au	Ag	Pb	Cu	Zn
1	366.3′-369′	None	None	None	0.478	2.9
{2	374.7′-379′	None	None	None	0.182	1.5
3}	379′-382.6′	None	None	None	0.182	1.4
{4	387′-392′	Tr	None	None	0.759	3.0
5}	392′-397′	None	None	None	0.885	4.0
6	397′-399′	None	None	None	0.126	0.1
7	359′-366.3′	None	None	None	0.321	0.65
8	369′-373′	None	None	None	0.075	Tr

DRILL HOLE LOG FOR DX-12

LOCATION: Zone 18; 7.80E, 2.00N — ELEVATION: 473′ — BEARING & INCLINATION: S 33°E, 85°

0-14′:	Overburden, soil and saprolite.
14′-43′:	Quartz-chlorite gneiss; weathered and iron stained.
43′-71′:	Chlorite schist, with gneissic zones; microfolding present; sparse garnets.
71′-300′:	Quartz-chlorite gneiss, with subordinate chlorite schist beds; variably garnet- and pyrite-bearing; trace sphalerite 171.5′; high-angle fault 265′.
300′-468′:	Chlorite schist, with minor gneiss zones; quartz veins 301′-308′, 311′-314′, 327′-328′, 339′-344′, 377′-379′, 391′-395′, 415′-416′, 418′-420′; microfolding common; pyritic below 415′; local calcite-filled fractures.

TOTAL DEPTH: 468′

DRILL HOLE LOG FOR DX-13

LOCATION: Zone 18; 7.70E, 0.82N. — ELEVATION: 480′ — BEARING & INCLINATION: S 33°E, 45°

0-19′:	Overburden, soil and saprolite.
19′-192′:	Chlorite schist and quartz-chlorite gneiss in alternating sequence; variably pyritic with heaviest concentration 135′-160′; sparsely garnetiferous.
192′-196′:	Milky quartz, pyritic.
196′-212′:	Chlorite schist; brecciated and pyritic below 200′; traces of pyrrhotite and chalcopyrite throughout breccia zone.
212′-216′:	Semi-massive pyrite and pyrrhotite with sphalerite and chalcopyrite.
216′-250′:	Chlorite schist; brecciated and pyritic 216′-220′, 227′-229′; intense microfolding 245′-250′; very sparse garnets.

TOTAL DEPTH: 250′

DX-13 ASSAYS:

No.	INTERVAL	Au	Ag	Pb	Cu	Zn
1	200′-203′	Tr	None	None	0.088	0.60
{2	203′-208′	Tr	None	None	0.403	0.95
3	208′-212′	Tr	None	None	0.226	Tr
4	212′-217′	Tr	None	None	1.020	2.95
5}	217′-220′	Tr	0.2	None	0.970	0.50
6	220′-222′	Tr	None	None	0.025	0.05

DRILL HOLE LOG FOR DX-14

LOCATION: Zone 18; 7.69E, 0.31S   ELEVATION: 495′   BEARING & INCLINATION: S 33°E, 45°

0-13′: Overburden, soil and saprolite
13′-78′: Quartz-chlorite gneiss; highly weathered.
78′-198′: Chlorite schist; garnets nearly totally absent; brecciated 113′-160′, 178′-186′; disseminated pyrite 115′-158′, 178′-186′, 192′-198′; disseminated pyrrhotite, sphalerite and chalcopyrite 110′-142′ with no significant concentration.

TOTAL DEPTH: 198′

DX-14 ASSAYS:

No.	INTERVAL	Au	Ag	Pb	Cu	Zn
1	109′-114′	Tr	None	None	0.018	0.45
2	114′-119′	Tr	None	None	0.044	0.55
3	119′-124′	None	None	None	0.094	0.15
4	124′-129′	Tr	None	None	0.138	0.15
5	129′-134′	None	None	None	0.157	0.15
6	134′-135′	None	None	None	0.176	0.20

DRILL HOLE LOG FOR DX-17

LOCATION: Zone 18; 11.00E, 2.20N   ELEVATION: 486′   BEARING & INCLINATION: S 37°E, 60°

0-22′: Overburden, soil and saprolite.
22′-45′: Quartz-hornblende-chlorite gneiss.
45′-85′: Chlorite schist; brecciated and pyritic 55′-80′; traces of sphalerite and chalcopyrite 63′; 6″ diabase dikes at 70′ and 71′; garnetiferous 64′-81′.
85′-111′: Quartz-chlorite gneiss; pyritic in top 5′.
111′-130′: Hornblende-quartz-chlorite schist.
130′-203′: Quartz-chlorite gneiss; sparse garnets; disseminated pyrite 139′-161′, 170′-172′; diabase dikes 155′-157′; 161′-166′, 172′-175′; milky quartz 180′-184′; brecciation 149′-151′, 158′-170′, 184′-187′.
203′-426′: Chlorite schist, with gneissic zones 228′-234′, 319′-327′; some milky quartz 263′-266′; 281′-287′, 289′-291′, 299′-301′, 349′-353′, 456′-460′; sparse garnets in scattered zones; brecciated and pyritic 203′-227′, 247′-259′, 276′-279′, 327′-330′, 378′-425′; traces of chalcopyrite 209.5′, 224.5′, 321.5′; sphalerite stringers with pyrrhotite 324.5′; scattered magnetite 216′-225′; disseminated pyrrhotite, sphalerite and chalcopyrite 396′-426′.
426′-431′: Semi-massive pyrite and sphalerite with traces of chalcopyrite.
431′-480′: Chlorite schist; milky quartz 456′-460′; pyritic to 450′; no garnets; brecciated 447′-450′.

TOTAL DEPTH: 480′

DX-17 ASSAYS:

No.	INTERVAL	Au	Ag	Pb	Cu	Zn
1	394.5′-396.5′	None	None	None	0.012	0.2
2	396.5′-402′	None	None	None	0.195	1.4
3	402′-407′	None	None	None	0.220	1.2
4	407′-412′	Tr	None	None	0.863	0.4
5	412′-417′	None	None	None	0.264	1.4
6	417′-422′	None	None	None	0.283	1.2
7	422′-424′	None	None	None	0.094	Tr
{8	424′-429′	None	None	None	0.220	4.0
9	429′-432.5′	None	None	None	0.107	1.4
10	432.5′-434.5′	None	None	None	0.018	None

DRILL HOLE LOG FOR DX-18

LOCATION: Zone 18; 11.00E, 2.20N   ELEVATION: 486′   BEARING & INCLINATION: S 37°E, 45°

0-25′: Overburden, soil and saprolite.
25′-40′: Quartz-chlorite gneiss; weathered.
40′-86′: Chlorite schist; brecciated 63′-74′, 80′-82′; pyritic 56′-86′; garnet-bearing 60′-86′; diabase dike 54′-56′; traces of sphalerite 57′-58′; traces of chalcopyrite and sphalerite 63.5′-64′.
86′-189′: Quartz-chlorite gneiss; diabase dike 103′-106′; disseminated pyrite common; local areas of minor brecciation; traces of sphalerite 124′-127′; diabase dike 180′-181.5′.
189′-208′: Diabase dike.
208′-221′: Quartz-chlorite gneiss; brecciated.
221′-230′: Chlorite-biotite schist.
230′-257′: Milky quartz; fractured and lightly pyritic.
257′-304′: Chlorite schist; disseminated pyrite; garnet-bearing to 286′; brecciated 265′-267′, 300′-304′.
304′-374′: Quartz-chlorite gneiss; scattered garnet zones; brecciated nearly throughout; disseminated pyrite common; traces of sphalerite at 308.5′, 321′, 323′; scattered showings of pyrrhotite, chalcopyrite and sphalerite 365′-374′.
374′-398′: Semi-massive pyrite, pyrrhotite, sphalerite, and chalcopyrite; mineralized chlorite schist breccia 391′-394′, 395′-397′.
398′-420′: Chlorite schist and quartz-chlorite gneiss; brecciated to 411′; disseminated pyrite; traces of chalcopyrite, sphalerite and pyrrhotite 398′-404′.
420′-459′: Quartz-chlorite gneiss; scattered garnets and disseminated pyrite; traces of pyrrhotite and chalcopyrite 450′-455′.

TOTAL DEPTH: 459′

DX-18 ASSAYS:

No.	INTERVAL	Au	Ag	Pb	Cu	Zn
1	365′-370′	None	None	None	0.088	1.0
2	370′-374′	Tr	None	None	0.220	0.4
3	374′-379′	Tr	None	0.15	0.396	4.9
4	379′-384′	Tr	None	None	1.264	6.0
5	384′-390.5′	Tr	0.1	None	0.548	7.5
6	390.5′-394′	None	None	None	0.378	1.5
7	394′-398′	Tr	None	None	0.567	4.3
8	398′-400′	Tr	None	None	0.176	0.3

DRILL HOLE LOG FOR DX-19

LOCATION: Zone 18; 11.00E, 2.20N   ELEVATION: 486′   BEARING & INCLINATION: S 37°E, 75°

0-21′: Overburden, soil and saprolite.
21′-41′: Quartz-hornblende-chlorite gneiss; pyritic.
41′-49′: Milky quartz.
49′-108′: Chlorite schist; disseminated pyrite below 70′; brecciated 77′-108′; garnetiferous below 85′; trace chalcopyrite 82′; heavy concentration of hornblende 71′-74′.
108′-139′: Quartz-chlorite gneiss; disseminated pyrite; sparsely garnet-bearing.
139′-151′: Chlorite schist; sparse pyrite.
151′-207′: Quartz-chlorite gneiss; variably garnetiferous and pyritic.
207′-224′: Diabase dike.
224′-255′: Chlorite schist, with gneissic zones; brecciated and pyritic throughout; scattered chalcopyrite 236′-246.5′; schist slightly vuggy.
255′-259.5′: Milky quartz.
259.5′-260.5′: Diabase dike.
260.5′-268′: Hornblende-quartz-chlorite gneiss.
268′-281′: Quartz-chlorite gneiss; pyritic; zones of light brecciation.
281′-287′: Diabase, with 1.5′ gneiss 283.5′-285′.
287′-354′: Chlorite schist; thin breccia zones and microfolding; scattered chalcopyrite and pyrrhotite 330′-332′; sparsely garnetiferous and pyritic; diabase 311′-315′, 320′-321′, 322′-327′, 328′-329′, 337′-339′.
354′-365′: Quartz-chlorite gneiss.
365′-379′: Milky quartz.
379′-446′: Quartz-chlorite gneiss; scattered pyrite and garnets; minor zones of brecciation; disseminated pyrrhotite 387′-395′; diabase 432′-433′.
446′-458′: Milky quartz; fractured and pyritic.
458′-482′: Chlorite schist; diabase 476′-477′.
482′-484.5′: Milky quartz.
484.5′-493′: Hornblende-quartz-chlorite gneiss; pyritic.
493′-504′: Hornblende-quartz-chlorite gneiss; disseminated sulfides 493′-494.5′, semi-massive pyrite, sphalerite, chalcopyrite 494.5′-498′, barren 498′-501′, semi-massive sulfides 501′-502′, disseminated sulfides 502′-504′.
504′-555′: Chlorite schist; brecciated 505′-510′; disseminated and stringer sulfides 505′-507′, 519′-523′; diabase 523′-527′, 531.5′-538′.
555′-557′: Diabase.

TOTAL DEPTH: 557′

DX-19 ASSAYS:

No.	INTERVAL	Au	Ag	Pb	Cu	Zn
1	490.5′-492.5′	None	None	None	0.018	0.2
2	492.5′-497.8′	Tr	None	None	1.771	5.4
3	497.8′-500.8′	None	None	None	0.025	None
4	500.8′-502′	Tr	0.3	None	0.239	8.8
5	502′-504′	Tr	0.5	0.20	0.132	2.1

DRILL HOLE LOG FOR DX-20

LOCATION: Zone 18; 11.00E, 1.06N ELEVATION: 501′ BEARING & INCLINATION: S 37°E, 45°

0-37′: Overburden, soil and saprolite.
37′-71.5′: Milky quartz, weathered.
71.5′-80′: Diabase.
80′-100′: Chlorite schist; brecciated and pyritic 86′-100′; scattered chalcopyrite and sphalerite 87′-94′.
100′-103′: Diabase.
103′-111.5′: Quartz-chlorite gneiss.
111.5′-124.5′: Diabase.
124.5′-133′: Chlorite schist; fault 125′-127′; garnetiferous; microfolding.
133′-142′: Diabase.
142′-147.5′: Milky quartz, fractured.
147.5′-151′: Chlorite-biotite schist.
151′-157.5′: Milky quartz.
157.5′-159.5′: Chlorite-biotite schist
159.5′-171′: Milky quartz.
171′-192′: Chlorite schist; garnetiferous; pyritic below 184′.
192′-198′: Milky quartz.
198′-322′: Chlorite schist; brecciated and pyritic 199′-204′, 242′-318′; milky quartz, fractured and pyritic, 211′-215′, 249′-253′; generally garnetiferous 222′-285′; scattered chalcopyrite grains 270′-294′; scattered magnetite 312′-317′.
322′-331′: Milky quartz.
331′-336′: Chlorite schist; pyritic.

TOTAL DEPTH: 336′

DX-20 ASSAYS:

No.	INTERVAL	Au	Ag	Pb	Cu	Zn
1	85′-87′	None	None	None	0.025	0.1
{2	87′-94.5′	Tr	None	None	0.226	2.0
3	94.5′-96′	Tr	None	None	0.050	Tr
4	270′-275′	Tr	0.3	None	0.195	None
5	275′-280′	None	None	None	0.088	None
6	280′-285′	Tr	None	None	0.144	None
7	285′-290′	Tr	None	None	0.365	0.3
8	290′-294′	None	None	None	0.289	0.3

DRILL HOLE LOG FOR DX-21

LOCATION: Zone 18; 11.00E, 3.36N ELEVATION: 475′ BEARING & INCLINATION: S 37°E, 75°

0-5′: Broken rock, no soil overburden.
5′-55′: Hornblende-quartz-chlorite gneiss; generally massive.
55′-74′: Diabase dike; high angle contacts.
74′-114′: Chlorite schist; scattered calcite veins; minor breccias 85′-87′, 91′-94′; chalcopyrite specks 86′.
114′-121′: Diabase.
121′-134′: Chlorite schist.
134′-139.5′: Milky quartz.
139.5′-164′: Chlorite schist; pyritic.
164′-174.5′: Milky quartz; high-grade sphalerite in thin veins.
174.5′-218′: Chlorite schist; pyrite and sphalerite 178′-179′; high sericite content 179′-182′; scattered areas of weak brecciation; disseminated pyrite.
218′-285′: Quartz-hornblende-chlorite gneiss; sparse garnets; brecciated and pyritic 255′-260′, 270′-285′.
285′-294′: Chlorite schist; some brecciation and pyrite.
294′-307′: Milky quartz.
307′-337′: Quartz-hornblende-chlorite gneiss; sparse garnets; sparse fractures.
337′-344′: Chlorite schist; some brecciation.
344′-465′: Quartz-hornblende-chlorite gneiss; disseminated pyrite nearly throughout; strong fracturing below 395′; diabase 397′-398′; garnet-bearing 400′-440′; disseminated pyrrhotite 404′-465′ with traces of chalcopyrite.
465′-639′: Hornblende-quartz-chlorite gneiss; scattered pyrrhotite 465′-475′; strongly fractured to 520′; moderate to strong brecciation 540′-630′; variably pyritic and chloritic in breccia area.
639′-656′: Quartz-hornblende-chlorite gneiss; some fracturing.

TOTAL DEPTH: 656′

DX-21 ASSAYS:

No.	INTERVAL	Au	Ag	Pb	Cu	Zn
1	166′-169′	Tr	None	None	0.126	6.3
2	169′-172′	Tr	None	None	0.176	2.7

DRILL HOLE LOG FOR 18-04

LOCATION: Zone 18; 0.25E, 1.20N (approx.) ELEVATION: 530′ (approx.) BEARING & INCLINATION: S 33°E (?), 45°

0′-60′: Overburden, soil and saprolite; no core recovery.
60′-71′: Chlorite schist, siliceous.
71′-109′: Quartzite schist, in places chloritic; coarse, granular sulfides associated with siliceous sections; 71′-88′ well mineralized, 88′-109′ semi-massive; sulfides are strongly leached with some secondary chalcocite.
109′-110′: Quartz vein.
110′-194′: Chlorite schist, siliceous; 109′-115′ weakly mineralized; 136′-145′ abundant quartz "eyes".

TOTAL DEPTH: 194′

18-04 ASSAYS:

No.	INTERVAL	Au	Ag	Cu	Zn
1	71′-74′	0.005	Tr	0.17	9.90
2	74′-81′	0.01	Tr	0.64	0.40
3	81′-88′	Tr	Tr	0.27	0.59
4	88′-92′	0.015	Tr	0.57	8.52
5	92′-98′	0.01	Tr	0.22	7.53
6	98′-102′	0.01	Tr	0.27	4.75
7	102′-106′	Tr	0.18	0.12	4.85
8	106′-109′	Tr	0.24	0.32	14.55

DRILL HOLE LOG FOR 18-05

LOCATION: Zone 18; 0.20W, 2.50N (approx.) ELEVATION: 535′ (approx.) BEARING & INCLINATION: S 33°E, 45°

0-75′: Overburden, soil and saprolite; no core recovery.
75′-127′: Chlorite schist, siliceous; intensely silicified locally.
127′-147′: Siliceous chlorite schist; heavily mineralized sections are in "quartzite schist", 5-10% pyrite with variable amounts of sphalerite.
147′-171′: Chlorite schist, siliceous.
171′-187′: "Quartzite schist" with some chloritic sections; sulfides, principally pyrite, are coarse, granular and semi-massive; variable amounts of sphalerite and traces of chalcopyrite.
187′-256′: Chlorite schist, siliceous; some sections entirely silicified; pronounced quartz "eyes" 231′-241′.

TOTAL DEPTH: 256′

18-05 ASSAYS:

No.	INTERVAL	Au	Ag	Cu	Zn
E-26	127′-130′	Tr	0.22	0.05	5.14
E-27	137′-144′	Tr	0.30	0.22	2.08
E-28	171′-175.5′	Tr	0.19	0.12	5.94
E-29	175.5′-177.5′	0.015	0.22	0.05	6.04
E-30	177.5′-181.5′	Tr	Tr	0.05	0.10
E-31	181.5′-187.0′	0.01	0.10	0.37	9.40

DRILL HOLE LOG FOR 18-11

LOCATION: Zone 18; 4.80E, 3.00N ELEVATION: 524′ BEARING & INCLINATION: S 33°E, 45°

0-39′: Overburden, soil and saprolite.
39′-85′: Hornblende gneiss; biotite and siliceous; partly oxidized.
85′-114′: Quartz-sericite schist.
114′-269′: Hornblende gneiss; with biotite, garnets and chlorite; 214′-269′ increasingly siliceous.
269′-300′: Chlorite schist; garnetiferous.
300′-322′: Shear zone; chloritic; 2-3% pyrite.
322′-361′: Chloritic shear zone with siliceous zones; massive sulfides appear to be associated with siliceous zones; pyrite, sphalerite and chalcopyrite.
361′-388′: Chlorite schist (shear zone?).

TOTAL DEPTH: 388′

18-11 ASSAYS:

No.	INTERVAL	Cu	Zn
E-111	329′-334′	0.39	0.57
E-112	334′-339′	0.27	5.44
E-113	339′-344′	0.29	12.35
E-114	344′-349′	0.78	6.46
E-115	349′-354′	1.39	3.63
E-116	354′-358′	0.87	2.27
E-117	358′-361′	0.92	10.44

DRILL HOLE LOG FOR 18-25

LOCATION: Zone 18; 4.65E, 1.60N — ELEVATION: 513′ — BEARING & INCLINATION: S 33°E, 45°

0-75′: Overburden, soil and saprolite.
75′-181′: Hornblende gneiss; some minor silicified zones; 97′-106′ minor pyrite and shearing; 157′-162′ strong silicification.
181′-195′: Shear zone; weak; chloritic; 5% pyrite.
195′-211′: Chlorite shear zone; 10-15% pyrite; garnets and biotite; pronounced shearing 60-70° to core axis.
211′-225′: Chloritic shear zone; pyrite, sphalerite and chalcopyrite.
225′-240′: Hornblende gneiss.

TOTAL DEPTH: 240′

18-25 ASSAYS:

No.	INTERVAL	Cu	Zn
E-181	206′-211′	0.52	0.66
E-182	211′-215′	0.58	15.31
E-183	215′-217′	0.55	1.12
E-184	217′-220′	4.15	1.72
E-185	220′-225′	0.81	3.95

DRILL HOLE LOG FOR 18-26

LOCATION: Zone 18; 4.90E, 5.00N — ELEVATION: 520′ — BEARING & INCLINATION: S 33°E, 60°

0-77′: Overburden, soil and saprolite.
77′-108′: Quartz-sericite schist; hornblende-bearing 96′-100′.
108′-378′: Hornblende gneiss; minor sections of quartz-sericite schist; pyritic 241′-243′.
378′-381′: Quartz vein.
381′-429′: Hornblende gneiss.
429′-442′: Quartz-sericite schist.
442′-474′: Hornblende gneiss.
474′-563′: Chloritic shear zone; scattered disseminated pyrite zones.
563′-577′: Quartz-sericite schist.
577′-597′: Hornblende gneiss.

TOTAL DEPTH: 597′

ZONE 24

DRILL HOLE LOG FOR DM-1

LOCATION: Zone 24; 7.52E, 0.94N — ELEVATION: 528′ — BEARING & INCLINATION: S 23°E, 45°

0-85′: Overburden, soil and saprolite.
85′-107′: Quartz-hornblende/tremolite-chlorite gneiss; pyritic 85′-91′, 95′-102′; garnetiferous 95′-102′; trace chalcopyrite 106.5′.
107′-125′: Semi-massive pyrite, sphalerite, chalcopyrite, and pyrrhotite; sphalerite varies from brown to black.
125′-132′: Quartz-chlorite gneiss; pyritic; trace chalcopyrite 125.5′.
132′-220′: Quartz-hornblende tremolite-chlorite gneiss and hornblende-chlorite schist interlayered; fault 150′ in a thin chlorite schist; fault, with pyrite and magnetite, 170′; garnetiferous 170′-208′; sparsely pyritic; traces of pyrrhotite and chalcopyrite 193′-194′.
220′-228′: Chlorite schist; brecciated and pyritic; biotite replacing chlorite in places.
228′-232′: Semi-massive pyrite with traces of chalcopyrite and sphalerite.
232′-237′: Chlorite schist; brecciated and pyritic; 0.5′ massive pyrite 234.5′.
237′-353′: Quartz-hornblende/tremolite-chlorite gneiss and hornblende-chlorite schist interlayered; generally garnetiferous; variably pyritic; local zones of brecciation; 1′ vein quartz 298′; strong pyrrhotite with trace chalcopyrite 311′-312.5′; trace chalcopyrite 341′.

TOTAL DEPTH: 353′

DM-1 ASSAYS:

No.	INTERVAL	Au	Ag	Pb	Cu	Zn
1	106′-110′	Tr	0.4	None	0.453	4.0
2	110′-114′	0.005	None	0.30	0.214	4.4
3	114′-119′	Tr	0.5	0.35	0.504	4.1
4	119′-122′	Tr	0.6	None	0.910	2.7
5	122′-124.6′	Tr	0.4	None	0.409	3.8
6	124.6′-126.4′	Tr	0.2	None	0.113	0.5
7	225′-227′	Tr	None	None	0.050	0.1
8	227′-232′	Tr	0.1	None	0.006	None
9	232′-235.5′	None	None	None	0.075	None
10	235.5′-238′	Tr	0.1	None	0.075	0.5

DRILL HOLE LOG FOR DM-2

LOCATION: Zone 24; 7.52E, 0.94N ELEVATION: 528′ BEARING & INCLINATION: S 23°E, 75°

0-55′:	Overburden, soil and saprolite.
55′-120′:	Quartz-hornblende-chlorite-biotite gneiss; disseminated pyrite below 70′; garnetiferous below 97′; trace chalcopyrite 107,′, 111′, 114′; 0.5′ thick chalcopyrite 117′.
120′-129′:	Semi-massive pyrite, pyrrhotite, sphalerite, and chalcopyrite.
129′-213′:	Quartz-hornblende-chlorite gneiss; scattered chalcopyrite grains 137′-143′; trace chalcopyrite 150′; fault 170′; pyritic 129′-143′, 169′-175′, 207′-213′; variably garnetiferous.
213′-218′:	Chlorite schist; brecciated and pyritic.
218′-221′:	Semi-massive pyrite with trace sphalerite and chalcopyrite.
221′-230′:	Chlorite schist; brecciated and pyritic; trace chalcopyrite 225′.
230′-253′:	Quartz-hornblende-chlorite gneiss; garnetiferous throughout.
253′-292′:	Chlorite schist, with hornblende gneiss zones; brecciated nearly throughout; pyritic; scattered chalcopyrite 254′-271′, 284′-292′.
292′-320′:	Hornblende-chlorite schist; generally brecciated and pyritic; chalcopyrite concentrations 292′-294′, 299.5′-301′, 311.5′-316′.
320′-505′:	Quartz-hornblende-chlorite gneiss; garnetiferous throughout; hornblende schist zones; generally pyritic to 385′; traces of chalcopyrite 359′, 365′, 475′.

TOTAL DEPTH: 505′

DM-2 ASSAYS:

No.	INTERVAL	Au	Ag	Pb	Cu	Zn
1	112′-113.7′	Tr	None	None	0.151	Tr
2	113.7′-117′	0.010	1.4	None	2.125	2.00
3	117′-119.7′	0.010	0.2	None	0.535	0.45
4	119.7′-124′	Tr	0.6	None	0.352	7.30
5	124′-129′	0.010	0.8	None	0.289	3.15
6	129′-131′	Tr	None	None	0.214	0.50
7	213.3′-217′	Tr	None	None	0.069	0.15
8	217′-222′	Tr	None	None	0.056	0.05
9	222′-228.5′	Tr	None	None	0.081	0.05
10	252′-254′	Tr	None	None	0.170	Tr
11	254′-258′	Tr	None	None	1.083	0.1
12	258′-260′	Tr	None	None	0.113	None
13	260′-265′	Tr	None	None	0.724	1.1
14	265′-267.5′	Tr	0.2	None	0.743	1.4
15	267.5′-269.5′	Tr	None	None	0.025	None

DRILL HOLE LOG FOR DM-3

LOCATION: Zone 24; 7.52E, 1.25N ELEVATION: 525′ BEARING & INCLINATION: —; 90°

0-29′: Overburden, soil and saprolite.
29′-62′: Quartz-hornblende-chlorite gneiss; biotitic; garnet-bearing to 55′.
62′-137.5′: Hornblende-chlorite schist and quartz-hornblende-chlorite gneiss interlayered; high-angle fault 75′; quartz veins 109′, 124′, 128′, 140′; disseminated pyrite 131′-137.5′; very sparse garnets.
137.5′-155.5′: Semi-massive pyrite with highly variable amounts of sphalerite and chalcopyrite; includes zones of hornblende schist and gneiss; 0.5′ vein quartz 140′.
155.5′-185′: Quartz-hornblende-chlorite gneiss; garnetiferous; pyritic 176′-180′; 1′ pyrrhotite with chalcopyrite and sphalerite 174′.
185′-208′: Hornblende-chlorite schist; garnetiferous below 198′.
208′-210′: Milky quartz veins.
210′-255′: Quartz-hornblende-chlorite gneiss; garnetiferous to 231′; pyritic below 227′ with heavy concentrations 235′-248′ carrying trace chalcopyrite and sphalerite; 0.5′ semi-massive pyrite 249.5′.
255′-307′: Hornblende-chlorite schist; brecciated 262′-278′, 292′-305′; disseminated pyrite below 262′.
307′-311.5′: Semi-massive pyrrhotite with chalcopyrite.
311.5′-333′: Hornblende-chlorite-biotite schist; brecciated and pyritic throughout; scattered chalcopyrite to 330′; garnetiferous.
333′-351′: Chlorite schist; brecciated and pyritic throughout; garnetiferous; 0.2′ massive pyrrhotite and chalcopyrite 339′.
351′-425′: Quartz-hornblende-chlorite gneiss; disseminated pyrite to 369′; variably garnetiferous; trace chalcopyrite 370′, 400′.

TOTAL DEPTH: 425′

DM-3 ASSAYS:

No.	INTERVAL	Au	Ag	Pb	Cu	Zn
1	131′-135′	Tr	None	None	0.144	0.20
2	135′-138.8′	Tr	None	None	0.378	1.05
3	138′-140.5′	Tr	None	None	0.018	0.25
4	140.5′-145.5′	0.005	0.6	0.20	0.541	3.35
5	145.5′-150.5′	0.010	0.7	Tr	0.793	4.50
6	150.5′-155.5′	Tr	1.0	0.10	2.125	5.45
7	155.5′-157′	Tr	None	None	0.025	0.05
8	157′-165′	Tr	None	None	0.056	Tr
9	174.4′-175.8′	None	None	None	0.107	2.65
10	233′-235′	Tr	None	None	0.018	Tr
11	235′-240′	Tr	0.3	None	0.037	0.15
12	240′-245′	Tr	0.4	None	0.012	0.05
13	245′-250′	Tr	None	None	0.075	None
14	250′-252′	None	0.2	None	0.081	None
15	304.5′-306.5′	Tr	0.5	None	0.025	None
16	306.5′-310′	Tr	0.7	None	1.315	Tr
17	310′-315′	Tr	0.4	None	0.226	Tr
18	315′-320′	Tr	0.5	None	0.151	Tr
19	320′-326′	Tr	0.9	None	0.170	Tr
20	326′-328′	Tr	0.8	None	0.207	Tr

DRILL HOLE LOG FOR DM-4

LOCATION: Zone 24; 7.52E, 2.25N   ELEVATION: 530′   BEARING & INCLINATION: –; 90°

0-33′:	Overburden, soil and saprolite.
33′-52′:	Quartz-hornblende-chlorite gneiss; sparse garnets below 44′.
52′-65′:	Hornblende-chlorite schist; sparse garnets below 59′.
65′-83′:	Quartz-hornblende-chlorite gneiss; garnetiferous to 87′; fault, with pyrite, 78′.
83′-90′:	Hornblende-chlorite schist.
90′-114′:	Quartz-hornblende-chlorite gneiss; uniform.
114′-124′:	Hornblende-chlorite schist.
124′-166′:	Quartz-hornblende-chlorite gneiss; variably pyritic and garnet-bearing.
166′-182′:	Hornblende-chlorite gneiss.
182′-187′:	Quartz-hornblende-chlorite gneiss; disseminated pyrite.
187′-191.5′:	Semi-massive pyrite and pyrrhotite with sphalerite and chalcopyrite.
191.5′-217.5′:	Hornblende-chlorite schist; sparse pyrite and garnets; 7″ high-grade sphalerite and chalcopyrite with pyrrhotite at base of unit.
217.5′-279′:	Quartz-hornblende-chlorite gneiss; garnetiferous; pyritic at top and base; trace chalcopyrite 220′.
279′-289′:	Hornblende-chlorite schist; brecciated; very small garnets; pyritic; scattered pyrrhotite below 285′; trace chalcopyrite 285′.
289′-292′:	Milky quartz with pyrite.
292′-297′:	Hornblende-chloride schist; brecciated and pyritic; massive pyrite stringers with traces of zinc and copper.
297′-304.5′:	Chlorite schist breccia; semi-massive pyrite 299′-300.5′; schist pyritic and garnetiferous.
304.5′-327′:	Hornblende-chlorite schist; brecciated; pyritic and garnetiferous; trace chalcopyrite 325′.
327′-344′:	Quartz-chlorite gneiss and chlorite schist; brecciated; garnetiferous and pyritic; scattered chalcopyrite grains 327′-339′ associated with pyrrhotite; chalcopyrite concentration 341′.
344′-358′:	Hornblende-chlorite schist; brecciated and pyritic; scattered chalcopyrite throughout.
358′-364′:	Chlorite schist; brecciated and pyritic; disseminated chalcopyrite to 363′.
364′-388′:	Hornblende-chlorite schist; gneissic below 382′; brecciated to 375′; pyritic throughout.
388′-406′:	Chloride schist and quartz-chlorite gneiss; semi-massive pyrite with zinc and copper 389.5′-391′; schist/gneiss brecciated and pyritic.
406′-434′:	Quartz-hornblende-chlorite gneiss; generally pyritic and garnetiferous.

TOTAL DEPTH: 434′

DM-4 ASSAYS:

No.	INTERVAL	Au	Ag	Pb	Cu	Zn
1	180′-182′	0.005	0.2	None	0.270	Tr
2	182′-186′	0.005	None	None	0.270	3.10
3	186′-191′	Tr	0.2	None	0.957	6.65
4	191′-193′	Tr	None	None	0.075	0.25
5	285′-291′	Tr	None	None	0.050	Tr
6	291′-296′	Tr	None	None	0.037	Tr
7	296′-301′	Tr	None	None	0.025	Tr
8	339.5′-345′	Tr	None	None	0.315	Tr
9	345′-349′	Tr	0.1	None	0.711	Tr
10	349′-350.5′	Tr	0.1	None	1.008	None
11	388′-389.5′	Tr	None	None	0.151	0.35
12	389.5′-391′	Tr	0.2	None	0.143	3.50
13	391′-396′	Tr	None	None	0.075	0.20
14	396′-401′	Tr	None	None	0.062	0.25
15	401′-404′	Tr	None	None	0.132	0.05

DRILL HOLE LOG FOR DM-5

LOCATION: Zone 24; 7.52E, 3.25N ELEVATION: 528′ BEARING & INCLINATION: —; 90°

0-33′: Overburden, soil and saprolite.
33′-56′: Quartz-hornblende gneiss; trace garnets and pyrite 51′-52′.
56′-78′: Hornblende schist; pyritic and garnetiferous 65′-70′.
78′-111′: Quartz-hornblende gneiss; variably garnetiferous; trace chalcopyrite in breccia 94′-95′.
111′-121′: Hornblende schist; garnetiferous.
121′-179′: Quartz-hornblende gneiss; disseminated pyrite 139′-143′; fault 146′; generally garnetiferous; disseminated pyrite and pyrrhotite 168′-173′.
179′-189′: Hornblende schist.
189′-202′: Quartz-hornblende gneiss; lightly garnetiferous.
202′-207.5′: Semi-massive pyrite, chalcopyrite and sphalerite; gneiss 203′-204′.
207.5′-312′: Quartz-hornblende gneiss; breccia 210′; erratically pyritic; garnetiferous nearly through; traces of pyrrhotite 281′, 290′, and associated with chalcopyrite 307′; brecciated 305′-312′.
312′-317′: Hornblende schist; brecciated and pyritic.
317′-333′: Chlorite schist; brecciated and pyritic; high in hornblende and biotite 326′-328′; scattered chalcopyrite 320′-326′; massive pyrite 328′-329′.
333′-342′: Quartz-hornblende gneiss; garnetiferous; brecciated and pyritic.
342′-381′: Hornblende schist; brecciated and pyritic; garnetiferous throughout, milky quartz 356.5′-358.2′; trace chalcopyrite 362.5′, 363.5′; disseminated chalcopyrite 366′-375′.
381′-392′: Chlorite schist, garnet-bearing; brecciated and pyritic to 390′.
392′-401′: Hornblende schist.
401′-414′: Quartz-hornblende schist; pyritic and brecciated nearly throughout; garnetiferous; trace chalcopyrite associated with pyrrhotite 404′-406′; disseminated chalcopyrite 410′-414′.
414′-429′: Quartz-chlorite-hornblende gneiss; scattered chalcopyrite 418′-426′ with the best concentration at 422′-424′; garnetiferous; pyritic and brecciated.
429′-433′: Hornblende schist.
433′-438′: Milky quartz with garnets and pyrite.
438′-485′: Quartz-hornblende-chlorite gneiss; variably garnetiferous; traces of pyrite.

TOTAL DEPTH: 485′

DM-5 ASSAYS:

No.	INTERVAL	Au	Ag	Pb	Cu	Zn
1	199.5′-201.5′	Tr	None	None	0.044	None
{ 2	201.5′-207′	Tr	0.4	None	0.660	4.45
3	207′-209′	Tr	None	None	0.056	Tr
⎧ 4	320′-325′	None	None	None	0.119	None
⎨ 5	325′-330′	None	None	None	0.025	None
⎩ 6	330′-335′	None	None	None	0.037	None
⎧ 7	378′-381′	Tr	0.2	None	0.315	0.90
⎨ 8	381′-386′	None	None	None	0.037	None
⎩ 9	386′-391′	None	None	None	0.012	0.05
⎧ 10	418.5′-422′	None	None	None	0.081	0.20
⎩ 11	422′-426′	None	None	None	0.226	Tr

DRILL HOLE LOG FOR DM-6

LOCATION: Zone 24; 7.52E, 4.31N ELEVATION: 528′ BEARING & INCLINATION: —; 90°

0-20′: Overburden, soil and saprolite.
20′-189′: Quartz-hornblende-chlorite gneiss; variably garnet-bearing; scattered traces of pyrite; fault 106′; traces of pyrrhotite and chalcopyrite 90.5′, 140′.
189′-194′: Quartz-chlorite-hornblende gneiss; brecciated and pyritic; trace chalcopyrite 192′.
194′-214′: Quartz-hornblende-chlorite gneiss; brecciated and pyritic; 194′-199′; pyrrhotite scattered throughout brecciated area with traces of chalcopyrite; garnetiferous below 202′.
214′-236.5′: Hornblende-chlorite schist; garnetiferous below 231′1; trace chalcopyrite 220.5′, 239′.
236.5′-241.5′: Semi-massive pyrite, sphalerite and chalcopyrite; zone fracture controlled.
241.5′-272′: Quartz-hornblende-chlorite gneiss; trace pyrite; fault 263′; garnetiferous below 265′.
272′-301′: Hornblende schist; scattered garnets.
301′515′: Quartz-hornblende-chlorite gneiss; garnetiferous to 450′ and 505′-515′; trace chalcopyrite 333′, 336′; breccia with iron sulfides 338′-340′; brecciated and pyritic 359′-448′; semi-massive iron sulfides 357′-358′; traces of pyrrhotite and chalcopyrite scattered from 364′-480′; milky quartz 393′-394′; high in chlorite 432′-443′; brecciated and pyritic 460′-490′; pyritic 490′-515′.

TOTAL DEPTH: 515′

DM-6 ASSAYS:

No.	INTERVAL	Au	Ag	Pb	Cu	Zn
1	235′-236.3′	Tr	0.1	None	0.018	0.4
{ 2	236.3′-241.3′	Tr	0.2	0.2	0.390	4.9
3	241.3′-243′	None	None	None	0.044	0.2
⎧ 4	406′-411′	None	None	None	0.113	None
⎨ 5	411′-416′	None	None	None	0.352	None
⎩ 6	416′-421.5′	Tr	0.1	None	0.163	None

DRILL HOLE LOG FOR DM-7

LOCATION: Zone 24; 7.52E, 5.31N   ELEVATION: 523′   BEARING & INCLINATION: –; 90°

0-32′:	Overburden, soil and saprolite.
32′-129′:	Quartz-hornblende-chlorite gneiss; scattered garnet zones; trace pyrite; trace chalcopyrite 73′, 104′.
129′-149′:	Hornblende-chlorite schist; sparse garnets.
149′-231′:	Quartz-hornblende-chlorite gneiss; trace chalcopyrite 153′; variably pyritic and garnet-bearing; fault 187′.
231′-253′:	Hornblende-chlorite schist; pyrrhotite stringers 237′-238′; garnetiferous below 244′.
253′-257′:	Disseminated pyrite and sphalerite 253′-255′; semi-massive pyrite 255′-257′.
257′-305′:	Quartz-hornblende-chlorite gneiss; scattered, large garnets; milky quartz with chlorite stringers 268′-271′.

TOTAL DEPTH: 305′

DM-7 ASSAYS:

No.	INTERVAL	Au	Ag	Pb	Cu	Zn
1	250′-253′	None	None	None	0.006	None
{ 2	253′-257′	Tr	0.4	Tr	0.214	4.4
3	257′-259.8′	None	None	None	0.006	Tr

DRILL HOLE LOG FOR DM-8

LOCATION: Zone 24; 7.52E, 6.31N   ELEVATION: 516′   BEARING & INCLINATION: –; 90°

0-25′:	Overburden, soil and saprolite.
25′-96′:	Quartz-hornblende-chlorite gneiss; garnet-bearing below 41′; biotitic 55′-65′; sparse pyrite.
96′-123′:	Hornblende-biotite schist; garnetiferous; zones of microfolding.
123′-157′:	Quartz-hornblende-chlorite gneiss; garnetiferous throughout; fault 133′
157′-173′:	Hornblende-chlorite schist.
173′-254′:	Quartz-hornblende-chlorite gneiss; garnetiferous to 215′; no pyrite.
254′-281′:	Hornblende-chlorite schist; very sparse garnets; pyrrhotite stringers 260′; traces of sphalerite and chalcopyrite 275′-276′; 2″ pyrrhotite with minor chalcopyrite in fracture 278′.
281′-292′:	Quartz-hornblende-chlorite gneiss.
292′-334′:	Hornblende-chlorite schist; sparse garnets and trace pyrite; milky quartz 312′-317′.
334′-414′:	Quartz-hornblende-chlorite gneiss; sparse garnets; trace chalcopyrite 371.5′.
414′-456′:	Hornblende-chlorite schist; brecciated below 422′; pyritic below 430′; garnetiferous below 445′; fault 431′.
456′-488′:	Chlorite schist; biotitic 460′-480′; brecciated and pyritic throughout; garnetiferous; pyrrhotite concentration 458′-460′; scattered chalcopyrite grains 469′-487′ associated with pyrrhotite.
488′-505′:	Hornblende-chlorite schist; brecciated and pyritic; garnet-bearing.

TOTAL DEPTH: 505′

DRILL HOLE LOG FOR DM-9

LOCATION: Zone 24; 4.51E, 0.85N   ELEVATION: 546′   BEARING & INCLINATION: S 23°E, 60°

0-51′:	Overburden, soil and saprolite.
51′-92′:	Quartz-hornblende-chlorite gneiss; very sparse garnets.
92′-109′:	Semi-massive pyrite, pyrrhotite, chalcopyrite, sphalerite; chalcopyrite locally in very high concentrations; no brecciation in hanging or footwall.
109′-173′:	Quartz-hornblende-chlorite gneiss; pyritic 113′-126′, 143′-150′; thin (0.5′-1.0′) massive sulfide zones 115′-118′; variably garnetiferous.
173′-197′:	Chlorite-biotite-hornblende schist; brecciated and pyritic throughout; garnet-bearing to 182′; disseminated pyrrhotite and chalcopyrite grains 178′-182′.
197′-311′:	Hornblende-biotite-chlorite schist; garnetiferous nearly throughout; brecciated and pyritic; 0.5′ massive pyrite 209′; scattered chalcopyrite 221′-258′ with concentrations at 244′, 245′, 252′, 254′, 258′.
311′-344′:	Quartz-hornblende-chlorite gneiss; brecciated and pyritic to 328′; breccia area garnetiferous; trace chalcopyrite 316.5′, 325′-326′, 335.5′.

TOTAL DEPTH: 344′

DM-9 ASSAYS:

No.	INTERVAL	Au	Ag	Pb	Cu	Zn
1	90′-92′	Tr	0.7	None	0.044	None
2	92′-97′	Tr	1.1	None	0.965	3.7
3	97′-102′	Tr	1.1	None	0.863	3.1
4	102′-103′	Tr	0.5	None	0.207	None
5	103′-106.5′	Tr	1.5	None	1.930	3.4
6	106.5′-109.4′	Tr	7.2	None	18.47	8.2
7	109.4′-111′	Tr	0.6	None	0.119	None
8	114′-115′	Tr	None	None	0.396	None
{ 9	115′-118.5′	0.005	1.2	None	0.914	12.7
10	118.5′-120′	Tr	None	None	0.233	None

DRILL HOLE LOG FOR DM-10

LOCATION: Zone 24; 4.51E, 1.50N — ELEVATION: 548′ — BEARING & INCLINATION: S 23°E, 75°

0-42′:	Overburden, soil and saprolite.
42′-71′:	Hornblende-chlorite schist; very fine pyrite 47′-64′.
71′-83′:	Quartz-hornblende-chlorite gneiss; fractured; light pyrite.
83′-118′:	Hornblende-chlorite schist/sulfide zone; lightly pyritic; sparse garnets; no brecciation; sulfide zone 111′-118′ with thin semi-massive zones of pyrite and minor sphalerite and chalcopyrite.
118′-138′:	Quartz-hornblende-chlorite gneiss; sparse garnets and trace pyrite.
138′-148′:	Hornblende-chlorite schist.
148′-200′:	Quartz-hornblende-chlorite gneiss; trace chalcopyrite 194′; large garnets below 156′; disseminated pyrite below 160′; trace chalcopyrite and sphalerite 184′.

TOTAL DEPTH: 200′

DM-10 ASSAYS:

No.	INTERVAL	Au	Ag	Pb	Cu	Zn
{ 1	110′-116′	Tr	0.4	Tr	0.403	1.9
2	116′-118′	Tr	0.1	None	0.088	1.1

DRILL HOLE LOG FOR DM-11

LOCATION: Zone 24; 4.51E, 2.15N — ELEVATION: 549′ — BEARING & INCLINATION: –; 90°

0-50′:	Overburden, soil and saprolite.
50′-145.5′:	Quartz-hornblende-chlorite gneiss; garnetiferous; horizontal jointing; generally pyritic; disseminated magnetite 68′-140′; silicified zone 144′-145′.
145.5′-159′:	Semi-massive pyrite, pyrrhotite, sphalerite, and chalcopyrite; ore zone vuggy.
159′-181′:	Hornblende-chlorite schist; horizontal jointing; garnetiferous throughout; pyritic to 170′.
181′-350′:	Quartz-hornblende-chlorite gneiss; disseminated magnetite nearly throughout; pyritic throughout; horizontal jointing persists to 255′; numerous traces of pyrrhotite and chalcopyrite, best concentration 310′-312′; biotite-rich zones below 256′.
350′-355′:	Quartz-chlorite-hornblende gneiss; pyritic; trace chalcopyrite 353′-354′.

TOTAL DEPTH: 355′

DM-11 ASSAYS:

No.	INTERVAL	Au	Ag	Pb	Cu	Zn
1	143.5′-145.5′	None	None	None	None	None
{ 2	145.5′-150.5′	0.090	0.3	0.15	0.270	8.0
3	150.5′-155.5′	0.005	0.2	None	0.100	4.5
4 }	155.5′-159.1′	0.010	0.3	Tr	0.315	5.7
5	159.1′-161.1′	Tr	None	None	None	None

DRILL HOLE LOG FOR DM-12

LOCATION: Zone 24; 4.51E, 3.15N — ELEVATION: 541′ — BEARING & INCLINATION: –; 90°

0-50′:	Overburden, soil and saprolite.
50′-70′:	Quartz-hornblende-chlorite gneiss; horizontal jointing; garnetiferous; pyritic 61′-66′.
70′-94′:	Hornblende-chlorite schist; scattered magnetite 67′-85′; pyritic 75′-80′.
94′-101′:	Quartz-hornblende-chlorite gneiss; garnetiferous.
101′-105′:	Hornblende schist.
105′-151′:	Quartz-hornblende-chlorite gneiss; garnetiferous to 140′; stringers of milky quartz 118′-120′; scattered magnetite 110′-118′; trace chalcopyrite 111.5′, 114′.
151′-178′:	Hornblende-chlorite schist/sulfide zone; massive sulfides at 170.5′-171.5′, 176′-177′; massive pyrite low in Zn and Cu sulfides.
178′-210′:	Quartz-hornblende-chlorite gneiss; pyritic 178′-180′; garnet-bearing below 199′.
210′-245′:	Hornblende-chlorite schist; garnetiferous; pyritic below 232′; 0.5′ milky quartz at base.

TOTAL DEPTH: 245′

DM-12 ASSAYS:

No.	INTERVAL	Au	Ag	Pb	Cu	Zn
1	168.5′-170.5′	0.005	None	None	0.006	None
{2	170.5′-171.5′	0.005	None	None	0.056	3.45
3	171.5′-173.5′	None	None	None	0.044	0.45

DRILL HOLE LOG FOR DM-13

LOCATION: Zone 24; 4.51E, 4.15N   ELEVATION: 546′   BEARING & INCLINATION: —; 90°

0-72′:	Overburden, soil and saprolite.
72′-84′:	Hornblende-chlorite schist; limonite stained.
84′-92′:	Quartz-hornblende-chlorite gneiss.
92′-149′:	Hornblende-chlorite schist; variably garnet-bearing throughout.
149′-160′:	Quartz-hornblende-chlorite gneiss; disseminated pyrite.
160′-170′:	Hornblende-chlorite schist; pyritic.
170′-190′:	Quartz-hornblende-chlorite gneiss; garnetiferous; fractured; sparse pyrite.
190′-217′:	Hornblende-chlorite schist; pyritic 200′-209′; 0.5′ pyrite and sphalerite with trace chalcopyrite 209.5′.
217′-218′:	Milky quartz.
218′-265′:	Quartz-hornblende-chlorite gneiss; garnet-bearing below 225′; milky quartz 231′-232′; much chlorite 232′-235′.

