MINERAL POTENTIAL STUDY

GREENSTONE BELT BOULDER TRACING

TOWNSHIP 60 - 65 NORTH, RANGE 11 - 27 WEST

ELY - BIGFORK AREA
NORTHERN MINNESOTA

LOCATION STUDY AREA

REPORT 318

1997

Minnesota Department of Natural Resources
Division of Minerals

MINERALIZED CLAST STUDY
GREENSTONE BELT BOULDER TRACING

ELY-BIGFORK AREA, NORTHERN MINNESOTA
TOWNSHIP 60-65 NORTH, RANGE 11-27 WEST

1997

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SUMMARY

The Ely-Bigfork area of northern Minnesota is an Archean granite-greenstone belt. Low cost sampling of glacial clasts and pebble sampling in gravel pits have revealed several areas of high potential for lode gold and volcanogenic massive sulfide deposits. Sample sites were carefully searched for mineralized rock and evidence of alteration. Mineralized samples were analyzed using a reconnaissance analytical package with these results (gold values from 6 to 3,598 ppb, arsenic values 10 to 1,900 ppm, zinc 100 to 2,899 ppm, copper 100 to 14,944 ppm and lead 20 to 248 ppm, nickel 133 to 3,126 ppm and barium 600 to 1,980 ppm). These values combined with observed alteration and favorable geology mapped seventeen mineralized clast areas (MCAs).

In the eastern part of the area two important MCAs for gold and VMS mineralization correlate very well with high pebble counts for quartzite, metasediments and felsic volcanics. There are also favorable lithologies; iron formation, metasediments, mafic and felsic volcanics with fault contacts. MCAs form distinctive southwest trending boulder trains from the Rainy Lobe glaciation. In the central part of the area MCAs also correlate very well with favorable lithologic units and structural features. In most of this area the glacial Koochiching Lobe from the northwest covers the Rainy Lobe and there is less distinctive development of boulder trains. In the western part of the area there are strong analytical anomalies, with less explicit coincidence with structural features and bedrock lithology. In the western Koochiching Lobe glacial deposits there is some development of boulder trains, but they are not as well defined as they are to the east.

The location of the source of mineralized samples is indicated by: 1. Development of mineralized-altered boulder dispersal trains. 2. The amount of mineralized rock at the sample site which decreases with distal dispersion and denudation. and 3. Study of megascopically determined lithology frequency distribution for randomly collected samples of 100 pebbles from each site. The pebble lithologies are grouped to match lithologic units so that they can be compared with mapped bedrock lithology (Morey 1996). Irrespective of the nature of glacial cover, i.e. Rainy Lobe in the East or Koochiching Lobe in the central and western parts of the area, there is good correlation found between the pebble frequency distributions and bedrock geology. This indicates that although there has been increased dispersion and denudation in the western one-third of the study area mineralized rock samples are still relatively close to their bedrock source. In the far west irregular frequency distribution of carbonate pebbles from the Koochiching lobe suggests reworking of a local as yet unmapped source.

INTRODUCTION

A large area in northern Minnesota has complex Archean bedrock geology. These geologic units have undergone several periods of tectonic deformation, igneous activity and alteration. Bedrock lithologies, structure, alteration, mineral occurrences (Southwick, 1993, Jirsa, et al., 1991, Sims, 1985, Morey, 1996, Martin, 1985) and geochemistry (Alminas-Cartwright maps and Project 296, Martin, et. al., 1989, Peterson, Doctoral Thesis in Progress) indicate there should be undiscovered valuable metallic mineral deposits. These features are similar to those hosting such deposits in Canada and Scandinavia. Previous studies as shown on The Index of Projects and Study Area Location, Figure 1 have produced encouraging results.

The objective of this project is to provide a reconnaissance study of mineral potential for a sixty-one township area in northern St. Louis County, southeastern Koochiching County and northeastern Itasca County where previous work indicates economic mineral deposits potential. The objective of this study is achieved by analysis of mineralized clast samples found in glacial drift deposits from 144 sample sites. This method is cost effective and has been used successfully in Canada and Scandinavia where there are areas of shallow drift.

To enhance these methods and present detailed geology in the western part of the project area where glacial drift deposits are deeper, inferred geology-mineral potential maps for twenty-six contiguous townships are in progress under contract with the Minnesota Geological Survey, for the Department of Natural Resources. The maps are made from geophysical interpretations of airborne magnetic surveys, gravity data and any other pertinent data.

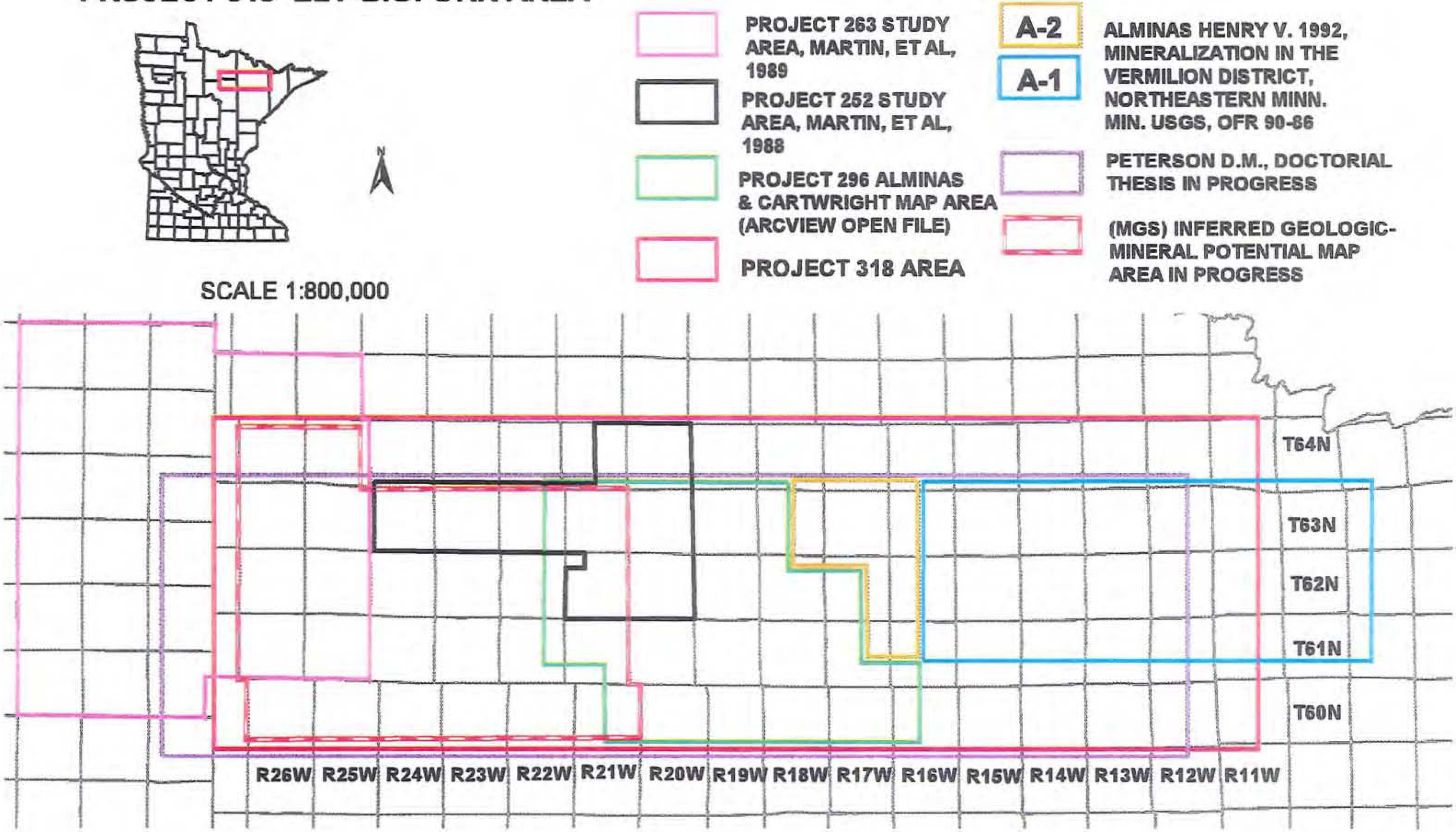
The Ely-Bigfork Area is described as T60-64N, R11-27W, (excluding T62N, R14W because of active leases; and T64N, part of R21W and all of R22W and R23W which are in the Nett Lake Indian Reservation. Also pebble counts were not done in or close to the area referred to as the Boundary Waters Canoe Area Wilderness Mineral Management Corridor). In the eastern part of the area, bedrock is partially covered by thin glacial deposits. Ranges 11 through 20 West have considerable outcrop. West of Range 20 West, glacial deposits increase in thickness to about 100 feet at the western edge of the study area, however, there are still scattered outcrops particularly in the southwestern part of the study area (Olsen and Mossler, 1982, Southwick, 1993) .