TOTAL DEPTH: 265′

DRILL HOLE LOG FOR DM-18

LOCATION: Zone 24; 9.85E, 2.15N   ELEVATION: 501′   BEARING & INCLINATION: S 23°E, 60°

0-29′:	Overburden, soil and saprolite.
29′-84′:	Quartz-hornblende-chlorite gneiss; garnet-bearing throughout; fractured and veined.
84′-100′:	Hornblende-chlorite schist; faulted and brecciated below 89′.
100′-105′:	Quartz-hornblende-chlorite gneiss; brecciated and pyritic.
105′-115′:	Quartz-chlorite-hornblende gneiss; high in biotite below 106′; pyritic throughout.
115′-130′:	Quartz-hornblende chlorite gneiss; garnetiferous; strong jointing.
130′-135′:	Quartz-chlorite-hornblende gneiss; pyritic.
135′-179′:	Quartz-hornblende-chlorite gneiss; semi-massive sulfide zones, mostly pyrite or pyrrhotite with varying amounts of sphalerite and chalcopyrite; semi-massive sulfides 136.7′-139.9′, 144′-145.7′, 153.7′-162.3′, 164.9′-165.2′, 167.3′-171.9′; disseminated pyrrhotite and chalcopyrite 165.2′-167.3′; scattered chalcopyrite in fractures 172′-179′.
179′-249′:	Quartz-hornblende-chlorite gneiss; garnetiferous throughout.
249′-270′:	Quartz-chlorite-biotite gneiss; disseminated chalcopyrite 254′-268′; pyritic throughout.
270′-292′:	Quartz-hornblende-chlorite gneiss; garnetiferous.
292′-300′:	Chlorite schist; semi-massive sulfides, high sphalerite, 293.8′-294.6′; disseminated chalcopyrite 294.6′-300′.
300′-342′:	Quartz-hornblende-chlorite gneiss; garnetiferous and pyritic throughout; scattered chalcopyrite 325′-330′.
342′-360′:	Quartz-chlorite-hornblende gneiss; garnetiferous; pyritic to 350′.

TOTAL DEPTH: 360′

DM-18 ASSAYS:

No.	INTERVAL	Au	Ag	Pb	Cu	Zn
1	134.5′-136.5′	None	0.4	None	0.107	None
2	136.5′-139.9′	Tr	0.3	None	0.459	2.10
3	139.9′-143.6′	None	0.2	None	0.037	0.10
4	143.6′-145.7′	Tr	0.4	None	0.592	2.25
5	145.7′-153.3′	Tr	None	None	0.056	0.10
6	153.3′-158.3′	Tr	None	None	0.378	7.90
7	158.3′-162.3′	Tr	0.6	None	0.730	6.70
8	162.3′-164.6′	Tr	None	None	0.018	0.05
9	164.6′-167.4′	Tr	0.6	None	1.323	0.95
10	167.4′-172.0′	Tr	1.2	None	1.814	5.80
11	172′-179′	Tr	None	None	0.403	0.15
12	179′-181′	None	None	None	0.012	None
13	252′-254′	None	None	None	0.132	0.25
14	254′-259′	None	None	None	0.113	0.25
15	259′-264′	None	0.3	None	0.081	0.25
16	264′-270′	Tr	None	None	0.088	0.10
17	270′-272′	None	None	None	0.006	0.10
18	291.5′-293.5′	None	None	None	0.151	0.50
19	293.5′-295.5′	Tr	None	None	0.636	11.10
20	295.5′-300′	Tr	None	None	0.598	0.65
21	300′-302′	None	None	None	0.037	0.10

DRILL HOLE LOG FOR DM-19

LOCATION: Zone 24; 9.85E, 1.15N   ELEVATION: 501′   BEARING & INCLINATION: S 23°E, 60°

0-75′:	Overburden, soil and saprolite.
75′-98′:	Quartz-hornblende-chlorite gneiss; pyritic; garnets 93′-95′; 0.1′ semi-massive pyrite, sphalerite and chalcopyrite at 77.5′.
98′-112′:	Hornblende-chlorite schist; oxidized.
112′-114′:	Milky quartz.
114′-138′:	Hornblende-chlorite schist; ore zones show strong leaching of sphalerite; semi-massive to massive sulfides (pyrite, sphalerite, chalcopyrite) 113.8′-115.5′, 121′-126.9′, 133′-138.5′; 0.3′ milky quartz 128.5′.
138′-214′:	Quartz-hornblende-chlorite gneiss; garnetiferous 141′-155′, 183′-215′; zone of faulting and brecciation 158′-171′; stringers of pyrite, pyrrhotite and chalcopyrite 200′-201.5′.
214′-228′:	Quartz-chlorite-biotite gneiss; large pyrite cubes 214′; scattered specks of pyrite and chalcopyrite 214′-225′.
228′-304′:	Quartz-hornblende-chlorite gneiss; garnetiferous; schistose 265′-270′.

TOTAL DEPTH: 304′

DM-19 ASSAYS:

No.	INTERVAL	Au	Ag	Pb	Cu	Zn
1	111.7′-113.7′	None	None	None	0.050	Tr
2	113.7′-115.5′	Tr	None	None	0.390	3.75
3	115.5′-120.4′	Tr	0.6	None	0.214	0.30
4	120.4′-126.3′	Tr	0.2	None	0.579	3.90
5	126.3′-131.9′	None	None	None	0.044	0.30
6	131.9′-133.3′	Tr	None	None	1.016	1.15
7	133.3′-138.5′	Tr	0.7	0.20	1.041	7.00
8	138.5′-140.5′	None	None	None	0.003	0.05

DRILL HOLE LOG FOR DM-20

LOCATION: Zone 24; 9.95E, 3.15N   ELEVATION: 501′   BEARING & INCLINATION: S 23°E, 60°

0-33′:	Overburden, soil and saprolite.
33′-130′:	Quartz-hornblende-chlorite gneiss; core broken and iron stained 33′-37′; garnetiferous 40′-75′, 100′-109′; milky quartz 85′-87′; silicified 109′-114.5′.
130′-193′:	Hornblende-chlorite schist; zone of minor faults 137′-145′; no garnets; high in biotite 182′-193′; chalcopyrite and pyrrhotite as fracture fillings 182′-193′.
193′-216′:	Quartz-hornblende-chlorite gneiss; chalcopyrite and pyrrhotite in fractures 193′-194′; semi-massive iron sulfides, sphalerite and chalcopyrite 201.5′-202.5′; pyrite and chalcopyrite in stringers 209.5′; 0.3′ semi-massive sulfides 211.5′; chalcopyrite and sphalerite fracture fillings 214′; semi-massive pyrrhotite, chalcopyrite and sphalerite 215′-216′.
216′-293′:	Quartz-hornblende-chlorite gneiss; garnetiferous; fractured 240′-255′; scattered chalcopyrite specks 216′-221′; chalcopyrite fracture fillings 221.5′, 224.5′-226′; milky quartz 275′-276′; fault zone 276′-277′.
293′-323′:	Quartz-chlorite-biotite gneiss; schistose 300′-305′; pyritic throughout; scattered chalcopyrite grains 295′-296′, 306′-307′, 309′-310′, 320′-321′; drag folds 316′-317′.
323′-342′:	Quartz-hornblende-chlorite gneiss; garnetiferous; fractured.
342′-355′:	Quartz-chlorite-biotite gneiss; pyritic throughout; scattered sphalerite and chalcopyrite 342′-343.5′; semi-massive sulfides 343.5′-346′; disseminated chalcopyrite 346′-354.5′.
355′-394′:	Quartz-hornblende gneiss; large hornblende crystals throughout; semi-massive sphalerite-pyrite 362′-363′; scattered chalcopyrite grains 364′-392′.

TOTAL DEPTH: 394′

DM-20 ASSAYS:

No.	INTERVAL	Au	Ag	Pb	Cu	Zn
1	187.3′-189.3′	Tr	None	None	0.006	None
2	189.3′-194′	Tr	0.1	None	0.850	0.55
3	194′-201.5′	Tr	None	None	0.012	None
4	201.5′-204′	Tr	None	None	0.453	1.10
5	204′-211.5′	None	None	None	None	0.30
6	211.5′-216.5′	Tr	None	None	0.466	2.25
7	216.5′-221.5′	None	None	None	0.075	0.05
8	221.5′-226.5′	None	None	None	0.138	0.05
9	226.5′-228.5′	None	None	None	0.050	None
10	303′-305′	None	0.1	None	0.018	None
11	305′-310′	None	None	None	0.069	None
12	310′-312′	None	0.1	None	0.037	1.0
13	340′-342′	None	None	None	None	None
14	342′-346.8′	Tr	0.1	None	0.642	0.75
15	346.8′-348.5′	Tr	None	None	0.069	0.60
16	348.5′-352.3′	Tr	None	None	0.655	1.20
17	352.3′-355′	Tr	None	None	0.189	1.50
18	355′-357′	None	0.1	None	0.006	None
19	359.7′-361.7′	None	0.2	None	None	0.3
20	361.7′-363.4′	None	None	None	0.006	4.9
21	363.4′-365.4′	None	None	None	0.006	1.3

DRILL HOLE LOG FOR DM-21

LOCATION: Zone 24; 9.85E, 4.33N   ELEVATION: 506.5′   BEARING & INCLINATION: S 23°E, 60°

0-32′: Overburden, soil and saprolite.
32′-41′: Quartz-hornblende gneiss; iron stained; fractured.
41′-55′: Hornblende-chlorite schist; garnetiferous 42′-50′.
55′-62′: Quartz-hornblende gneiss; sparsely pyritic.
62′-90′: Hornblende-chlorite schist; fault and drag-folds 69′-71′; milky quartz 83′-84′; quartz with thin bands of nearly pure hornblende 86′-88′.
90′-112′: Quartz-hornblende gneiss.
112′-127′: Hornblende-chlorite schist; quartz veins 112′, 106′-107′, 108′-109′, 111′, 116′; fault 122′.
127′-133′: Quartz-hornblende-chlorite gneiss; garnet-bearing.
133′-139′: Hornblende-chlorite schist.
139′-163′: Quartz-hornblende-chlorite gneiss; fault 147′-148′; garnetiferous 151′-160′.
163′-173′: Hornblende-chlorite schist; garnetiferous; faults with breccia 168′, 172′.
173′-202′: Quartz-hornblende-chlorite gneiss; milky quartz 181′-183′; disseminated pyrrhotite 180′-185′; fault 191′.
202′-211′: Hornblende-chlorite schist; minor faults 202′-206′, 207′-210′.
211′-237′: Quartz-hornblende-chlorite gneiss; pyritic and garnetiferous; chalcopyrite grains 222′, 229′, 236′.
237′-261.5′: Quartz-hornblende-chlorite gneiss; pyritic throughout; semi-massive to massive zones of pyrite, sphalerite, chalcopyrite, and pyrrhotite 237′-240′, 243′-249′, 256.5′-261.5′; sphalerite-chalcopyrite fracture fillings 255′-256′.
261.5′-289′: Quartz-hornblende-chlorite gneiss; sparsely pyritic; garnetiferous 270′-283′, 287′-289′; faults 265′, 271′, 280′; schistose and high in chlorite 283′-285′.
289′-298′: Hornblende-chlorite schist; minor fault 294′.
298′-325′: Quartz-hornblende-chlorite gneiss; garnetiferous; faults 300′, 303′, 307′; 0.5′ quartz 320′.
325′-334′: Hornblende-chlorite schist; fault 333′.
334′-353′: Quartz-hornblende-chlorite gneiss; garnetiferous 335′-347′; minor faults 336′, 338′; pyritic 345′-347′; large hornblende crystals 334′-347′; schistose 347′-353′.
353′-455′: Quartz-chlorite-hornblende gneiss; semi-massive pyrite 354′-355.5′; schistose 356′-358′; very high in biotite 356′-361′; disseminated pyrrhotite and chalcopyrite 354′-361′; much (20-30%) disseminated pyrite 365′-380′; high in biotite 371′-380′; semi-massive pyrite 384.5′-386.5′; disseminated chalcopyrite 386.5′-400′; high in magnetite 386′-387′; heavy silica zone 405′-410′; scattered chalcopyrite grains 410′-417′; high in magnetic 411′-412.5′; disseminated chalcopyrite and magnetite 417′-425′; semi-massive sulfide zone, high in sphalerite 425.5′-426.7′; scattered pyrrhotite and chalcopyrite grains 427′-454′.

TOTAL DEPTH: 454′

DM-21 ASSAYS:

No.	INTERVAL	Au	Ag	Pb	Cu	Zn
1	234.5′-236.5′	Tr	None	None	0.069	None
2	236.5′-240′	Tr	None	None	0.081	2.75
3	240′-242.5′	Tr	None	None	0.088	0.45
4	242.5′-246′	Tr	0.5	Tr	0.346	2.70
5	246′-249.1′	Tr	0.4	0.10	0.081	13.15
6	249.1′-255′	Tr	0.2	None	0.277	0.35
7	255′-258.2′	Tr	0.8	None	2.099	5.45
8	258.2′-261.5′	Tr	0.1	None	0.107	3.60
9	261.5′-263.5′	Tr	None	None	0.012	None
10	408′-410′	Tr	None	None	0.037	0.20
11	410′-415′	Tr	None	None	0.674	0.05
12	415′-420′	None	None	None	0.428	Tr
13	420′-423.8′	None	None	None	0.157	0.05
14	423.8′-424.8′	None	None	None	0.126	0.55
15	424.8′-426.7′	None	None	None	0.466	16.80
16	426.7′-428.7′	None	None	None	0.157	0.60

DRILL HOLE LOG FOR DM-22

LOCATION: Zone 24; 9.85E, 5.53N ELEVATION: 511′ BEARING & INCLINATION: S 23°E, 60°

0-50′: Overburden, soil and saprolite.
50′-147′: Quartz-hornblende-chlorite gneiss; garnet-bearing 58′-70′, 123′-142′; schistose zones; thin quartz veins 80′, 89′, 90′, 95′, 98′, 100′, 101′, 102′, 103′; milky quartz 133′-134″, 143′-146′; zone of faulting and brecciation 108′-120′.
147′-161′: Hornblende-chlorite gneiss; fault 159′.
161′-193′: Quartz-hornblende-chlorite gneiss; garnetiferous below 170′; minor faults 161′, 162′, 169′; schistose 166′-170′.
193′-215′: Hornblende-chlorite schist; 2″ calcite vein 208′.
215′-264′: Quartz-hornblende-chlorite gneiss; quartz veins 238′, 241′, 254′, 260′; garnetiferous 224′-250′; local disseminated pyrite; sphalerite, chalcopyrite and pyrrhotite grains 245′-246′; schistose 257′-260′.
264′-275′: Quartz-hornblende-chlorite gneiss; semi-massive to massive sulfides (pyrite, sphalerite, chalcopyrite, pyrrhotite; 263.6′-266.4′, 270′-273′; three stages of sphalerite noted.
275′-327′: Quartz-hornblende-chlorite gneiss; scattered pyritic zones, with trace chalcopyrite 292′; garnetiferous 287′-291′, 307′-325′.
327′-343′: Hornblende-chlorite schist; zone of minor faults 337′-340′; 0.3′ quartz vein at base.
343′-380′: Quartz-hornblende-chlorite gneiss; garnetiferous throughout; milky quartz 359′-361′.
380′-406′: Quartz-chlorite-hornblende gneiss; pyritic, locally to 25%; schistose 395′-397′.
406′-409′: Massive pyrite.
409′-514′: Quartz-chlorite-hornblende, gneiss; milky quartz 431′-433′, 438′-440′; brown mica common; disseminated pyrite throughout; disseminated chalcopyrite and pyrrhotite 440′-480′ with local concentrations; semi-massive pyrite with minor chalcopyrite 451′-451.5′; very high in quartz and garnets 499′-506′.

TOTAL DEPTH: 514′

DM-22 ASSAYS:

No.	INTERVAL	Au	Ag	Cu	Zn
1	261.6′-263.6′	Tr	0.1	0.056	None
⎡2	263.6′-266.4′	None	0.8	1.474	3.80
⎨3	266.4′-269.9′	None	None	0.075	0.05
⎣4	269.9′-273.2′	Tr	0.6	0.478	5.40
5	273.2′-275.2′	None	None	0.025	0.05
6	440′-442′	Tr	None	0.069	None
⎡7	442′-447′	Tr	None	0.346	None
⎨8	447′-453′	Tr	None	0.441	None
⎣9	453′-458′	Tr	None	0.378	None
10	458′-460′	Tr	None	0.037	None

DRILL HOLE LOG FOR DM-23

LOCATION: Zone 24; 9.85E, 5.53N ELEVATION: 511′ BEARING & INCLINATION: S 23°E, 80°

0-36′: Overburden, soil and saprolite.
36′-179′: Quartz-hornblende-chlorite gneiss; milky quartz 48′-49′, 97′-98′; oxidized fault zones 84′-87′, 90′-92′; minor faults 115′, 119′; sparsely garnetiferous.
179′-225′: Hornblende-chlorite schist; sparsely garnetiferous.
225′-295′: Quartz-hornblende-chlorite gneiss; pyritic 225′-236′, 292′-295′; quartz-healed faults with pyrite and magnetite 240′, 243′, 250′; semi-massive sulfides, mostly pyrrhotite, 255.2′-256.1′; magnetite in semi-massive to massive bands 292′-295′.

TOTAL DEPTH: 295′

DM-23 ASSAYS:

No.	INTERVAL	Au	Ag	Cu	Zn
1	253′-255′	Tr	None	0.044	None
⎧2	255′-256.1′	Tr	None	1.619	4.45
⎩3	256.1′-257.4′	Tr	0.1	0.081	0.15
4	257.4′-259.4′	Tr	None	0.0006	Tr

DRILL HOLE LOG FOR DM-24

LOCATION: Zone 24; 10.86E, 1.18N ELEVATION: 496′ BEARING & INCLINATION: S 23°E, 45°

0-67′: Overburden, soil and saprolite.
67′-102′: Quartz-chlorite-hornblende gneiss; biotite common; pyritic throughout; traces of disseminated chalcopyrite 67.5′-87.5′; sphalerite and chalcopyrite specks and veinlets 95′-100′.
102′-142′: Quartz-hornblende-chlorite gneiss; massive pyrite seam 123′; pyritic below 130′; drag folds 138′-140′.
142′-148.7′: Semi-massive to massive pyrite with pyrrhotite, sphalerite and chalcopyrite.
148.7′-173.6′: Quartz-hornblende-chlorite gneiss; fault zone 150′-156′, 166′-169′.
173.6′-176.6′: Semi-massive to massive pyrite with pyrrhotite, sphalerite and chalcopyrite.
176.6′-259′: Quartz-hornblende-chlorite gneiss; pyrite fracture fillings with traces of sphalerite and chalcopyrite 181′-184′; quartz-healed fault 193.5′; fault zone with breccia 204′-213′; fault 244′; pyritic below 250′.
259′-266′: Chlorite schist; high in biotite and pyrite; trace disseminated chalcopyrite.
266′-269′: Semi-massive to massive pyrite.
269′-273′: Chlorite schist; high in pyrite and biotite.
273′-321′: Quartz-hornblende-chlorite gneiss; garnetiferous to 304′; minor faults 275′, 288′, 299′, 304′; schistose 300′-309′.

TOTAL DEPTH: 321′

DM-24 ASSAYS:

No.	INTERVAL	Au	Ag	Cu	Zn
1	140′-142′	Tr	None	0.018	None
{ 2	142′-147′	Tr	0.7	1.360	2.55
{ 3	147′-148.7′	0.030	0.6	0.743	0.80
4	148.7′-150.7′	Tr	None	0.138	0.15
5	170.6′-172.6′	None	None	0.012	None
6	172.6′-173.6′	Tr	None	0.094	0.10
{ 7	173.6′-176.6′	Tr	0.3	1.008	4.95
{ 8	176.6′-178.6′	Tr	None	0.050	0.05

DRILL HOLE LOG FOR DM-25

LOCATION: Zone 24; 10.86E, 3.40N ELEVATION: 520′ BEARING & INCLINATION: –; 90°

0-27′: Overburden, soil and saprolite.
27′-130′: Quartz-hornblende-chlorite gneiss and hornblende-chlorite schist in alternating sequence; pyritic 64′-67′, 118′-126′; fault 70′; fracture zone 100′-110′.
130′-157′: Quartz-hornblende-chlorite gneiss; strongly fractured 134′-135′.
157′-182′: Hornblende-chlorite schist; milky quartz 173′-174′, 175′-176′.
182′-237′: Quartz-hornblende-chlorite gneiss; pyritic 182′-184′; 195′-199′, 216′-218′, 229′-237′; faults 193′, 205′, 211′, 225′; disseminated pyrite, pyrrhotite, sphalerite, and chalcopyrite 216.5′-218.1′.
237′-246′: Semi-massive to massive pyrite, pyrrhotite, sphalerite, and chalcopyrite; 3″ band of magnetite at 246′.
246′-325′: Quartz-hornblende-chlorite gneiss; faults 259′, 306′, 308′; thin bands of semi-massive sulfides 269′-271′; sparsely garnetiferous; schistose 302′-306′; thin quartz veins 285′, 318′, 323′.
325′-344′: Hornblende-chlorite schist; fault 335′; pyritic 342′-344′; gneissic 340′-344′.
344′-354′: Chlorite-hornblende schist; pyritic; scattered chalcopyrite grains; high in biotite.
354′-360′: Semi-massive pyrite; high in muscovite.
360′-387′: Quartz-chlorite-hornblende gneiss; high in biotite and pyrrhotite 365′-380′; traces of chalcopyrite; pyritic throughout; massive pyrite 383.8′-385′; schistose 372′-380′.
387′-405′: Quartz-hornblende-chlorite gneiss; pyritic and garnetiferous.
405′-429′: Quartz-chlorite-hornblende gneiss; pyritic and garnetiferous; high in biotite and pyrrhotite 405′-417′; 2″ band semi-massive chalcopyrite 406.5′; scattered specks and stringers of chalcopyrite 406.5′-413′.
429′434′: Semi-massive sphalerite 429′-432′; disseminated sphalerite 433′-434′.
434′-475′: Quartz-chlorite-hornblende gneiss; schistose 450′-455′; pyritic; sparse garnets; traces of chalcopyrite nearly throughout; zones of much biotite.

TOTAL DEPTH: 475′

DM-25 ASSAYS:

No.	INTERVAL	Au	Ag	Cu	Zn
1	233.5′-235.5′	Tr	None	0.012	None
2	235.5′-236.9′	Tr	None	0.308	0.2
{ 3	236.9′-241.9′	None	None	0.346	3.9
{ 4	241.9′-245.5′	None	None	0.428	5.9
5	245.5′-247.5′	None	None	0.012	None
6	404′-406′	Tr	None	0.018	None
7	406′-408′	None	None	0.107	None
8	408′-413.5′	None	None	0.560	None
9	413.5′-418.5′	Tr	None	0.170	Tr
10	418.5′-423.5′	None	None	0.088	None
11	423.5′-427′	None	None	0.075	0.3
12	427′-428.9′	None	None	0.081	None
{ 13	428.9′-432′	None	None	0.056	24.3
{ 14	432′-434′	None	None	0.037	1.2
15	434′-436′	None	None	0.056	0.5

DRILL HOLE LOG FOR DM-26

LOCATION: Zone 24; 10.86E, 4.30N ELEVATION: 520′ BEARING & INCLINATION: –; 90°

0-45′: Overburden, soil and saprolite.
45′-81′: Quartz-hornblende-chlorite gneiss; sparsely garnetiferous; faults 61′-62′, 73′-75′.
81′-111′: Hornblende-chlorite schist; fault zone 86′-91′, 107′-110′.
111′-190′: Quartz-hornblende-chlorite gneiss; variably garnet-bearing; sparse pyrite; fault zone 184′-189′.
190′-220′: Hornblende-chlorite schist; fault zone 206′, 219′.
220′-257′: Quartz-hornblende-chlorite gneiss; thin quartz and calcite veins 222′-227′; fault zone with breccia 236′-239′; very sparse garnets; pyritic 239′-243′, 254′-257′.
257′-267′: Semi-massive to massive pyrite and pyrrhotite with sphalerite and chalcopyrite.
267′-304′: Quartz-hornblende-chlorite gneiss; 2″ band of magnetite 267.4′; 0.5′ quartz veins 286′, 288′; disseminated to semi-massive sulfides, pyrite and chalcopyrite, 296′-297.6′.
304′-306.5′: Semi-massive pyrite and pyrrhotite with chalcopyrite.
306.5′-392′: Quartz-hornblende-chlorite gneiss; 2″ band of chalcopyrite, pyrrhotite and sphalerite 313′; sparsely garnetiferous; schistose 321′-330′, 363′-379′; vein quartz 382′-383′, 386′-387′; pyritic below 383′.
392′-404.5′: Quartz-chlorite-hornblende gneiss and chlorite schist; pyritic; scattered chalcopyrite grains 393′-402′; high in biotite 396′-399′.
404.5′-406′: Semi-massive pyrite.
406′-420′: Quartz-chlorite-hornblende gneiss; trace disseminated chalcopyrite throughout; high in biotite.
420′-446′: Quartz-hornblende-chlorite gneiss; generally pyritic; trace chalcopyrite 435′-439′.
446′-460′: Quartz-chlorite-hornblende gneiss; scattered specks and stringers of chalcopyrite; garnetiferous.
460′-505′: Quartz-hornblende and quartz-chlorite gneiss alternating; trace disseminated chalcopyrite 469′-479′, 492′-504′; generally garnetiferous and pyritic.

TOTAL DEPTH: 505′

DM-26 ASSAYS:

No.	INTERVAL	Au	Ag	Cu	Zn
1	254.9′-256.9′	Tr	None	0.018	None
2	256.9′-260.4′	Tr	None	0.226	5.40
3	260.4′-264′	Tr	None	0.012	4.70
4	264′-267′	Tr	None	0.365	5.00
5	267′-269′	Tr	None	0.006	None
6	302.6′-304.6′	Tr	None	None	0.05
7	304.6′-306.7′	Tr	0.3	0.730	2.60
8	306.7′-309.1′	Tr	None	0.006	0.20

DRILL HOLE LOG FOR DM-27

LOCATION: Zone 24; 11.00E, 1.00S ELEVATION: 495′ BEARING & INCLINATION: –; 90°

0-35′: Overburden, soil and saprolite.
35′-48′: Quartz-chlorite-hornblende gneiss; pyritic throughout.
48′-100′: Quartz-hornblende-chlorite gneiss and hornblende schist in alternating sequence; faults at 53′, 55′, 62′, 69′, 73′, 78′, 91; 2″ band semi-massive pyrite with sphalerite and chalcopyrite 90.8′.
100′-109′: Quartz-hornblende-chlorite gneiss.
109′-121′: Quartz-hornblende-chlorite gneiss; semi-massive pyrite with chalcopyrite and sphalerite, mostly in thin bands, at 109′-110′, 113′, 114′, 115′, 116′, 118′, 119′, 121′, with scattered magnetite.
121′-165′: Quartz-hornblende-chlorite gneiss; pyritic 121′-126′; 152′-153′; schistose 135′-139′; faults 134′, 139′, 160′; scattered magnetite seams 155′-160′.

TOTAL DEPTH: 165′

DRILL HOLE LOG FOR DM-28

LOCATION: Zone 24; 7.85E, 1.00S ELEVATION: 500′ BEARING & INCLINATION: –; 90°

0-27′: Overburden, soil and saprolite.
27′-39′: Hornblende-chlorite schist; fault zone 30′-32′.
39′-65′: Quartz-hornblende-chlorite gneiss; 1′ band massive pyrite with chalcopyrite and magnetite 61′.
65′-67′: Semi-massive pyrite with sphalerite and chalcopyrite; fault at base.
67′-83.5′: Quartz-hornblende-chlorite gneiss; thin seam of semi-massive pyrite at 76.8′.
83.5′-88′: Quartz-hornblende-chlorite gneiss; thin bands and fracture fillings of pyrite with sphalerite and chalcopyrite; magnetite present 86′-88′.
88′-164′: Quartz-hornblende-chlorite gneiss; garnetiferous; pyritic 160′-164′.
164′-177′: Quartz-chlorite gneiss and chlorite schist; pyritic throughout; massive pyrite 171.5′-173′.
177′-205′: Quartz-hornblende-chlorite gneiss; garnetiferous; pyritic 185′-187′.

TOTAL DEPTH: 205′

DRILL HOLE LOG FOR 24-08

LOCATION: Zone 24; 11.60E, 2.80N (approx.) ELEVATION: 515′ BEARING & INCLINATION: S 23°E, 45°

0-36′: Overburden, soil and saprolite.
36′-138′: Quartz-biotite-hornblende schist with garnets.
138′-177′: Mineralized zone in siliceous chlorite schist; weakly mineralized with semi-massive pyrite stringers and bands of 10% pyrite and 5% sphalerite; scattered chalcopyrite specks.
177′-190′: Quartz-hornblende gneiss.
190′-196′: Quartz-sericite schist.
196′-212′: Semi-massive to massive sulfides as follows:
- 196′-201′: 30-40% pyrite, 2-3% sphalerite
- 201′-201.5′: barren
- 201.5′-202.5′: 15-20% pyrite
- 202.5′-209′: weakly mineralized
- 209′-212′: 50-60% pyrite, 15-20% sphalerite.

212′-223′: Hornblende gneiss.
223′-226′: Semi-massive sulfides; 70-80% pyrrhotite and pyrite, 3-5% sphalerite, 1-2% chalcopyrite.
226′-232′: Hornblende gneiss.
232′-233′: Minerals are 70-80% pyrrhotite and pyrite, 7-10% sphalerite, 1% chalcopyrite.
233′-254′: Hornblende gneiss.

TOTAL DEPTH: 254′

24-08 ASSAYS:

No.	INTERVAL	Cu	Zn
E- 93	196′-201′	0.29	2.61
E- 94	201.5′-202.5′	0.32	3.97
E- 95	209′-212′	0.66	8.05
E-118	223′-226′	1.14	1.81
E-119	232′-233′	0.34	7.48

DRILL HOLE LOG FOR 24-09

LOCATION: Zone 24; 11.60E, 2.80N (approx.) ELEVATION: 515′ BEARING & INCLINATION: S 23°E, 80°

0-29′: Overburden, soil and saprolite.
29′-191′: Hornblende gneiss; with garnets and biotite; siliceous and chloritic; fractured zone 115′-130′.
191′-193′: Minerals are 20-25% pyrite, 1% chalcopyrite.
193′-305′: Hornblende gneiss.
305′-328′: Quartzite schist, with biotite and garnets; about 50% pyrite in semi-massive to massive veins up to 18″; pyrite very coarse crystalline; minor chalcopyrite 324′-328′.
328′-339′: Hornblende gneiss.

TOTAL DEPTH: 339′

24-09 ASSAY:

No.	INTERVAL	Cu	Zn
E-124	191′-193′	0.15	2.04

Geochemical Exploration and Sulfide Mineralization[1]

By

Richard S. Good

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ABSTRACT

Computerized plots of concentration values for copper, zinc, lead, iron, manganese and cobalt from HCl leached, fine sand fractions of 339 samples of stream sediments show close spatial association with ferruginous quartzites; these quartzites are within the amphibole gneiss unit of the Chopawamsic Formation. Concentrations defined as anomalous are two standard deviations above the mean; but values between 1 and 2 deviations above the mean were also useful in delineating sulfide zones. Iron in surface waters, gold in panned concentrates, and silver in unconcentrated sediments are good discriminators for pinpointing massive sulfides.

A new massive sulfide prospect was discovered by following up geochemical reconnaissance with additional geochemical and geophysical surveys in the area of Cattail Creek, Willis Mountain quadrangle. Other geochemical anomalies were seen in reconnaissance studies in the area of Tongue Quarter Creek, in the vicinity of the Bondurant Mine, and in areas of the Appomattox State Forest.

The massive sulfide deposits of the area lie within the Appalachian-Caledonide North Atlantic Metallo-

[1] Portions of this report may be quoted if credit is given to the Virginia Division of Mineral Resources. It is recommended that reference to this report be made in the following form: Good, R.S., 1981, Geochemical exploration and sulfide mineralization, *in* Geologic investigations in the Willis Mountain and Andersonville quadrangles, Virginia: Virginia Division of Mineral Resources Publication 29, p. 48-69.

genic province, and like other massive and semi-massive sulfide deposits of this province, formed syngenetically with the volcanic and sedimentary rocks containing them. Evidence for a syngenetic relationship includes conformable sulfide and host rock contacts, lack of alteration at hanging-wall contacts, and the remarkably close association of sulfide bodies with ferruginous quartzite.

The sulfide bodies were probably formed on the ocean floor by hot brines or fumaroles in distal volcanic fractures in a back-arc basin during Cambrian time.

INTRODUCTION

In 1979 the Division of Mineral Resources began geochemical reconnaissance of Andersonville and Willis Mountain quadrangles by stream-sediment analyses. Previous surveys on trace elements in stream sediments in the Piedmont (Good and Fordham, 1977; Good, Fordham and Halladay, 1977; Good, 1978; Good, unpublished reconnaissance, Goochland County; Fordham, unpublished reconnaissance, Fluvanna County) showed that in surveys using low density sampling (1-5 samples per square mile), anomalies were very likely to be low-level. Commonly only one or two samples are as much as two standard deviations above the arithmetic mean. Many (perhaps more than one-half) of the near-surface, massive or disseminated-massive sulfide bodies in the Piedmont are not recognized in stream-sediment analyses because the bodies are mantled by thick overburden (50 to 100 feet; 15 to 30 m) or because surface drainage is away from them.

Variability of metal values within the sediment samples was kept relatively small by analyzing only the fine-sand fraction (0.177 to 0.0625 mm; 80 to 230 mesh). The silt-clay (less than 0.0625 mm) fraction contains 2 to 4 times higher metal values than fine sand fractions (Good and Fordham, 1977, p. 29). Particles larger than 2 mm were sieved from the sediment sample with a stainless steel sieve in the field. The fine-sand fraction was separated from dried sediment in the laboratory. This fraction was then treated with hot 1:1 hydrochloric acid, which primarily removes the iron oxide coatings, and the leachate was analyzed by standard techniques of atomic absorption spectroscopy for copper, zinc, lead, iron, manganese, cobalt, nickel, chromium, rubidium, strontium, barium, lithium, silver and cadmium. Another split of the fine-sand fraction was analyzed by X-ray diffraction techniques. These data were used to make semi-quantitative estimates of plagioclase, microcline, amphibole, chlorite, mica, and epidote content. The leached residue was examined by binocular microscope for pyrite and gahnite, and further polarizing microscopic and X-ray work was done as needed.

Element concentrations from 186 sediment samples in the Andersonville and 153 sediment samples in the Willis Mountain quadrangles were plotted on 7.5-minute quadrangle maps. Statistical refinement of the data was made by using a reiterative computer program which eliminates extremely high values, values which have distorting effects on the mean and standard deviation. This refinement allows smaller values to be considered anomalous, and helps identify mineralized areas with low concentrations of metals. The validity of the reiterative statistical program was established using known areas of mineralization.

The data were plotted using a computer contouring program, SYMAP (Figures 1-8). Trace-metal values for sediment samples are shown in Figures 1-6. Plots of all 14 trace metals and also semi-quantative data on sediment mineralogy are on open file at the Virginia Division of Mineral Resources. Concentration values of the 14 trace metals at each of the 339 sample stations along with plots of the stations (Figures 9 and 10) are in the appendix.

Detailed geochemical work was done on sediments, and surface waters as well, at the Morris property (Zone 24) located in the Andersonville quadrangle (Plates 1 and 2, Figures 1 through 8). Finally, a new area of potentially valuable sulfide mineral deposits, the area of Cattail Creek (Plate 1), a zone not reported in the paper by Young in Publication 29, was identified. Results of water, stream-sediment and soil geochemistry and of magnetometer, self-potential, and electromagnetic surveys indicate that this area warrants further investigation, including drilling. Much of the anomaly of this area is on the Allen property. Data for the Zone 24 and Cattail Creek areas are on open file at the Virginia Division of Mineral Resources.

The writer gratefully acknowledges the assistance of Oliver Fordham, Jr. in programming the SYMAP computer program; Jacqueline Kennamer for atomic absorption analyses; Joshua Rosen for collection of samples and laboratory work; and North American Exploration, Inc. for assistance in geophysical surveying at the Cattail Creek prospect.

SULFIDE OCCURRENCES AND GEOCHEMICAL RESULTS

The distribution of some massive sulfide prospects and the location of abandoned gold mines in the Andersonville and Willis Mountain quadrangles is shown in Plate 1. These sulfide bodies are in the upper unit of the Chopawamsic Formation, which consists mainly of interlayered amphibole gneiss and biotite gneiss. The amphibole gneiss unit, which is interpreted as a metamorphosed andesitic basalt or basaltic flow or tuff, is interbanded with a felsic unit which is thought to be either a recrystallized rhyodacite or volcaniclastic marine sediment. Either, the amphibole gneiss or the interbedded felsic subfacies may be the host rock for sulfides. The Chopawamsic biotite-gneiss facies is interpreted as being probably a metamorphosed volcanic marine sediment ("greywacke").

Base-metal geochemical anomalies are remarkably associated with the amphibole gneiss of the Chopawamsic unit, particularly in areas containing ferruginous quartzites as mapped by Marr (1980A, 1980B). Computerized SYMAP printouts showing contoured anomalies for copper, zinc, lead, iron, manganese, and cobalt in stream sediment are illustrated in Figures 1-6. X-ray diffraction estimates of stream sediment mineralology show that areas containing abundant amphibole and relatively large amounts of plagioclase roughly outline the limits of the Chopawamsic amphibole gneiss. These distributions are depicted in SYMAPS in Figures 7 and 8. The major results of the study follow.

I. Sampling and general comments:

1. On a regional reconnaissance density of 1-5 samples per square mile, stream-sediment anomalies of metals are generally low. Some anomalies in areas of known sulfide mineralization were not much greater than two standard deviations above a reiterated arithmetic mean; other "possibly anomalous" stations near documented sulfide mineralization were only between one and two standard deviations above the mean. Increased density of sampling greatly increases time and expense of exploration and can best be offset by confining sample areas to favorable rock formations. The most favorable formation for concentrations of metallic sulfides in the area is the amphibole gneiss unit of the Chopawamsic Formation.
2. Because concentrations of metals in sediments, even in mineralized areas, were low, data were modified as follows. Extremely high values were eliminated prior to computation of arithmetic mean and standard deviation. This process allows relatively low concentration to be identified as anomalies. This analysis was found to be more useful than one in which all data are used and in which logarithmic or geometric means are calculated.
3. Because there are unequal concentrations of metals in the various size fractions of the sediment, with silt-clay particles having generally 2 to 4 times the concentrations of fine sand, the sediments were sieved and only the fine-sand fraction was analyzed.
4. Experiments in leaching sediments separately with hot 1:1 HCl and hot nitric acid-perchloric showed that the HCl treatment gave higher values for lead, about the same values for zinc and silver, and lower values for copper.
5. From atomic absorption analyses of 20 stream-sediment samples (10 were at anomalous and 10 were at background levels) it would appear that trace metal anomalies in general are independent of magnetite content of sediment. More than 85 percent of trace metal content of hot, 1:1 leaches of sediment was in diatomaceous films and iron-oxide coatings on the sediment. There were very low to no concentrations of these metals in magnetite.
6. Metal concentration values in stream sediment were contoured by computer using a SYMAP program. These maps are useful and timesaving, but have limitations in interpretation because of downstream transport of the sediments beyond formational contacts. In addition, the computer program used does not incorporate location data defining individual drainage basins; thus contour lines may not follow drainage basin boundaries.
7. Metal concentrations as extracted from stream sediments by using hot HCl leach defined as anomalous were: 17 ppm for copper, 50 ppm for zinc, 12 ppm for lead, 5 percent for iron, 728 ppm for manganese, and 15 ppm for cobalt. These values were based on reiterated arithmetic means and standard deviations calculated for 339 samples from both quadrangles. Threshold or possibly anomalous values lie between one and two standard deviations above the mean. Means and standard deviations were:

	Mean	Standard Deviation
Copper	7.99 ppm	4.46
Zinc	25.73 ppm	11.96

	Mean	Standard Deviation
Lead	6.99 ppm	2.49
Iron	2.11 ppm	1.42
Manganese	342	193
Cobalt	7.00 ppm	2.81

8. Spearman rank correlation coefficients between metals in stream sediments found to be statistically significant at the 99.9% level were: nickel and chromium (0.80) cobalt and manganese (0.78), cobalt and copper (0.74), iron and zinc (0.67), zinc and manganese (0.65), nickel and cobalt (0.65), rubidium and lithium (0.63) iron and copper (0.55). Slight or moderate associations were shown for amphibole and plagioclase (0.44), chromium and chlorite (0.38) and copper and chlorite (0.31).
9 Trace metal values in soil formed over known sulfide mineralizations for copper, zinc, and lead are all generally in the 100-500 ppm range, and locally are much higher.
10. Silver is a good discriminator element for HCl leaches of stream sediments used in search of base-metal anomalies. Silver concentrations in HCl leaches is 1-2 ppm, and at places higher, near massive sulfides but is not detectable at all in background samples or false anomalies.
11. Gahnite (zinc spinel) is a heavy-mineral guide to metamorphosed zinc-bearing massive sulfide mineralization. It occurs in trace amounts throughout the Chopawamsic Formation in the immediate vicinity of zinc-bearing massive sulfides that have undergone amphibolite-grade metamorphism. It was identified at the Zone 18 anomaly (Plates 1 and 2) near the Willis River in an area of gossan which contained trenches.
12. Residues from HCl-leached stream sediments commonly show pyrite in the vicinity of massive sulfides; the pyrite content can be estimated semi-quantitatively by binocular microscope examination.

II. Results of sediment and water chemistry analyses at Zone 24 (see Appendix Figures 1-3):

1. Iron in spring and stream water can be measured rapidly and accurately in the field and is a powerful guide to massive sulfide occurrences. In the streams around Zone 24 (Plates 1 and 2) iron concentrations of 10-21 ppm were found in springs with iron flocculent, 2-11 ppm in small streams a few hundreds of meters from the mostly subsurface sulfide bodies, and less than 1 ppm in background waters.
2. Springs near sulfide zones not disturbed by mining are commonly only slightly acid (pH 5.6-6.1); the most acid water near the Zone 24 massive sulfide had a pH of only 5.8 in a spring containing iron-hydroxide flocculent. Such acid, iron-bearing seeps are soon diluted in headwaters of small streams, and pH values are raised to values of 6.3 to 6.4. Background values range from 6.8-7.4.
3. Zinc in water near Zone 24 massive sulfides was not detectable (0.02 ppm) except at one iron flocculent spring which showed 0.54 ppm.
4. Copper is generally not detectable in waters of the area by atomic absorption techniques. Of 34 water samples in drainage near Zone 24 only two showed copper; values were 0.01-0.02 ppm.
5. Gold (which is detectable by analysis of panned concentrates) is a good pathfinder and discriminator element for massive sulfide exploration. At Zone 24 only two panned sediment samples taken very close to the sulfide ore zone showed detectable gold (1.8 and 0.04 ppm), the rest were below the detection limit of 0.02 ppm.
6. In reconnaissance geochemistry in stream sediments, lead shows anomalies at only one or two stations, never over broad zones.

III. Geochemical characteristics of stratigraphic units:

1. The Candler Formation—stream sediments derived from rocks of the Candler are geochemically characterized by high lithium and high strontium values and much mica; the mica is the source mineral of the metals.
2. Ultramafic rocks in the Chopawamsic Formation—stream sediments from these rocks have anomalously high chromium and nickel values and abundant chlorite.
3. Biotite gneiss of the Chopawamsic Formation—stream sediments derived from these rocks contain microcline and no amphibole based on X-ray diffraction determinations.
4. Mafic metavolcanic unit of the Chopawamsic—stream sediments from the unit

contain abundant amphibole and relatively large amounts of plagioclase based on X-ray diffraction determinations.

5. Ferruginous quartzite-bearing portions of the Chopawamsic Formation—iron coatings of fine sand in stream sediments near outcrops of this rock showed anomalously high values for zinc, copper, lead, iron, and manganese.
6. The Arvonia Formation—rocks of this formation are geochemically characterized in the stream sediments by high lithium and low plagioclase values and no amphibole.
7. Rocks of the Farmville basin—these rocks are geochemically delineated by strikingly high lithium, strontium, barium, and rubidium concentrations in the stream sediments in the basin. The elements are mainly in the feldspars and micas which make up much of the arkosic rocks of the basin.

IV. Results at selected areas:

1. A very strong copper and barium anomaly is shown near an old gold prospect in the Tongue Quarter Creek area in the northeast part of the Andersonville quadrangle.
2. Stream sediment anomalies were found for copper, lead, and cobalt near the Bondurant mine, 1 mile (1.6 km) southwest of Andersonville (Plate 1).
3. New areas for massive sulfide explorations were suggested from geochemical reconnaissance. One area near Cattail Creek, Willis Mountain quadrangle (Figures 1-8) was examined in detail. Results of water, stream sediment, and soil chemistry analyses and of magnetic, self-potential, and electromagnetic surveys are on open file at the Virginia Division of Mineral Resources. Anomalies for the geochemical data are similar to those of Zone 24. Drilling is recommended for the Cattail Creek area.
4. Other areas recommended for further investigation include several anomalous regions within the Appomattox State Forest in the western portion of the Andersonville quadrangle and areas showing multi-element anomalies in the Farmville basin (Figures 1-6).

ORIGIN OF THE SULFIDE DEPOSITS

The Chopawamsic Formation is clearly a highly favored rock unit for sulfide deposition. Exploration efforts should focus on it as a prime reconnaissance target throughout the entire gold-pyrite belt. The Chopawamsic rocks, originally described in northern Virginia by Southwick, Reed, and Mixon (1971), have been traced southwestward from about 50 kilometers south of Washington, D.C. for at least 175 kilometers (Higgens and others, 1973; Pavlides and others, 1974; Pavlides, unpublished data; Conley and Johnson, 1975; Conley and Marr, 1980). In northern Virginia and southward to the mineral district in central Virginia, the Chopawamsic has a content of major oxides and trace elements (particularly the rare earths titanium and zirconium) suggestive of rocks belonging to tholeiitic island-arc suites; some of the samples are calc-alkaline in character. (Gair, Pavlides, and Cranford, 1980). In central Virginia, whole-rock analyses of interlayered felsic and mafic Chopawamsic volcanic rocks on the western limb of the Columbia syncline suggest that the rocks were originally sodium-bearing rhyolites (ocean soaked tuffs?) and andesitic basalts. (Good, 1978, p. 107). Chopawamsic rocks of the Columbia syncline bear evidence of both subaqueous and subaerial origins. For example, delicately laminated mafic rocks with graded bedding are suggestive of subaqueous tuffs, and ellipsoidal epidosite masses there may represent pillow lavas. Subaerial conditions are indicated by thin, amygdaloidal amphibolites (Good, Fordham, and Halladay, 1973, 1974, 1977). These rock are similar to Chopawamsic rocks in the Willis Mountain and Andersonville quadrangles.

Based on the data above and on lithologies of Candler and Chopawamsic rocks, the Candler-Chopawamsic volcanic-sedimentary belt is interpreted as representing two geologic environments, a back-arc basin and an inner arc of a double-island-arc system, which was east of the back-arc basin. Both environments were east of the ancestral North American plate. The Chopawamsic may be coeval with either Carolina slate belt or Charlotte belt rocks of southern Virginia and North Carolina. Candler rocks, which conformably underlie the Chopawamsic, represent marine sediments of the back-arc basin or, possibly, of a more westerly located, less volcanic or non-volcanic facies partly coeval with Chopawamsic volcanics. During late Precambrian time, a sea-floor spreading-center developed in the back-arc basin; by Cambrian time a southeast dipping subduction zone was developed under the Chopawamsic island arc. This generalized model is based on ideas of Good and others (1973)

GEOCHEMICAL RECONNAISSANCE OF THE ANDERSONVILLE AND WILLIS MTN. QUADS
COPPER IN STREAM SEDIMENTS (PPM), 80-230 MESH, 50% HCL EXTRACTION
CONTOUR INTERVALS BASED ON ARITHMETIC STANDARD DEVIATION UNITS

FREQUENCY DISTRIBUTION OF DATA POINT VALUES IN EACH LEVEL

LEVEL	1	2	3	4	5
SYMBOLS	....1....	++++2++++	00003 0000	8888 4 8888	■■■■5■■■■
FREQ.	176	95	39	14	11

SYMBOLS FOR COPPER (PPM). $\bar{Y}$ = 7.99.

1 <7.99; <$\bar{Y}$

2 7.99-12.45; $\bar{Y}$ TO 1 S.D.

3 12.45-16.91; 1 TO 2 S.D.

4 16.91-21.37; 2 TO 3 S.D.

5 >21.37; >3 S.D.

$\bar{Y}$, ARITHMETIC MEAN; S.D., STANDARD DEVIATION

Figure 1. Computer map for copper leachate, with geology. Stratigraphic symbols follow. Cambrian (?) Candler Formation, A. Cambrian Chopawamsic Formation: amphibole gneiss, B; biotite gneiss/volcanic rocks, C; ferruginous quartzites, dashed line. Cambrian plagioclase granite, D. Ordovician Arvonia Formation, E. Triassic rocks (undivided), F.

GEOCHEMICAL RECONNAISSANCE OF THE ANDERSONVILLE AND WILLIS MTN. QUADS

ZINC IN STREAM SEDIMENTS(PPM), 80-230 MESH, 50% HCL EXTRACTION

CONTOUR INTERVALS BASED ON ARITHMETIC STANDARD DEVIATION UNITS

FREQUENCY DISTRIBUTION OF DATA POINT VALUES IN EACH LEVEL

LEVEL	1	2	3	4	5
SYMBOLS	....1....	++++2++++	00003000 0	8888488888	■■■■5■■■■
FREQ.	187	84	37	15	12

SYMBOLS FOR ZINC (PPM) MAP. $\bar{Y}$ = 25.73 PPM.

1 <25.73; <$\bar{Y}$

2 25.73 - 37.69; $\bar{Y}$ TO 1 S.D.

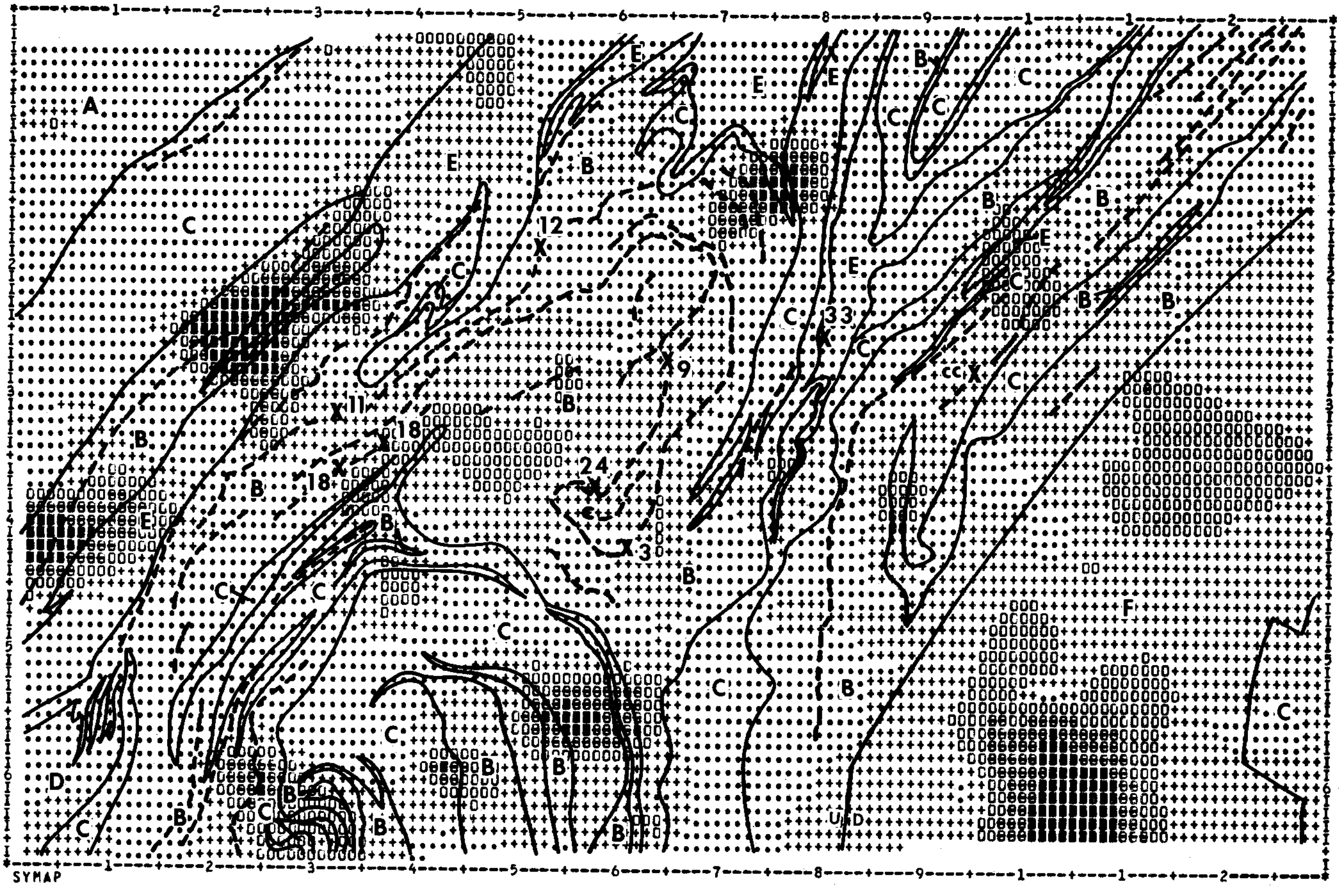
3 37.69 - 49.65; 1 TO 2 S.D.

4 49.65 - 61.61; 2 TO 3 S.D.

5 >61.61; >3 S.D.

$\bar{Y}$ = ARITHMETIC MEAN; S.D. = STANDARD DEVIATION

Figure 2. Computer map for zinc leachate with geology. Stratigraphic symbols follow. Cambrian (?) Candler Formation, A. Cambrian Chopawamsic Formation: amphibole gneiss, B; biotite gneiss/volcanic rocks, C; ferruginous quartzites, dashed line. Cambrian plagioclase granite, D. Ordovician Arvonia Formation, E. Triassic rocks (undivided), F.



GEOCHEMICAL RECONNAISSANCE OF THE ANDERSONVILLE AND WILLIS MTN. QUADS
LEAD IN STREAM SEDIMENTS(PPM), 80-230 MESH, 50% HCL EXTRACTION
CONTOUR INTERVALS BASED ON ARITHMETIC STANDARD DEVIATION UNITS

0 1 mi.
0 1 km.

X3 SULFIDE ZONES

FREQUENCY DISTRIBUTION OF DATA POINT VALUES IN EACH LEVEL

LEVEL	1	2	3	4	5
SYMBOLS	••••1••••	++++2++++	OOOO3OOOO	ØØØØ4ØØØØ	■■■■5■■■■
FREQ.	154	124	33	14	10

SYMBOLS FOR LEAD (PPM) MAP. $\bar{Y}$ = 6.99 PPM.

1	<6.99; <$\bar{Y}$	4	11.97 - 14.14; 2 TO 3 S.D.
2	6.99 - 9.48; $\bar{Y}$ TO 1 S.D.	5	>14.14; >3 S.D.
3	9.48 - 11.97; 1 TO 2 S.D.		

$\bar{Y}$ = ARITHMETIC MEAN; S.D. = STANDARD DEVIATION

Figure 3. Computer map for lead leachate with geology. Stratigraphic symbols follow. Cambrian (?) Candler Formation, A. Cambrian Chopawamsic Formation: amphibole gneiss, B; biotite gneiss/volcanic rocks, C; ferruginous quartzites, dashed line. Cambrian plagioclase granite, D. Ordovician Arvonia Formation, E. Triassic rocks (undivided), F.

Geology after Marr (1980)

GEOCHEMICAL RECONNAISSANCE OF THE ANDERSONVILLE AND WILLIS MTN. QUADS
IRON IN STREAM SEDIMENTS(%), 80-230 MESH, 50% HCL EXTRACTION
CONTOUR INTERVALS BASED ON ARITHMETIC STANDARD DEVIATION UNITS

0 1 mi.
0 1 km.

X_3 SULFIDE ZONES

FREQUENCY DISTRIBUTION OF DATA POINT VALUES IN EACH LEVEL

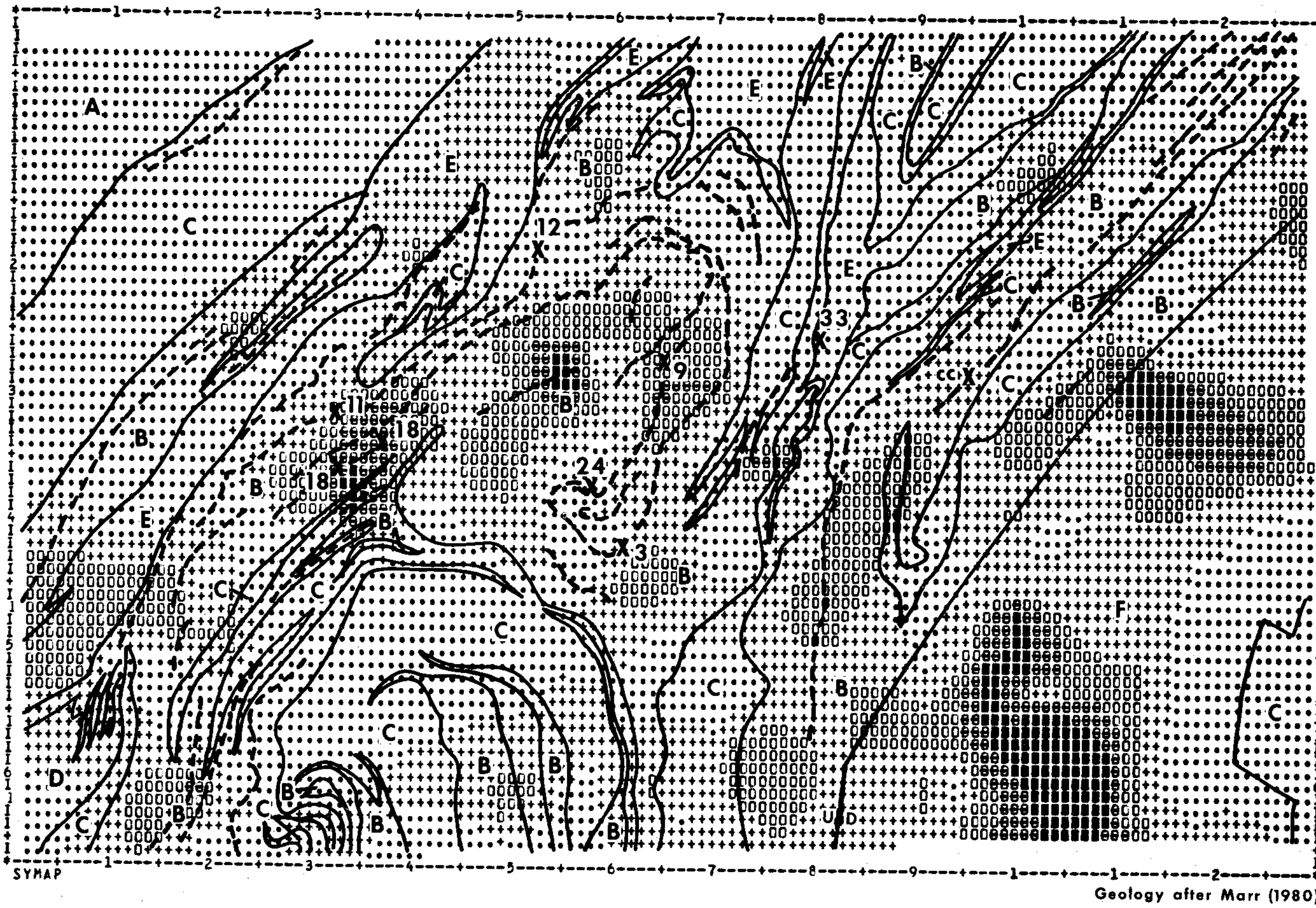
LEVEL	1	2	3	4	5
SYMBOLS	....1....	++++2++++	OOOO3OOOO	ØØØØ4ØØØØ	■■■■5■■■■
FREQ.	199	76	26	19	13

SYMBOLS FOR IRON (%), $\bar{Y}$ = 2.11%.

1 <2.11;<$\bar{Y}$
2 2.11-3.53; $\bar{Y}$ TO 1 S.D.
3 3.53-4.95; 1 TO 2 S.D.
4 4.95-6.37; 2 TO 3 S.D.
5 >6.37; >3 S.D.

$\bar{Y}$, ARITHMETIC MEAN; S.D., STANDARD DEVIATION

Figure 4. Computer map for iron leachate with geology. Stratigraphic symbols follow. Cambrian (?) Candler Formation, A. Cambrian Chopawamsic Formation: amphibole gneiss, B; biotite gneiss/volcanic rocks, C; ferruginous quartzites, dashed line. Cambrian plagioclase granite, D. Ordovician Arvonia Formation, E. Triassic rocks (undivided), F.



GEOCHEMICAL RECONNAISSANCE OF THE ANDERSONVILLE AND WILLIS MTN. QUADS
MANGANESE IN STREAM SEDIMENTS(PPM), 80-230 MESH, 50% HCL EXTRACTION
CONTOUR INTERVALS BASED ON ARITHMETIC STANDARD DEVIATION UNITS

0 1 mi.
0 1 km.

X_3 SULFIDE ZONES

FREQUENCY DISTRIBUTION OF DATA POINT VALUES IN EACH LEVEL

LEVEL	1	2	3	4	5
SYMBOLS	....1....	++++2++++	000030000	0000400000	■■■■5■■■■
FREQ.	199	76	40	13	7

SYMBOLS FOR MANGANESE (PPM) MAP. $\bar{Y}$ = 342 PPM.

1	<342; <$\bar{Y}$	4	728 - 921; 2 TO 3 S.D.
2	342 - 535; $\bar{Y}$ TO 1 S.D.	5	>921; >3 S.D.
3	535 - 728; 1 TO 2 S.D.		

$\bar{Y}$ = ARITHMETIC MEAN; S.D. = STANDARD DEVIATION

Figure 5. Computer map for manganese leachate with geology. Stratigraphic symbols follow. Cambrian (?) Candler Formation, A. Cambrian Chopawamsic Formation: amphibole gneiss, B; biotite gneiss/volcanic rocks, C; ferruginous quartzites, dashed line. Cambrian plagioclase granite, D. Ordovician Arvonia Formation, E. Triassic rocks (undivided), F.

GEOCHEMICAL RECONNAISSANCE OF THE ANDERSONVILLE AND WILLIS MTN. QUADS

COBALT IN STREAM SEDIMENTS(PPM), 80-230 MESH, 50% HCL EXTRACTION

CONTOUR INTERVALS BASED ON ARITHMETIC STANDARD DEVIATION UNITS

0 1 mi.

0 1 km.

X_3 SULFIDE ZONES

FREQUENCY DISTRIBUTION OF DATA POINT VALUES IN EACH LEVEL

LEVEL	1	2	3	4	5
SYMBOLS	....1....	++++2++++	OOOO3OOOO	ØØØØ4ØØØØ	████5████
FREQ.	175	97	39	19	5

SYMBOLS FOR COBALT (PPM). $\bar{Y}$ = 7.00 PPM.

1 <7.00; <$\bar{Y}$

2 7.00-10.81; $\bar{Y}$ TO 1 S.D.

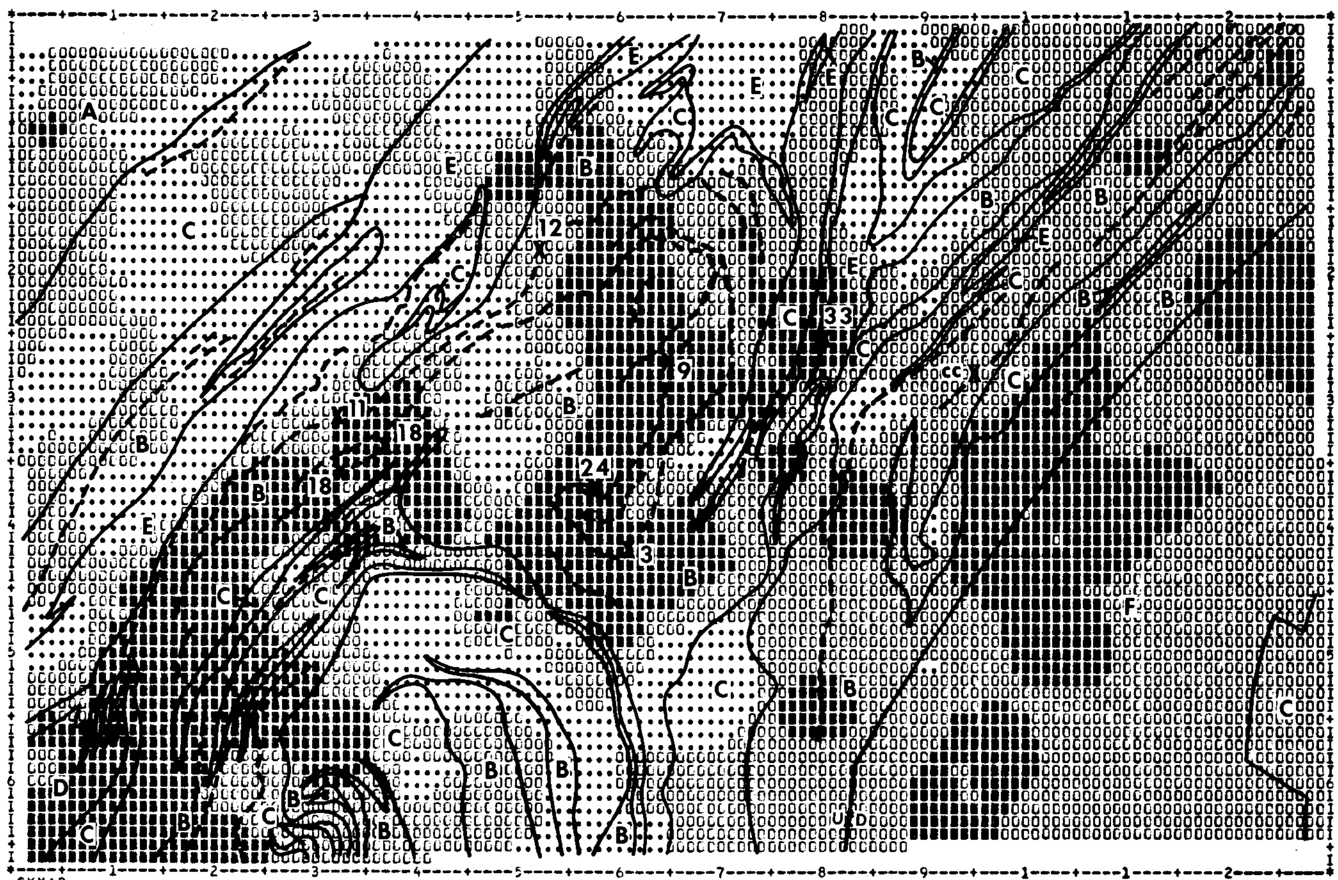
3 10.81-14.62; 1 TO 2 S.D.

4 14.62-18.43; 2 TO 3 S.D.

5 >18.43; >3 S.D.

$\bar{Y}$, ARITHMETIC MEAN; S.D., STANDARD DEVIATION

Figure 6. Computer map for cobalt leachate, with geology. Stratigraphic symbols follow. Cambrian (?) Candler Formation, A. Cambrian Chopawamsic Formation: amphibole gneiss, B; biotite gneiss/volcanic rocks, C; ferruginous quartzites, dashed line. Cambrian plagioclase granite, D. Ordovician Arvonia Formation, E. Triassic rocks (undivided), F.



Geology after Marr (1980)

GEOCHEMICAL RECONNAISSANCE OF THE ANDERSONVILLE AND WILLIS MTN. QUADS

PLAGIOCLASE IN STREAM SEDIMENTS(XRD CHART UNITS), 80-230 MESH

CONTOUR INTERVALS SELECTED BY R. S. GOOD

0 1 mi.

0 1 km.

X_3 SULFIDE ZONES

FREQUENCY DISTRIBUTION OF DATA POINT VALUES IN EACH LEVEL

LEVEL	1	2	3
SYMBOLS	....1....	OOOO2OOOO	████3████
FREQ.	87	142	106

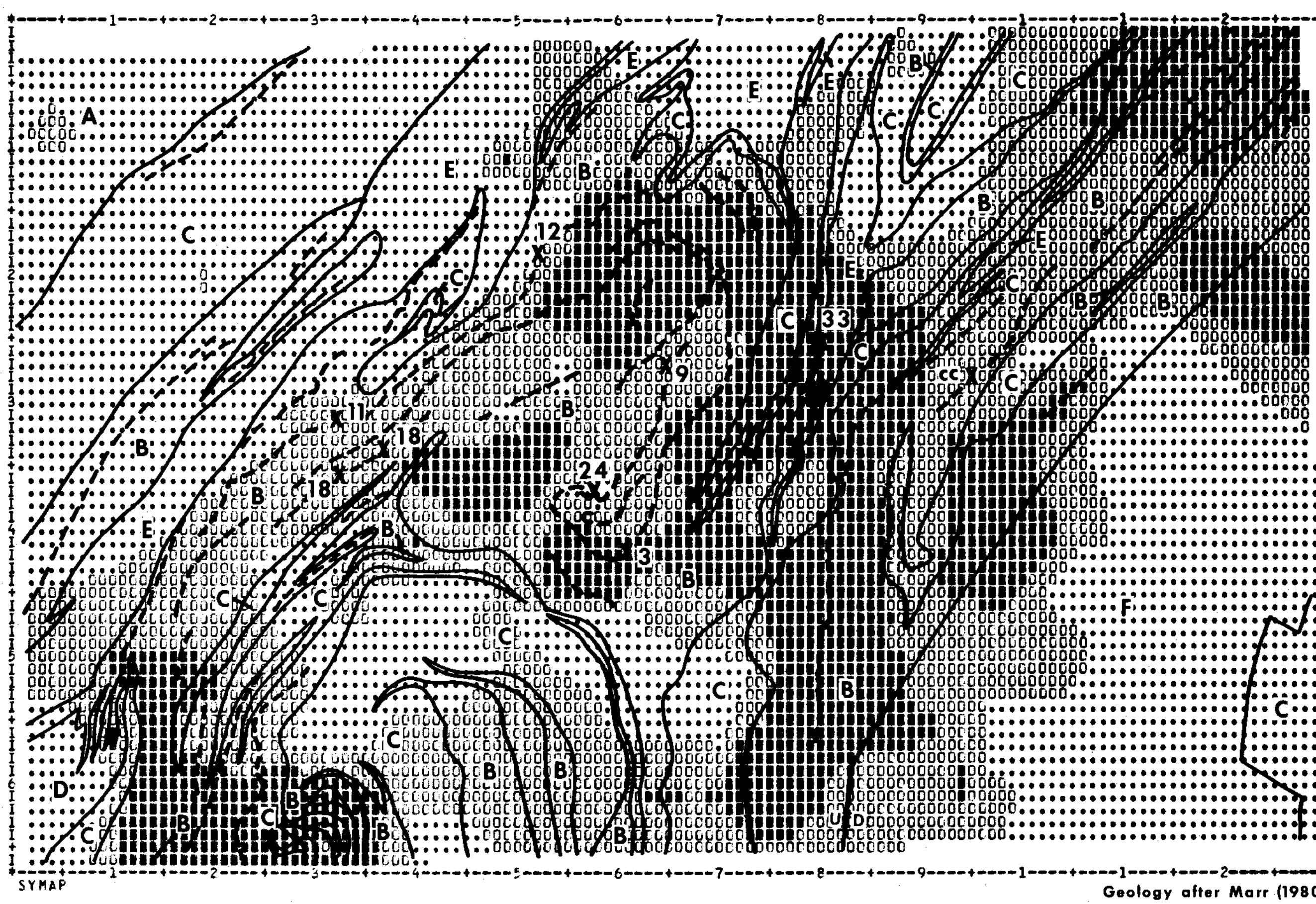
SYMBOLS FOR PLAGIOCLASE (WT.%) MAP.

1 1-5%

2 6-15%

3 16-25%

Figure 7. Computer map for plagioclase with geology. Stratigraphic symbols follow. Cambrian (?) Candler Formation, A. Cambrian Chopawamsic Formation: amphibole gneiss, B; biotite gneiss/volcanic rocks, C; ferruginous quartzites, dashed line. Cambrian plagioclase granite, D. Ordovician Arvonia Formation, E. Triassic rocks (undivided), F.



GEOCHEMICAL RECONNAISSANCE OF THE ANDERSONVILLE AND WILLIS MTN. QUADS

AMPHIBOLE IN STREAM SEDIMENTS(XRD CHART UNITS), 80-230 MESH

CONTOUR INTERVALS SELECTED BY F. S. GOOD

0 1 mi.

0 1 km.

X3 SULFIDE ZONES

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FREQUENCY DISTRIBUTION OF DATA POINT VALUES IN EACH LEVEL
 LEVEL          1          2          3
          ******************************
          .........  OOOOOOOOO  ■■■■■■■■■
          .........  OOOOOOOOO  ■■■■■■■■■
 SYMBOLS  ....1....  OOOO2OOOO  ■■■■3■■■■
          .........  OOOOOOOOO  ■■■■■■■■■
          .........  OOOOOOOOO  ■■■■■■■■■
          ******************************
 FREQ.    133        125        77
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SYMBOLS FOR AMPHIBOLE (WT. %) MAP.

1 0- 3%

2 3-10%

3 10-20%

Figure 8. Computer map for amphibole with geology. Stratigraphic symbols follow. Cambrian (?) Candler Formation, A. Cambrian Chopawamsic Formation: amphibole gneiss, B; biotite gneiss/volcanic rocks, C; ferruginous quartzites, dashed line. Cambrian plagioclase granite, D. Ordovician Arvonia Formation, E. Triassic rocks (undivided), F.

and on recent, deep seismic data gathered by the Consortium for Continental Reflection Profiling project (Cook, Brown, and Oliver, 1980).

Massive sulfides in the Chopawamsic Formation of the gold-pyrite belt of northern and central Virginia Piedmont are part of the Appalachian—Caledonide North Atlantic metallogenic province, which extends from Alabama to Newfoundland and on into northwestern Europe. This ocean-separated province has remarkably similar geological and geochemical features throughout its length. Many economically valuable sulfide bodies were formed syngenetically with enclosing rocks, mostly in late Precambrian, Cambrian, or Ordovician time. The deposits originated on the ocean floor and were preserved in tuffs, lavas, and marine sediments in the ocean basins adjacent to ancient island arcs or along fractures in oceanic or back-arc spreading centers.

This volcanogenic concept of sulfide mineralization is based on many independent investigations, but has only recently been widely accepted in the English-speaking geological community. Ohashi (cited in Watanabe, 1970, p. 424) working on the Kuroko deposits of Japan, and Carstens (cited in Oftedahl, 1958, p. 5), working independently on some Caledonide sulfides in Norway, reported similar revolutionary concepts concerning the volcanic and oceanic origins of sulfides in 1919. These ideas gained wide acceptance among European and Japanese geologists from 1920 onwards, but the volcanogenic-sedimentary concept was generally ignored by English-speaking geologists. The hydrothermal concepts of Lindgren, whose *Mineral Deposits* was in its 4th printing in 1933, and of others of his school, dominated thinking on ore genesis until Oftedahl's (1958) forceful paper, "A Theory of Sedimentary Ores," and Stanton's (1959, 1960) papers on conformable pyritic bodies in marine sediments. These works stimulated the publication of many papers on ore genesis in the 1960's (Williams, 1961, 1966; Goodwin, 1962 and 1965; Fisher, 1960; Croxford, 1964; Gilmour, 1965; Roscoe, 1965; Hutchinson, 1965; Kinkle, 1966; Kalliokoski, 1965; Vokes, 1966, 1969; Tatsumi (1970).

By 1970 there was widespread recognition that many concordant massive sulfides formed at the same time as the host rocks that enclose them; examples were cited mainly from the Archean, the late Precambrian, early Paleozoic, the Tertiary, and the Recent. The volcanogenic concept was strengthened with the discovery of deposition of sulfides and manganese oxides along the mid-Atlantic Ridge, of metal-rich brines in the Red Sea and Salton Sea (Bischoff and Manheim, 1969; Degens and Ross, 1969), of a "working-model" of continuing pyrite and marcasite deposition from submarine fumaroles in water-soaked tuffs in the Mediterranean Sea (Honnorez and others, 1971), and of hydrothermal deposition of base-metal sulfides from submarine smoke plumes northeast of the Galapagos Islands at the Nazca-Cocos plate boundary. (Ballard and Grassle, 1979). Further development of volcanogenic concepts in the 1970's involved fitting the model to concepts developed from plate tectonics, including the recognition that massive sulfide deposits are concentrated along subduction zones or along spreading centers on the ocean floor (Sawkins, 1972, Guild, 1973; Strong, 1976).

Today, research is aimed at synthesis of many separate investigations on experimental chemical and physical models of sulfide formation, on the details of whole-rock and trace-element chemistry of the host rocks, and on more accurate dating of sulfides and hosting rocks. An extensive bibliography on stratabound massive sulfides in the Appalachian and Caledonide orogens is in Sangster (1980). A map of volcanogenic sulfides from Alabama to Maine is in Gair and Slack (1979).

In the Willis Mountain and Andersonville quadrangles it is apparent from drill-core sections (Plates 3-6) that chalcopyrite-, sphalerite-, and galena-bearing pyrite bodies are lenselike in form, and that these bodies were essentially conformable with the original bedding of the enclosing volcanic or volcano-sedimentary rock before they were folded and metamorphosed. One of the most obvious and persistent observations in the field is the associated occurrence of ferruginous quartzite beds and sulfide zones.

Furthermore, at Zone 24 the sulfide deposit does not show significant alteration on the hanging-wall side (the stratigraphic top) (Riesmeyer, 1969). Examination of sulfide occurrences in the area does not disclose that sulfide mineralization follows fault or shear zones. Further, there are no major intrusive bodies in the area. A small body of plagioclase granite intrudes the Chopawamsic in the southwest part of the Andersonville quadrangle.

The stratabound massive and disseminated pyrite mineralizations within the Chopawamsic rocks probably formed on the ocean floor from volcanically derived hydrothermal sources during waning volcanism. The metals were probably deposited subaqueously, either as metal brine seeps or as cyclic fumaroles, perhaps forcefully as "smoke plumes," in a back-arc basin during Chopawamsic time. The hydrothermal fluids reached the ocean floor either at the tops or on the flanks of volcanic centers (proximal deposits), or through satellite fractures along the trend-line of a series of volcanic centers. Precipitation was primarily caused by a drop in temperature as the heated fluids (80-300°C) entered the cold waters of the deep ocean and by the sudden change from acidic (pH 4-5) to alkaline (pH 8) conditions produced by this emergence of the metal-charged fluids. However, unusually high volumes and temperatures of the fluids could have delayed precipitation, and density currents might have carried the metal-rich brine some distance from the vent, forming distal deposits. Without violent seismic activity, steep slopes, or active turbidity currents, the metal precipitates were buried and preserved by additional volcaniclastic marine sediment or volcanic material. Proximal sulfides at places were disrupted by resurgent and explosive activity (steam blowouts) which caused local brecciation of rock and folding and slumping of soft sediments and led to late-stage precipitation of copper, zinc, and lead sulfides. Such deposits are vertically zoned; lead and zinc are commonly in the upper part of the sulfide body, although these metals originally may have been precipitated at the bottom of the deposit. After uninterrupted buildup of sulfide sediment, some sulfide deposits on top of a volcanic center moved downslope by gravity away from the vent. These deposits were probably diluted during transport, whereupon they gave rise to distal deposits of disseminated pyrite in the volcaniclastic sediment. Distal sulfide deposits, the common ones in the study area, also formed directly along satellite hydrothermal plumbing systems some distance from the volcanic center. As the fumarolic emanations persisted, the metal precipitates either built up until the vent was clogged, or the top of the sulfide zone was sealed by a chert capping formed from the deposition of opaline silica. Ferruginous quartzites, so closely associated with sulfide pods in the Chopawamsic rocks, are thus considered to represent iron-charged opaline silica deposits precipitated as chert along linear fractures satellite to an arcuate system of volcanic centers. The precipitation of silica is probably effected by the sharp drop in temperature accompanying its emergence from the fracture. At 200°C the solubility of amorphous silica in water is about 870 ppm; at 25°C, it is about 134 ppm. The solubility of amorphous silica is little affected by pH over the appropriate ranges (about 2 to 8). These relationships also apply to quartz, but the values for solubility are: for 200°C, 269 ppm; for 25°C, 10 ppm (or less) (Holland and Malinin, p. 469). In the absence of submarine volcanic disturbance, these fractures were sealed by silica deposition, thus accounting for their very limited thickness from a few meters or less to a few tens of meters. Later, these fracture-derived cherts were recrystallized to form magnetite- or magnetite-hematite-bearing quartzites.

With this model of ore genesis, sulfide deposition is seen as very strongly controlled by the conditions in the marine sedimentation basin, the phase and strength of volcanism, and the location of vent sources. Bedded deposits with graded bedding need not be explained as "molecule for molecule" replacement in permeable, chemically susceptible rocks, and ore solutions need no fault or shear zones for their emplacement. Cross-cutting vein systems associated with or under massive sulfides are seen as hydrothermal plumbing systems (epithermal deposits) originally formed beneath the ocean floor or beneath a volcanic vent, but not above such a vent. Zoning and paragenesis of metals is explained as being the result of an evolving chemical activity in a single vent system, and lateral zoning is explained as being controlled by distance from vent source and temperature of the hot metal brine, not by later "remobilization" during metamorphism.

Sulfide lenses probably occur along hinge lines and axial traces of folds in the Willis Mountain and Andersonville quadrangles. Such distribution would have resulted from attenuation and duplication of beds by polyphase folding, not from structural control of hydrothermal deposition in favored permeable or fractured locations. The geometry of folds associated with the sulfides is seen as being controlled by primary sedimentation, including soft-sediment slumping, local deformation and brecciation by submarine volcanic steam blowouts, and not alone by later deformation of indurated rock. Even the location of folding axes is probably partially controlled by occurrences of primary, soft-sediment folds. Sediments and volcaniclastics with low competence and also fractured volcanic centers would be favored sites for later folding.

A volcanic origin is suggested for some gold deposits in the Willis Mountain and Andersonville quadrangles in spite of the observation that some quartz veins cut across bedding. The quartz veins may represent deposits formed in epithermal fumarolic feeder pipes or may even represent submarine cherts (which would become "reefs" or quartzite beds) deposited from hot springs on the ocean floor. Thus the veins would be the product of near-surface processes rather than deep-seated ones. This idea of origin is supported by the observation that ore-grade gold deposits are originating in subaerial hot springs in New Zealand (Weissburg, 1969), and that some Carolina slate belt vein deposits are interpreted to be volcanogenic (Worthington and Kiff, 1970). Gold deposits in the Columbia syncline both in Arvonia-age quartzite beds (recrystallized cherts ?) within mica schists and in Chopawamsic rocks were ascribed to volcanogenic sources, possibly submarine fumaroles (Good and others, 1973; 1974; 1977). In the Willis Mountain-Andersonville quadrangles, gold deposits in the Arvonia Formation have been explained as being fossil placers in Arvonia sediments. The gold source was rocks of the Chopawamsic Formation (Conley and Marr, 1980).

It is also probable that kyanite deposits in the area are volcanogenic. Field evidence in support of this idea includes the following: (1) the occurrence of kyanite in the gossan and drill cores of the Chopawamsic Formation at Zone 24; (2) the widespread occurrence of pyrite (generally about 1 percent) in kyanite quartzite at Willis and Woods mountains; (3) occurrence of pipe-like features containing clay and vein quartz in kyanite quartzites at Willis Mountain; (4) the common occurrence of fuchsite in kyanite schists; (5) the presence of topaz in trace amounts in kyanite quartzites in the Willis Mountain area.

RECENT EXPLORATION AND FUTURE PROSPECTS

The Willis Mountain and Andersonville quadrangles area has not been exhaustively prospected geochemically and very probably contains undiscovered sulfide bodies, some of which will have no geophysical signature in airborne electromagnetic surveys and may have no gossan. Geochemical and geophysical exploration for sulfide bodies in the area of investigation was conducted in the 1970's by several mining companies, including: Texas Gulf Sulfur, Continental Oil, Phelps Dodge, Anaconda, and Callahan Mining. Airborne electromagnetic surveys followed by soil geochemistry and ground-based self-potential, magnetometer and electromagnetic surveys for selected areas were commonly used. Stream-sediment chemistry was used in some areas. Much of the information produced by these several surveys has remained in private company-files and the results and extent of coverage are not known.

For mining to begin in the area, either new discoveries of large-tonnage bodies will need to be made or tonnages of current prospects will need to be increased by showing that bodies from two or perhaps three sulfide zones can be leased at one time and milled at one site. The Morris property (Zone 24) was considered marginally economic in the 1970's. Changing market conditions based on increased industrial demand, dwindling domestic reserves and diminished foreign sources, or inflated prices for base-metals, may well hasten sulfide mining in the area during the 1980's. Resources would include copper, zinc, lead, gold, silver, and perhaps tin and pyrite.

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WILLIS MOUNTAIN 7½' QUADRANGLE

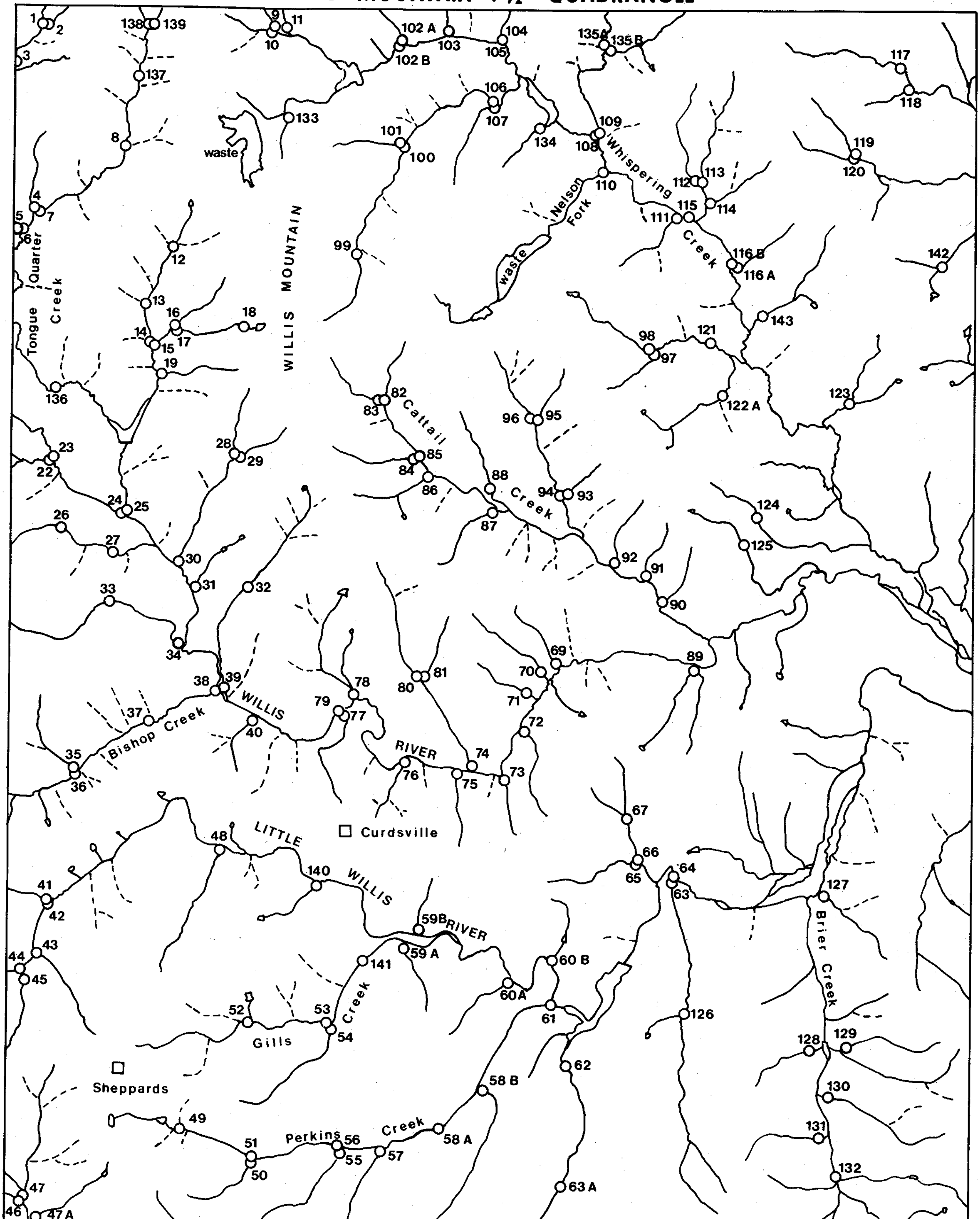

Figure 9. Map of sampling stations in the Willis Mountain 7.5-minute quadrangle.

ANDERSONVILLE 7½' QUADRANGLE

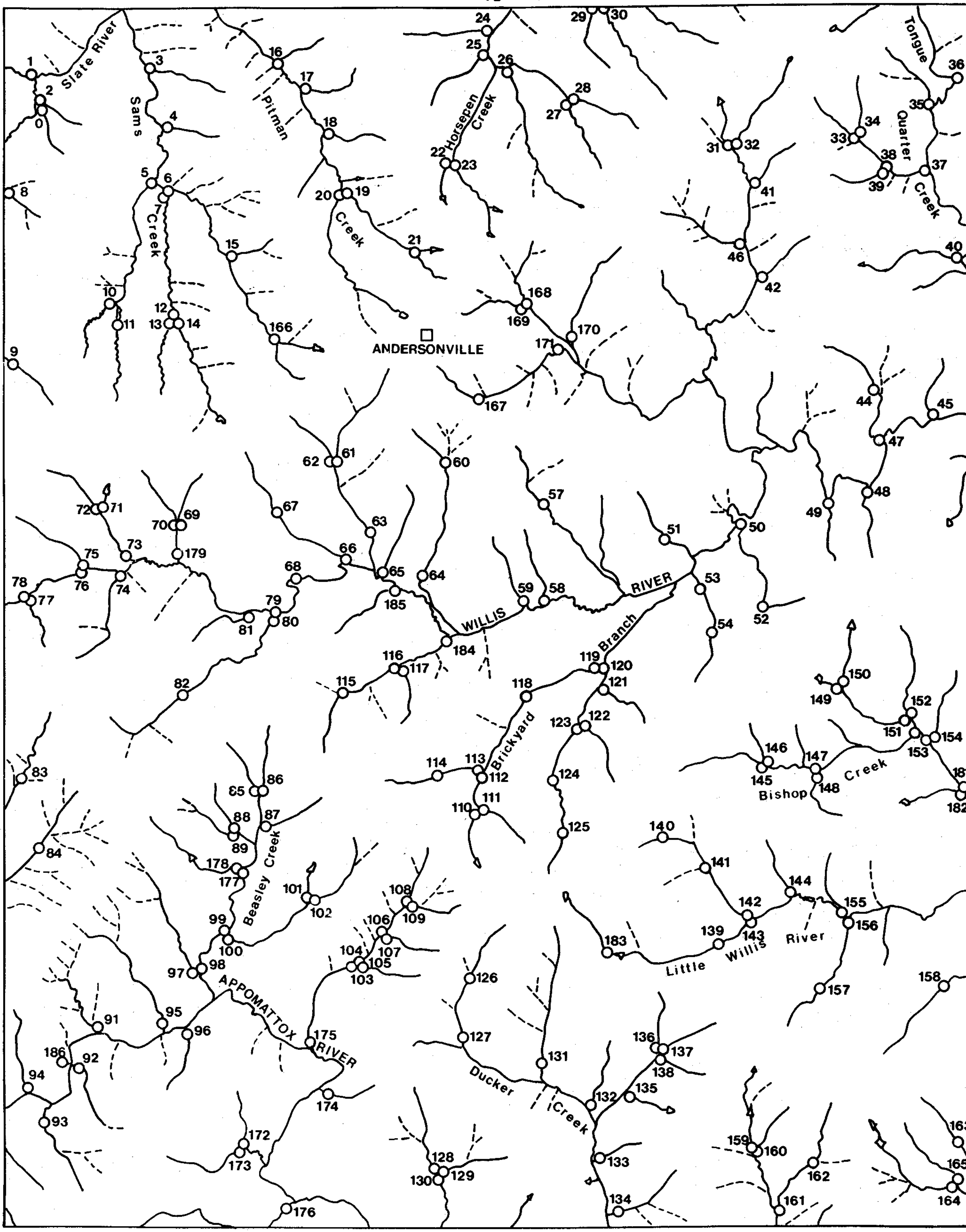

Figure 10. Map of sampling stations in the Andersonville 7.5-minute quadrangle.