County road maps and U.S. Geological Survey 7.5 minute topographic maps were used for sample site locations. Plat books and Public

FIGURE 1

PROJECT 318 ELY-BIGFORK AREA

INDEX OF STUDIES



Recreation Information Maps PRIM[1] were used for determining land ownership. From these maps a rough estimate of land surface ownership indicates about seventy percent of the land within the project area is government owned. In the eastern part of the area (The Superior National Forest) government ownership is about sixty percent State or County and forty percent Federal. In the Kabetogama, Sturgeon River, Koochiching and George Washington State Forests government surface ownership is about ninety percent with eighty percent being State or County. In the Nett Lake Indian Reservation ownership is either private, Federal or Bureau of Indian Affairs. Most of the private ownership is around the small cities or villages, the larger lakes in the area and along the larger streams or rivers. In the Tower-Soudan-Ely area mining companies own much of the private ownership, and/or the minerals which were probably separated from the surface and retained by the mining industry. Considerable private ownership is also owned by forest products industry.

The local economy is based on taconite mining on the Mesabi Iron Range, logging and manufacture of forest products, recreation and service industries, with some small farms. Access and sample locations are generally good in the eastern and southern part of the study area and poor in the northwestern corner, although there is not a uniform distribution of sample sites anywhere in the area.

Acknowledgements

Eduard Dahlberg, Manager of the Mineral Potential Evaluation Section, initiated the project and encouraged the pebble counting part of the project. Darold "Ricco" Riihiluoma collected the pebble count samples and helped collect mineralized samples also magnetic susceptibility samples. Ricco and Michael "Mike" Ellett did most of the computer work making maps and figures. Ricco also provided a lot of help with the sample analysis. Dennis Martin helped arrange the sample analysis program and offered good suggestions on procedure. Phil Pippo wrote contracts and helped resolve problems with analytical work. J.D. Lehr contributed the section on glacial geology. Helen Koslucher, Sue Saban and Diane Melchert contributed word-processing and data entry skills. Coleen Keppel and Dorothy Cencich helped with computer problems and Coleen made the pebble count frequency distribution graphs. Other staff members worked on the project as needed.

REGIONAL GEOLOGIC SETTING

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[1]PRIM maps are a comprehensive overview of the recreational facilities and opportunities found in Minnesota. These maps also display government land surface ownership and private land surface ownership. They are available from the DNR Information Center, 500 Lafayette Road, St. Paul, MN 55155-4040.

The survey area is underlain by Archean lithologic units as shown on Plate 1, modified from a digital map compiled by Morey, 1996. This map is in the pocket at the back of the report as a mylar overlay at 1:750,000 scale. It is used with the other 1:750,000 scale maps in the report. The mineral potential area is a strip of east-west metamorphosed Archean mafic and felsic volcanics with metatsediments which have been folded, faulted and intruded by granitoid rocks. North of the granite-greenstone mineral potential area is the Vermilion Granitic Complex (Agr) and the granite rich migmatites (Agm) also the Paragneisses and schist rich migmatites (Asm). South of the mineral potential area are the Giants Range Granites, also (Agr).

Within the area of interest there are: Mafic metavolcanic rocks (Amv) which are dominantly basalt, but include thin units of metasediments, including iron-formation; Metasedimentary rocks (Ams) which include graywacke, slate, conglomerate, arenite, graphitic slate, fine-grained felsic volcanogenic and volcaniclastic rocks and their metamorphic equivalents. This unit continues to the northwest out of the project area; Mixed metavolcanic rocks (Amm)-mafic to felsic volcanic sequences having variable amounts of felsic volcanogenic and volcaniclastic rocks and lean iron-formation; A small amount of (Aps) which are paragneisses, schist, and amphibolite-(metamorphic equivalent of units Amv and Ams, may include components of unit Agr); These rock units are intruded by post-tectonic to late-tectonic granitoid intrusions of the Algoman orogen (Agd)-includes multiphase intrusions of hornblende-pyroxene and biotite-bearing monzonite, monzodiorite, diorite, and granodiorite; Intrusions of (Ami) post-tectonic mafic intrusions-which include gabbro, peridotite, pyroxenite, and their metamorphic equivalents. As shown on the map these rocks have been faulted and sheared by multiple deforming events. Together they form a geologic terrane with significant economic mineral potential.