APPENDIX: GEOCHEMICAL DATA FOR ANDERSONVILLE AND WILLIS MOUNTAIN QUADRANGLES

Sa.No.	UTM(N)	UTM(E)	Ele.	SO	Li	Cr	Mn	Fe	Co	Ni	Cu	Zn	Ag	Ba	Pb	Sr	Cd	Rb	chl	ma	am	mr	pg	ep
AN 0	4151640	710400	439	1	2.8	12.	142.	.77	4.	6.	4.	16.	0.0	30.	9.	10.6	0.0	7.	9.	39.	9.	0.	54.	11.
AN 1	4152050	710320	428	1	2.3	9.	239.	.81	3.	4.	4.	15.	0.0	20.	6.	3.2	0.0	5.	3.	11.	0.	0.	20.	0.
AN 2	4151770	710360	434	1	3.3	10.	133.	.80	4.	4.	5.	25.	0.0	20.	5.	3.3	0.0	8.	0.	11.	3.	0.	7.	0.
AN 3	4152140	711630	433	1	2.0	13.	155.	.72	3.	5.	4.	15.	0.0	20.	6.	5.4	0.0	5.	14.	30.	3.	0.	26.	0.
AN 4	4151460	711820	448	1	1.5	20.	153.	1.22	5.	7.	4.	14.	0.0	20.	7.	3.8	0.0	3.	18.	31.	0.	0.	16.	0.
AN 5	4150860	711700	459	2	1.7	17.	149.	.96	5.	6.	6.	13.	0.0	20.	3.	5.3	0.0	4.	4.	12.	0.	0.	22.	20.
AN 6	4150740	711860	463	2	.9	15.	244.	1.01	3.	5.	5.	14.	0.0	10.	6.	2.3	0.0	3.	0.	9.	0.	3.	28.	0.
AN 7	4150700	711820	463	2	1.1	16.	231.	1.20	5.	7.	6.	17.	0.0	10.	5.	2.5	0.0	4.	5.	19.	4.	0.	13.	0.
AN 8	4150680	710020	469	1	3.4	10.	224.	1.01	6.	6.	4.	27.	0.0	30.	5.	4.3	0.0	9.	5.	30.	0.	0.	32.	0.
AN 9	4148740	710150	557	1	2.4	10.	222.	.72	3.	4.	2.	22.	0.0	20.	5.	2.2	0.0	6.	10.	25.	0.	0.	37.	0.
AN 10	4149460	711260	520	1	.9	16.	108.	1.66	5.	6.	5.	12.	0.0	10.	5.	1.5	0.0	2.	15.	56.	0.	0.	25.	0.
AN 11	4149220	711320	534	1	1.1	11.	131.	.94	6.	6.	5.	20.	0.0	10.	6.	1.9	0.0	3.	12.	37.	0.	0.	36.	0.
AN 12	4149320	711980	513	2	1.1	22.	230.	1.56	5.	7.	7.	15.	0.0	10.	6.	2.7	0.0	3.	7.	18.	4.	0.	20.	4.
AN 13	4149270	711960	516	1	1.6	27.	301.	1.85	7.	10.	12.	19.	0.0	20.	8.	3.6	0.0	4.	7.	11.	6.	6.	15.	4.
AN 14	4149260	712000	515	1	.5	5.	167.	.37	1.	1.	4.	8.	0.0	10.	5.	.9	0.0	2.	0.	9.	0.	7.	10.	0.
AN 15	4150020	712600	509	1	1.3	9.	210.	1.02	3.	5.	7.	17.	0.0	10.	4.	1.9	0.0	6.	0.	22.	0.	0.	9.	0.
AN 16	4152240	713080	453	1	2.4	12.	229.	.91	4.	6.	4.	20.	0.0	20.	5.	3.4	0.0	7.	0.	8.	0.	0.	25.	0.
AN 17	4151980	713400	470	1	1.2	6.	150.	.38	1.	3.	3.	10.	0.0	10.	5.	2.0	0.0	3.	6.	55.	0.	0.	14.	0.
AN 18	4151460	713660	482	1	2.0	13.	204.	1.06	5.	7.	5.	29.	0.0	10.	5.	2.2	0.0	6.	5.	24.	0.	0.	11.	0.
AN 19	4150780	713900	501	2	1.0	22.	337.	1.95	6.	8.	8.	20.	0.0	20.	6.	2.6	0.0	5.	5.	7.	0.	0.	27.	0.
AN 20	4150780	713840	500	1	1.0	21.	195.	1.39	5.	7.	7.	15.	0.0	10.	7.	2.1	0.0	4.	9.	21.	0.	0.	35.	0.
AN 21	4150120	714700	550	2	.7	13.	148.	.65	3.	4.	5.	17.	0.0	10.	6.	1.4	0.0	3.	19.	12.	0.	0.	30.	0.
AN 22	4151160	715070	520	1	1.9	26.	268.	1.59	9.	14.	15.	24.	0.0	30.	7.	5.3	0.0	7.	10.	8.	0.	0.	25.	4.
AN 23	4151160	715120	516	1	1.0	16.	198.	.98	6.	6.	6.	10.	0.0	10.	6.	1.6	0.0	5.	3.	8.	0.	0.	15.	0.
AN 24	4152680	715500	465	1	1.7	68.	258.	5.99	10.	15.	8.	26.	0.0	20.	9.	1.7	0.0	4.	4.	22.	0.	0.	8.	0.
AN 25	4152420	715460	470	1	1.9	63.	172.	5.41	13.	19.	11.	32.	0.0	20.	8.	2.7	0.0	5.	17.	33.	0.	0.	15.	0.
AN 26	4152240	715710	477	2	1.7	33.	191.	2.23	9.	11.	9.	21.	0.0	20.	5.	2.0	0.0	5.	16.	22.	4.	0.	32.	0.
AN 27	4151870	716420	523	1	1.1	14.	254.	1.42	8.	7.	15.	20.	0.0	30.	7.	3.0	0.0	8.	43.	5.	0.	0.	20.	7.
AN 28	4151920	716460	525	1	.7	21.	198.	.71	5.	8.	9.	10.	0.0	20.	7.	1.3	0.0	4.	75.	10.	0.	0.	37.	4.
AN 29	4152940	716720	480	1	1.1	34.	154.	2.66	6.	11.	9.	17.	0.0	20.	9.	2.5	0.0	5.	17.	32.	0.	0.	21.	0.
AN 30	4152950	716820	480	1	1.4	21.	259.	1.55	5.	8.	8.	15.	0.0	20.	10.	2.1	0.0	7.	21.	33.	0.	0.	15.	0.
AN 31	4151400	718300	545	1	3.7	15.	295.	1.26	5.	5.	5.	22.	0.0	20.	7.	.8	0.0	5.	0.	17.	0.	0.	0.	0.
AN 32	4151420	718320	545	1	5.9	25.	700.	2.11	9.	8.	10.	57.	0.0	30.	11.	1.4	0.0	7.	11.	34.	0.	0.	9.	0.
AN 33	4151540	719720	498	1	3.9	27.	291.	1.52	8.	9.	7.	21.	0.0	30.	5.	1.7	0.0	7.	0.	7.	8.	0.	32.	0.
AN 34	4151560	719760	497	1	6.9	20.	478.	2.93	10.	8.	7.	54.	0.0	50.	5.	2.5	0.0	11.	8.	12.	13.	0.	45.	0.
AN 35	4151920	720580	457	1	5.7	52.	355.	3.09	12.	18.	15.	28.	0.0	80.	8.	2.4	0.0	8.	0.	5.	8.	0.	8.	0.
AN 36	4152240	720880	478	2	2.6	33.	302.	3.12	10.	9.	7.	30.	0.0	550.	12.	5.3	0.0	6.	0.	12.	3.	0.	13.	0.
AN 37	4151170	720520	443	2	4.0	20.	518.	5.66	13.	8.	9.	30.	0.0	30.	8.	2.3	0.0	6.	0.	7.	12.	0.	25.	0.
AN 38	4151200	720100	466	2	10.0	18.	736.	3.44	16.	9.	11.	88.	0.0	90.	8.	3.7	.6	19.	6.	14.	7.	0.	41.	0.
AN 39	4151160	720100	467	1	6.0	5.	495.	2.89	6.	3.	4.	85.	0.0	70.	9.	3.1	0.0	19.	0.	16.	2.	0.	58.	0.
AN 40	4150200	720900	411	1	2.2	13.	445.	2.49	8.	4.	7.	20.	0.0	10.	6.	2.0	0.0	3.	18.	16.	58.	0.	48.	0.
AN 41	4150970	718560	518	1	4.4	50.	468.	1.91	16.	22.	12.	17.	0.0	50.	7.	2.0	0.0	2.	15.	0.	17.	0.	51.	0.
AN 42	4149910	718640	478	1	.7	8.	114.	1.50	2.	3.	1.	12.	0.0	10.	5.	.7	0.0	1.	0.	35.	0.	0.	23.	0.
AN 44	4148680	720000	420	1	2.3	30.	385.	3.56	13.	10.	12.	28.	0.0	20.	5.	1.5	0.0	3.	7.	4.	28.	0.	52.	0.
AN 45	4148380	720700	379	1	1.5	7.	662.	5.05	15.	5.	14.	34.	0.0	20.	7.	3.0	0.0	2.	0.	20.	20.	0.	75.	0.
AN 46	4150300	718460	489	1	3.0	10.	312.	.59	5.	5.	3.	16.	0.0	30.	7.	1.9	0.0	4.	8.	50.	3.	0.	50.	0.
AN 47	4148110	720100	381	1	2.5	33.	657.	7.40	18.	9.	13.	49.	0.0	20.	7.	2.2	0.0	3.	0.	0.	17.	5.	45.	0.
AN 48	4147520	719980	390	1	.6	9.	327.	4.94	9.	4.	9.	27.	0.0	20.	7.	1.2	0.0	1.	0.	0.	15.	0.	60.	0.
AN 49	4147410	719530	405	1	1.5	8.	1038.	6.16	11.	6.	10.	275.	0.0	20.	10.	2.7	.5	2.	0.	0.	3.	0.	14.	0.
AN 50	4147120	718480	428	1	.7	8.	449.	4.99	9.	4.	14.	70.	0.0	10.	8.	2.7	0.0	1.	0.	0.	18.	0.	5.	0.
AN 51	4146900	718660	450	1	.8	15.	626.	4.33	9.	6.	11.	35.	0.0	10.	8.	1.5	0.0	1.	18.	7.	0.	0.	43.	0.
AN 52	4146180	718800	489	1	.6	7.	546.	3.71	8.	3.	9.	42.	0.0	10.	10.	3.0	0.0	1.	0.	0.	30.	0.	12.	23.
AN 53	4146380	718080	440	1	1.2	25.	540.	14.47	22.	11.	14.	57.	0.0	10.	10.	4.9	.6	2.	0.	0.	6.	0.	11.	0.
AN 54	4145900	718220	467	1	.7	8.	629.	3.64	9.	4.	11.	23.	0.0	10.	10.	4.8	0.0	1.	0.	0.	36.	0.	11.	12.
AN 57	4147280	716280	508	1	1.1	48.	496.	2.06	9.	9.	6.	20.	0.0	20.	6.	1.2	0.0	3.	0.	19.	4.	0.	37.	0.
AN 58	4146200	716320	456	1	1.7	29.	855.	10.37	24.	10.	30.	55.	0.0	20.	11.	1.8	.6	2.	0.	0.	12.	0.	75.	0.
AN 59	4146180	716080	459	1	2.2	118.	901.	4.82	25.	24.	14.	39.	0.0	20.	8.	2.4	.6	3.	10.	0.	15.	0.	72.	0.
AN 60	4147720	715120	534	1	1.2	44.	215.	2.40	6.	9.	6.	12.	0.0	20.	7.	.8	0.0	3.	2.	30.	0.	0.	7.	0.
AN 61	4147680	713880	528	1	2.7	29.	577.	2.94	16.	13.	14.	41.	0.0	30.	34.	2.3	0.0	8.	0.	11.	0.	0.	4.	0.
AN 62	4147700	713860	530	1	7.0	66.	591.	2.65	16.	25.	28.	35.	0.0	50.	14.	1.6	0.0	16.	13.	11.	4.	4.	0.	0.
AN 63	4146920	714300	498	2	.9	17.	187.	1.26	4.	3.	4.	15.	0.0	10.	13.	.7	0.0	2.	0.	8.	0.	0.	11.	0.
AN 64	4146480	714900	482	1	.6	21.	369.	1.44	7.	4.	8.	18.	0.0	10.	9.	.9	0.0	1.	0.	6.	11.	0.	22.	0.
AN 65	4146450	714440	482	1	.6	8.	135.	.54	2.	2.	3.	10.	0.0	20.	18.	.6	0.0	1.	6.	21.	0.	0.	18.	0.
AN 66	4146580	714050	489	1	.9	7.	231.	.69	2.	2.	4.	10.	0.0	10.	7.	.9	0.0	1.	0.	15.	0.	0.	10.	0.
AN 67	4147120	713200	564	1	1.0	16.	192.	1.59	3.	2.	5.	26.	0.0	20.	8.	.8	0.0	3.	0.	0.	0.	0.	3.	0.
AN 68	4146360	713450	498	3	1.3	10.	357.	.89	4.	3.	4.	13.	0.0	10.	7.	1.0	0.0	3.	3.	15.	0.	0.	11.	0.
AN 69	4146940	712060	553	1	.9	16.	212.	.91	5.	5.	16.	20.	0.0	10.	7.	1.6	0.0	3.	32.	11.	0.	0.	52.	3.
AN 70	4146920	712050	553	1	.5	10.	125.	.52	3.	3.	5.	12.	0.0	10.	4.	1.1	0.0	4.	12.	11.	0.	0.	14.	0.
AN 71	4147100	711200	580	1	.4	7.	86.	.34	1.	3.	2.	10.	0.0	10.	6.	1.0	0.0	2.	0.	14.	0.	0.	13.	0.
AN 72	4147100	711160	579	1	1.7	32.	189.	2.18	6.	14.	11.	30.	0.0	20.	5.	2.3	0.0	9.	0.	42.	0.	0.	13.	0.
AN 73	4146580	711500	553	2	1.0	20.	156.	1.19	5.	6.	10.	16.	0.0	20.	6.	1.5	0.0	8.	24.	28.	3.	0.	12.	3.
AN 74	4146380	711460	556	2	.6	13.	191.	1.06	5.	3.	7.	15.	0.0	20.	8.	1.0	0.0	4.	28.	8.	0.	0.	33.	0.
AN 75	4146440	711020	567	2	1.7	18.	113.	1.00	8.	10.	13.	22.	0.0	20.	7.	1.8	0.0	11.	0.	8.	0.	0.	14.	0.
AN 76	4146400	711020	566	2	1.8	20.	223.	.98	5.	8.	10.	19.	0.0	30.	9.	2.5	0.0	11.	23.	18.	0.	0.	22.	0.
AN 77	4146060	710420	596	1	1.8	17.	280.	1.02	3.	7.	9.	21.	0.0	10.	6.	1.9	0.0	6.	6.	51.	0.	0.	29.	0.
AN 78	4146100	710360	595	1	.8	8.	130.	.51	2.	2.	4.	12.	0.0	10.	3.	1.7	0.0	2.	5.	31.	0.	0.	12.	0.
AN 79	4145960	713230	509	3	1.4	14.	203.	.81	4.	4.	6.	16.	0.0	10.	7.	1.0	0.0	3.	7.	8.	0.	0.	10.	0.
AN 80	4145920	713220	510	1	2.7	9.	210.	.94	4.	3.	4.	13.	0.0	10.	6.	.7	0.0	3.	0.	18.	0.	0.	8.	0.
AN 81	4145960	712920	518	1	.9	8.	324.	.63	3.	3.	3.	9.	0.0	10.	6.	1.2	0.0	2.	4.	18.	0.	0.	17.	2.
AN 82	4145000	712180	562	1	1.3	12.	268.	1.19	5.	4.	6.	18.	0.0	10.	12.	1.0	0.0	2.	0.	20.	0.	0.	8.	2.
AN 83	4144000	710380	558	1	2.3	20.	561.	1.94	11.	8.	12.	40.	0.0	50.	16.	2.2	0.0	11.	19.	10.	0.	0.	27.	0.
AN 84	4143220	710580	511	1	3.7	62.	655.	4.54	18.	22.	20.	35.	0.0	40.	6.	2.5	0.0	5.	35.	13.	11.	0.	17.	0.
AN 85	4143950	713080	500	1	2.1	20.	517.	2.54	11.	6.	15.	32.	0.0	20.	5.	1.9	0.0	3.	15.	2.	15.	0.	45.	0.
AN 86	4143950	713120	498	1	2.8	15.	397.	3.15	12.	6.	28.	38.	0.0	30.	8.	2.6	0.0	3.	60.	7.	12.	0.	80.	0.
AN 87	4143550	713140	481	1	.9	7.	250.	.68	3.	4.	3.	11.	0.0	20.	3.	1.1	0.0	4.	0.	3.	5.	58.	60.	0.
AN 88	4143510	712840	499	1	3.3	10.	579.	2.82	17.	6.	22.	40.	0.0	30.	7.	2.4	0.0	4.	17.	3.	13.	4.	55.	0.
AN 89	4143460	712800	498	1	2.2	8.	681.	2.93	14.	5.	18.	31.	0.0	20.	7.	2.1	0.0	3.	12.	0.	12.	0.	57.	0.
AN 91	4141180	711330	402	1	2.3	6.	522.	2.65	8.	4.	7.	47.	0.0	20.	7.	1.7	0.0	4.	7.	8.	6.	0.	30.	0.
AN 92	4140740	711100	408	1	.6	6.	209.	3.21	2.	3.	2.	15.	0.0	10.	6.	.8	0.0	2.	0.	4.	0.	0.	85.	0.
AN 93	4140080	710720	411	1	1.8	7.	325.	1.28	4.	4.	8.	34.	0.0	30.	8.	14.1	0.0	5.	0.	10.	0.	0.	60.	3.
AN 94	4140480	710520	409	1	.6	2.	320.	.97	3.	1.	2.	8.	0.0	10.	3.	.6	0.0	1.	0.	0.	0.	0.	30.	0.
AN 95	4141280	712070	400	1	2.0	9.	469.	2.60	12.	6.	38.	29.	0.0	30.	8.	2.7	0.0	3.	18.	5.	15.	0.	44.	0.
AN 96	4141180	712340	399	1	.8	8.	289.	1.32	6.	3.	5.	16.	0.0	10.	5.	2.6	0.0	2.	0.	0.	17.	0.	80.	0.
AN 97	4141860	712420	396	1	1.0	10.	111.	1.12	3.	3.	6.	14.	0.0	10.	6.	2.1	0.0	3.	19.	0.	18.	0.	80.	6.
AN 98	4141880	712480	393	3	1.1	14.	301.	1.12	7.	5.	7.	11.	0.0	20.	4.	3.1	0.0	6.	14.	4.	14.	0.	68.	4.
AN 99	4142320	712740	423	2	.9	9.	298.	1.76	6.	3.	8.	20.	0.0	20.	4.	1.0	0.0	3.	2.	0.	22.	0.	80.	4.
AN 100	4142260	712780	425	2	.9	15.	242.	.90	6.	5.	8.	9.	0.0	20.	4.	2.9	0.0	8.	10.	0.	20.	0.	80.	10.
AN 101	4142720	713700	500	1	1.6	25.	424.	1.02	10.	10.	10.	12.	0.0	40.	7.	2.9	0.0	12.	25.	0.	14.	0.	65.	11.
AN 102	4142710	713730	498	1	.7	9.	755.	.99	7.	3.	6.	11.	0.0	30.	5.	1.6	0.0	9.	0.	0.	12.	0.	65.	8.
AN 103	4142010	714280	445	2	1.4	30.	241.	1.81	8.	7.	7.	15.	0.0	30.	6.	1.5	0.0	6.	8.	7.	12.	0.	50.	0.
AN 104	4142040	714320	447	2	1.1	19.	147.	1.00	3.	5.	5.	12.	0.0	10.	4.	1.1	0.0	2.	24.	10.	12.	0.	54.	0.
AN 105	4142020	714330	450	1	1.5	27.	286.	2.09	8.	6.	7.	18.	0.0	30.	5.	1.9	0.0	5.	7.	8.	10.	0.	48.	0.
AN 106	4142420	714560	467	2	1.2	18.	215.	1.53	4.	7.	6.	24.	0.0	20.	7.	1.4	0.0	4.	8.	7.	13.	0.	50.	0.
AN 107	4142330	714580	468	1	1.7	18.	254.	1.38	5.	7.	7.	28.	0.0	30.	5.	2.0	0.0	6.	4.	0.	9.	0.	53.	0.
AN 108	4142820	714820	493	1	.5	4.	96.	.62	0.	2.	2.	21.	0.0	10.	6.	.7	0.0	4.	0.	10.	0.	0.	21.	0.
AN 109	4142700	714840	495	1	.5	5.	139.	1.04	2.	2.	2.	35.	0.0	20.	7.	.7	0.0	2.	0.	8.	0.	0.	33.	0.
AN 110	4143780	715580	542	1	1.5	18.	264.	1.86	7.	6.	14.	24.	0.0	40.	9.	2.6	0.0	5.	15.	15.	8.	0.	30.	3.
AN 111	4143810	715620	543	1	1.0	12.	96.	.85	3.	4.	6.	14.	0.0	20.	5.	1.6	0.0	6.	0.	8.	12.	0.	23.	0.
AN 112	4144200	715640	519	2	.7	14.	171.	1.13	4.	4.	6.	11.	0.0	10.	7.	1.1	0.0	2.	0.	0.	12.	0.	31.	0.
AN 113	4144250	715620	519	1	1.1	15.	463.	1.89	7.	6.	8.	30.	0.0	20.	7.	2.2	0.0	4.	10.	0.	0.	0.	66.	0.
AN 114	4144190	715120	544	1	1.0	6.	116.	1.29	2.	3.	3.	34.	0.0	10.	6.	1.3	0.0	2.	8.	8.	0.	0.	14.	0.
AN 115	4145100	714020	518	1	1.4	9.	289.	1.87	8.	5.	40.	28.	0.0	30.	6.	1.5	0.0	3.	47.	4.	12.	0.	80.	0.
WM 42	4142850	721770	428	2	1.8	13.	575.	2.74	7.	4.	6.	24.	0.0	40.	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
WM 43	4142270	721640	445	1	2.6	9.	114.	.87	4.	4.	6.	20.	0.0	50.	5.	2.7	0.0	10.	0.	6.	0.	14.	15.	5.

APPENDIX: GEOCHEMICAL DATA FOR ANDERSONVILLE AND WILLIS MOUNTAIN QUADRANGLES

Sa.No.	UTM(N)	UTM(E)	Ele.	SO	Li	Cr	Mn	Fe	Co	Ni	Cu	Zn	Ag	Ba	Pb	Sr	Cd	Rb	chl	ma	am	mr	pg	ep
AN 116	4145410	714640	488	1	1.9	10.	637.	2.10	13.	5.	17.	40.	0.0	40.	5.	2.4	0.0	6.	12.	0.	15.	0.	60.	0.
AN 117	4145400	714680	489	1	1.9	10.	697.	2.18	15.	7.	14.	38.	0.0	50.	6.	2.9	0.0	9.	6.	0.	15.	0.	80.	0.
AN 118	4145120	716120	490	2	2.0	19.	954.	3.00	13.	6.	15.	55.	0.0	40.	11.	2.3	0.0	5.	9.	6.	10.	0.	29.	0.
AN 119	4145460	716940	459	2	1.0	16.	455.	2.12	6.	6.	9.	44.	0.0	20.	9.	1.9	0.0	3.	9.	6.	10.	0.	42.	0.
AN 120	4145460	716980	460	2	1.1	20.	373.	4.40	7.	5.	10.	31.	0.0	20.	8.	1.9	0.0	3.	7.	7.	29.	0.	80.	0.
AN 121	4145220	716980	468	1	.7	13.	361.	5.83	8.	4.	11.	25.	0.0	10.	9.	1.0	0.0	2.	0.	0.	6.	0.	32.	3.
AN 122	4144780	716760	494	1	.9	23.	285.	.89	5.	5.	4.	12.	0.0	10.	4.	.8	0.0	3.	0.	0.	20.	0.	58.	0.
AN 123	4144760	716730	492	1	1.4	29.	294.	1.96	7.	8.	7.	16.	0.0	30.	8.	1.7	0.0	5.	10.	17.	11.	0.	32.	0.
AN 124	4144160	716440	523	1	2.5	28.	381.	2.56	9.	12.	14.	27.	0.0	50.	10.	2.8	0.0	10.	23.	23.	12.	0.	25.	0.
AN 125	4143580	716560	559	1	.3	5.	69.	1.74	2.	0.	3.	9.	0.0	10.	10.	.4	0.0	2.	0.	0.	0.	0.	0.	0.
AN 126	4141900	715560	545	1	.3	4.	201.	1.53	2.	0.	2.	10.	0.0	20.	4.	1.7	0.0	2.	0.	7.	0.	0.	38.	0.
AN 127	4141220	715500	503	1	.3	3.	71.	.88	1.	0.	1.	8.	0.0	20.	4.	1.1	0.0	3.	0.	12.	0.	0.	55.	7.
AN 128	4139680	715260	413	1	1.0	13.	303.	2.99	8.	2.	9.	22.	0.0	40.	11.	2.5	0.0	5.	8.	12.	75.	0.	37.	0.
AN 129	4139680	715300	413	1	2.1	11.	479.	2.09	9.	5.	15.	56.	0.0	120.	12.	4.5	0.0	13.	8.	0.	11.	0.	45.	3.
AN 130	4139640	715260	410	2	1.1	12.	326.	2.25	5.	4.	9.	25.	0.0	50.	9.	2.8	0.0	6.	9.	11.	10.	0.	32.	2.
AN 131	4140960	716400	470	1	.5	13.	254.	2.15	5.	4.	4.	14.	0.0	30.	5.	2.4	0.0	5.	0.	13.	8.	0.	33.	3.
AN 132	4140460	716970	448	1	.4	12.	414.	3.51	4.	3.	2.	19.	0.0	20.	8.	4.5	0.0	2.	0.	0.	12.	0.	15.	20.
AN 133	4139880	717100	438	1	.9	10.	330.	3.31	6.	4.	6.	22.	0.0	40.	8.	1.8	0.0	6.	0.	3.	4.	0.	37.	0.
AN 134	4139280	717320	429	1	.9	6.	227.	1.75	4.	2.	3.	13.	0.0	30.	6.	1.9	0.0	6.	8.	17.	0.	0.	23.	0.
AN 135	4140600	717380	461	1	.9	19.	426.	4.01	6.	6.	9.	28.	0.0	20.	15.	3.0	0.0	3.	0.	9.	13.	0.	16.	5.
AN 136	4141140	717720	478	1	.7	28.	435.	6.33	8.	6.	4.	16.	0.0	30.	11.	3.4	0.0	3.	0.	10.	10.	4.	15.	35.
AN 137	4141120	717750	480	1	.8	67.	315.	4.01	10.	10.	6.	21.	0.0	30.	9.	4.9	0.0	2.	12.	4.	8.	0.	26.	4.
AN 138	4141040	717720	477	1	.5	12.	325.	3.02	6.	3.	4.	21.	0.0	30.	7.	1.6	0.0	4.	3.	12.	5.	0.	39.	0.
AN 139	4142350	718380	503	1	.4	11.	250.	1.22	4.	2.	3.	11.	0.0	20.	8.	1.8	0.0	2.	0.	0.	5.	5.	12.	5.
AN 140	4143540	717720	545	1	.4	7.	294.	1.75	3.	2.	3.	13.	0.0	20.	5.	2.2	0.0	3.	0.	14.	3.	0.	21.	0.
AN 141	4143200	718230	517	1	.8	11.	219.	2.60	5.	3.	4.	14.	0.0	40.	7.	3.4	0.0	5.	0.	26.	6.	0.	45.	3.
AN 142	4142640	718740	491	1	.4	7.	92.	.76	2.	2.	5.	13.	0.0	20.	4.	1.7	0.0	5.	0.	12.	6.	0.	35.	4.
AN 143	4142620	718750	491	1	.3	11.	278.	1.07	4.	1.	2.	13.	0.0	20.	10.	1.4	0.0	3.	0.	0.	7.	3.	15.	10.
AN 144	4142920	719200	479	1	.4	8.	92.	.77	2.	2.	3.	13.	0.0	20.	4.	1.2	0.0	4.	0.	0.	0.	4.	16.	4.
AN 145	4144360	718860	475	1	1.5	19.	313.	1.84	8.	5.	11.	25.	0.0	20.	6.	1.9	0.0	4.	14.	0.	20.	0.	50.	0.
AN 146	4144380	718900	475	1	1.4	11.	445.	3.05	12.	7.	14.	32.	0.0	20.	10.	1.9	0.0	3.	0.	0.	3.	0.	46.	0.
AN 147	4144320	719460	453	2	1.1	11.	199.	1.25	5.	4.	7.	23.	0.0	20.	4.	1.4	0.0	4.	5.	17.	16.	0.	80.	0.
AN 148	4144260	719460	455	2	1.8	34.	406.	2.28	9.	9.	11.	23.	0.0	10.	7.	1.8	0.0	3.	10.	5.	44.	0.	54.	0.
AN 149	4145280	719700	487	1	.7	6.	302.	3.60	5.	3.	9.	45.	0.0	10.	10.	1.4	0.0	1.	0.	0.	0.	0.	80.	0.
AN 150	4145310	719730	488	1	.5	6.	231.	2.69	6.	3.	19.	45.	0.0	10.	8.	.9	0.0	1.	0.	0.	7.	0.	77.	0.
AN 151	4144940	720480	430	2	.9	9.	485.	14.81	15.	5.	12.	114.	0.0	10.	14.	1.9	.5	2.	0.	0.	6.	0.	12.	0.
AN 152	4144970	720520	430	1	.7	5.	474.	3.99	8.	4.	7.	90.	0.0	10.	7.	1.3	0.0	2.	0.	0.	5.	0.	40.	0.
AN 153	4144800	720580	417	3	1.0	14.	266.	1.85	6.	4.	8.	23.	0.0	10.	4.	1.3	0.0	3.	0.	0.	17.	0.	51.	0.
AN 154	4144700	720780	410	1	1.1	8.	633.	11.07	13.	5.	7.	59.	0.0	10.	14.	1.9	.5	2.	0.	0.	14.	0.	36.	0.
AN 155	4142720	719800	464	1	.7	8.	679.	.78	7.	3.	4.	18.	0.0	30.	4.	1.9	0.0	4.	0.	9.	0.	8.	80.	0.
AN 156	4142640	719860	464	1	.5	9.	172.	1.31	3.	3.	3.	13.	0.0	20.	8.	2.0	0.0	3.	0.	13.	3.	4.	20.	4.
AN 157	4141860	719560	501	1	.6	6.	383.	7.52	6.	2.	3.	25.	0.0	10.	14.	1.6	.5	2.	0.	6.	7.	0.	20.	0.
AN 158	4141900	720980	481	1	.7	11.	272.	5.50	7.	5.	5.	21.	0.0	30.	12.	1.4	0.0	3.	0.	11.	0.	10.	8.	0.
AN 159	4140020	718840	455	1	1.8	22.	824.	2.44	12.	10.	15.	44.	0.0	80.	11.	6.7	0.0	8.	0.	7.	16.	0.	27.	0.
AN 160	4140000	718880	456	1	.5	3.	267.	2.10	2.	1.	5.	19.	0.0	30.	5.	1.7	0.0	3.	0.	33.	4.	3.	17.	0.
AN 161	4139300	719140	422	1	.6	17.	190.	1.19	3.	4.	4.	14.	0.0	20.	7.	1.8	0.0	3.	0.	10.	12.	8.	17.	15.
AN 162	4139900	719560	478	1	.9	35.	271.	1.04	3.	5.	4.	18.	0.0	10.	7.	4.6	0.0	3.	0.	0.	14.	8.	11.	12.
AN 163	4140120	721200	430	1	4.8	67.	537.	2.88	17.	50.	26.	48.	0.0	60.	7.	16.3	0.0	6.	0.	0.	16.	0.	37.	0.
AN 164	4139660	721160	419	1	1.2	9.	652.	8.61	8.	4.	5.	40.	0.0	10.	11.	2.4	.5	2.	0.	0.	10.	0.	12.	0.
AN 165	4139720	721200	420	1	.8	6.	276.	1.94	4.	3.	3.	16.	0.0	20.	9.	2.1	0.0	2.	0.	8.	11.	0.	22.	5.
AN 166	4149060	713160	549	1	1.0	20.	253.	.52	5.	8.	3.	8.	0.0	10.	4.	2.7	0.0	3.	7.	0.	5.	0.	17.	3.
AN 167	4148480	715520	563	1	.9	15.	298.	1.00	2.	4.	8.	18.	0.0	20.	15.	.9	0.0	2.	3.	14.	0.	0.	7.	0.
AN 168	4149560	716000	535	1	3.7	32.	376.	1.80	9.	12.	11.	37.	0.0	50.	10.	2.1	0.0	7.	23.	8.	5.	0.	20.	0.
AN 169	4149540	715960	536	1	3.1	23.	332.	1.56	6.	7.	10.	28.	0.0	30.	12.	1.0	0.0	6.	7.	6.	0.	0.	4.	0.
AN 170	4149200	716520	506	1	1.8	10.	737.	1.22	7.	5.	3.	36.	0.0	20.	5.	.9	0.0	3.	0.	19.	0.	0.	6.	0.
AN 171	4149080	716400	505	1	3.4	20.	189.	1.17	5.	6.	4.	24.	0.0	10.	8.	.9	0.0	5.	0.	34.	0.	0.	3.	0.
AN 172	4139920	713020	396	1	1.8	14.	767.	2.01	15.	5.	12.	27.	0.0	30.	6.	4.2	0.0	4.	0.	0.	17.	0.	38.	8.
AN 173	4139880	713020	397	1	1.2	14.	497.	2.30	10.	5.	13.	22.	0.0	20.	4.	4.1	0.0	3.	18.	0.	42.	0.	48.	13.
AN 174	4140540	713970	400	1	1.1	20.	233.	2.05	6.	4.	16.	21.	0.0	20.	14.	1.4	0.0	3.	20.	12.	15.	0.	27.	0.
AN 175	4141080	713760	381	2	1.5	33.	301.	3.55	5.	7.	9.	23.	0.0	20.	7.	1.5	0.0	5.	8.	8.	7.	0.	49.	0.
AN 176	4139240	713520	382	1	1.7	21.	276.	2.37	5.	5.	7.	25.	0.0	30.	8.	2.0	0.0	5.	2.	10.	20.	0.	45.	4.
AN 177	4143040	712940	457	3	1.3	10.	395.	2.76	7.	3.	9.	21.	0.0	10.	3.	1.3	0.0	3.	20.	4.	12.	0.	70.	0.
AN 178	4143080	712900	458	1	3.5	9.	892.	2.95	15.	6.	16.	50.	0.0	40.	7.	2.4	0.0	6.	42.	4.	4.	0.	40.	0.
AN 179	4146620	712080	540	2	.6	9.	243.	.63	3.	2.	6.	13.	0.0	10.	3.	.9	0.0	3.	17.	4.	0.	0.	37.	0.
AN 180	4144660	720760	409	3	.8	10.	282.	2.90	6.	2.	8.	38.	0.0	10.	7.	1.0	0.0	2.	0.	0.	16.	0.	50.	0.
AN 181	4144180	721140	396	3	1.2	16.	604.	5.70	12.	5.	19.	89.	0.0	20.	6.	1.6	.6	4.	3.	6.	17.	7.	43.	0.
AN 182	4144180	721140	397	1	1.2	14.	648.	7.45	12.	5.	11.	91.	0.0	10.	11.	2.0	.5	2.	0.	0.	13.	0.	77.	0.
AN 183	4142220	717140	569	1	.9	3.	100.	.70	1.	2.	2.	11.	0.0	10.	5.	1.1	0.0	5.	0.	5.	0.	14.	0.	5.
AN 184	4145740	715200	469	2	1.2	10.	685.	2.73	8.	4.	8.	30.	0.0	20.	6.	1.9	0.0	2.	4.	0.	7.	10.	37.	0.
AN 185	4146280	714600	477	1	1.3	56.	360.	1.73	4.	7.	4.	16.	0.0	10.	8.	1.1	0.0	2.	4.	4.	2.	0.	33.	0.
AN 186	4140800	710900	408	1	1.8	5.	534.	2.36	5.	4.	4.	36.	0.0	20.	5.	1.5	0.0	4.	5.	0.	0.	0.	37.	0.
WM 1	4152880	721320	530	1	.6	2.	14.	.13	1.	2.	1.	9.	0.0	10.	3.	.8	0.0	3.	0.	15.	0.	0.	3.	0.
WM 2	4152840	721350	528	1	.7	2.	15.	.19	2.	1.	2.	11.	0.0	10.	3.	1.4	0.0	2.	0.	41.	0.	0.	6.	2.
WM 3	4152390	721020	488	2	2.1	8.	49.	.72	1.	4.	7.	21.	0.0	30.	5.	1.3	0.0	14.	0.	20.	0.	0.	5.	0.
WM 4	4150760	721320	432	1	2.6	52.	214.	1.81	6.	9.	7.	30.	0.0	30.	4.	1.6	0.0	8.	4.	20.	15.	0.	19.	0.
WM 5	4150550	721120	415	3	2.1	14.	410.	2.43	7.	4.	5.	25.	0.0	50.	6.	1.8	0.0	3.	0.	4.	10.	0.	30.	0.
WM 6	4150510	721160	416	3	1.4	10.	151.	1.36	2.	1.	4.	25.	0.0	30.	5.	.8	0.0	3.	0.	12.	5.	5.	25.	0.
WM 7	4150710	721360	430	2	1.9	8.	142.	1.20	4.	2.	11.	40.	0.0	30.	9.	.8	0.0	4.	0.	46.	0.	9.	24.	0.
WM 8	4151490	722310	487	2	3.8	6.	69.	.66	3.	5.	5.	19.	0.0	10.	5.	.7	0.0	7.	0.	70.	4.	0.	6.	0.
WM 9	4152930	723980	478	1	4.1	9.	38.	1.10	3.	6.	11.	28.	0.0	60.	11.	2.4	0.0	11.	0.	70.	2.	0.	4.	0.
WM 10	4152920	723960	479	1	3.5	12.	59.	1.14	3.	5.	8.	30.	0.0	40.	6.	1.4	0.0	7.	3.	70.	2.	6.	59.	0.
WM 11	4152950	724120	480	1	1.0	4.	183.	.69	3.	3.	4.	12.	0.0	30.	3.	1.4	0.0	3.	6.	53.	3.	0.	9.	4.
WM 12	4150380	722910	462	1	1.7	138.	227.	3.66	15.	31.	32.	40.	0.0	40.	16.	8.5	0.0	4.	4.	35.	9.	0.	30.	0.
WM 13	4149740	722620	420	1	1.3	55.	223.	3.79	10.	16.	13.	23.	0.0	20.	12.	3.6	0.0	3.	16.	53.	40.	18.	42.	13.
WM 14	4149260	722680	400	1	1.9	47.	237.	1.68	7.	13.	13.	22.	0.0	30.	8.	3.3	0.0	4.	25.	5.	19.	0.	33.	0.
WM 15	4149240	722720	399	2	1.6	35.	257.	1.36	7.	11.	11.	25.	0.0	20.	3.	1.5	0.0	3.	9.	0.	27.	0.	50.	0.
WM 16	4149470	722940	430	1	1.4	25.	298.	.92	7.	7.	5.	16.	0.0	20.	3.	1.6	0.0	3.	3.	0.	25.	0.	32.	0.
WM 17	4440450	722960	428	1	2.9	56.	262.	1.91	11.	18.	16.	29.	0.0	20.	4.	2.7	0.0	5.	0.	0.	52.	0.	50.	0.
WM 18	4449520	723760	530	1	3.0	32.	157.	2.73	6.	10.	12.	65.	0.0	20.	7.	2.3	0.0	8.	0.	0.	12.	0.	52.	0.
WM 19	4448920	722830	390	1	2.2	88.	394.	2.64	12.	17.	17.	19.	0.0	30.	4.	2.3	0.0	4.	18.	0.	41.	0.	73.	0.
WM 22	4147900	721600	367	2	1.1	7.	595.	6.34	13.	5.	10.	62.	0.0	10.	8.	1.5	0.0	2.	0.	0.	10.	0.	60.	0.
WM 23	4147940	721620	364	4	1.2	18.	683.	6.08	11.	5.	8.	59.	0.0	10.	7.	1.7	.5	2.	0.	0.	10.	0.	29.	0.
WM 24	4147320	722440	357	5	1.2	17.	483.	3.22	9.	6.	8.	44.	0.0	20.	6.	1.6	0.0	2.	0.	0.	12.	0.	30.	0.
WM 25	4147340	722490	357	4	1.9	34.	287.	6.02	12.	8.	11.	31.	0.0	20.	6.	1.6	0.0	3.	10.	9.	20.	5.	33.	0.
WM 26	4147140	721740	426	1	1.7	6.	755.	4.96	16.	4.	14.	50.	0.0	20.	9.	2.3	0.0	3.	6.	0.	14.	0.	75.	0.
WM 27	4146870	722360	375	1	1.3	7.	538.	3.39	11.	5.	10.	33.	0.0	10.	6.	1.9	0.0	3.	3.	0.	18.	0.	75.	0.
WM 28	4148040	723710	428	1	1.7	25.	237.	1.06	6.	7.	8.	17.	0.0	20.	4.	1.4	0.0	4.	3.	0.	24.	0.	63.	0.
WM 29	4148000	723740	430	1	.6	5.	115.	.42	1.	2.	2.	17.	0.0	10.	4.	1.1	0.0	2.	0.	8.	11.	0.	60.	0.
WM 30	4146780	723100	358	2	2.9	27.	195.	1.33	7.	8.	11.	30.	0.0	30.	5.	2.0	0.0	8.	5.	7.	25.	0.	50.	0.
WM 31	4146500	723300	355	1	3.7	36.	254.	1.18	7.	10.	11.	26.	0.0	50.	6.	1.7	0.0	12.	0.	13.	30.	0.	32.	0.
WM 32	4146540	723920	402	1	1.1	6.	244.	.77	5.	3.	5.	16.	0.0	30.	5.	2.2	0.0	3.	3.	7.	25.	10.	15.	6.
WM 32 G	4146540	723920	402	1	.8	7.	266.	1.07	4.	4.	4.	13.	0.0	20.	6.	2.5	0.0	2.	0.	0.	21.	4.	11.	13.
WM 33	4146300	722310	400	1	1.1	16.	339.	1.71	7.	4.	5.	30.	0.0	20.	6.	1.4	0.0	3.	0.	0.	21.	6.	12.	13.
WM 34	4145820	723160	349	1	3.9	25.	1003.	3.36	19.	11.	17.	67.	0.0	60.	11.	2.5	0.0	11.	9.	0.	13.	0.	75.	3.
WM 35	4144380	722010	380	1	1.5	36.	270.	2.05	6.	6.	8.	20.	0.0	20.	5.	2.2	0.0	4.	0.	0.	23.	0.	33.	0.
WM 36	4144350	722020	380	3	.6	10.	218.	1.88	5.	2.	6.	22.	0.0	10.	5.	1.0	0.0	3.	0.	0.	19.	0.	51.	0.
WM 37	4144970	722860	358	3	1.7	19.	389.	2.93	6.	4.	10.	25.	0.0	30.	9.	2.3	0.0	5.	0.	0.	12.	0.	25.	6.
WM 38	4145350	723600	348	3	.9	20.	281.	4.78	7.	3.	5.	30.	0.0	10.	8.	1.3	0.0	3.	0.	0.	12.	0.	26.	0.
WM 39	4145340	723680	348	1	.8	10.	178.	.81	5.	3.	5.	16.	0.0	20.	6.	2.2	0.0	4.	0.	4.	7.	0.	25.	11.
WM 40	4145050	724060	347	1	2.1	13.	605.	2.43	12.	5.	21.	45.	0.0	40.	4.	2.6	0.0	7.	4.	0.	20.	18.	65.	0.
WM 41	4142880	721780	428	2	.8	9.	212.	1.40	4.	4.	4.	17.	0.0	20.	6.	2.3	0.0	3.	0.	0.	9.	8.	23.	4.
WM 42	4142850	721770	428	2	1.8	13.	575.	2.74	7.	4.	6.	24.	0.0	40.	8.	4.3	0.0	5.	0.	7.	8.	11.	20.	6.
WM 43	4142270	721640	445	1	2.6	9.	114.	.87	4.	4.	6.	20.	0.0	50.	5.	2.7	0.0	10.	0.	6.	0.	14.	15.	5.

APPENDIX: GEOCHEMICAL DATA FOR ANDERSONVILLE AND WILLIS MOUNTAIN QUADRANGLES

Sa.No.	UTM(N)	UTM(E)	Ele.	SO	Li	Cr	Mn	Fe	Co	Ni	Cu	Zn	Ag	Ba	Pb	Sr	Cd	Rb	chl	ma	am	mr	pg	ep
WM 44	4142880	721770	447	1	1.5	8.	299.	1.35	5.	4.	7.	26.	0.0	40.	6.	2.9	0.0	6.	4.	7.	3.	11.	9.	0.
WM 45	4141950	721500	448	1	.9	4.	315.	2.27	5.	2.	4.	22.	0.0	20.	5.	2.3	0.0	3.	0.	8.	0.	7.	6.	0.
WM 46	4139570	721560	392	1	1.0	7.	487.	2.92	5.	3.	6.	31.	0.0	20.	8.	3.4	0.0	3.	0.	0.	17.	5.	22.	6.
WM 47	4139560	721600	392	1	2.0	12.	229.	.99	5.	7.	15.	22.	0.0	50.	4.	5.6	0.0	9.	0.	4.	12.	9.	24.	10.
WM 47 A	4139220	721700	388	1	1.4	11.	498.	1.46	4.	5.	5.	21.	0.0	30.	4.	5.9	0.0	7.	0.	6.	7.	22.	33.	9.
WM 48	4143560	723710	399	1	1.5	27.	565.	4.80	8.	7.	6.	37.	0.0	20.	7.	4.0	0.0	5.	0.	0.	24.	6.	29.	8.
WM 49	4140340	723350	470	1	1.1	16.	643.	1.79	6.	6.	4.	19.	0.0	30.	6.	3.3	0.0	3.	0.	0.	25.	13.	35.	5.
WM 50	4140000	724190	431	1	1.9	8.	434.	1.24	6.	4.	3.	33.	0.0	20.	11.	3.4	0.0	4.	4.	3.	6.	30.	25.	5.
WM 51	4140040	724200	430	1	2.1	13.	448.	2.51	7.	5.	7.	36.	0.0	20.	8.	4.4	0.0	5.	0.	11.	9.	7.	43.	6.
WM 52	4141590	724120	409	1	1.2	13.	485.	2.73	7.	5.	4.	27.	0.0	10.	5.	3.2	0.0	3.	0.	0.	23.	4.	45.	6.
WM 53	4141610	725020	385	2	1.1	13.	909.	5.54	9.	6.	4.	44.	0.0	10.	11.	4.0	0.0	2.	0.	0.	10.	7.	20.	9.
WM 54	4141570	725040	385	1	1.2	22.	370.	1.34	9.	7.	6.	18.	0.0	20.	5.	3.1	0.0	3.	0.	0.	23.	10.	39.	5.
WM 55	4140160	725230	405	1	1.5	18.	389.	1.20	7.	6.	4.	27.	0.0	30.	8.	2.8	0.0	3.	0.	0.	13.	12.	45.	5.
WM 56	4140210	725220	405	2	2.0	29.	375.	3.28	12.	11.	11.	33.	0.0	20.	7.	2.6	0.0	3.	0.	0.	10.	4.	25.	0.
WM 57	4140190	725680	396	1	2.4	31.	612.	2.70	13.	14.	11.	38.	0.0	30.	9.	4.0	0.0	3.	16.	0.	13.	13.	58.	0.
WM 58 A	4140460	726360	359	2	1.3	15.	346.	2.11	5.	7.	4.	25.	0.0	20.	7.	3.1	0.0	3.	0.	0.	15.	9.	37.	3.
WM 58 B	4140880	726860	358	1	6.1	18.	881.	1.74	10.	11.	14.	41.	0.0	70.	13.	4.8	0.0	14.	0.	9.	4.	12.	68.	3.
WM 59 A	4142480	725840	377	1	.7	14.	331.	3.18	7.	2.	3.	23.	0.0	20.	7.	2.2	0.0	3.	0.	0.	0.	34.	16.	6.
WM 59 B	4142720	726010	371	1	2.0	22.	346.	1.82	9.	7.	6.	21.	0.0	20.	8.	6.0	0.0	3.	5.	4.	13.	18.	31.	7.
WM 60 A	4142160	727070	350	1	3.5	13.	1142.	1.51	11.	10.	7.	25.	0.0	60.	12.	2.8	0.0	7.	5.	0.	5.	14.	33.	0.
WM 60 B	4142420	727530	330	1	3.3	17.	914.	1.75	13.	9.	12.	28.	0.0	40.	10.	3.3	0.0	9.	0.	0.	14.	19.	62.	0.
WM 61	4141920	727580	325	3	1.2	12.	397.	2.41	6.	5.	5.	29.	0.0	20.	6.	2.8	0.0	3.	0.	0.	6.	14.	35.	3.
WM 62	4141220	727740	335	1	11.1	17.	1331.	2.16	20.	20.	15.	48.	0.0	120.	15.	7.3	0.0	20.	7.	9.	0.	0.	24.	0.
WM 63	4143380	728900	304	2	5.6	11.	310.	1.02	7.	7.	7.	29.	0.0	50.	9.	6.9	0.0	14.	4.	8.	0.	0.	41.	5.
WM 63 A	4139860	727740	362	1	13.6	16.	953.	2.23	15.	12.	15.	48.	0.0	90.	16.	6.3	0.0	28.	7.	7.	0.	0.	29.	0.
WM 64	4143400	728900	305	3	4.0	16.	475.	1.59	11.	8.	9.	34.	0.0	40.	7.	4.2	0.0	10.	7.	9.	6.	9.	36.	7.
WM 65	4143560	728480	318	1	3.4	19.	376.	1.60	10.	9.	8.	30.	0.0	30.	8.	3.8	0.0	7.	5.	0.	0.	16.	43.	0.
WM 66	4143600	728500	319	2	4.7	15.	426.	2.14	12.	9.	12.	32.	0.0	70.	9.	9.9	0.0	11.	12.	3.	0.	7.	36.	9.
WM 67	4144060	728360	332	2	4.4	17.	428.	2.10	12.	11.	9.	37.	0.0	60.	10.	8.7	0.0	10.	10.	7.	0.	7.	43.	0.
WM 69	4145820	727450	319	1	.9	8.	678.	5.11	9.	3.	10.	34.	0.0	20.	8.	3.2	0.0	2.	0.	0.	10.	0.	49.	0.
WM 70	4145680	727340	311	1	1.1	10.	479.	6.48	10.	8.	17.	32.	0.0	20.	8.	3.2	0.0	3.	0.	0.	30.	0.	40.	0.
WM 71	4145440	727160	315	1	1.0	8.	363.	1.81	8.	2.	17.	25.	0.0	20.	4.	2.3	0.0	3.	0.	0.	19.	0.	65.	0.
WM 72	4145000	727120	310	1	3.3	24.	599.	1.66	11.	9.	9.	33.	0.0	30.	7.	5.8	0.0	6.	5.	0.	27.	0.	40.	0.
WM 73	4144490	727920	318	1	2.4	23.	290.	1.60	7.	8.	5.	22.	0.0	20.	6.	6.2	0.0	3.	3.	0.	15.	20.	40.	0.
WM 74	4144570	726560	319	2	.8	9.	237.	3.60	7.	3.	12.	26.	0.0	20.	10.	1.9	0.0	3.	0.	7.	19.	7.	32.	0.
WM 75	4144520	726400	320	1	1.9	17.	449.	2.22	8.	8.	13.	28.	0.0	40.	7.	3.2	0.0	5.	0.	0.	28.	15.	75.	0.
WM 76	4144640	725800	324	1	2.1	13.	270.	1.03	7.	7.	7.	30.	0.0	60.	6.	2.7	0.0	9.	0.	10.	9.	12.	20.	9.
WM 77	4145180	725080	334	1	5.9	25.	710.	2.63	16.	12.	27.	110.	0.0	90.	19.	4.8	0.0	14.	7.	7.	6.	0.	45.	0.
WM 78	4145340	725180	336	2	1.2	23.	461.	4.18	8.	5.	8.	38.	0.0	20.	6.	3.0	0.0	4.	0.	3.	10.	0.	25.	15.
WM 79	4145180	725030	334	5	1.8	16.	823.	4.50	12.	6.	10.	60.	0.0	30.	7.	2.9	0.0	4.	0.	0.	24.	0.	42.	0.
WM 80	4145580	727920	372	1	1.5	20.	504.	6.06	10.	6.	14.	41.	0.0	30.	10.	2.5	0.0	4.	0.	0.	7.	5.	34.	0.
WM 81	4145580	727970	379	1	1.2	9.	322.	3.05	7.	3.	16.	22.	0.0	20.	8.	2.4	0.0	2.	0.	0.	12.	0.	53.	0.
WM 82	4148720	725400	450	1	.7	4.	318.	1.24	5.	2.	4.	18.	0.0	20.	5.	1.2	0.0	2.	0.	0.	9.	10.	21.	0.
WM 83	4148700	725360	450	1	.6	5.	188.	.86	5.	1.	5.	15.	0.0	20.	7.	1.2	0.0	2.	0.	9.	11.	10.	19.	4.
WM 84	4148060	725800	410	1	1.7	14.	249.	1.20	7.	6.	6.	25.	0.0	40.	7.	2.1	0.0	6.	0.	6.	14.	0.	20.	0.
WM 85	4148100	725820	407	2	1.7	10.	378.	1.46	8.	4.	6.	24.	0.0	30.	9.	2.2	0.0	4.	5.	6.	14.	6.	18.	3.
WM 86	4147900	725950	396	1	1.6	18.	430.	1.71	8.	5.	8.	33.	0.0	30.	6.	1.8	0.0	5.	0.	0.	15.	0.	43.	0.
WM 87	4147520	726720	358	1	.9	8.	307.	6.91	9.	5.	62.	41.	0.0	20.	8.	2.2	0.0	2.	4.	0.	10.	15.	33.	0.
WM 88	4147760	726680	368	1	1.6	24.	449.	6.45	13.	8.	21.	50.	0.0	20.	9.	2.2	0.0	4.	0.	3.	10.	0.	29.	0.
WM 89	4145820	729080	300	1	5.5	21.	556.	2.67	13.	13.	20.	57.	0.0	80.	10.	16.7	0.0	14.	12.	0.	0.	9.	53.	6.
WM 89 G	4145820	729080	300	1	4.0	20.	495.	3.92	12.	9.	15.	32.	0.0	60.	10.	16.2	0.0	9.	8.	6.	0.	11.	33.	10.
WM 90	4146540	728660	308	1	1.0	6.	241.	2.83	5.	4.	4.	27.	0.0	20.	8.	3.8	0.0	6.	0.	4.	0.	77.	28.	12.
WM 91	4146800	728500	318	1	2.1	12.	718.	3.83	10.	4.	14.	54.	0.0	30.	9.	3.6	0.0	2.	0.	0.	0.	0.	49.	0.
WM 92	4146940	728100	325	1	1.8	10.	658.	4.06	9.	6.	12.	38.	0.0	30.	8.	6.3	0.0	3.	0.	0.	20.	0.	62.	0.
WM 93	4147680	727500	353	1	1.2	3.	115.	.92	4.	2.	10.	25.	0.0	50.	7.	1.3	0.0	5.	0.	9.	0.	0.	57.	0.
WM 94	4147700	727460	353	2	1.0	11.	314.	14.05	11.	4.	15.	46.	1.0	20.	10.	2.2	.5	2.	0.	7.	8.	0.	22.	0.
WM 95	4148560	727160	409	1	1.1	9.	692.	4.64	15.	5.	21.	58.	0.0	40.	17.	1.7	0.0	3.	0.	5.	10.	7.	38.	0.
WM 96	4148560	727120	407	1	.8	8.	150.	1.78	4.	3.	13.	29.	0.0	30.	5.	1.2	0.0	3.	0.	6.	7.	8.	20.	3.
WM 97	4149380	728480	380	1	.5	5.	400.	4.22	7.	2.	10.	21.	0.0	10.	7.	1.6	0.0	2.	0.	0.	15.	0.	32.	0.
WM 98	4149400	728460	377	1	.7	8.	286.	2.43	5.	5.	12.	34.	0.0	20.	7.	1.7	0.0	3.	0.	0.	14.	0.	41.	0.
WM 99	4150390	725030	490	1	.6	3.	76.	.47	3.	2.	2.	11.	0.0	10.	4.	1.9	0.0	3.	0.	15.	0.	6.	15.	5.
WM 100	4151640	725560	432	1	1.2	3.	96.	.53	2.	3.	4.	13.	0.0	30.	3.	3.8	0.0	6.	0.	25.	0.	0.	22.	12.
WM 100 G	4151640	725560	432	1	.9	3.	80.	.48	1.	3.	2.	12.	0.0	20.	3.	3.0	0.0	5.	0.	19.	3.	7.	17.	22.
WM 101	4151660	725520	433	1	1.1	4.	118.	.56	4.	2.	3.	12.	0.0	20.	3.	5.6	0.0	6.	0.	5.	0.	4.	19.	17.
WM 101 G	4151660	725520	433	1	1.6	5.	114.	.71	5.	2.	5.	15.	0.0	40.	3.	3.9	0.0	10.	0.	8.	0.	4.	17.	16.
WM 102 A	4152820	725480	403	1	1.2	5.	232.	.96	5.	2.	5.	21.	0.0	30.	7.	1.8	0.0	6.	4.	11.	7.	0.	23.	7.
WM 102 B	4152780	725470	402	2	1.0	4.	395.	.87	5.	3.	5.	24.	0.0	30.	4.	7.2	0.0	5.	0.	8.	5.	3.	16.	12.
WM 103	4152990	725980	390	1	1.2	4.	125.	.70	4.	1.	4.	11.	0.0	20.	5.	5.9	0.0	6.	0.	15.	0.	4.	21.	22.
WM 104	4152920	726610	380	1	.7	3.	102.	.40	2.	2.	2.	14.	0.0	20.	3.	2.9	0.0	5.	0.	7.	5.	7.	20.	10.
WM 105	4152620	726680	360	3	1.4	6.	348.	1.05	5.	4.	7.	20.	0.0	30.	6.	7.0	0.0	6.	0.	14.	5.	7.	22.	10.
WM 106	4152200	726530	378	2	1.0	3.	164.	.47	3.	3.	4.	17.	0.0	30.	4.	4.0	0.0	6.	4.	10.	3.	0.	17.	12.
WM 107	4152120	726570	377	1	1.6	6.	178.	1.20	5.	4.	5.	25.	0.0	50.	4.	4.4	0.0	10.	0.	18.	6.	0.	31.	7.
WM 108	4151810	727740	335	3	2.1	4.	478.	1.11	5.	4.	9.	27.	0.0	70.	6.	5.7	0.0	16.	0.	29.	5.	0.	50.	7.
WM 109	4151810	727760	333	4	1.1	5.	159.	1.07	4.	2.	7.	16.	0.0	30.	3.	5.7	0.0	7.	0.	13.	13.	0.	29.	19.
WM 110	4151400	727820	332	1	2.1	7.	544.	2.08	9.	4.	8.	25.	0.0	40.	8.	4.1	0.0	6.	0.	6.	11.	8.	28.	7.
WM 111	4151930	728720	327	1	2.1	16.	332.	2.36	8.	9.	12.	31.	0.0	60.	3.	3.9	0.0	6.	4.	6.	28.	0.	37.	4.
WM 112	4151320	728920	345	1	2.4	8.	203.	.87	6.	4.	7.	27.	0.0	50.	5.	3.0	0.0	8.	0.	35.	9.	4.	16.	9.
WM 113	4151340	728960	345	1	2.3	9.	262.	1.18	5.	5.	7.	23.	0.0	50.	5.	4.0	0.0	5.	0.	3.	21.	0.	23.	11.
WM 114	4151080	729060	330	1	1.4	6.	477.	2.76	6.	2.	19.	48.	0.0	30.	6.	2.0	0.0	3.	5.	0.	12.	0.	68.	0.
WM 115	4150920	728820	320	4	.9	8.	314.	1.95	5.	3.	4.	21.	0.0	30.	5.	5.3	0.0	4.	0.	5.	9.	6.	21.	12.
WM 116 A	4150380	729360	318	1	1.1	7.	356.	14.87	14.	6.	9.	29.	1.0	20.	9.	2.0	.6	2.	0.	9.	12.	0.	30.	0.
WM 116 B	4150410	729330	313	4	1.7	10.	243.	1.16	6.	5.	8.	32.	0.0	40.	8.	2.8	0.0	8.	0.	18.	11.	0.	31.	6.
WM 117	4152690	731220	385	1	1.2	21.	288.	1.72	6.	5.	10.	22.	0.0	30.	6.	1.5	0.0	3.	0.	0.	23.	0.	37.	0.
WM 118	4152460	731320	378	1	1.4	11.	278.	3.47	10.	4.	12.	40.	0.0	30.	6.	1.5	0.0	6.	0.	3.	17.	0.	43.	0.
WM 119	4151700	730740	389	1	1.1	12.	205.	1.60	5.	6.	10.	23.	0.0	20.	6.	1.7	0.0	4.	17.	0.	21.	0.	24.	0.
WM 120	4151660	730720	388	1	.7	19.	281.	4.81	10.	5.	9.	23.	0.0	20.	6.	1.2	0.0	4.	5.	4.	17.	0.	35.	0.
WM 121	4149500	729140	316	2	.6	10.	360.	5.40	9.	5.	12.	27.	0.0	30.	9.	2.1	0.0	2.	0.	0.	13.	0.	21.	0.
WM 122 A	4149900	729280	315	2	1.0	11.	350.	5.77	8.	6.	13.	28.	0.0	20.	6.	2.7	0.0	4.	0.	0.	12.	0.	37.	47.
WM 123	4148870	730740	317	2	6.5	25.	462.	2.55	17.	14.	24.	36.	0.0	40.	8.	28.3	0.0	10.	23.	11.	20.	0.	58.	0.
WM 124	4147540	729740	336	1	1.7	18.	449.	1.73	9.	9.	7.	26.	0.0	40.	8.	7.1	0.0	4.	15.	9.	0.	0.	25.	8.
WM 125	4147220	729600	335	1	1.3	5.	1174.	3.15	7.	3.	4.	44.	0.0	20.	11.	3.1	0.0	3.	0.	0.	0.	0.	25.	0.
WM 126	4141860	729100	326	2	9.4	19.	631.	2.01	14.	16.	12.	43.	0.0	90.	11.	13.3	0.0	19.	10.	16.	0.	0.	39.	0.
WM 127	4143360	730660	299	1	5.3	7.	314.	1.15	7.	6.	6.	26.	0.0	60.	9.	12.0	0.0	12.	7.	8.	0.	0.	26.	0.
WM 128	4141500	730600	320	1	4.0	6.	142.	.69	4.	3.	3.	18.	0.0	40.	7.	9.8	0.0	9.	3.	12.	0.	8.	30.	4.
WM 129	4141520	730980	325	1	5.3	8.	147.	.70	4.	5.	3.	22.	0.0	30.	6.	3.7	0.0	13.	0.	17.	0.	24.	42.	4.
WM 130	4141960	730780	326	1	4.4	8.	222.	.84	4.	5.	5.	20.	0.0	40.	9.	6.5	0.0	12.	2.	10.	0.	12.	25.	4.
WM 131	4140500	730700	336	1	5.0	8.	247.	1.03	5.	6.	6.	27.	0.0	70.	8.	11.1	0.0	14.	0.	14.	0.	4.	34.	0.
WM 132	4140060	730900	339	2	4.7	10.	341.	1.17	6.	9.	8.	30.	0.0	50.	8.	10.3	0.0	12.	4.	12.	0.	6.	30.	5.
WM 133	4151970	724160	480	1	1.5	4.	196.	.86	4.	2.	4.	22.	0.0	30.	6.	4.0	0.0	3.	0.	3.	7.	0.	26.	9.
WM 134	4151900	727120	355	1	2.6	19.	349.	1.44	8.	9.	9.	39.	0.0	70.	6.	6.0	0.0	17.	0.	19.	5.	0.	37.	12.
WM 135 A	4152860	727780	345	1	.9	7.	193.	1.22	3.	2.	4.	16.	0.0	20.	5.	5.1	0.0	24.	0.	6.	5.	0.	16.	20.
WM 135 B	4152830	727820	348	1	.9	8.	329.	2.04	5.	4.	15.	43.	0.0	70.	10.	4.8	0.0	8.	0.	15.	9.	0.	31.	7.
WM 136	4148720	721540	380	3	1.8	21.	412.	3.83	8.	6.	6.	21.	0.0	20.	7.	1.9	0.0	3.	0.	0.	16.	0.	30.	0.
WM 137	4152280	722460	523	1	5.1	10.	95.	1.04	5.	5.	11.	28.	0.0	20.	6.	1.2	0.0	10.	0.	45.	3.	0.	7.	0.
WM 138	4152900	722500	547	2	1.0	5.	123.	.73	3.	3.	2.	15.	0.0	10.	5.	1.0	0.0	3.	0.	18.	0.	0.	4.	0.
WM 139	4152880	722560	547	1	2.5	10.	85.	.66	3.	5.	4.	23.	0.0	30.	6.	1.1	0.0	5.	0.	54.	0.	0.	7.	0.
WM 140	4148180	724840	390	1	1.0	14.	160.	.75	4.	2.	5.	17.	0.0	20.	5.	3.4	0.0	3.	0.	0.	30.	10.	25.	13.
WM 141	4142340	725400	375	2	.5	10.	350.	1.61	4.	4.	3.	14.	0.0	20.	7.	2.1	0.0	2.	0.	0.	17.	10.	21.	9.
WM 142	4150460	731740	349	2	4.8	12.	553.	3.33	8.	6.	4.	27.	0.0	30.	7.	7.5	0.0	3.	5.	4.	7.	0.	32.	0.
WM 143	4149860	729760	315	2	.9	6.	194.	4.29	5.	3.	3.	15.	0.0	20.	5.	1.1	0.0	2.	0.	0.	14.	0.	20.	0.