"The Canadian segment of the Archean Superior province is a major world source of lode gold. The gold deposits occur in or near regional transcurrent and oblique slip-shear deformation zones that comprise a conjugate set to a northwest-directed compression of the Superior province. These structures provided permeable pathways for the flow of large volumes of auriferous fluid derived from an external source (Sims and Day, 1992, p. M1)." The Archean greenstone-granite terrane of the Wawa subprovince in Minnesota has lithologies and structures very similar to those observed in the Canadian mining districts.

The Geological Survey of Canada map "Mineral Deposits of Canada" (Douglas, 1970) displays a close spacial relationship between gold deposits and volcanic associated massive sulphide deposits. The giant Kidd Creek massive sulfide mine is shown as being in volcanic rocks, intrusive equivalents, and associated eugeosynclinal sediments about twenty miles from the Hollinger gold mine in the same geological setting. In the mineral potential area Peterson's studies of DNR General Exploration Files (thesis in progress) indicate that there is potential for both gold deposits and massive sulfide deposits in the Ely-Bigfork area.

GLACIAL DEPOSITS

The modern landscape of the study area is the result of a combination of preglacial chemical weathering of Precambrian bedrock and glacial erosion/deposition during the late Cenozoic ice ages. From the late Cretaceous through the Tertiary Period, the Precambrian rocks of northern Minnesota were subjected to chemical weathering. The depth of weathering was greater over plutonic rocks and was especially deep along fractures and faults. The earliest late Cenozoic glaciations must have been very effective in removing the thick saprolite that developed in preglacial times. The chemical weathering and subsequent glacial erosion resulted in the accentuation of lithology and structure that is reflected in the modern geomorphology of the study area (Lehr and Hobbs, 1992).

The study area was glaciated repeatedly during the late Cenozoic ice age, however little is known about the early glaciations, since their deposits have either been eroded or occur only in the subsurface. In general, the eastern three-quarters of the study area is underlain by late Wisconsinan deposits resting on relatively unweathered Precambrian bedrock. Towards the western one-quarter of the study area, pre-Wisconsinan deposits of both northeastern and northwestern provenance overly a variable thickness of saprolite developed in the Precambrian bedrock (Martin and others, 1988; 1989). The geomorphology of the northeastern one third is dominated by landforms which reflect the lithology and structure of the bedrock.

During the late Wisconsinan, the study area was affected by glaciers advancing from both the northeast and the northwest. The earlier late Wisconsinan advances were of the Rainy lobe, which advanced from the northeast across the Precambrian rocks of the Canadian Shield. The Rainy lobe covered the study area for most of the late Wisconsinan stage and was quite effective in removing older glacial deposits and saprolite. In general, the lithology of Rainy lobe deposits in the study area closely reflects lithology of bedrock up-ice, generally unweathered rock eroded from the local granite-greenstone terrane (Lehr and Hobbs, 1992).