Abbreviations: Sa.No., Sample number; UTM, Universal Transverse Mercator; Ele., Elevation (ft.); SO, Stream order; A, Andersonville quadrangle; WM, Willis Mountain quadrangle; chl, chlorite; ma, mica; am, amphibole; mr, microcline; pg, plagioclase; ep, epidote.
Iron and mineral in percent; other parameters in ppm.

SELECTED MINERAL RESOURCES[1]

By

Palmer C. Sweet

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ABSTRACT

Mineral resources in the Andersonville-Willis Mountain quadrangles area consist of kyanite, massive sulfides, clay materials and construction materials. Occurrences of other resources present or reported in the area include feldspar and mica, coal, gold, iron, copper and manganese. Kyanite occurs on Willis Mountain, East Ridge, Woods Mountain and the Carwile property; it is being mined on Willis Mountain and East Ridge. By-product sand is also produced. No additional resources are currently produced in the area.

NON-METALLIC RESOURCES

KYANITE

Virginia is the leading state in the production of kyanite (Al_2SiO_5), a blue to white, transparent, non-metallic high aluminum silicate mineral. Production by the Kyanite Mining Corporation comes from two sites south of Dillwyn in the Willis Mountain quadrangle located in deposits of kyanite-bearing quartzites. The kyanite quartzite forms the prominent topographic feature known as Willis Mountain and a lower hill to the east known locally as East Ridge. Mining of the kyanite quartzite at Willis Mountain began in 1957 and has continued since that time. The kyanite from this mine is processed at plants adjacent to the mine site and in nearby

[1] Portions of this report may be quoted if credit is given to the Virginia Division of Mineral Resources. It is recommended that reference to this report be made in the following form: Sweet, P.C.,1981, Selected mineral resources, *in* Geologic investigations in the Willis Mountain and Andersonville quadrangles, Virginia: Virginia Division of Mineral Resources Publication 29, p. 70-75.

Dillwyn (Dillwyn 7.5-minute quadrangle). The establishment by the Kyanite Mining Corporation of a new mine and plant on East Ridge in 1978 effectively doubled kyanite productive capacity in Buckingham County. Potter (1975, p. 583) states that at least 65 million tons of 25 percent kyanite ore were estimated from diamond-drill reconnaissance at Willis Mountain. Open-pit mining of kyanite quartzite in this area is followed by three stages of crushing and drying. A high-intensity wet magnetic separator was recently set up as a more efficient method to remove impurities (Dixon, 1980).

The largest portion of the market for kyanite is making brick for rotary kilns and furnaces (Dixon, 1980). Some new applications are being developed in making stainless steel and fiber insulation. Kyanite may become a source of alumina for the production of aluminum metal.

Approximately 90 percent of the mullite (produced mostly from kyanite) is used as refractory lining in metallurgical and glass-manufacturing furnaces; the remaining 10 percent is used in kilns, saggers, boilers, and similar products. Synthetic mullite is produced by the calcining of high-alumina silicate minerals. Mullite is also made by sintering a mix of uniformly ground kaolin and alumina particles at very high temperatures. This sintering process, which yields impure, small crystal aggregates, was the first method used for obtaining synthetic mullite.

Clay Materials

Three residual-clay samples (R-7502, R-7505, and R-7506) were collected in the central to northeastern portion of the Andersonville quadrangle from the exposed surfaces of the lower unit of the Chopawamsic Formation and the Arvonia Formation. These samples reached an acceptable test hardness with a tolerable shrinkage; all three samples have a potential use for structural clay products.

In the central to southern part of the Andersonville quadrangle and the northern part of the Willis Mountain quadrangle, six residual-clay samples (R-7462, R-7463, R-7503, R-7507, R-7508 and R-7509) were taken over upper Chopawamsic amphibole gneiss and schist and biotite gneiss (Figure 1). The hardness of the fired material was low for five of

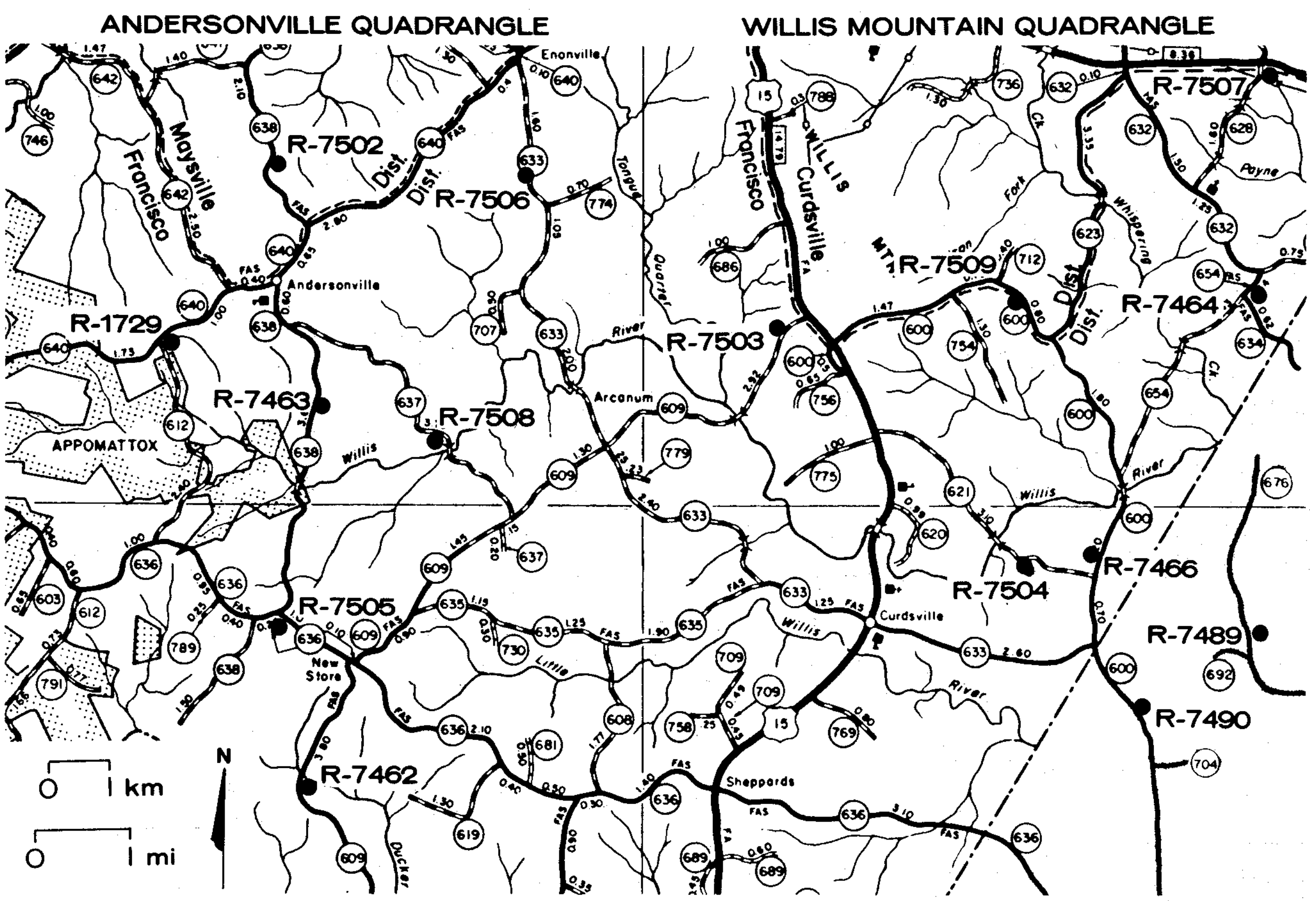

Figure 1. Clay sample localities.

these samples. The hardness of fired test briquets for a sixth sample, R-7507, was sufficient, but shrinkage was excessive. All six materials, according to the data, were evaluated to be unsuitable to make structural clay products. In the central and southeastern portion of the Willis Mountain quadrangle, five samples of residual clays (R-7464, R-7466, R-7489, R-7490 and R-7504 were collected in the area of Triassic-age rocks. Most of these samples have a good plasticity, and adequate hardness with tolerable shrinkage when fired (Table 1). One sample (R-7504), collected in a roadcut near Mt. Nebo Church, was found to have an excessive shrinkage at desired firing temperatures. This clay, if mixed with a minor amount of silt or sandy material, would probably make an acceptable material for structural products.

CONSTRUCTION MATERIALS

At present there are no active rock quarries or sand and gravel operations within the area of the Andersonville and Willis Mountain quadrangles. An area about 2.5 miles (4 km) east of Sheppards was examined by a crushed-stone operator as a potential

Table 1. Location and potential uses of clay materials from selected samples in the Andersonville and Willis Mountain quadrangles.

Sample Number	Location	Source	Sampled Interval	Potential Use
R-7464	Roadcut, 4.45 miles (7.17 km) east of Willis Mountain, on the east side of State Road 654 at its intersection with State Road 634.	Transported clay	Composite of three channel samples, equally spaced in the roadcut, from 3-foot-thick (1 m) clay in roadcut and from 1 foot (0.3 m) of augered clay.	Marginal for structural clay products (e.g., building-brick fired at 1,150°-1,250°C).
R-7466	Roadcut, 4.75 miles (7.65 km) northeast of Sheppards, on the northwest side of State Road 600, approximately 0.35 mile (0.56 km) by road north of its intersection with State Road 621.	Residual clay	Composite of two channel samples from 3.5-foot-thick (1.1 m) clay taken about 100 feet (30 m) apart in the highest part of the exposure.	Structural clay products (e.g., floor-brick, building-brick fired at 1,200°-1,250°C).
R-7489	Roadcut, 4.1 miles (6.6 km) east of Curdsville, Buckingham County, on the east side of State Road 676 approximately 0.1 mile (0.2 km) by road north of its intersection with State Road 692.	Residual clay	Composite of a channel sample taken from 5.5-foot-thick (1.7 m) clay; samples from southern end and center of the roadcut as well as from some of the hard shale below a micaceous siltstone.	Structural clay products (e.g., building-brick, floor-brick fired at 1,100°-1,200°C).
R-7490	Roadcut, 2.75 miles (4.43 km) east of Curdsville, on the northeast side of State Road 600 approximately 0.7 mile (1.1 km) by road north of its intersection with State Road 704.	Residual clay	Composite of three channel samples from 3.5-foot-thick (1.1 m) clay taken 15 feet (5 m) apart in the highest part of the exposure.	Structural clay products (e.g., floor-brick fired at 1,050°-1,150°C).
R-7502	Roadcut, 1.3 miles (2.1 km) north of Andersonville, on the east side of State Road 638 approximately 1.0 mile (1.6 km) by road south of its intersection with State Road 641.	Residual clay	Composite of three channel samples from 4-foot-thick (1 m) clay samples about 40 feet (12 m) apart.	Structural clay products (e.g., building-brick fired at 1,100°-1,250°C).
R-7505	Roadcut, 3.5 miles (5.6 km) south of Andersonville, on the south side of State Road 636 approximately 0.1 mile (0.2 km) by road east of its intersection with State Road 638.	Residual clay	Composite of two channel samples from 5-foot-thick (2 m) clay; samples taken 60 feet (18 m) apart.	Structural clay products (e.g., building-brick fired at 1,200°-1,250°C).
R-7506	Roadcut, 1.2 miles (1.9 km) south of Enonville, on the west side of State Road 633 approximately 0.4 mile (0.6 km) by road northwest of its intersection with State Road 774.	Residual clay	Composite of two channel samples from 6-foot-thick (2 m) clay; samples taken 50 feet (15 m) apart.	Structural clay products (e.g., building-brick fired at 1,150°-1,250°C).

quarry site in the late 1960's (J. MacDonald, 1979, personal communication). Examination of thin-sections by geologists at the Virginia Division of Mineral Resources from a core taken at this site near Perkins Creek off the north side of State Road 636 indicates that the rock is graywacke or metagraywacke. Quarrying operations were not established at the site.

Good exposures of Triassic-age diabase dikes occur along U.S. Highway 15 just north of Curdsville and on the east side of State Road 600 near the Buckingham-Cumberland county line. This greenish-black rock is highly resistant to physical breakdown. Such dikes are typically thin, elongate bodies with steep dip and are not suitable in physical form to sustain commercial quarrying. Diabase is not quarried within the area but is produced at several sites in northern Virginia, where it is more extensive, for crushed and dimension stone.

FELDSPAR AND MICA

There are numerous small pegmatitic intrusives in the Willis Mountain quadrangle. Two of these were prospected. One of these prospects is located in the prominent saddle on Willis Mountain. At this location several small pits and one trench were observed. Quartzo-feldspathic material and muscovite books up to five inches long are in the area around these pits and trenches. The site was prospected many years ago by a shaft 40 to 50 feet (12 to 15 m) deep (Espenshade and Potter, 1960, p. 53). Another prospect pit is one-half mile (0.8 km) southwest of the intersection of State Road 636 and U.S. Highway 15 at Sheppards. Quartzo-feldspathic material and muscovite books up to six inches long are on a small dump. The small size of most of the pegmatites in this area would limit their potential as a source of either feldspar or muscovite.

COAL

Several old coal prospects and pits are in the Farmville 7.5-minute quadrangle, the quadrangle immediately south of the Willis Mountain quadrangle. A coal mine which was opened in the area by the Piedmont Coal Company in the early 1860's produced intermittently until the early 1890's. This mine is located less than one mile (1.6 km) south of the Willis Mountain quadrangle. As recently as 1920, exploration for coal in this area was still being pursued.

In the southeast part of the Willis Mountain quadrangle, four holes were cored by the Division of Mineral Resources in 1979; the deepest was 180 feet (55 m). The holes penetrated arkosic sandstone containing thin beds of conglomerate and siltstone; one hole bottomed in basement rocks. No coal was penetrated. A four-inch coal seam was reported in a stream-cut in this area.

METALLIC RESOURCES

GOLD

Gold is associated with the massive sulfides. There are 8 old mines and prospects in the two quadrangles (Sweet, 1980). Most of the pits and trenches of these mines are found on linear ridges of micaceous quartzite and fine-grained quartz-sericite schist of the Arvonia Formation. The gold is thought to represent placer deposits formed on the eroded surface of Chopawamsic Formation rocks. Two of the largest mines in Buckingham County are located to the north of Dillwyn, outside of the quadrangles area. Within the quadrangles area, the Morrow mine in the Willis Mountain quadrangle was the largest gold producer. It was one of the first properties in Virginia on which underground mining was attempted; the mine was first known as the Booker mine in 1835 (Taber, 1913, p. 199). Later the property was operated by two companies (W. M. Moseley and Company and the Garnett Mining Company) at two mines along the same vein about 100 yards (91 m) apart; two small mills were in operation at this time. There were 257.77 troy pounds of gold produced by the Garnett and Moseley companies in 1850-1852. Over $60,000 (valued at $20.67 per troy ounce) in gold was recovered from placer gravels near the veins during the early history of the property. A 9 pound nugget as well as many masses of a few ounces each and grains of gold were found in a branch immediately south of the Garnett and Moseley mines (Taber, 1913, p. 205). In 1854, the property was controlled by an English company, which utilized a 72-stamp mill and two sets of tables for amalgamation purposes. It is believed that this mine was purchased by the same company (London and Virginia Gold and Copper Mining Company) that purchased the Eldridge mine, located north of Dillwyn, in 1853 (Sweet, 1971, p. 29). In 1865, the mines were shut down, but were worked in 1880 by the Morrow Mining Company. In 1938, the mine was again operated briefly, being developed by 5 shafts and 350 feet of drifts. In the mid-1970's three caved shafts, numerous caved pits, open cuts and trenches were on the property (Sweet, 1980, p. 8). Summary information on the history and evidence of workings at seven other old gold mines is presented in Table 2.

COPPER

There is a copper prospect at the southern end of Willis Mountain. Two shafts 40-50 feet (12-15 m) deep and about 100 yards (91 m) apart were sunk around 1870 (Taber, 1913, p. 133). Espenshade and Potter (1960, p. 53) state that the shafts have now caved in and that only a dump of pyrite and pyrrhotite, along with abundant amphibolite, garnet, and plagioclase feldspar and chlorite, are now at the site.

IRON

Many of the ferruginous quartzites in the Willis Mountain quadrangle have been prospected. A small ridge underlain by this quartzite lies due west of the end of Route 686, approximately one mile (1.6 km) west of U.S. Highway 15. This ridge contains numerous small pits and trenches. Prospecting of these ferruginous quartzites as possible sources of iron probably began around 1829 (when gold mining first became active in the area) and continued until the early 1860's. It is doubtful if any of the ore was shipped to iron furnaces (Espenshade and Potter, 1960, p. 53).

MANGANESE

A deposit of manganese oxides were worked near Curdsville (Espenshade, 1954, p. 93) in the 1880's or 1890's. Field mapping and also queries among local residents failed to reveal any information concerning this deposit. An exposure of amphibole gneiss along State Road 633 and about one-half mile (0.8 km) west of Curdsville may have been described as manganese because of its color, etc. Manganese films are common on joint surfaces in deeply weathered kyanite quartzite.

Table 2. Old gold mines in the Willis Mountain and Andersonville quadrangles. Locations are shown in Plate 1.

Mine	Quadrangle	Comments
Anderson	Andersonville	A placer mine was operated on this property in the 1830's. A 50-foot shaft connecting with a tunnel 70 yards long (reported by Taber, 1913, p. 195) had both caved by 1965. In the mid-1970's there were about 10 caved shafts, and a very large dump area at the site (Sweet, 1980, p. 7).
Bondurant	Andersonville	There was placer mining on some of the hillsides and branches on the property. A small stamp mill was built a few years later to crush the gold ore. In 1865 two parallel veins, 30 feet apart, were opened by 20-25-foot excavations and two shafts, 35- to 45-feet deep. Around 1875, a small stamp was operated for a short time. A 410-foot tunnel was driven from the creek to the southeast in the hillside in 1901; 5 parallel veins were encountered in this tunnel. In the mid-1970's caved shafts were on the site; materials in dump piles included quartzite with veinlets of quartz and disseminated pyrite, and some magnetite and specular hematite.
Copal (Kopall)	Andersonville	This prospect was active in the late 1880's. Three caved pits and small dumps with white quartz were at the site in 1974.
Flood (James Anderson's)	Andersonville	There was placer mining in the branches in the 1800's; a shaft and tunnel were opened before the Civil War. In the mid-1970's, about ten shallow pits were in the area as well as small covered dumps of rounded white quartz pebbles.
Gilliam	Andersonville	There were 7 cuts and a 20-foot shaft in 1865 (Taber, 1913, p. 195). In the mid-1970's, five caved pits, and small, covered quartz dumps were present (Sweet, 1980, p. 7).
Morrow (Booker, Garnett, Moseley)	Willis Mountain	See comments in text.
Seay	Willis Mountain	A mill, open cuts and shafts were on the property before the Civil War. a 50-foot shaft was sunk after the war. In the mid-1970's, there were caved pits, trench cuts and several dumps.
Willis Creek	Andersonville	In the mid-1970's, several shallow trenches were at the site.

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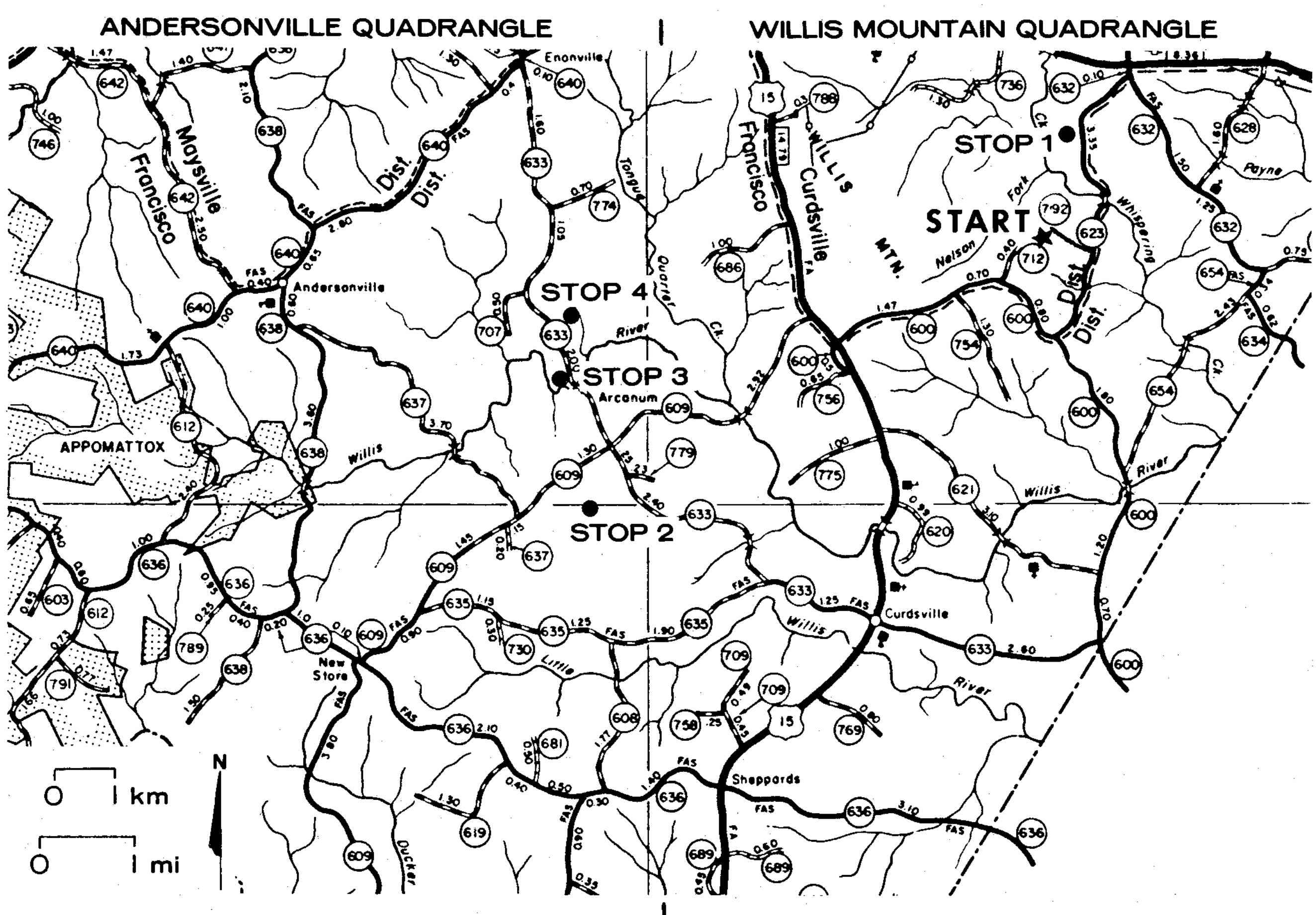
GENERAL APPENDIX

Field Trip Guide and Road Log

The field trip held during the 1981 annual meeting of the Virginia Section of the American Institute of Mining, Metallurgical, and Petroleum Engineers, Inc. begins with a tour of operations of the Kyanite Mining Corporation. The tour starts with a visit to the Willis Mountain mine site and processing area. This plant was opened in 1957. The second stop will be at the newest and most modern kyanite ore production plant in the world today—the East Ridge site. The plant has been in production for approximately two years, and construction at this plant is still underway. The kyanite occurs in kyanite-quartz-mica schist and in kyanite quartzite of the Arvonia Formation; most of the kyanite mined is from the kyanite quartzite. Sand, a by-product, is also marketed.

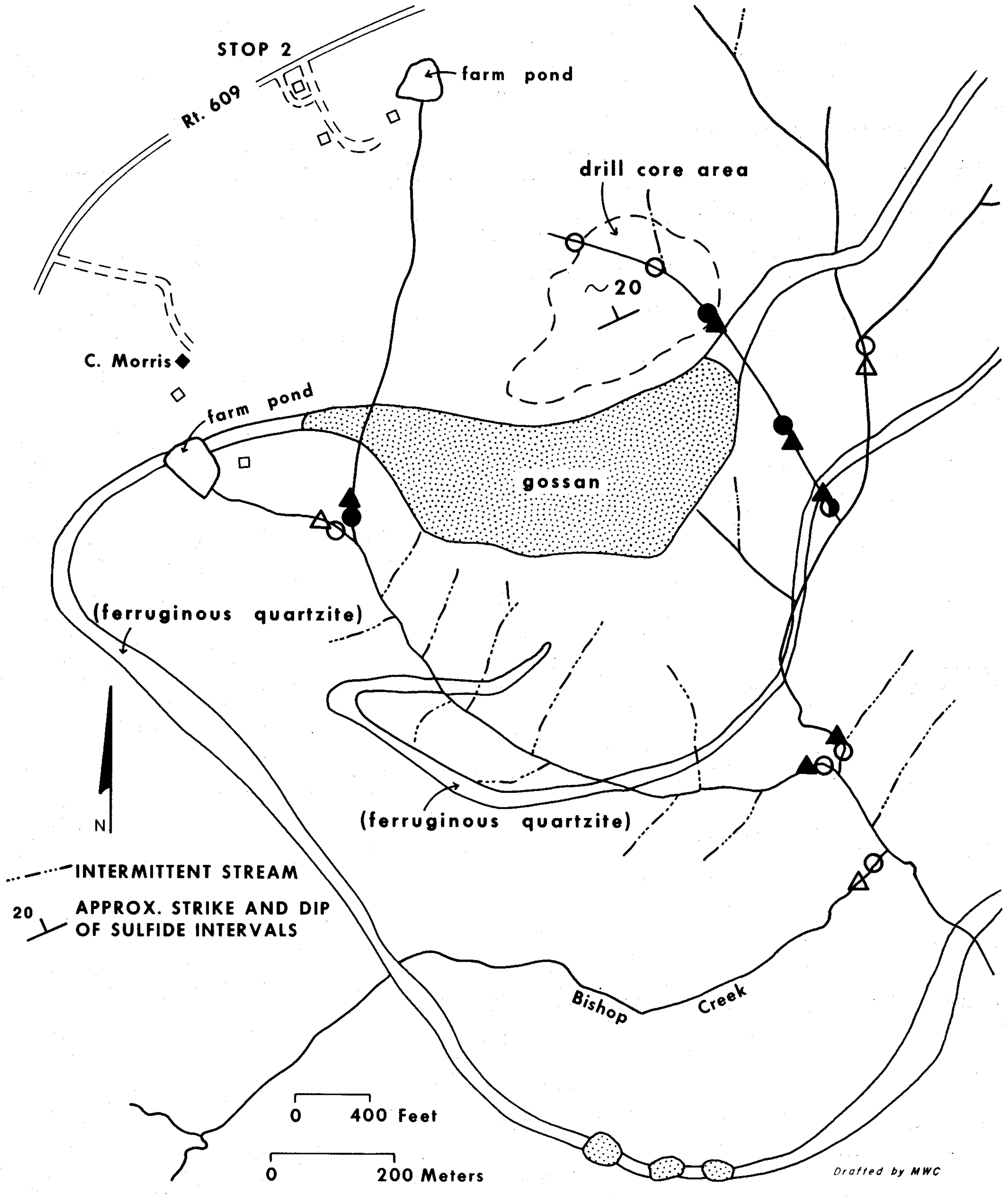
The four stops at rock outcrops show, in sequence, primary sedimentary structures in the Arvonia kyanite quartzite, gossan at the Zone 24 massive sulfide, amphibole gneiss of the upper part of the Chopawamsic Formation, and ferruginous quartzite. The ferruginous quartzite lies within the amphibole gneiss, and massive sulfides are associated with the ferruginous quartzites, especially where it has developed gossans. Locations of the stops are shown in Appendix Figure 1.

The Virginia Division of Mineral Resources, the Piedmont Planning District Commission, and the American Institute of Mining, Metallurgical, and Petroleum Engineers, Inc., who are jointly sponsoring the field trip, sincerely thank Kyanite Mining Corporation for leading the group through some of their operations.

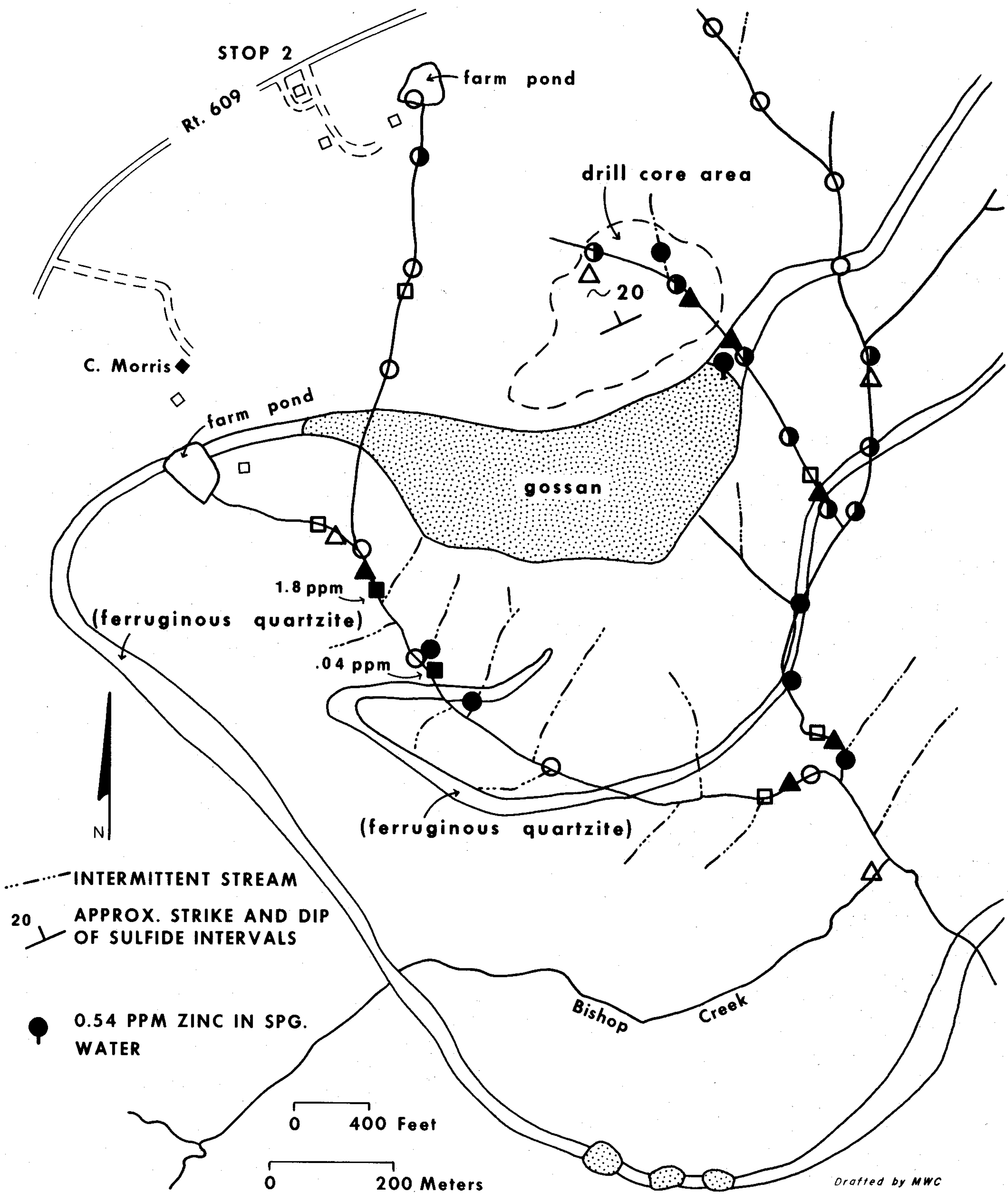


Appendix Figure 1. Location map for field trip stops.

Cumulative Mileage miles (km)	Distance miles (km)	EXPLANATION
0.0 (0.0)	0.0 (0.0)	Begin road log at the main gate of the East Ridge plant of The Kyanite Mining Corporation. Proceed east on State Road 792.
0.8 (1.3)	0.8 (1.3)	Intersection of State Road 792 and State Road 623. Turn left (north) on State Road 623.
1.2 (1.9)	0.4 (0.6)	Cross Whispering Creek.
2.1 (3.4)	0.9 (1.4)	*STOP 1.* Indian Gap farm; park on apron of road and walk 1/4 mi. (400 meters) WSW to top of small ridge. Kyanite quartzite: The Arvonia Formation at Willis Mountain is composed of kyanite-quartz-mica schist and an overlying kyanite quartzite. Both units are in the upper part of the Arvonia. The kyanite quartzite is composed of quartz and muscovite with varying amounts of muscovite. Accessory minerals include fuchsite (chromian muscovite), pyrite, graphite and rutile. The kyanite occurs as unoriented, disseminated crystals and as bands in quartz layers. These interlayers of kyanite and quartz reflect original compositions and preserve relict structures. Preserved primary structures consist of wedge-shaped sedimentary packages composed of interlayered quartzite and quartzose kyanite. The basal beds of many of these packages consist of "jelly bean" gravels that grade upward into fine quartzite and terminate at the top as a layer of almost pure kyanite. These packages are interpreted as representing fining-upward sequences. There are also large- and small-scale crossbeds and channel-fill structures preserved in the quartzite. Proceed south on State Road 623.
3.0 (4.8)	0.9 (1.4)	Cross Whispering Creek.
4.4 (7.0)	1.4 (2.2)	Intersection of State Road 623 and State Road 600. Turn right on State Road 600.
7.4 (12.0)	3.0 (4.8)	Intersection of State Road 600 and U.S. Highway 15; turn right (north) on U.S. Highway 15.
7.6 (12.2)	0.2 (0.4)	Intersection of U.S. Highway 15 and State Road 609. Turn left (west) on State Road 609.
8.9 (14.3)	1.3 (2.1)	Cross Willis River; continue on State Road 609.
10.4 (16.7)	1.5 (2.4)	Intersection of State Road 609 and State Road 633; continue on State Road 609.
10.7 (17.2)	0.3 (0.5)	*STOP 2.* Park beside State Road 609; walk due south 1/2 mi. (0.8 km). Zone 24: Oxidized massive pyrite with minor amounts of pyrrhotite, sphalerite and chalcopyrite and locally galena occur as lenses in an east-west zone of more than 1800 feet (548 m) by 700 feet (213 m) on the Calvin Morris property. Three nearly parallel lenses gently dip to the NNW with an average dip of 20° (Appendix Figures 2 and 3; Plate 6A). Although locally deformed, brecciated and sheared, the sulfide lenses, averaging about 15 feet (5 m) in thickness, are conformable with the foliation of the enclosing Chopawamsic Formation. Only the upper sulfide body contains consistently high concentrations of zinc and copper, although the other two lenses locally have high concentrations. Estimated reserves total 555,500 tons of 4.87% zinc and 0.98% copper (Young, this volume). The gossan area itself shows few fresh sulfide minerals. Concentrations of zinc and copper in the soil from 100 ppm to about 500 ppm roughly coincides with the gossan area (Plate 6A). The soil anomaly disappears abruptly to the north of the gossan because of the NW dip of the sulfide bodies. Copper and zinc soil anomalies appear only where the containing massive sulfide is less than 75 feet (23 m) below the surface. Intimately associated with the sulfide zone are two ferruginous quartzites thought to represent recrystallized iron-bearing cherts formed along volcanically generated fractures on the ocean floor (Good, this volume). The outcrop pattern of the ferruginous quartzites partially reflect polyphase deformation of the sulfide zones (Plate 1). Small-scale deformation seen in drill-core records includes highly contorted foliation, local brecciation and shear structures, but there is no indication on the surface that the sulfide body was emplaced or formed along a fault or shear zone. The breccias may even be primary and thus related to submarine volcanism during massive sulfide genesis (Good, this volume). Sulfide Zone 24 was clearly delineated by chemical analyses of stream sediment and surface water samples. Some of the results of these studies are shown in Appendix Figures 2 and 3.
11.0 (17.7)	0.3 (0.5)	Return east to intersection of State Road 609 and State Road 633; turn left (north) on State Road 633.
11.7 (18.8)	0.7 (1.1)	Bridge over Willis River.
11.8 (19.0	0.1 (0.2	*STOP 3.* Park vehicle and walk to outcrop on west side of road. Amphibole gneiss: The Chopawamsic Formation consists of a lower and an upper unit.



Appendix Figure 2. *Stop 2.* Sulfide Zone 24, copper and zinc concentrations in stream sediments. Distribution of gossan, ferruginous quartzite, and drill core area from plates 1 and 6A. Copper (circles) and zinc (triangles) concentration values in stream sediments: clear circles, 12 ppm or less; half clear circles, 13-17 ppm (1 to 2 standard deviations above reiterated arithmetic mean); dark circles, more than 17 ppm (more than 2 standard deviations above mean). Clear triangles, less than 50 ppm; dark triangles, 50-180 ppm (2 or more standard deviations above reiterated arithmetic mean).



Appendix Figure 3. *Stop 2.* Sulfide Zone 24, metal concentrations in water and in stream sediments. Iron concentrations in water (circles) and in stream sediments (triangles), and concentration of gold in panned concentrates (squares). Clear circles, less than 1 ppm; half clear circles, 1-5 ppm; dark circles, 6-21 ppm. Clear triangles, less than 5%; dark triangles 5% or more (2 or more standard deviations above reiterated arithmetic mean). Clear squares, no detectable gold. One zinc and no copper concentrations in surface waters were at detectable levels.

Cumulative Mileage miles (km)	Distance miles (km)	

EXPLANATION

The lower unit is composed of metagraywackes, metatuffs, metapelites and interlayered felsic and mafic metavolcanic rocks. The upper unit contains predominantly interlayered felsic and mafic metavolcanic rocks which are represented by biotite gneiss, amphibole gneiss, felsic (rhyodacitic) volcanic rocks, talc-tremolite schists and ferruginous quartzites. The amphibole gneiss is greenish black to black, medium- to coarse-grained and well lineated. It consists of coexisting amphibole (either tremolite-cummingtonite or hornblende-cummingtonite), plagioclase feldspar, quartz, biotite and epidote. Accessory minerals include apatite, calcite, zircon, rutile and sphene.

In this outcrop the lineation produced by the alignment of amphibole crystals defines an F_2 lineation which corresponds to the plunge of the F_2 folds. Type two interference patterns are exhibited in the rock by the contrast between lighter (plagioclase-bearing) and darker (amphibole-bearing layers. These small-scale folds form *M* symmetry patterns, which indicate that the outcrop is near the axial part of a fold, in this instance an F_3 anticline. Jointing is pronounced and appears to have been formed by tensional forces, developed late in the deformational history of the area. Proceed north on State Road 633.

12.5 (20.1)	0.7 (1.1)	*STOP 4.* Ferruginous quartzite: The Chopawamsic Formation contains interlayered ferruginous quartzites which occur as banded, persistent to discontinous lenses. The ferruginous quartzites are composed of magnetite, specular hematite and quartz with accessory amounts of garnet, zircon and apatite. Banding is produced by magnetite and specular hematite interlayered with quartz. The quartzites are intimately associated with gossans (weathered massive sulfide) zones. In many instances they provide "pathways" to these zones.

End of Road Log.

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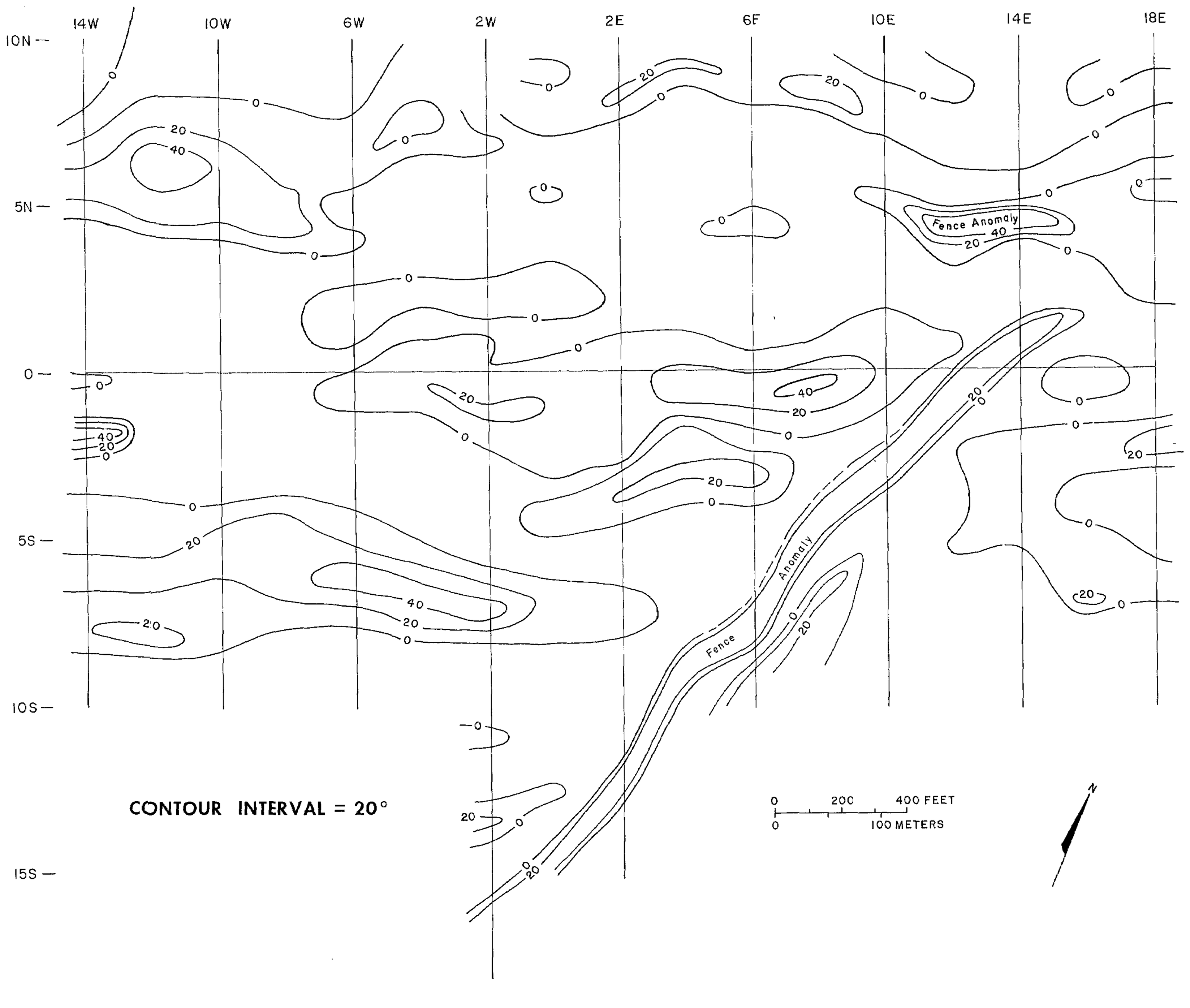
COMMONWEALTH OF VIRGINIA
DEPARTMENT OF CONSERVATION AND ECONOMIC DEVELOPMENT

PLATE 6B. SULFIDE ZONE 24, ANDERSONVILLE QUADRANGLE

VIRGINIA DIVISION OF MINERAL RESOURCES PUBLICATION 29
1981
PLATE 6B. SULFIDE ZONE 24



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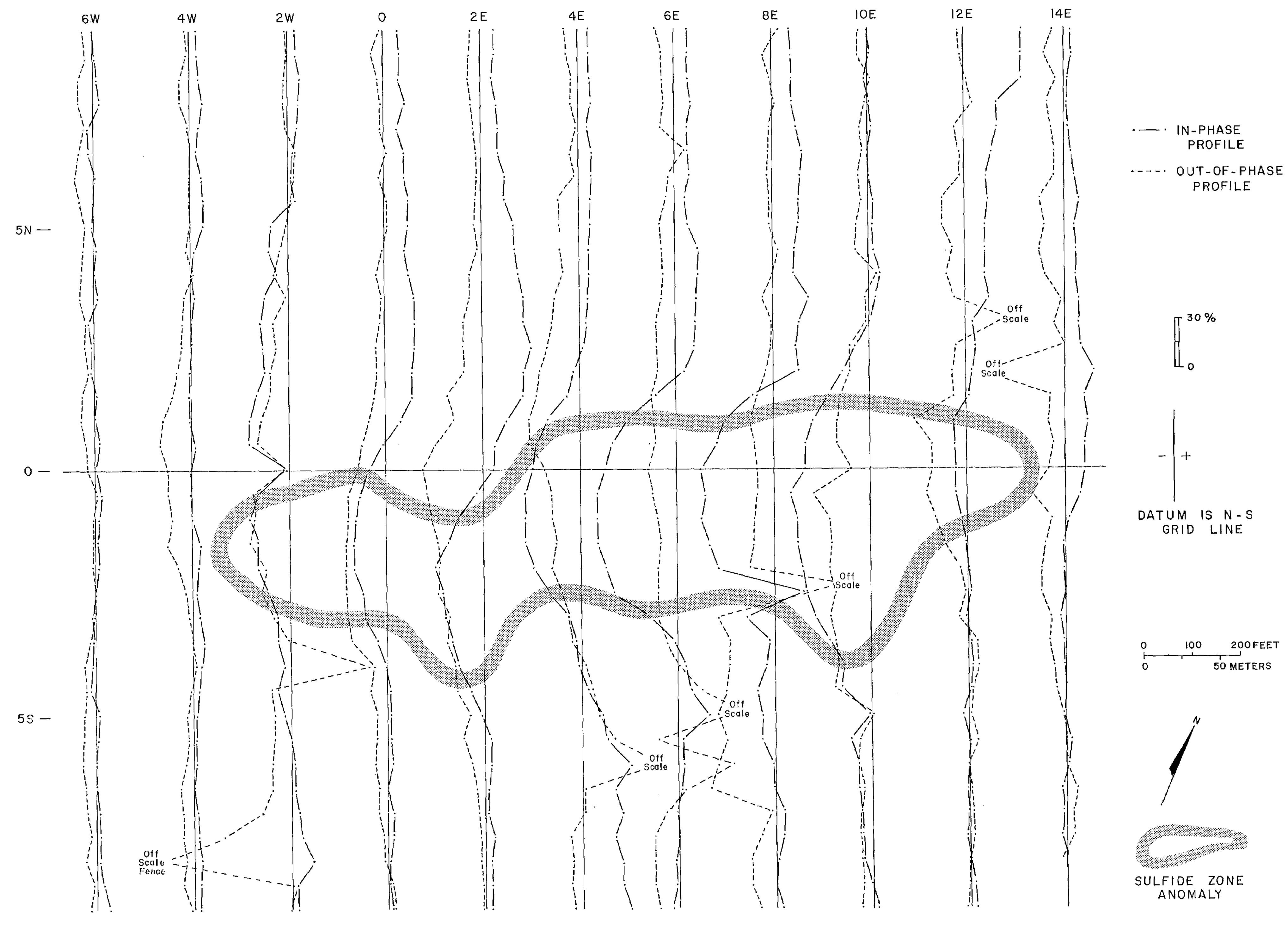
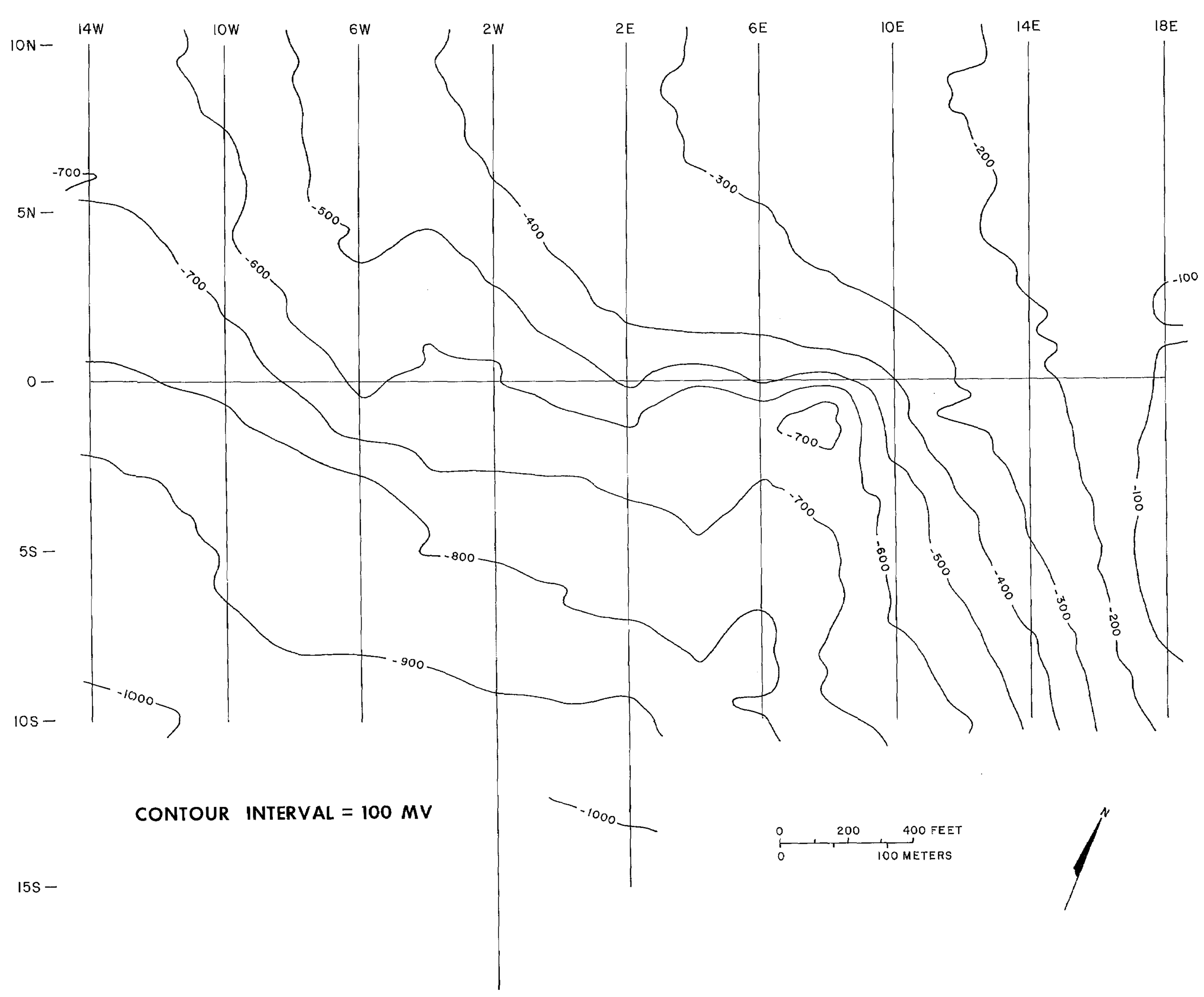
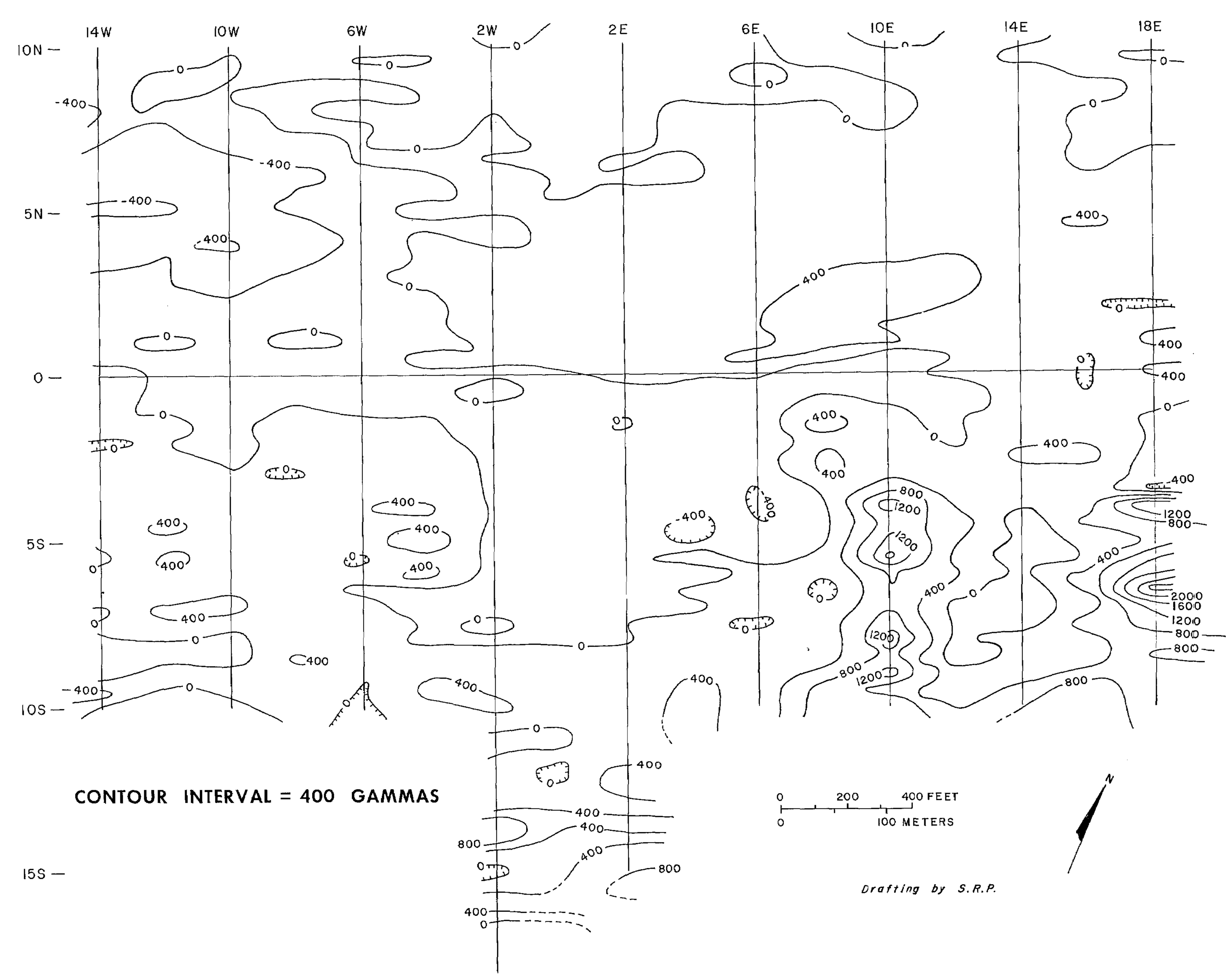


HORIZONTAL LOOP ELECTROMAGNETIC SURVEY



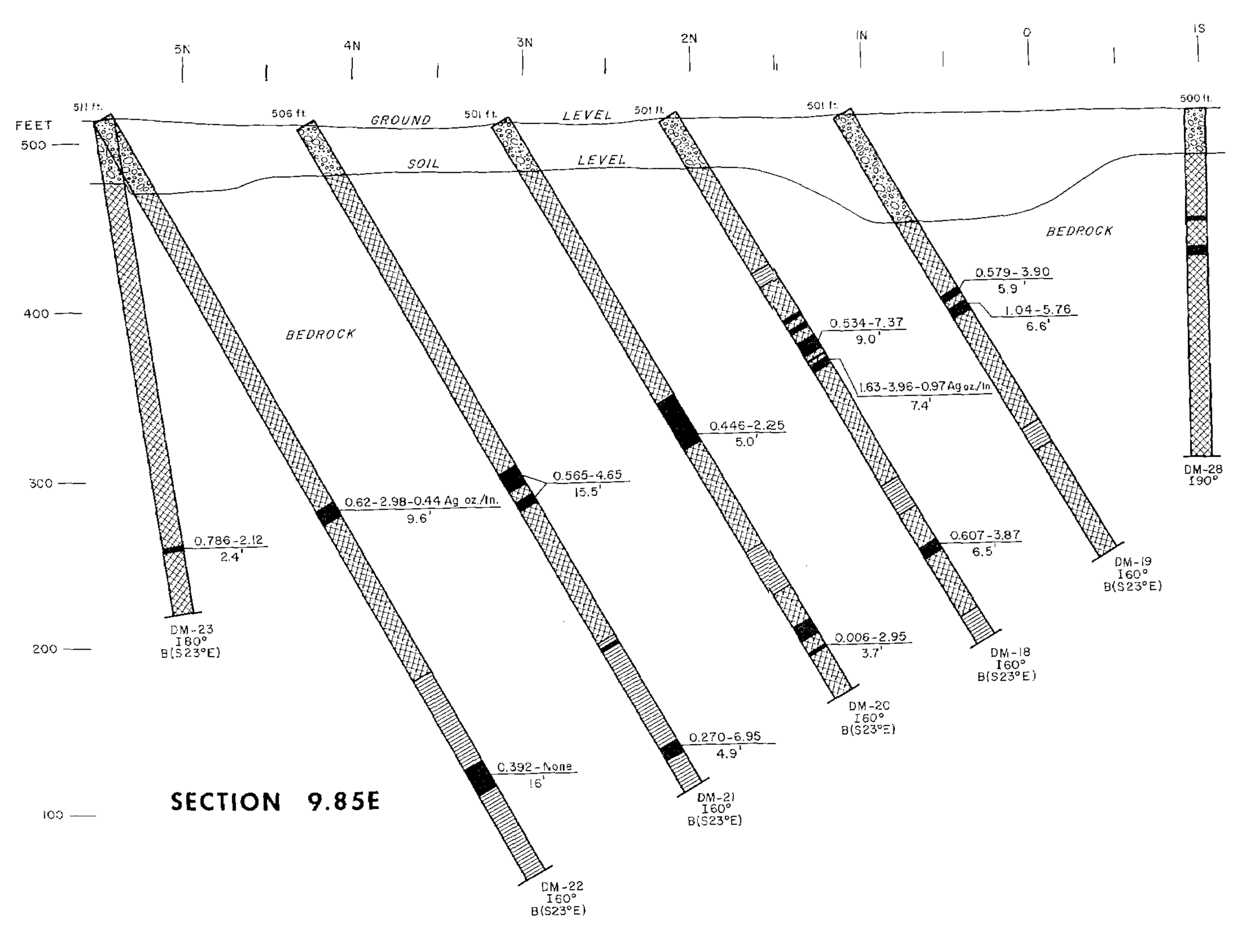
SELF-POTENTIAL CONTOURS



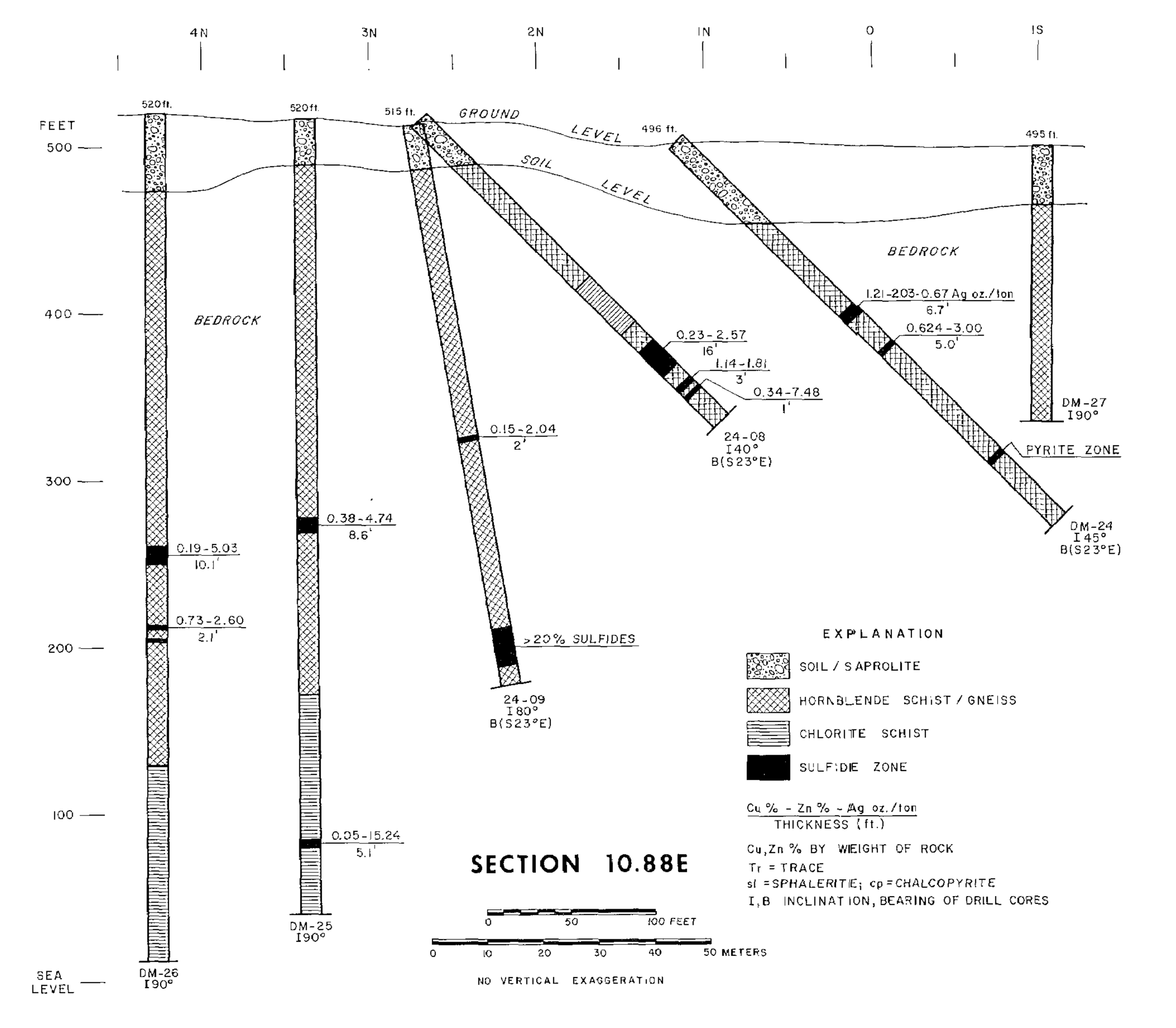
MAGNETIC SURVEY CONTOURS

EXPLANATION

- AREA OF GOSSAN FLOAT
- STRIKE AND DIP OF FOLIATION
- VERTICAL FOLIATION STRIKE
- STRIKE AND DIP OF JOINTS
- VIRGINIA MINING COMPANY DRILL HOLE, d, DRILL CORES DESCRIBED IN APPENDIX
- DOMEX DRILL HOLE (DM, DR, DX, DD). d, DRILL CORES DESCRIBED IN APPENDIX
- CONTOUR LINE
- CLOSED AREAS OF LOWER INTENSITY
- ROCK OUTCROP
- STREAM
- INTERMITTENT STREAM



SECTION 9.85E

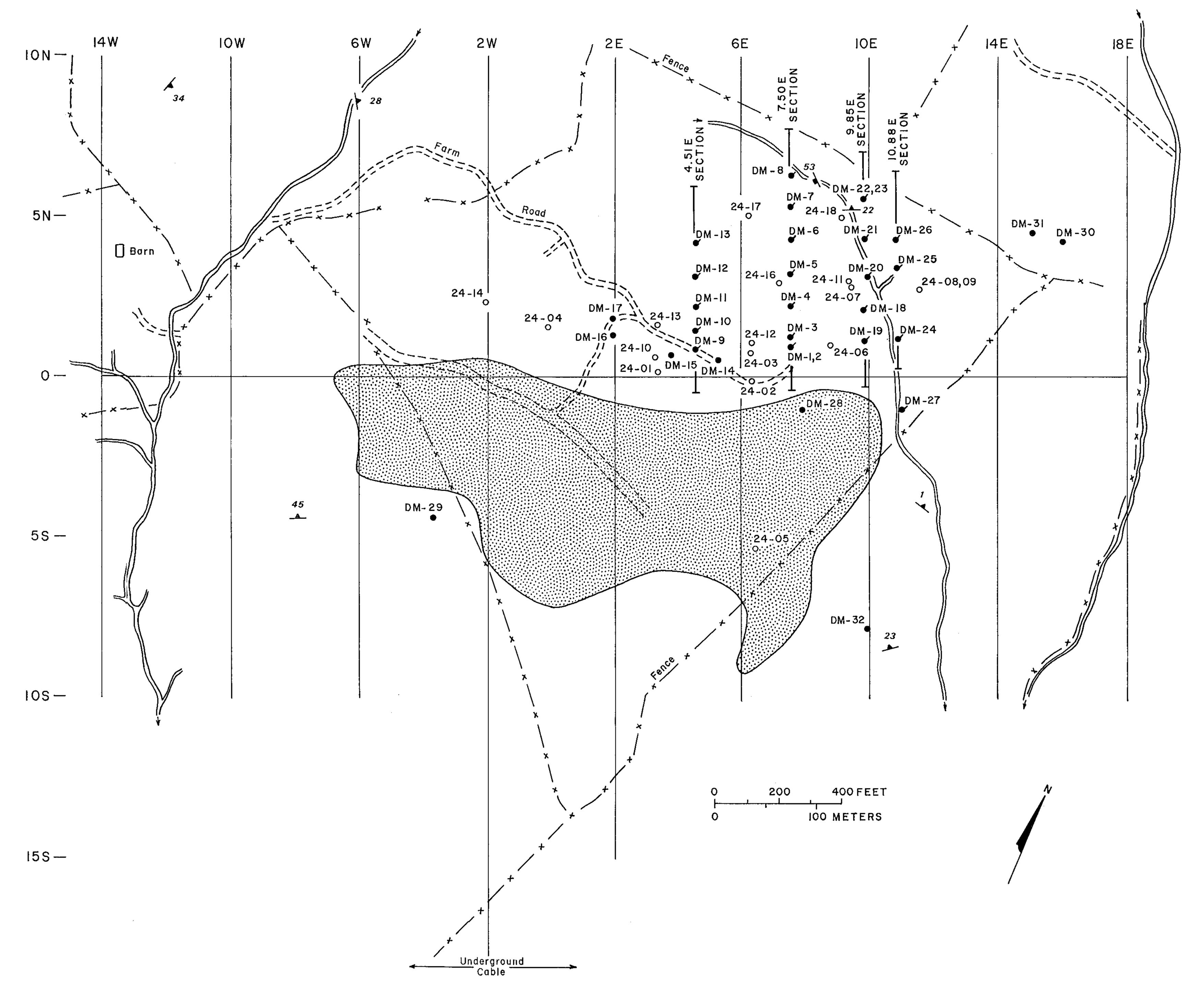


SECTION 10.88E

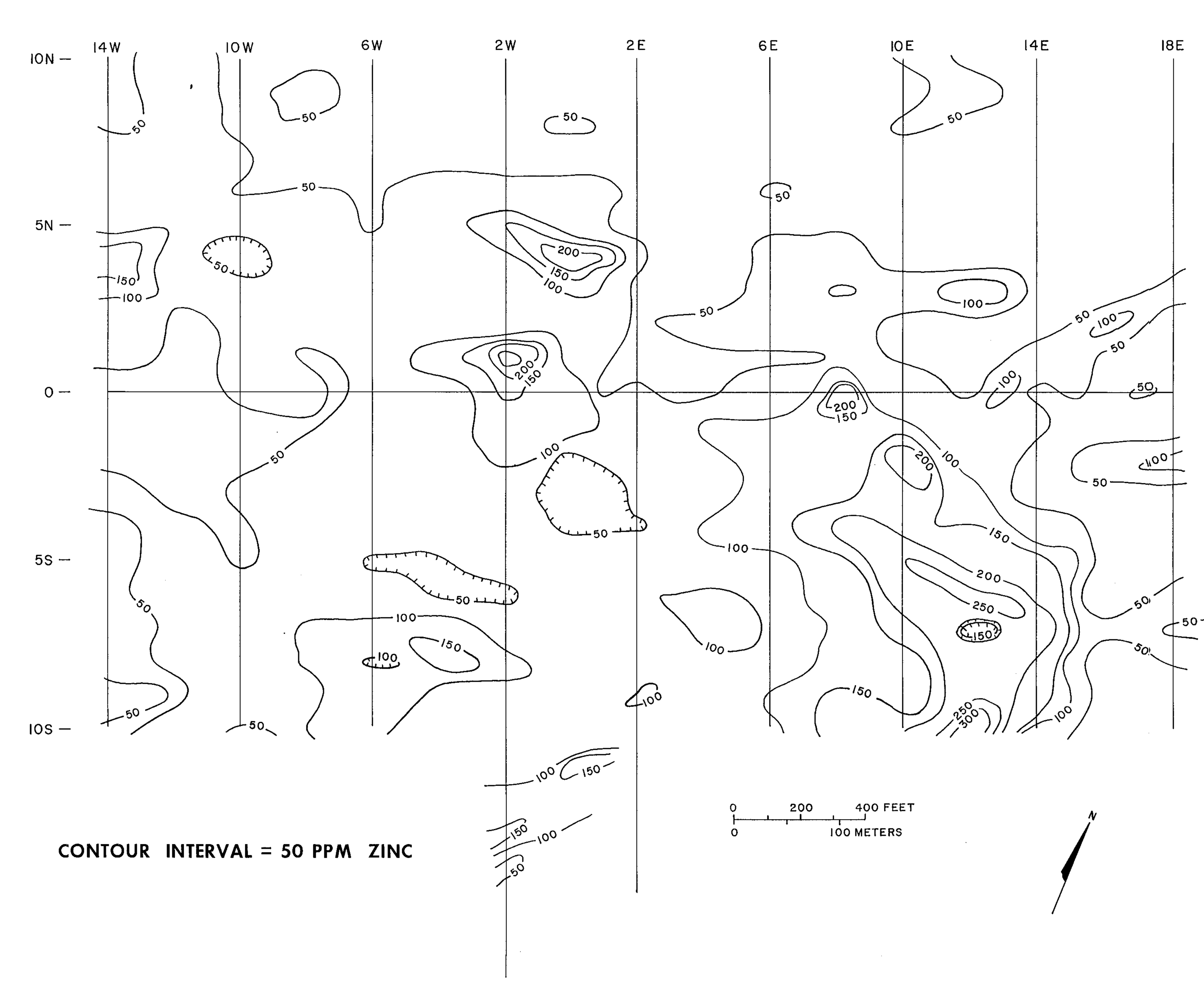
COMMONWEALTH OF VIRGINIA
DEPARTMENT OF CONSERVATION AND ECONOMIC DEVELOPMENT

PLATE 6A. SULFIDE ZONE 24, ANDERSONVILLE QUADRANGLE

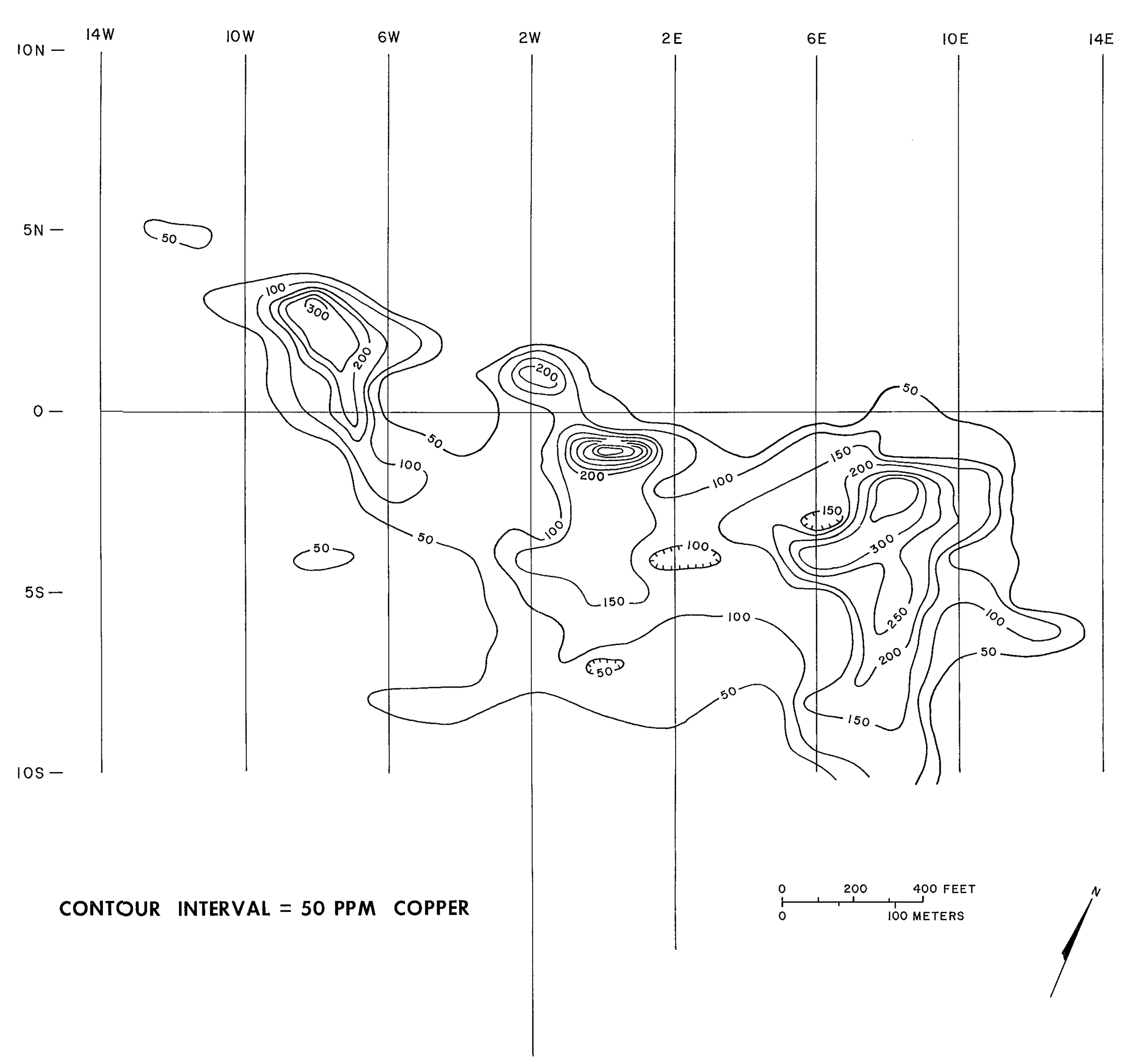
VIRGINIA DIVISION OF MINERAL RESOURCES PUBLICATION 29
1981
PLATE 6A. SULFIDE ZONE 24



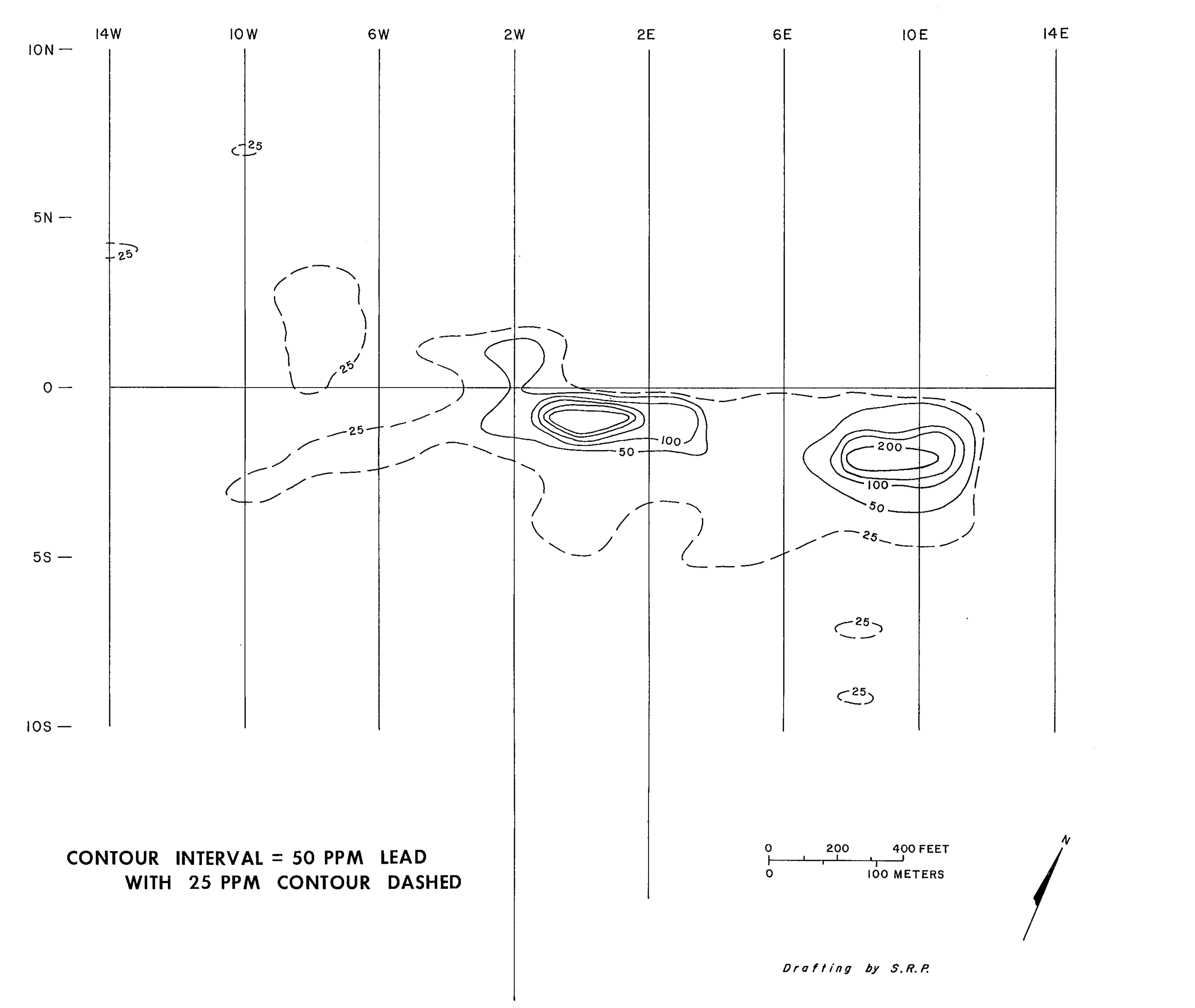
GEOLOGY AND CULTURE WITH DRILL HOLE LOCATIONS



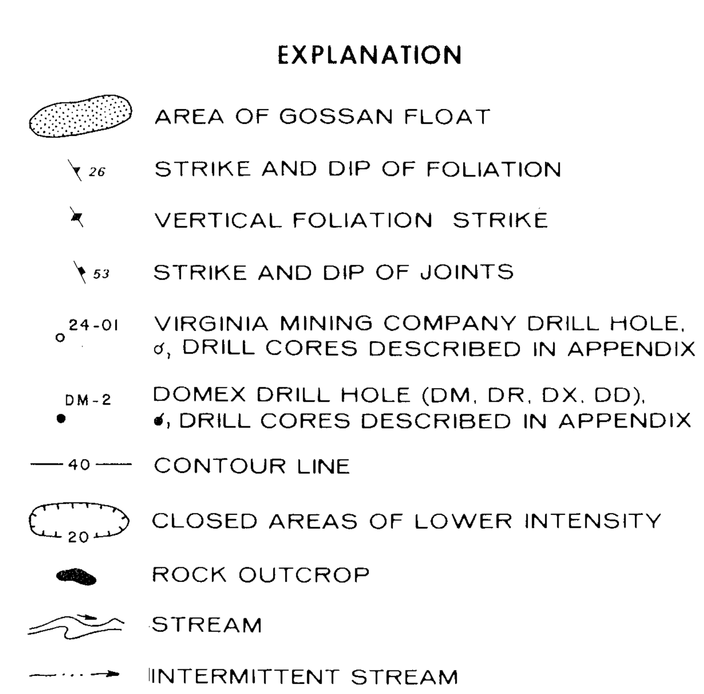
SOIL GEOCHEMISTRY - ZINC

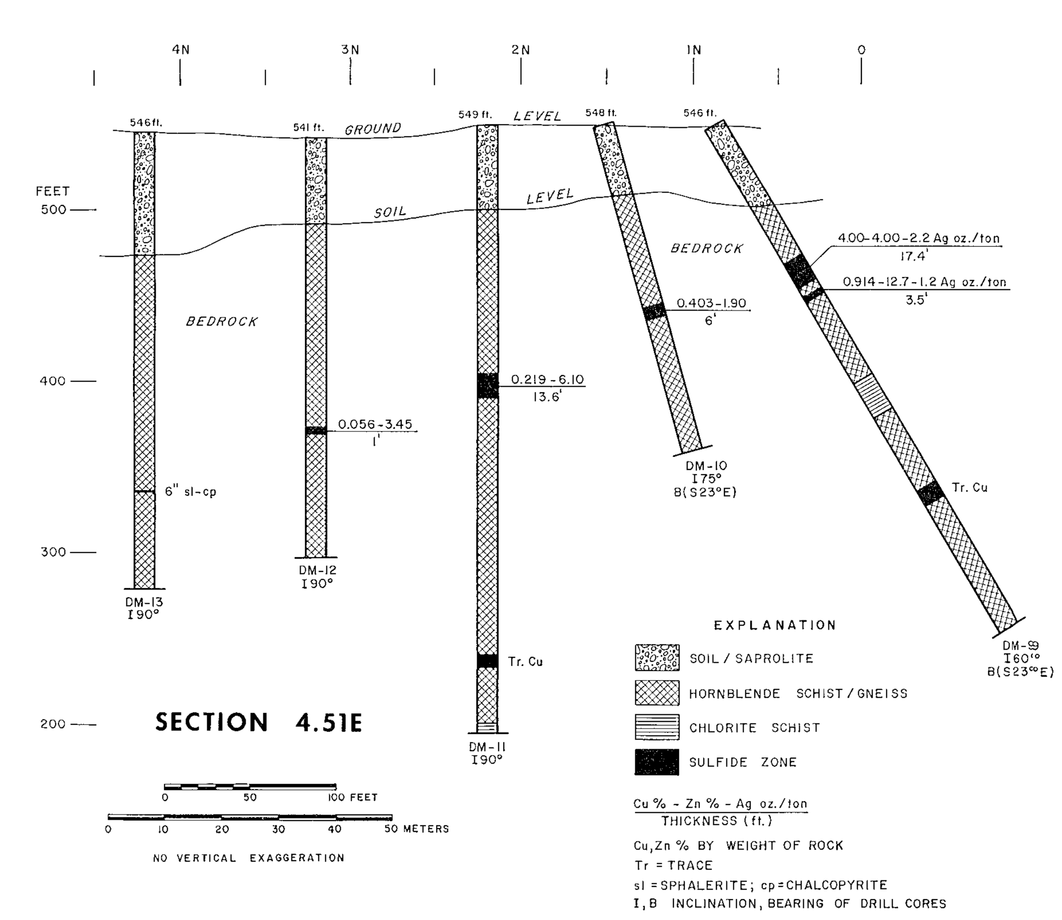


SOIL GEOCHEMISTRY - COPPER



SOIL GEOCHEMISTRY - LEAD





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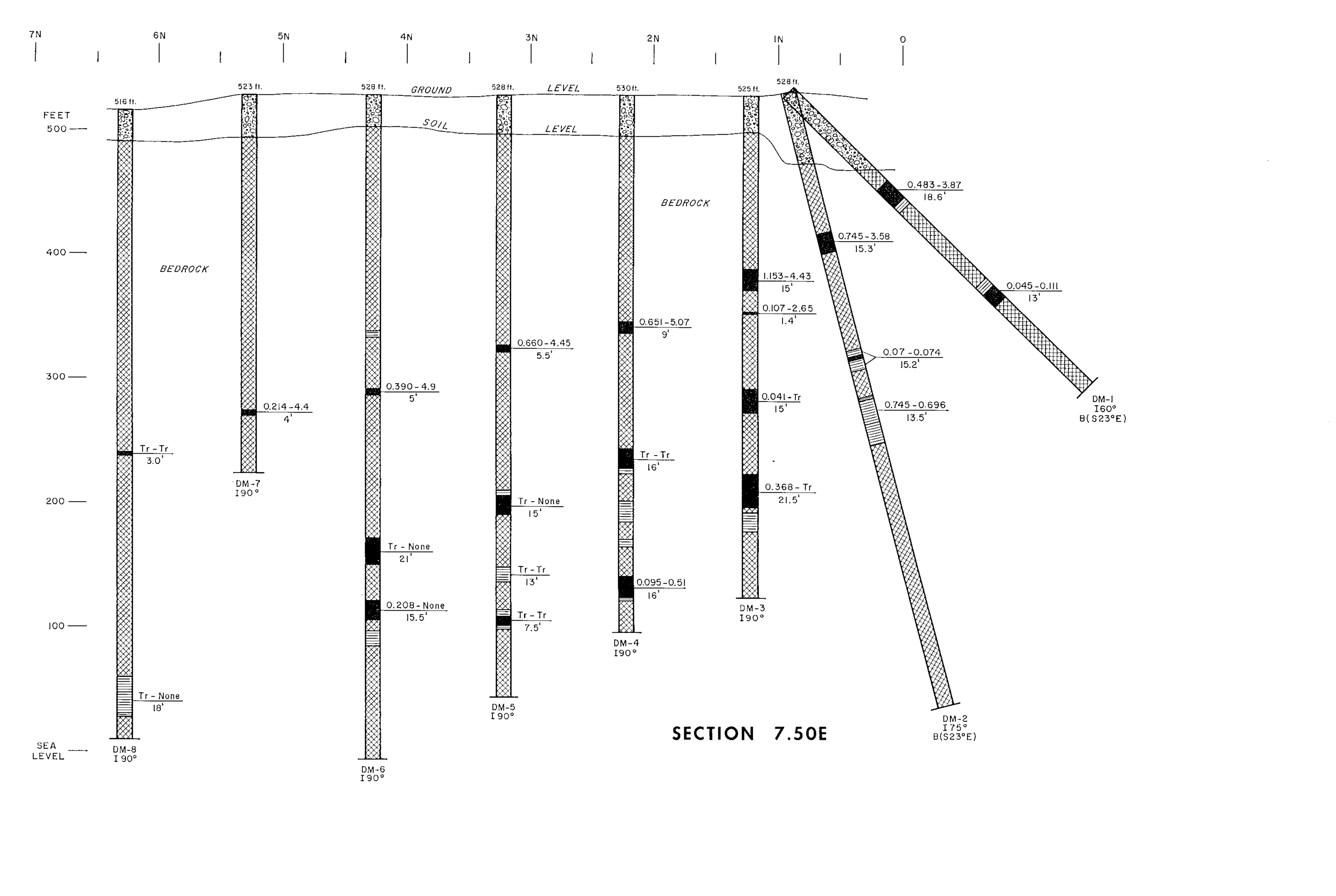
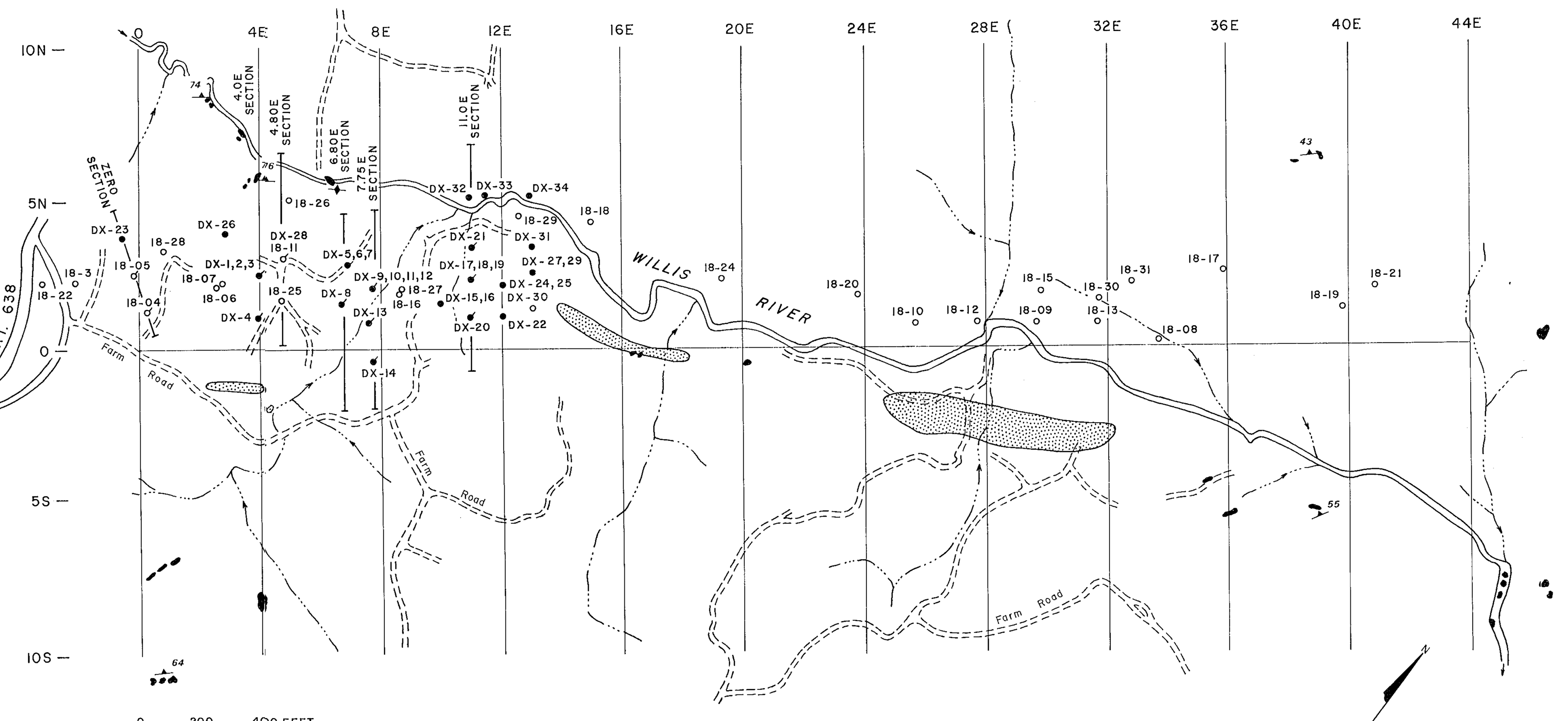


SECTION 7.50E

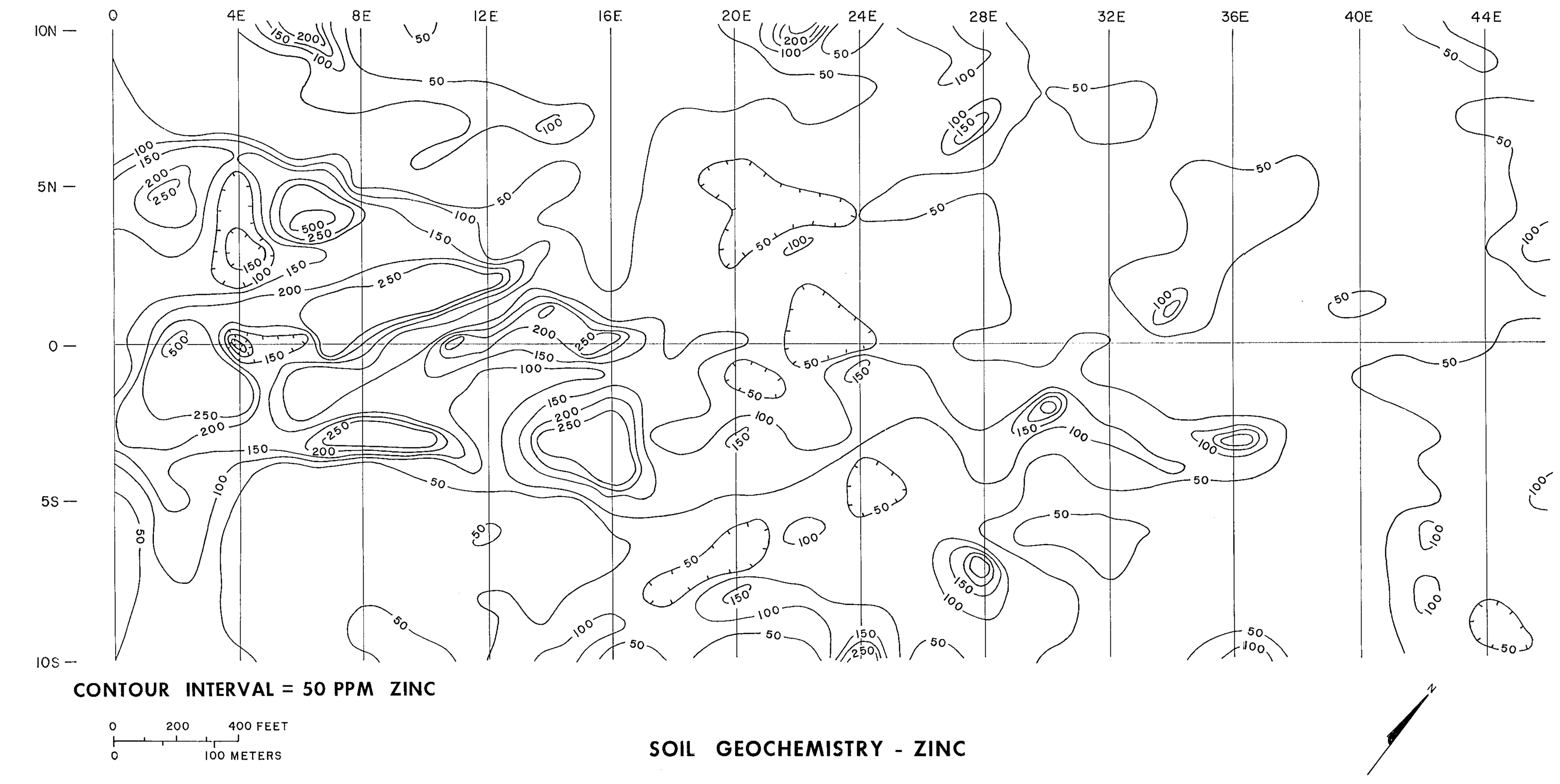
COMMONWEALTH OF VIRGINIA
DEPARTMENT OF CONSERVATION AND ECONOMIC DEVELOPMENT

PLATE 5. SULFIDE ZONE 18, ANDERSONVILLE QUADRANGLE

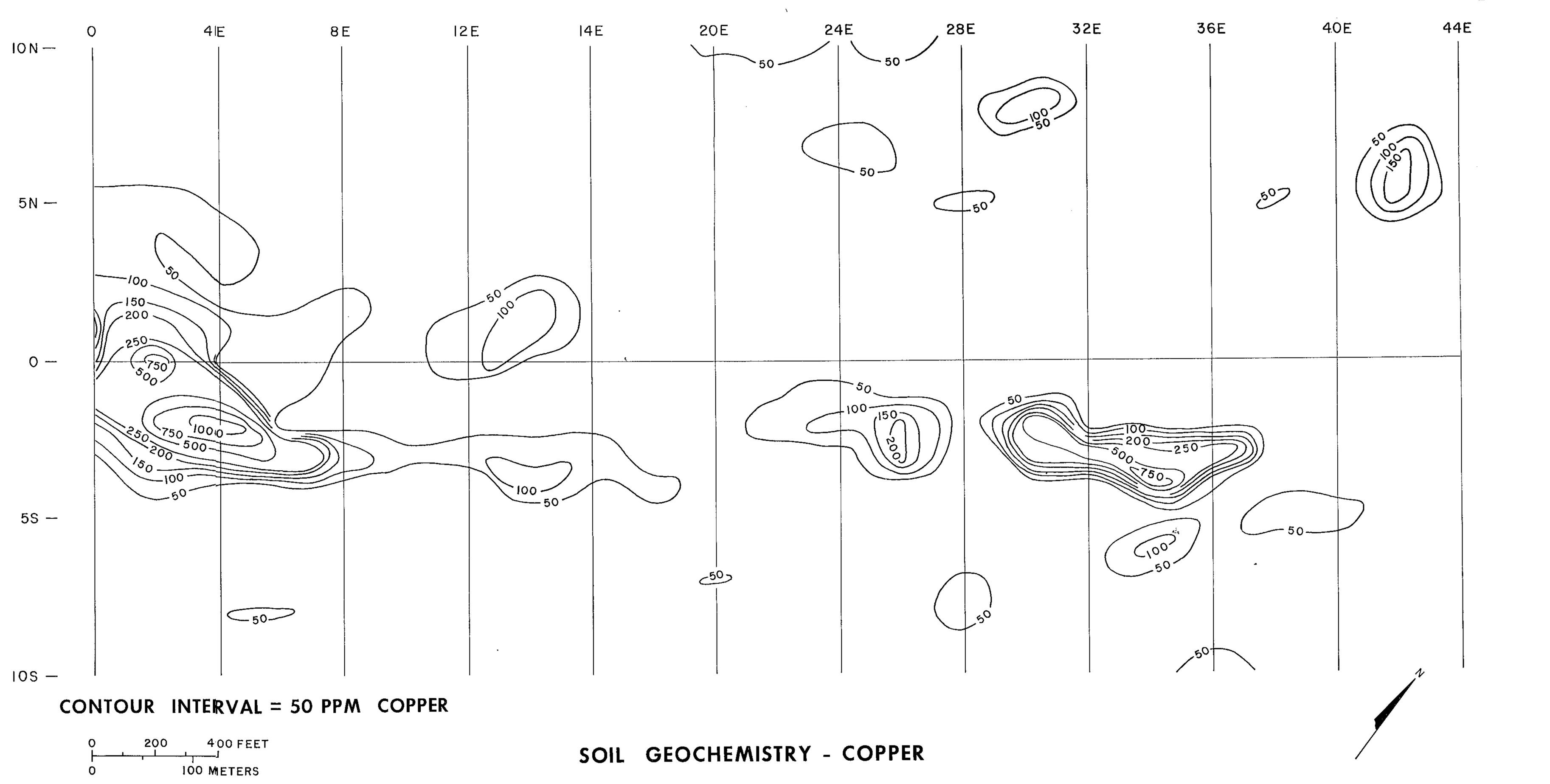
VIRGINIA DIVISION OF MINERAL RESOURCES PUBLICATION 29
1981
PLATE 5. SULFIDE ZONE 18



GEOLOGY AND CULTURE WITH DRILL HOLE LOCATIONS



SOIL GEOCHEMISTRY - ZINC



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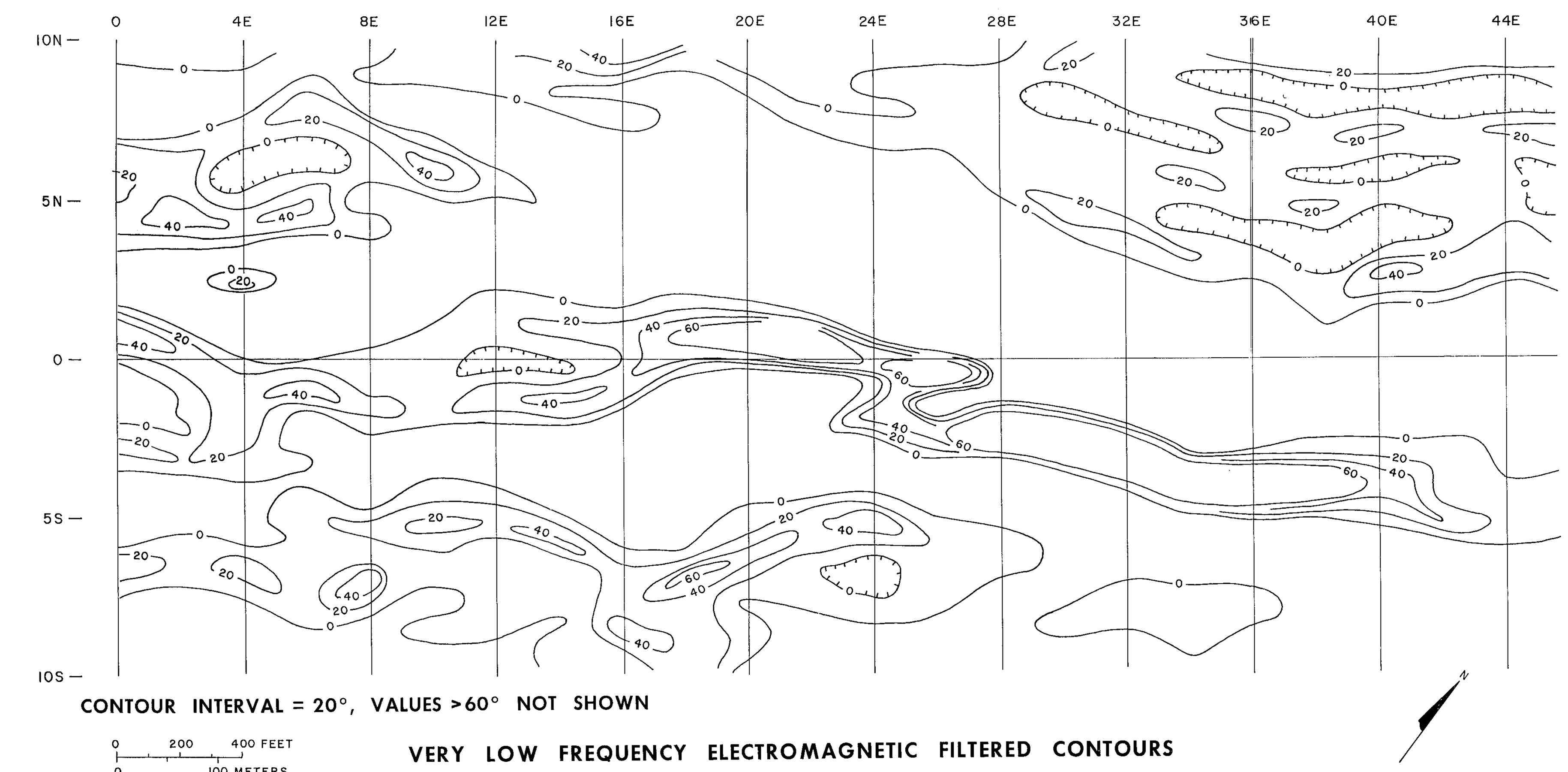
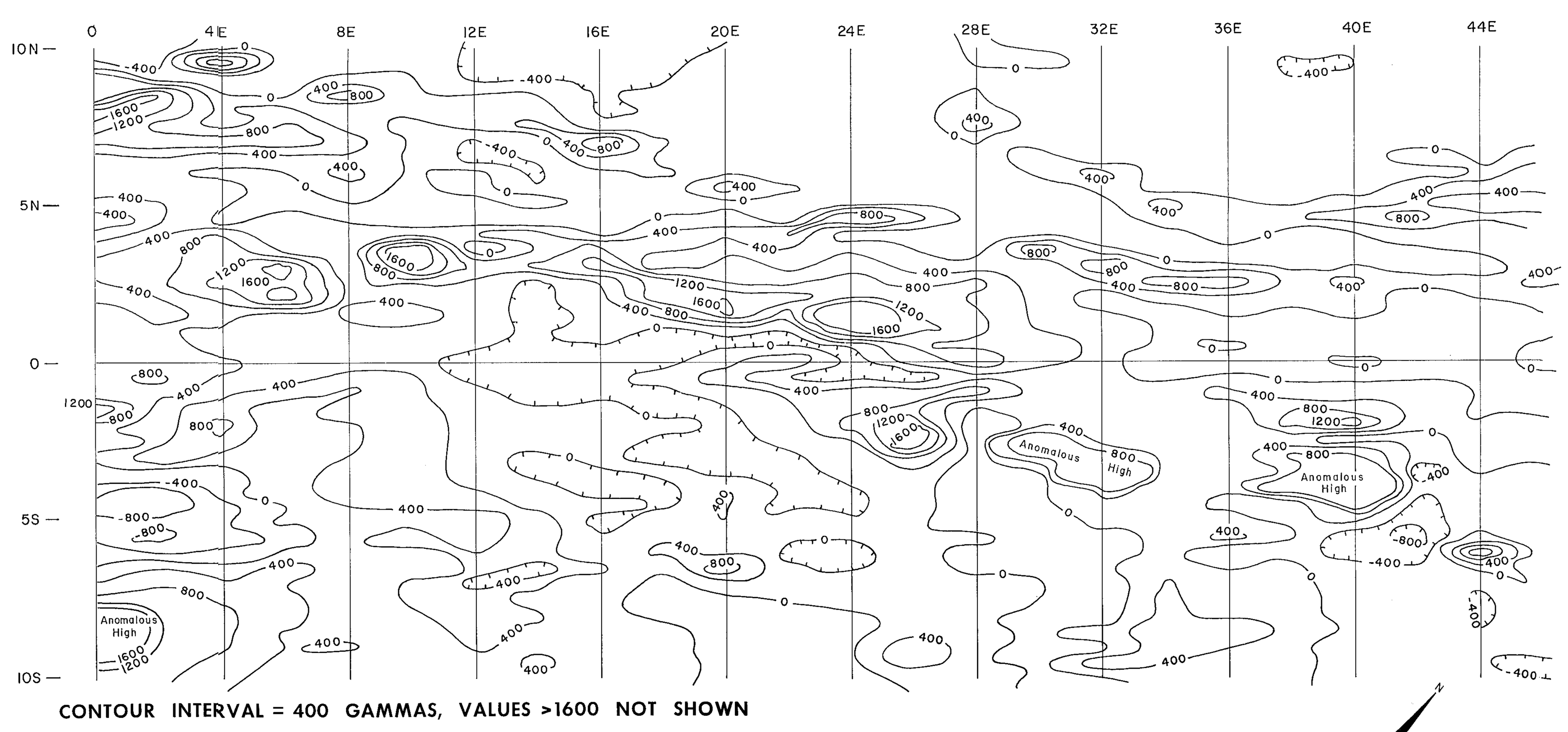
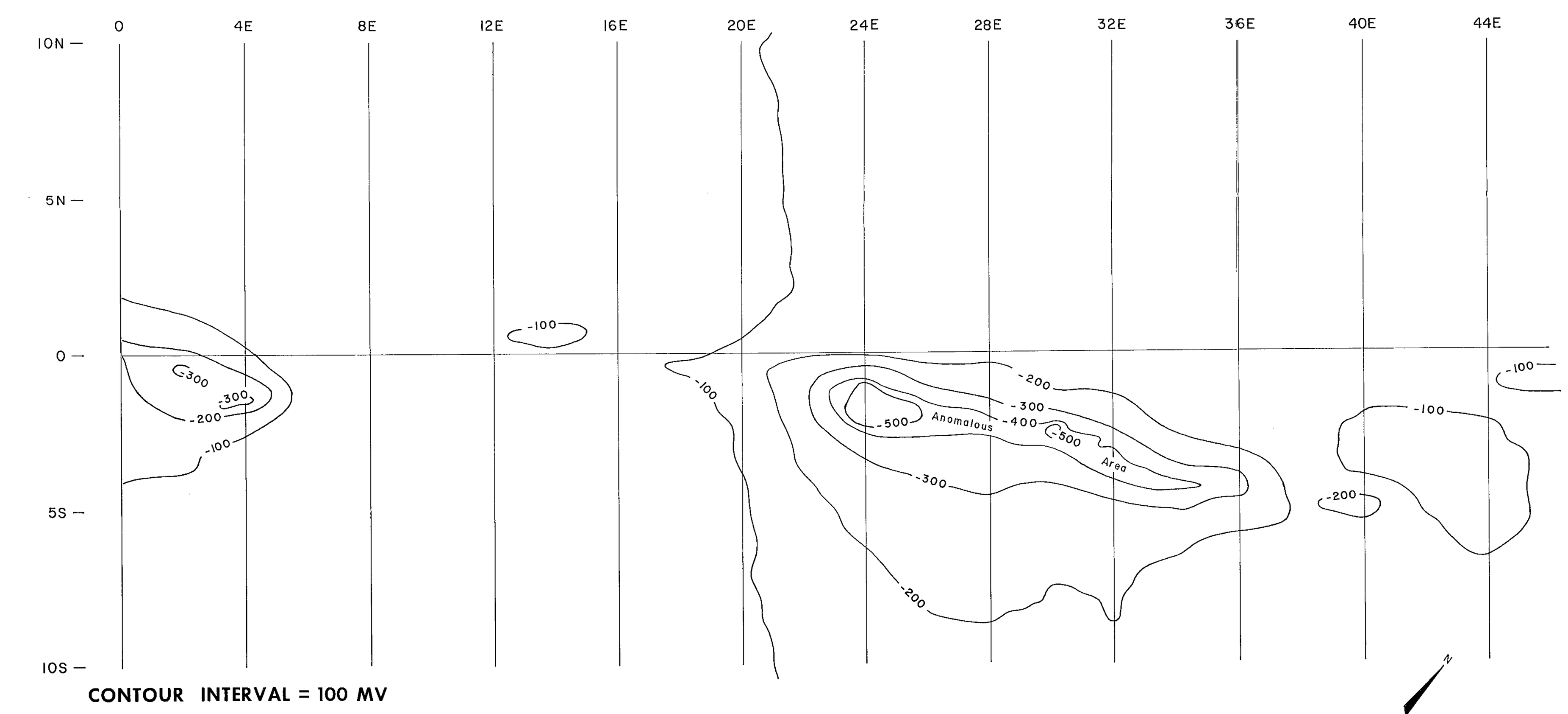


VERY LOW FREQUENCY ELECTROMAGNETIC FILTERED CONTOURS



MAGNETIC SURVEY CONTOURS

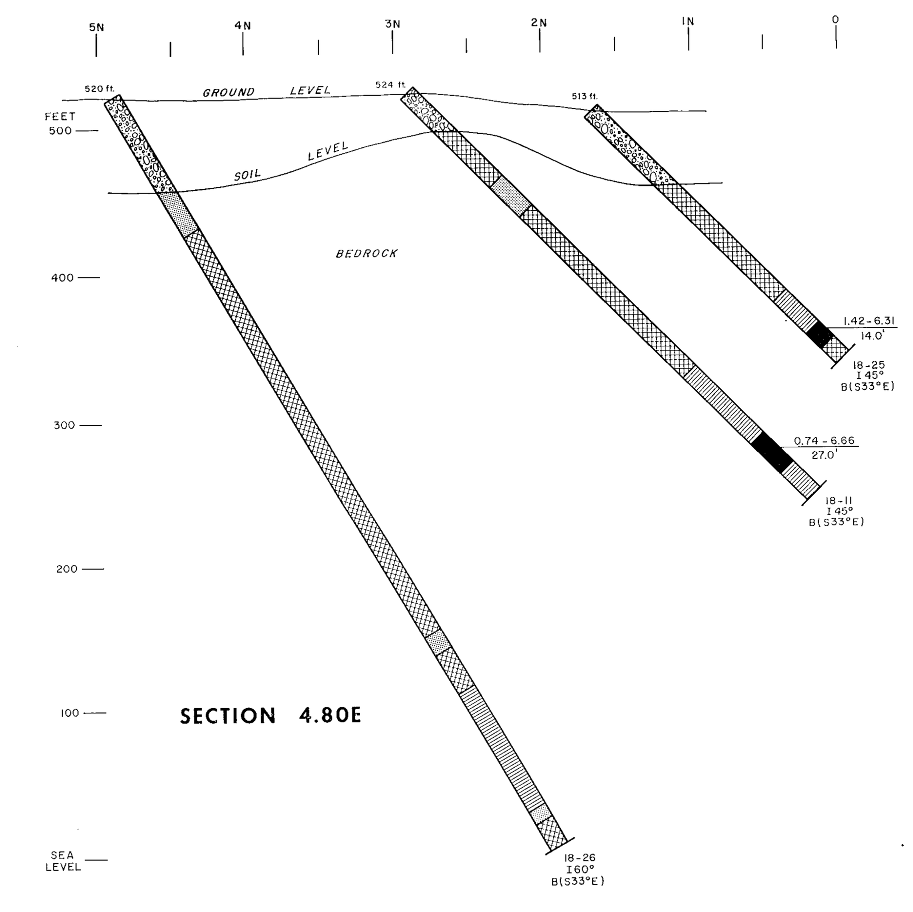


SELF-POTENTIAL CONTOURS

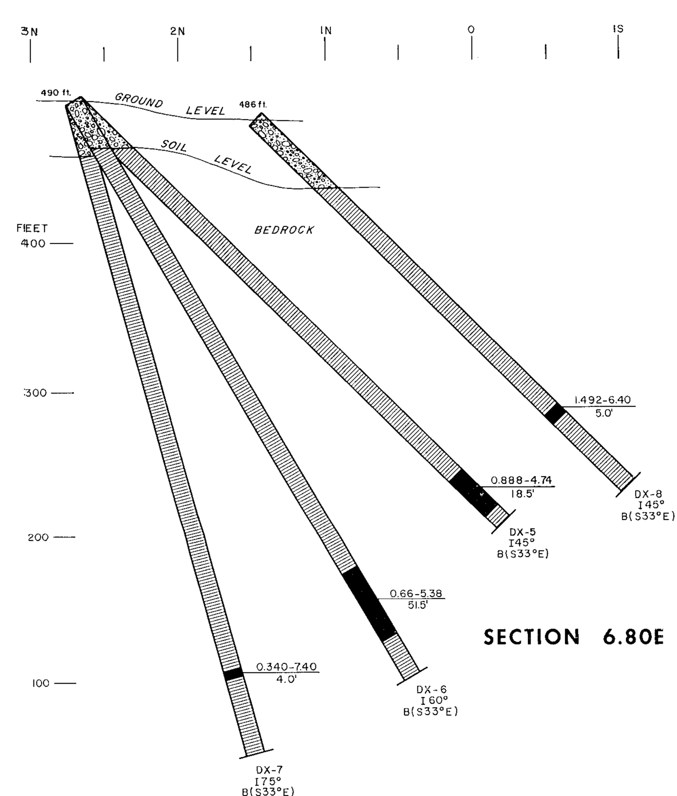
Drafting by S.R.P.

EXPLANATION

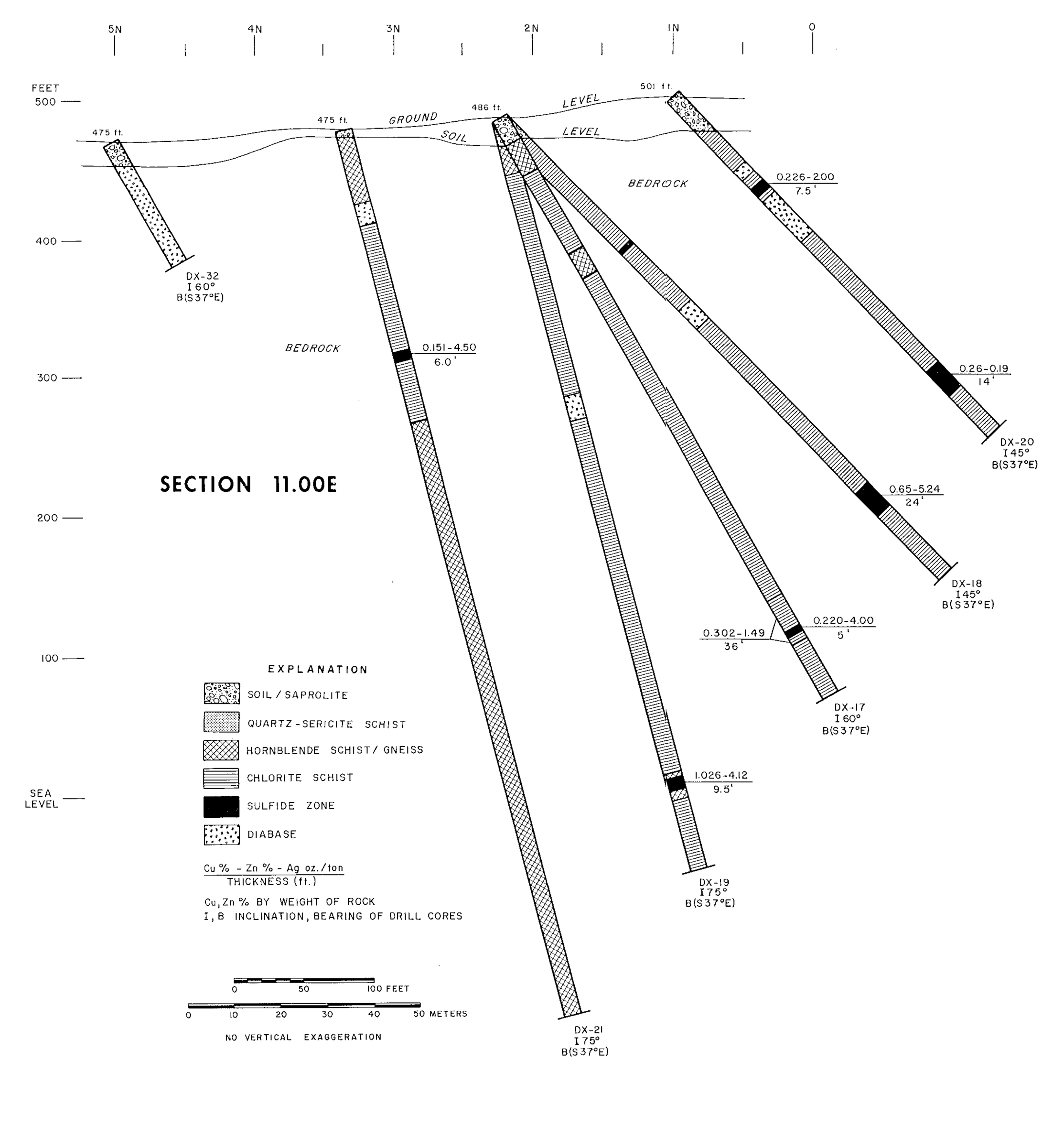
- AREA OF GOSSAN FLOAT
- STRIKE AND DIP OF FOLIATION
- VERTICAL FOLIATION STRIKE
- STRIKE AND DIP OF JOINTS
- 24-01 VIRGINIA MINING COMPANY DRILL HOLE, DRILL CORES DESCRIBED IN APPENDIX
- DM-2 DOMEX DRILL HOLE (DM, DR, DX, DD), DRILL CORES DESCRIBED IN APPENDIX
- 40 CONTOUR LINE
- 20 CLOSED AREAS OF LOWER INTENSITY
- ROCK OUTCROP
- STREAM
- INTERMITTENT STREAM



SECTION 4.80E



SECTION 6.80E



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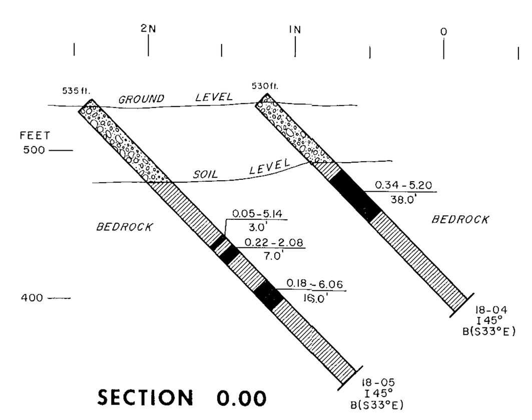
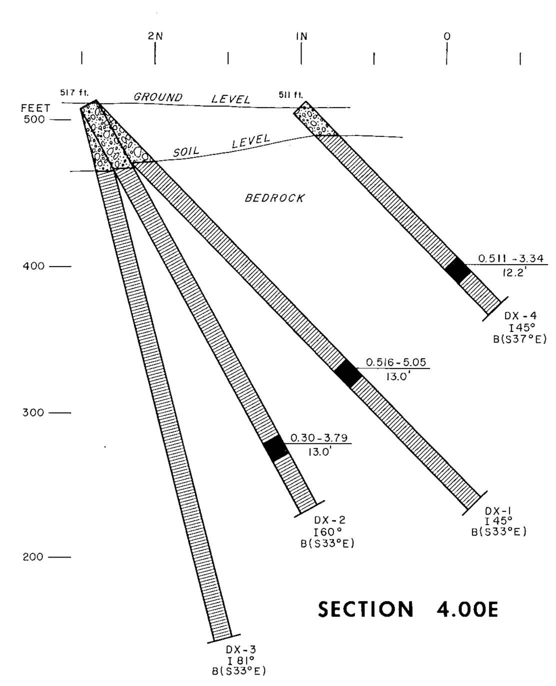


SECTION 0.00



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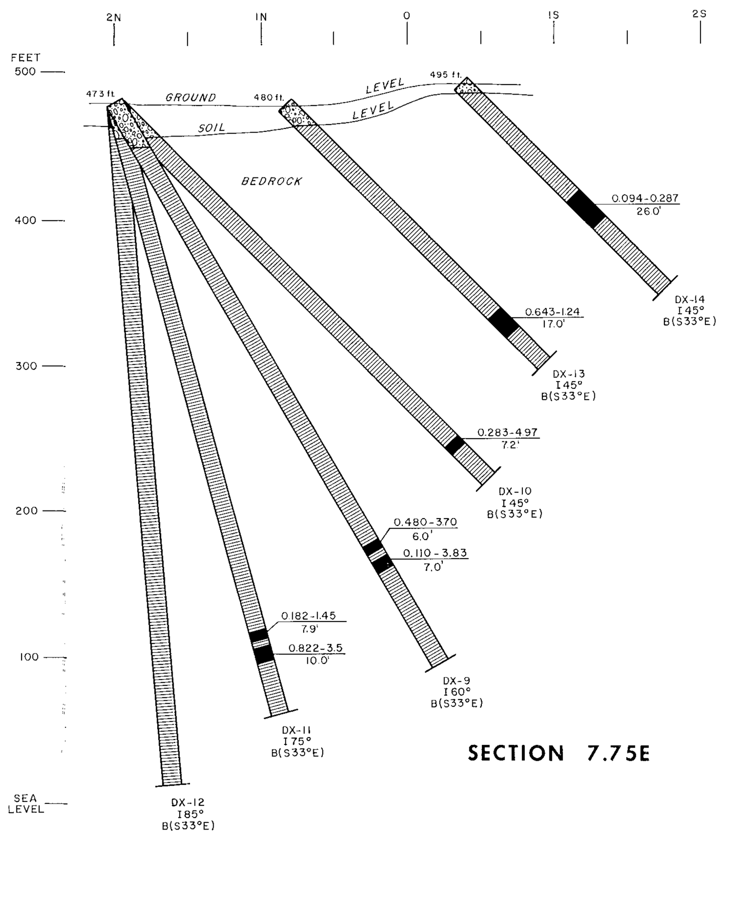
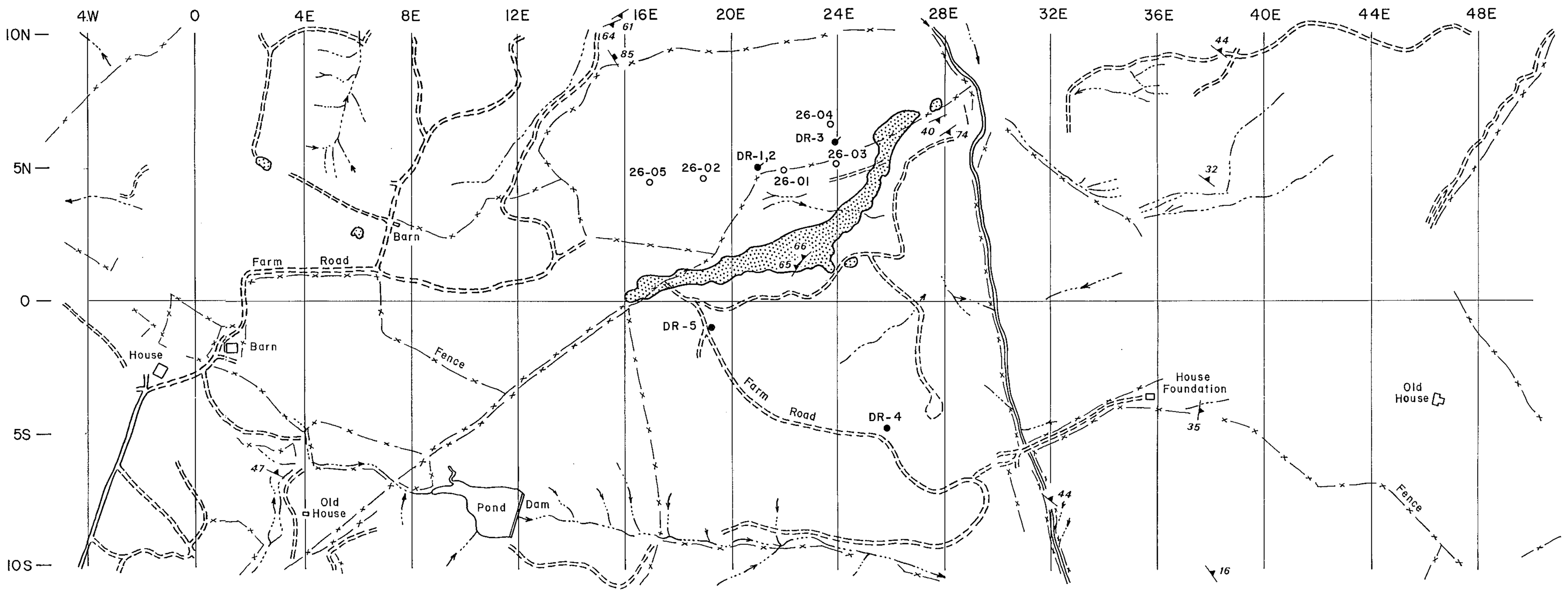


SECTION 7.75E

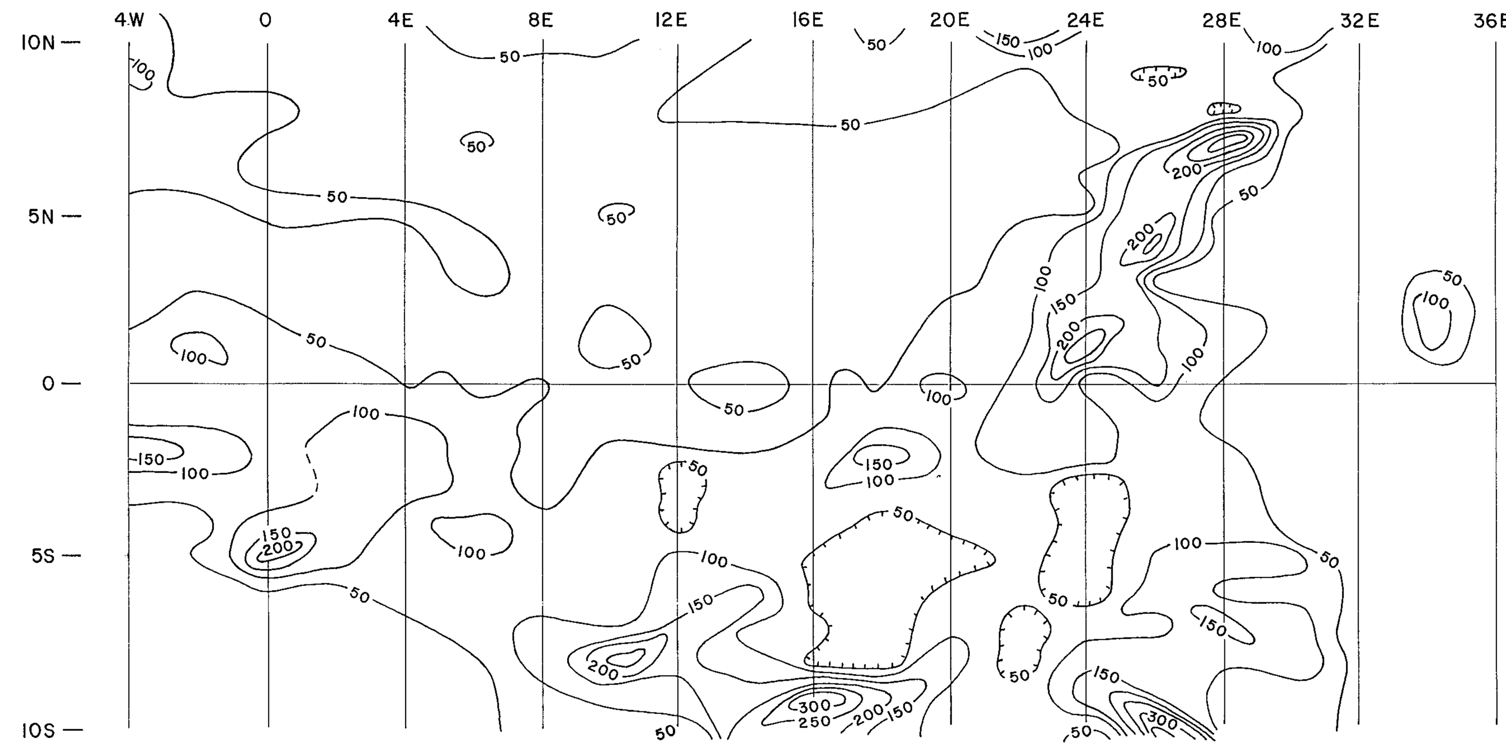
COMMONWEALTH OF VIRGINIA
DEPARTMENT OF CONSERVATION AND ECONOMIC DEVELOPMENT

PLATE 3. SULFIDE ZONE 3, ANDERSONVILLE AND WILLIS MOUNTAIN QUADRANGLES

VIRGINIA DIVISION OF MINERAL RESOURCES PUBLICATION 20
1981
PLATE 3. SULFIED ZONE 3

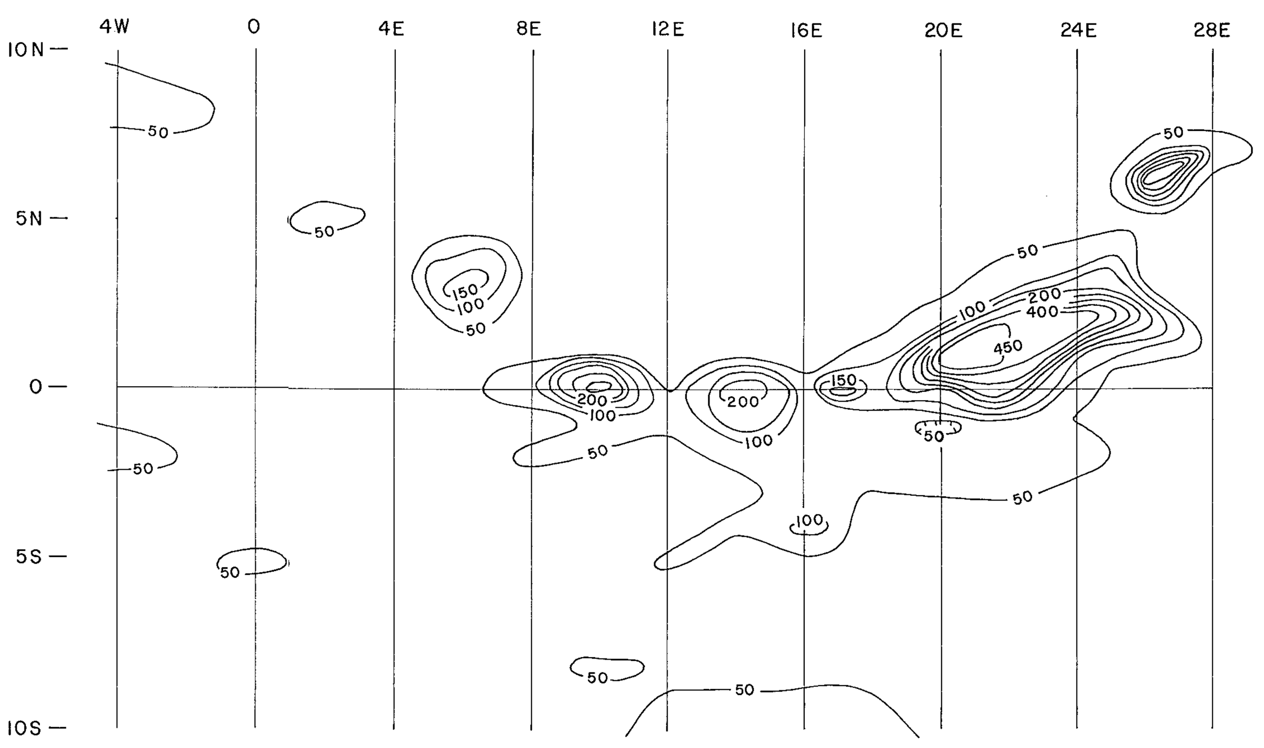


GEOLOGY AND CULTURE WITH DRILL HOLE LOCATIONS



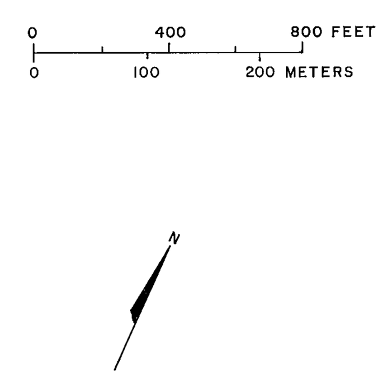
CONTOUR INTERVAL = 50 PPM ZINC

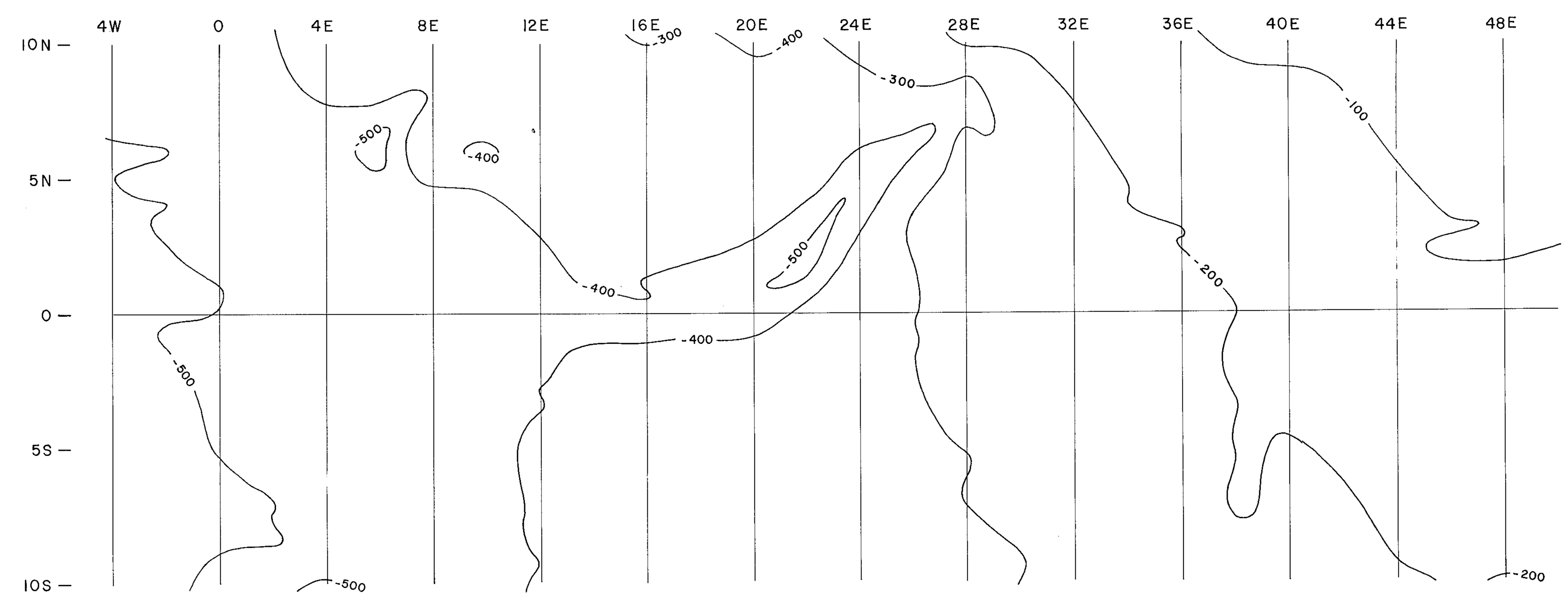
SOIL GEOCHEMISTRY - ZINC



CONTOUR INTERVAL = 50 PPM COPPER

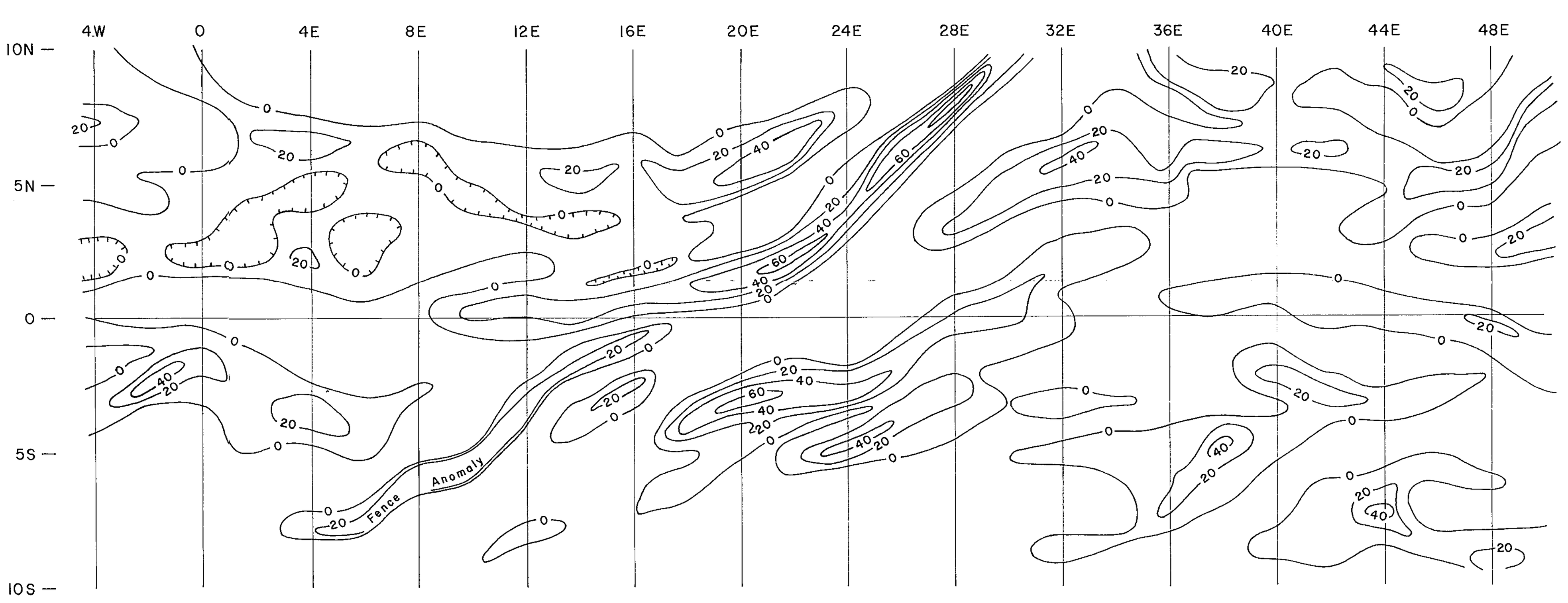
SOIL GEOCHEMISTRY - COPPER





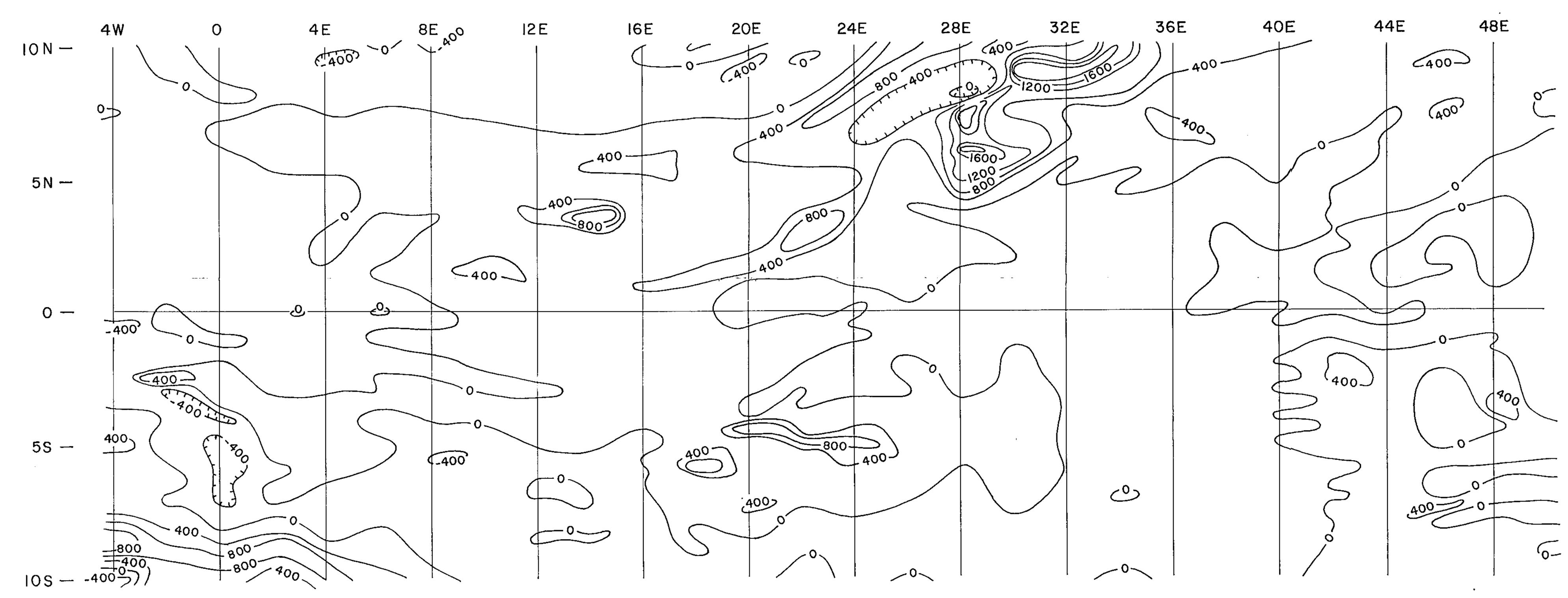
CONTOUR INTERVAL = 100 MV

SELF-POTENTIAL CONTOURS



CONTOUR INTERVAL = 20°

VERY LOW FREQUENCY ELECTROMAGNETIC FILTERED CONTOURS



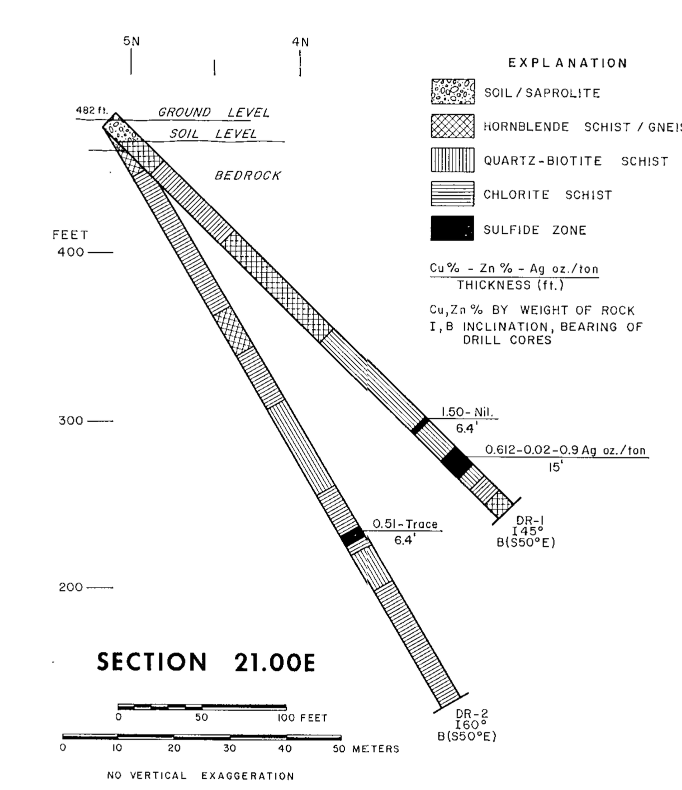
CONTOUR INTERVAL = 400 GAMMAS

MAGNETIC SURVEY CONTOURS

Drafting by S.R.P.

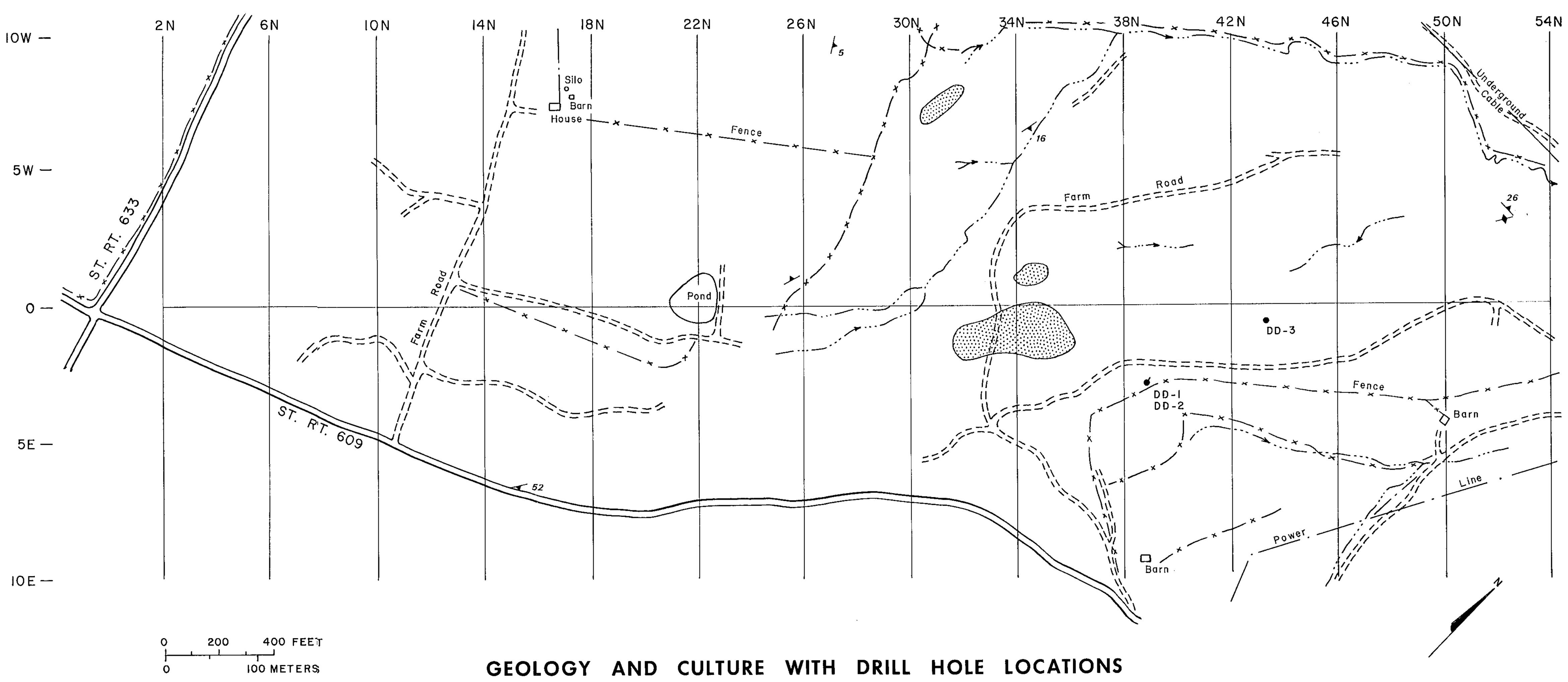
EXPLANATION

- AREA OF GOSSAN FLOAT
- 26 STRIKE AND DIP OF FOLIATION
- VERTICAL FOLIATION STRIKE
- 53 STRIKE AND DIP OF JOINTS
- 24-01 VIRGINIA MINING COMPANY DRILL HOLE, DRILL CORES DESCRIBED IN APPENDIX
- DM-2 DOMEX DRILL HOLE (DM, DR, DX, DD), DRILL CORES DESCRIBED IN APPENDIX
- 40 CONTOUR LINE
- 20 CLOSED AREAS OF LOWER INTENSITY
- ROCK OUTCROP
- STREAM
- INTERMITTENT STREAM

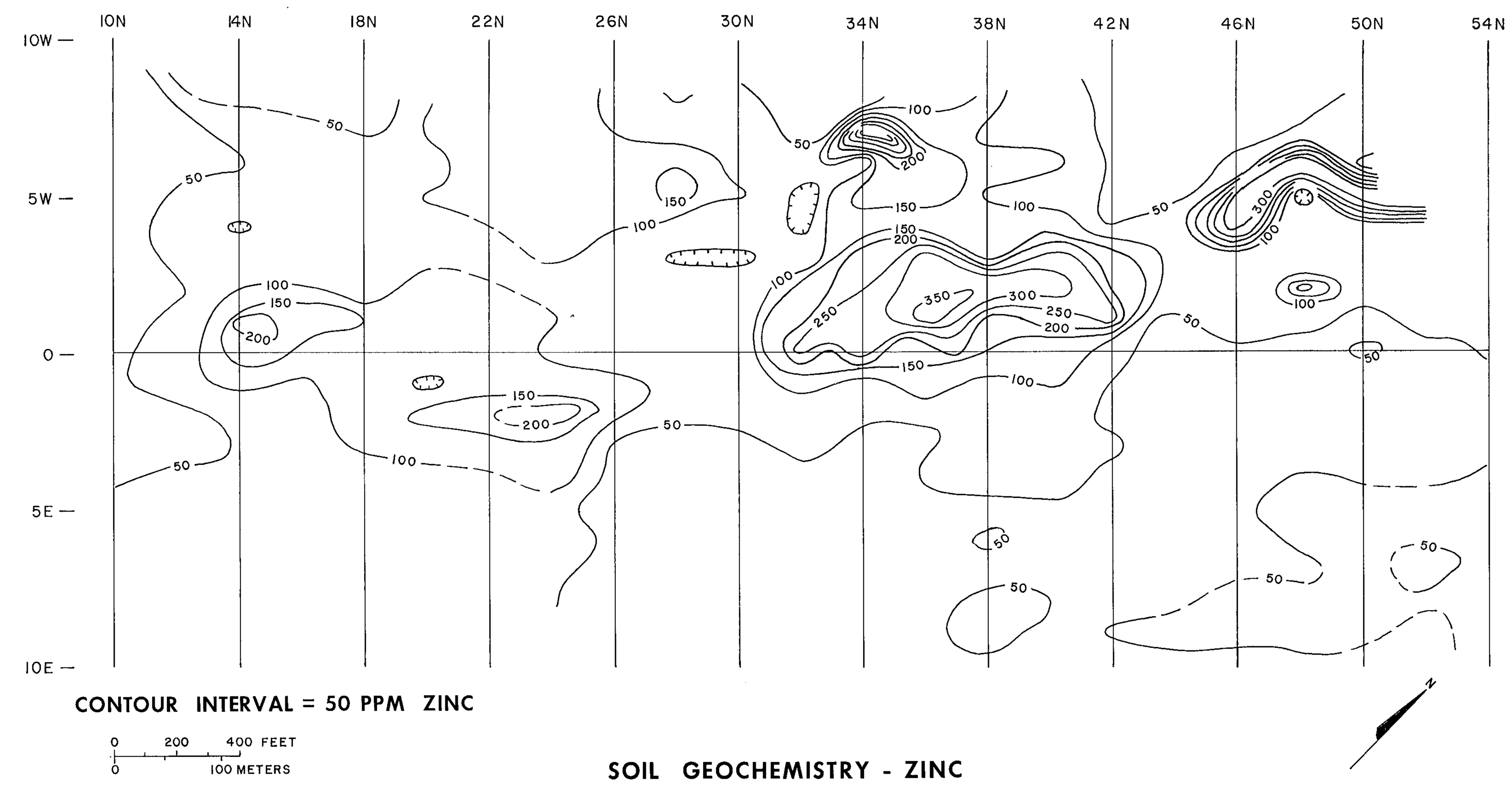


SECTION 21.00E

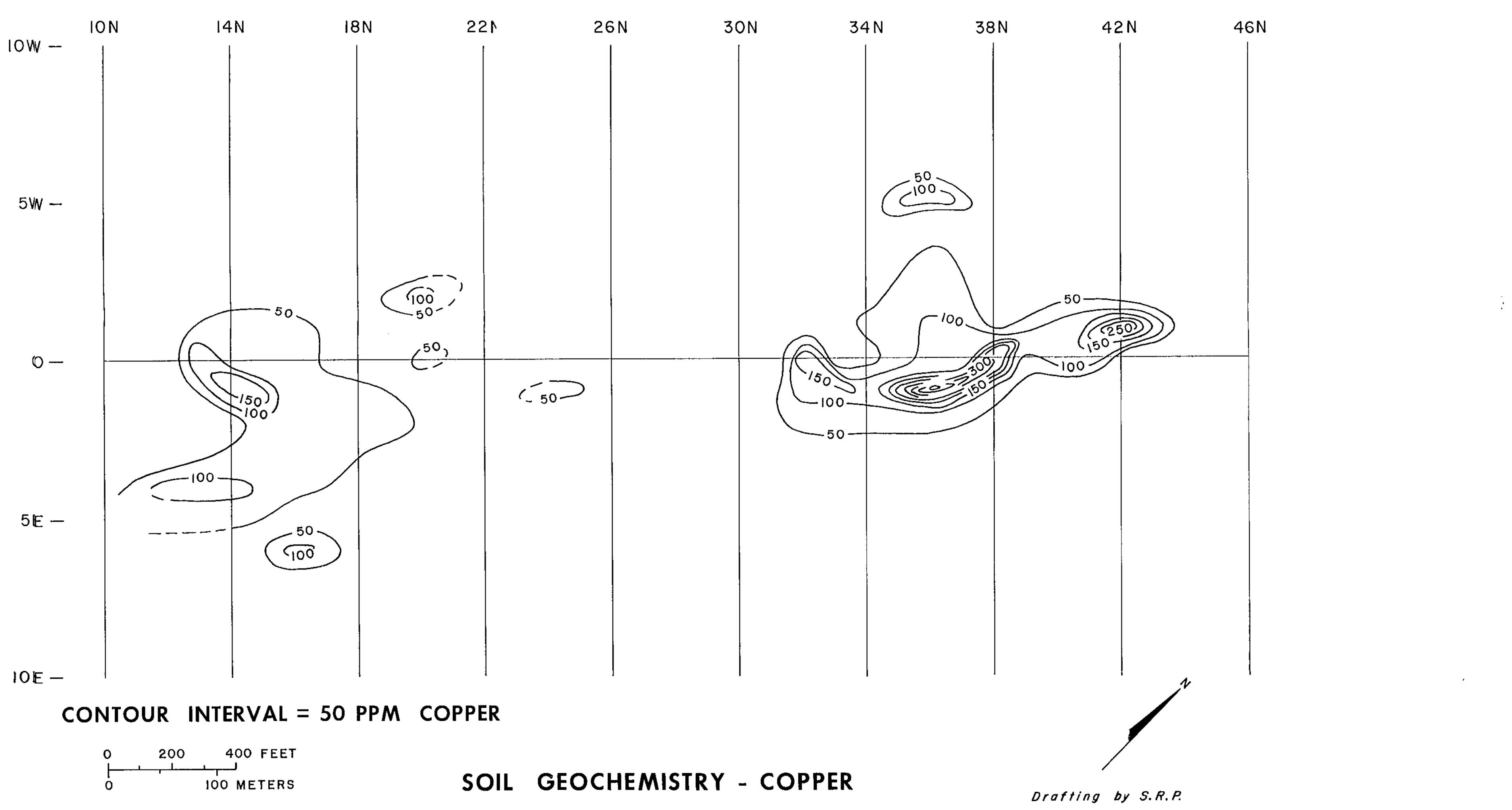
PLATE 4. SULFIDE ZONE 9, ANDERSONVILLE AND WILLIS MOUNTAIN QUADRANGLES



GEOLOGY AND CULTURE WITH DRILL HOLE LOCATIONS

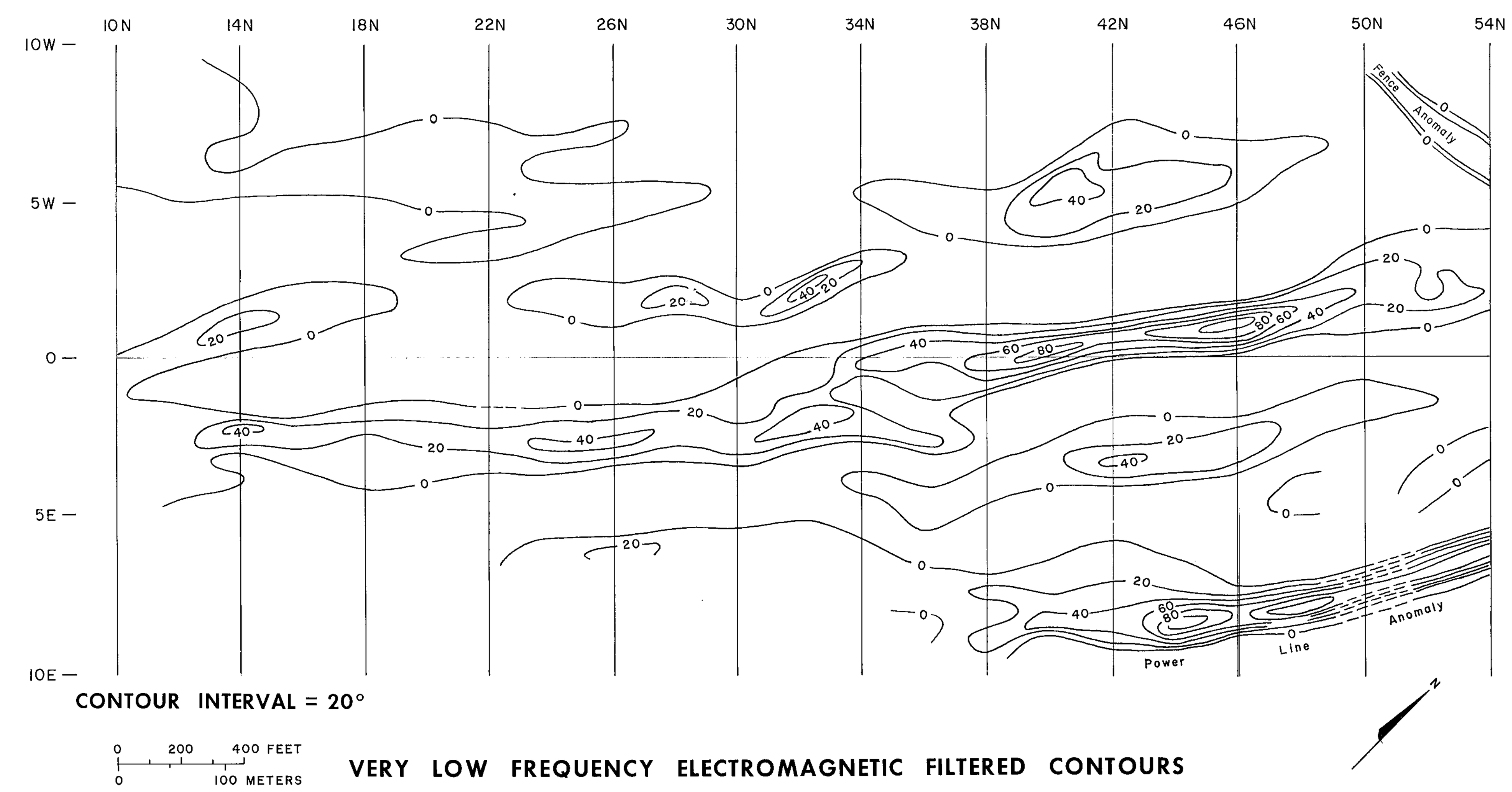


SOIL GEOCHEMISTRY - ZINC



SOIL GEOCHEMISTRY - COPPER

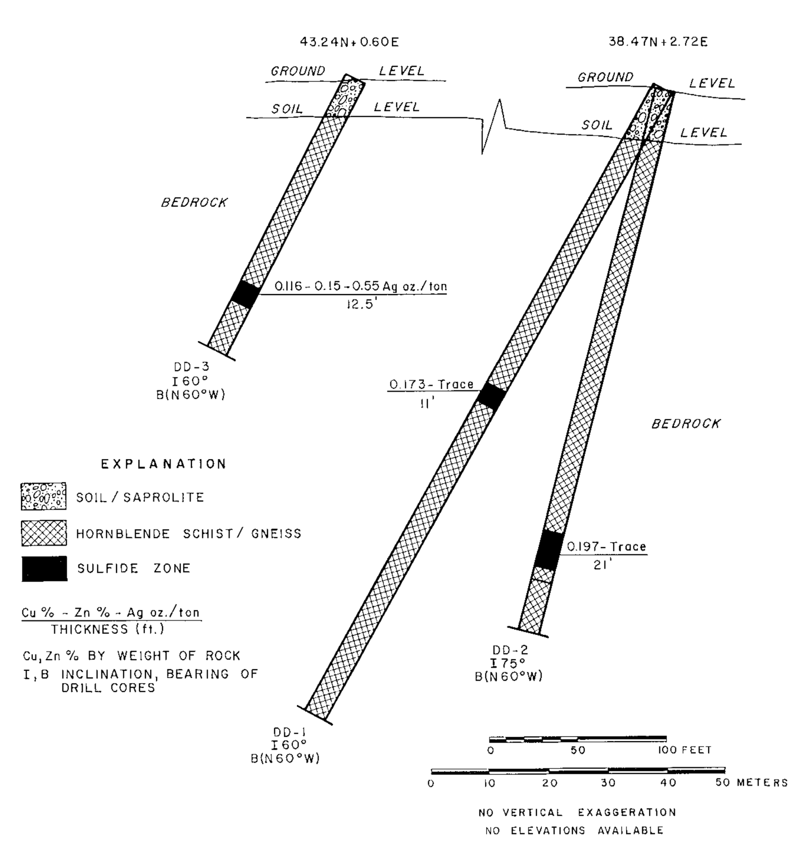
Drafting by S.H.P.

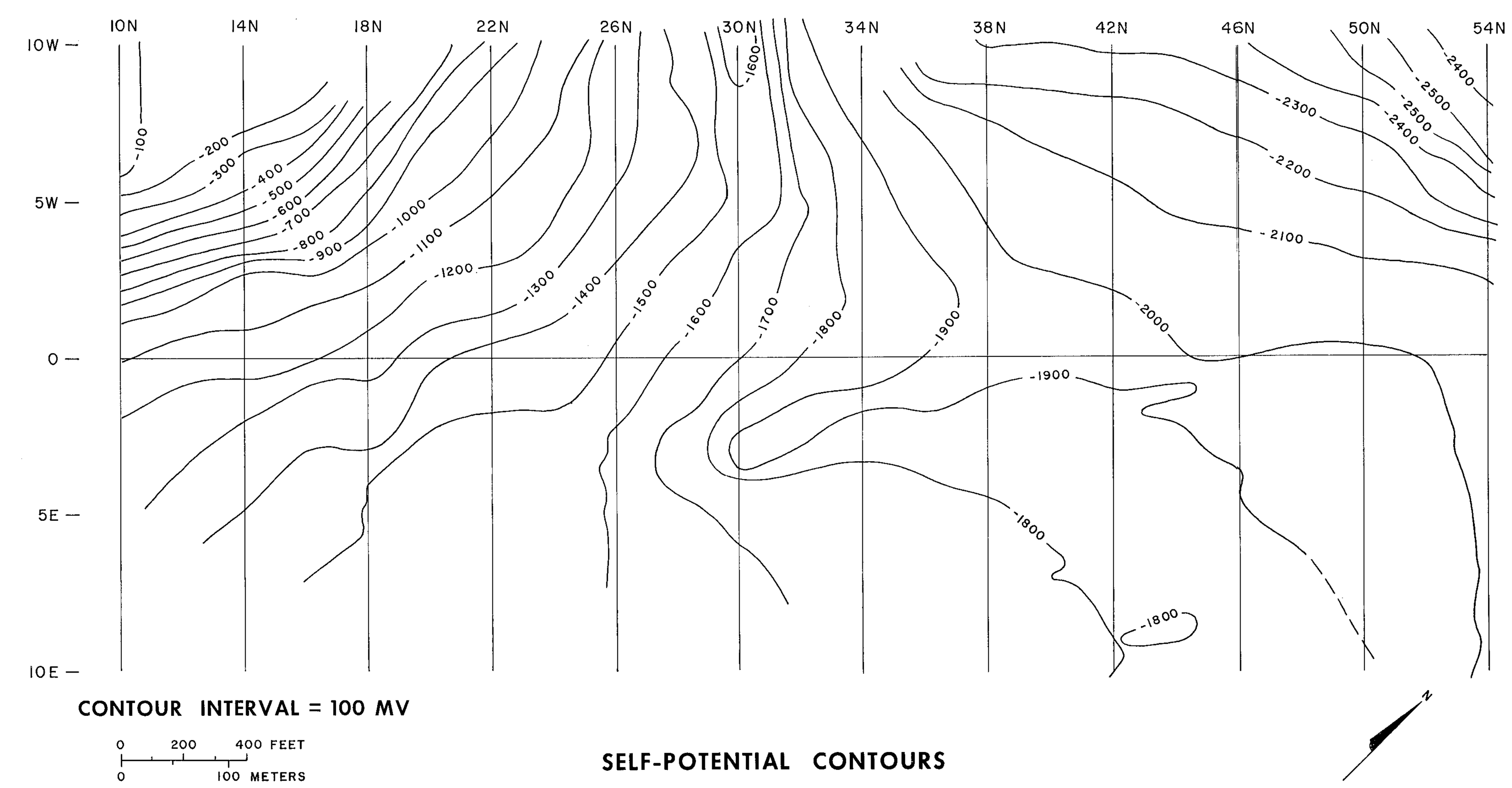


VERY LOW FREQUENCY ELECTROMAGNETIC FILTERED CONTOURS

EXPLANATION

- AREA OF GOSSAN FLOAT
- 26 STRIKE AND DIP OF FOLIATION
- VERTICAL FOLIATION STRIKE
- 53 STRIKE AND DIP OF JOINTS
- 24-01 VIRGINIA MINING COMPANY DRILL HOLE, DRILL CORES DESCRIBED IN APPENDIX
- DM-2 DOMEX DRILL HOLE (DM, DR, DX, DD), DRILL CORES DESCRIBED IN APPENDIX
- 40 CONTOUR LINE
- 20 CLOSED AREAS OF LOWER INTENSITY
- ROCK OUTCROP
- STREAM
- INTERMITTENT STREAM





SELF-POTENTIAL CONTOURS

PLATE 2. INDEX MAP FOR SULFIDE ZONES

VIRGINIA DIVISION OF MINERAL RESOURCES PUBLICATION 29
1981
PLATE 2. INDEX MAP FOR SULFIDE ZONES

Topographic base map by U. S. Geological Survey

Drafting by S.R.P.

EXPLANATION

SCALE 1:24,000

0 — 1 Mile

0 — 1 Kilometer

Contour Interval = 20 Feet

INDEX MAP

78°37'30" 78°30' 78°22'30"
37°30' MAP AREA 37°30'
37°22'30" 37°22'30"
78°37'30" 78°30' 78°22'30"

Andersonville Quadrangle — Willis Mountain Quadrangle

TYPES OF CONDUCTIVITY ANOMALIES, WHERE:

- 1A, 1B — 1 = VERY STRONG CONDUCTIVITY
- 2A, 2B — 2 = STRONG CONDUCTIVITY
- 3A, 3B — 3 = WEAK BUT DEFINITE CONDUCTIVITY
- X-TYPE — X = INDEFINITE CONDUCTIVITY
- A = DIRECT MAGNETIC CORRELATION
- B = NO DIRECT MAGNETIC CORRELATION

10/20 over 100: ELECTROMAGNETIC ANOMALY WITH 10 PPM IN PHASE, 20 PPM OUT OF PHASE AND 100 GAMMAS MAGNETIC CORRELATION

34/18: RADIOMETRIC ANOMALY SHOWING PEAK TO BACKGROUND RATIO IN CPS WITH PEAK OF 38 CPS AND BACKGROUND 22 CPS

WF = WEST FLANK MAGNETIC CORRELATION
EF = EAST FLANK MAGNETIC CORRELATION
F = POOR MAGNETIC CORRELATION
Br = BROAD MAGNETIC ANOMALY

FOLIATION

- 42 STRIKE AND DIP OF FOLIATION
- STRIKE OF VERTICAL FOLIATION

ZONE BOUNDARIES FOR WHICH GRIDS EXIST

GENERALIZED ZONE BOUNDARY

GOSSAN FLOAT

ZONES 3, 9, 18 AND 24 ARE DESCRIBED IN TEXT

PLATE 1. GEOLOGIC AND GEOPHYSICAL MAPS OF ANDERSONVILLE AND WILLIS MOUNTAIN QUADRANGLES

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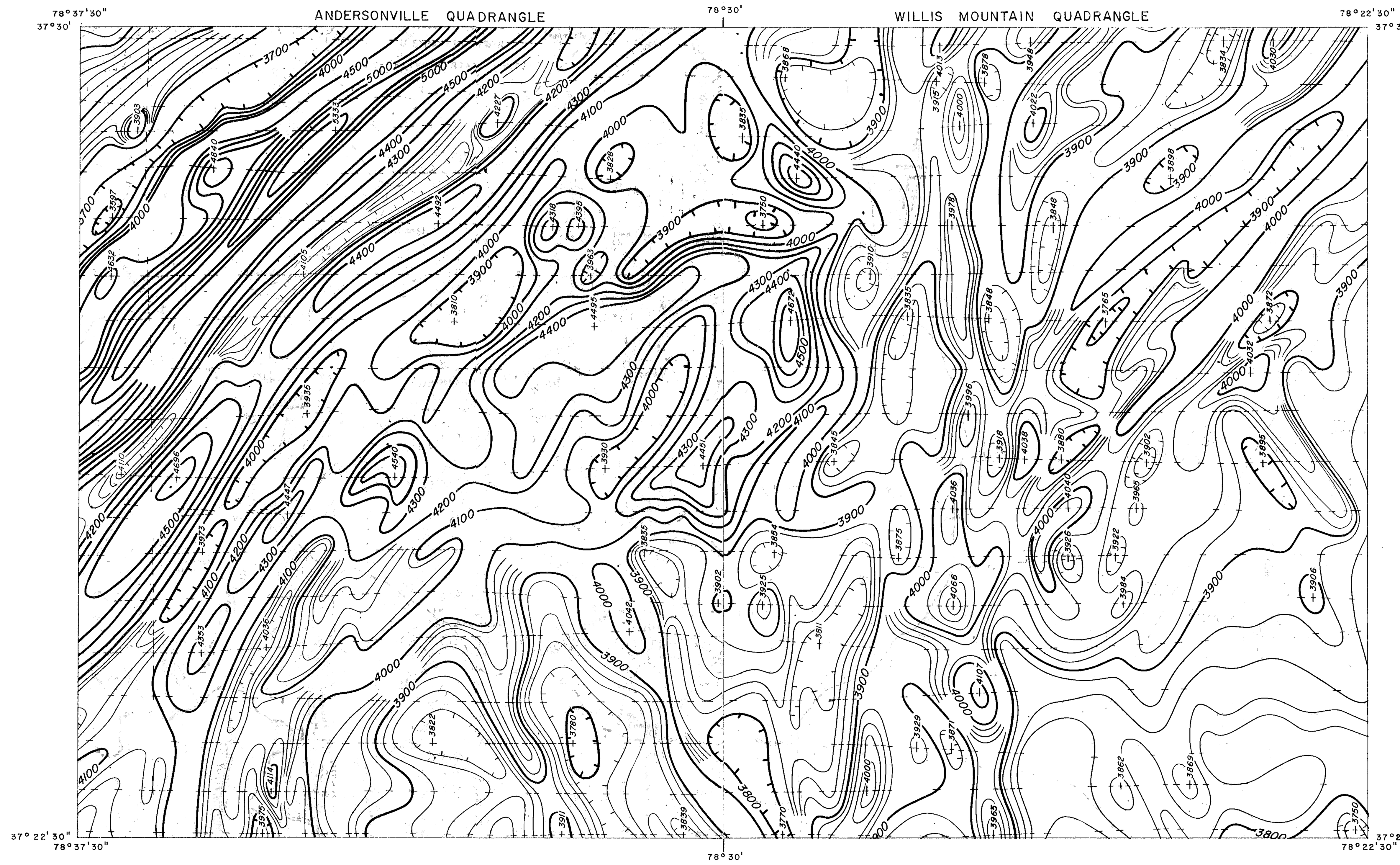
TOTAL INTENSITY
AEROMAGNETIC CONTOUR MAP



BASE MAP FROM U.S. GEOLOGICAL SURVEY
7 1/2 MINUTE QUADRANGLE SERIES
FLOWN APRIL - MAY 1970

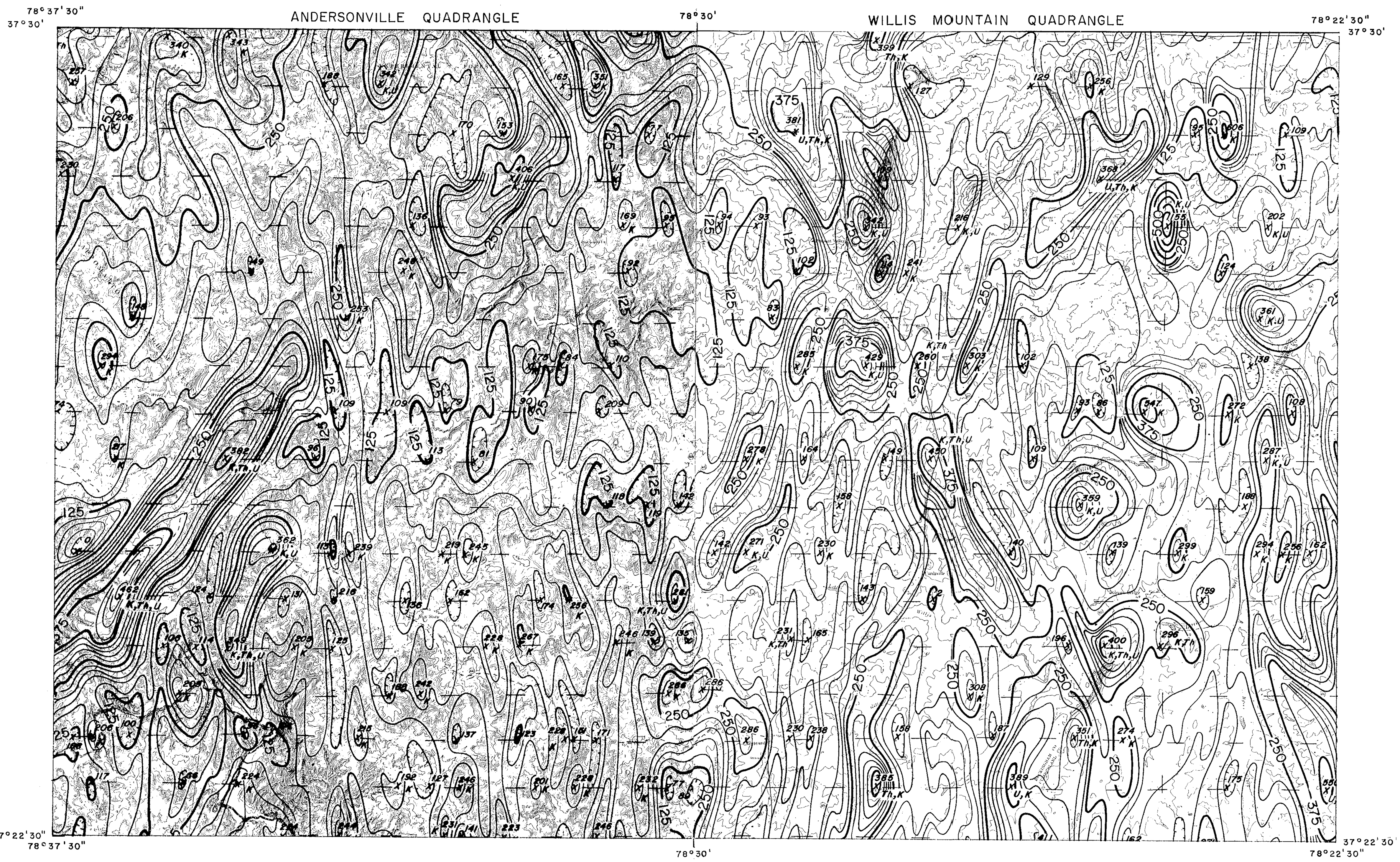
ALTITUDE 500' AMT
FLIGHT LINE SPACING 1/2 MILE
TOTAL INTENSITY CONTOUR VALUE = OBSERVED MAGNETIC FIELD — 53,000 GAMMAS

SCALE 1:62,500
1 1/2 0 1 MILE
CONTOUR INTERVAL 20 & 100 GAMMAS
1970

N
5°

INCLINATION OF FIELD +70°
APPROXIMATE FIELD INTENSITY: 57,000 GAMMAS
REGIONAL GRADIENT REMOVED: 8γ PER MILE AT N12°30'W

TOTAL COUNT
AERORADIOMETRIC CONTOUR MAP



BASE MAP FROM U.S. GEOLOGICAL SURVEY
7 1/2 MINUTE QUADRANGLE SERIES

GRID SIZE.............75 METERS (E-W) BY 200 METERS (N-S)
TRAVERSE SPACING......1/2 MILE
ALTITUDE..............500 A.M.T.

SCALE 1:62,500
1 1/2 0 1 MILE
CONTOUR INTERVAL 25 & 125 CPS
1979

N
5 1/2°

RADIONUCLIDES:
K - potassium 40
Th - thallium 208
U - bismuth 214
SPECTROMETER — GAD 5 - 502 IN^3

GEOLOGIC MAP OF ANDERSONVILLE AND WILLIS MOUNTAIN 7.5 MINUTE QUADRANGLES

CONTACT, EXPOSED OR INFERRED
FAULT, EXPOSED OR COVERED; U, UPTHROWN SIDE; D, DOWNTHROWN SIDE; ARROWS INDICATE DIRECTION OF RELATIVE MOVEMENT.

ACTIVE MINE
1, 2 KYANITE MINING CORPORATION

ABANDONED MINE
1 WILLIS CREEK (gold)
2 GILLIAM (gold)
3 FLOOD (gold)
4 BONDURANT (gold)
5 ANDERSON No.2 (gold)
6 ANDERSON No.1 (gold)
7 COPAL (gold)
8 SEAY (gold)
9 MORROW (gold)
10 MINE (copper)

X3 SULFIDE ZONES 3, 5, 9, 11, 12, 18, 24, 33, cc.

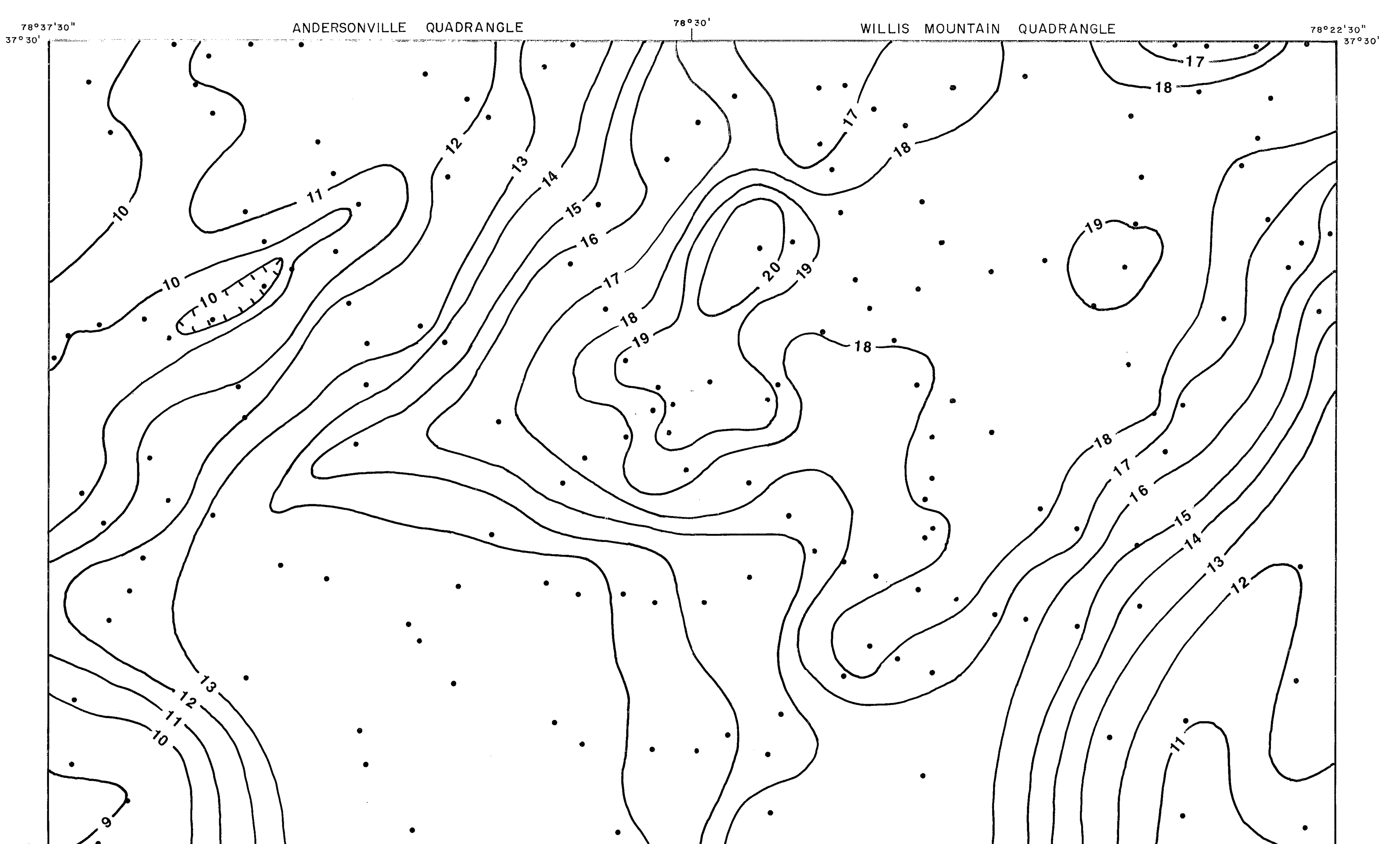
UNITS

TRIASSIC
- d — DIABASE DIKE
- Ћs — TRIASSIC SEDIMENTARY ROCKS (UNDIFFERENTIATED)

ORDOVICIAN
- Oa — ARVONIA FORMATION (UNDIFFERENTIATED)

CAMBRIAN — CHOPAWAMSIC FM.
- bgn — BIOTITE GNEISS
- agn — AMPHIBOLE GNEISS
- tts — TALC-TREMOLITE SCHIST
- FERRUGINOUS QUARTZITE
- GOSSAN ZONE
- iv — VOLCANIC ROCKS OF INTERMEDIATE COMPOSITION
- pgr — PLAGIOCLASE GRANITE
- cp — CANDLER FORMATION (UNDIFFERENTIATED)

SIMPLE BOUGUER
GRAVITY CONTOUR MAP



N
5 1/2°

SCALE 1:62,500
1 1/2 0 1 MILE
CONTOUR INTERVAL 1.0 MILLIGAL
1979

DATA AND CONTOURS
by
STANLEY S. JOHNSON

COMMONWEALTH OF VIRGINIA
DEPARTMENT OF CONSERVATION AND ECONOMIC DEVELOPMENT

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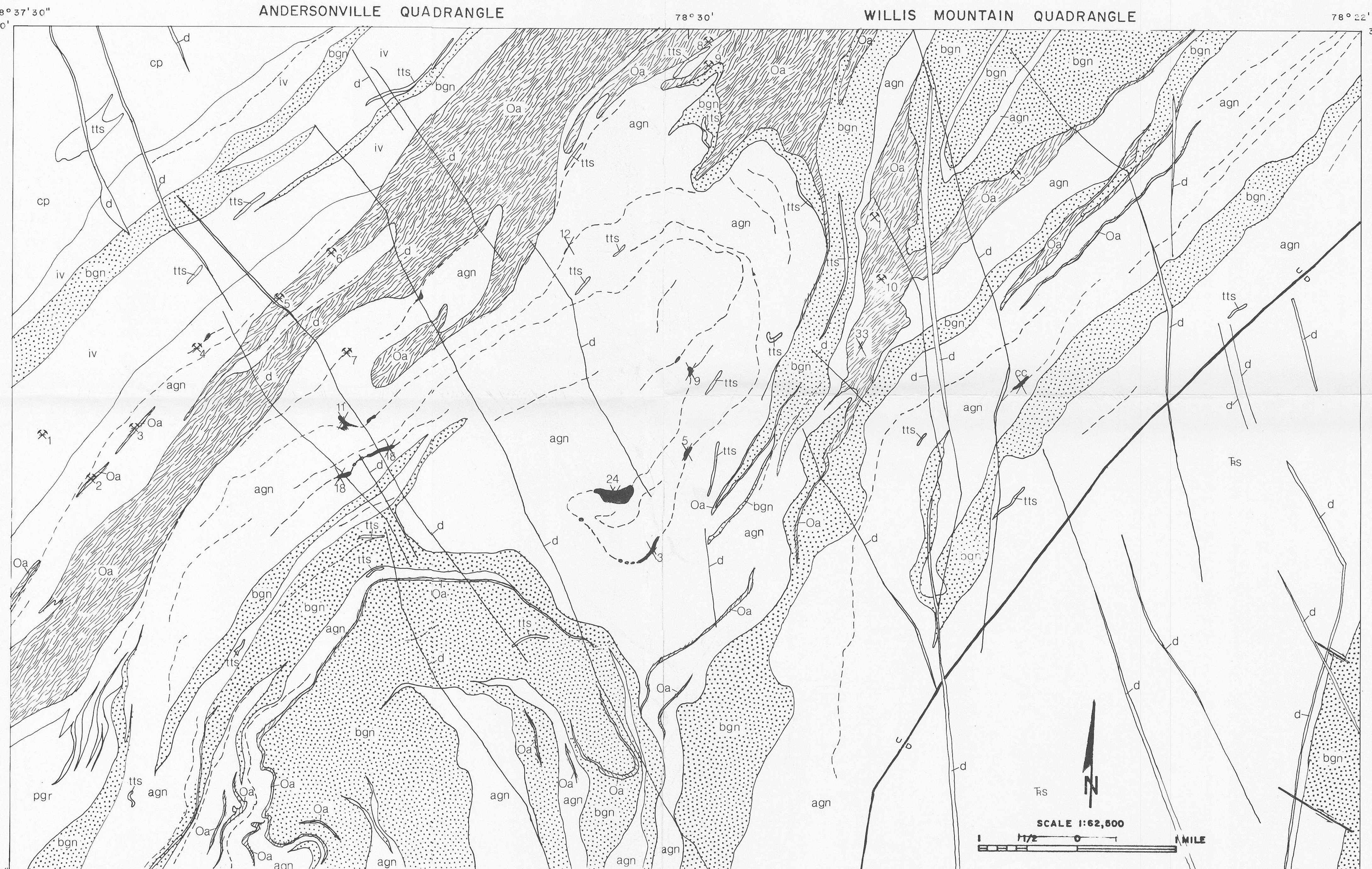

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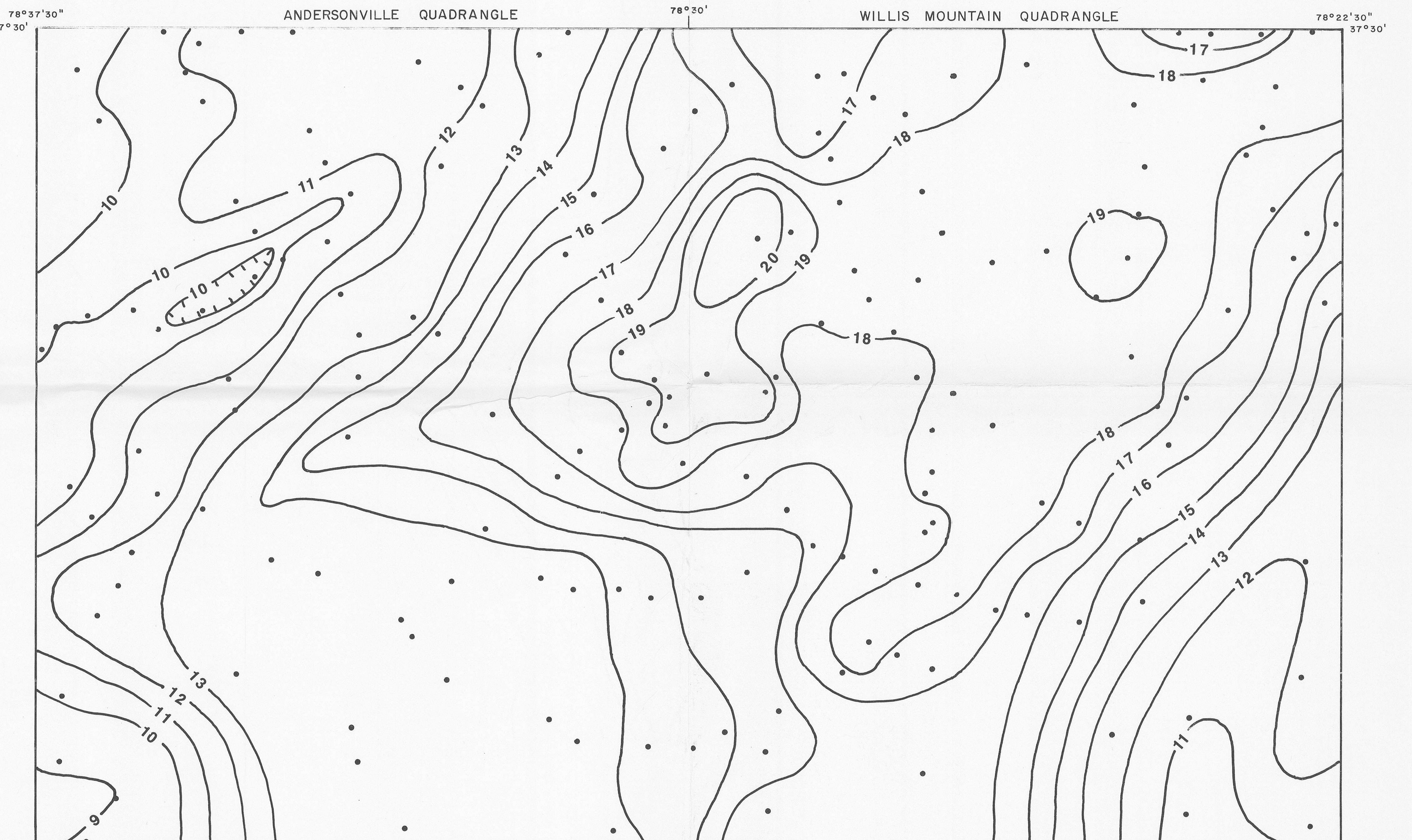

37°22'30" 78°37'30" 78°30' 37°22'30" 78°22'30"

N 5 1/2°

SCALE 1:62,500
1 1/2 0 1 MILE
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1979

DATA AND CONTOURS by STANLEY S. JOHNSON