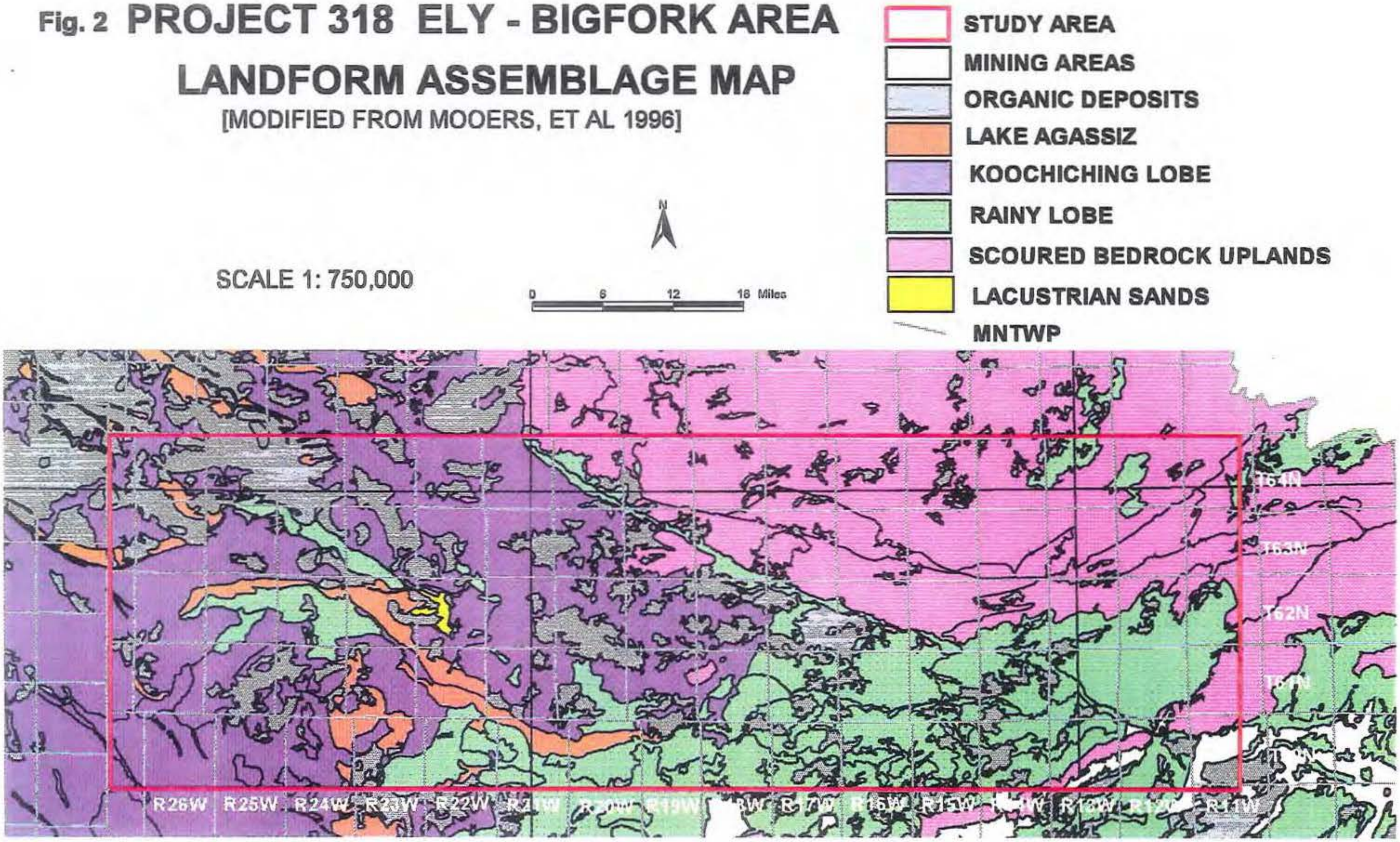
As the Rainy lobe retreated through the study area, its margin was fronted by a proglacial lake which affected deglaciation. As the ice margin periodically stabilized, generally east-west oriented end moraines were deposited. Where the ice margin was fronted by a lake, end moraines composed of subaqueously deposited sand and gravel formed. The prominent Vermilion moraine, trending northwestward from the south shore of Birch Lake and along the

Fig. 2 PROJECT 318 ELY - BIGFORK AREA

LANDFORM ASSEMBLAGE MAP

[MODIFIED FROM MOOERS, ET AL 1996]

SCALE 1: 750,000



south shore of Lake Vermilion, is a good example of one of these sand and gravel end moraines (Lehr and Matsch, 1987). Areas above approximately 1450 feet above sea level were not covered by glacial lakes for appreciable lengths of time. In these areas, ice marginal sedimentation produced more typical end moraines composed of till and related sediments (Lehr and Matsch, 1987). The areas between end moraines at these higher elevations contain a variety of glacial sediments, primarily till and outwash, in addition to bedrock outcrops (Lehr and Hobbs, 1992).

As the margin of the Rainy lobe was retreating through the eastern half of the study area, ice remained thick enough in the Lake Superior basin for Superior lobe outwash to be deposited in topographically low areas in the far eastern part of the study area (Hobbs and others, 1988; Lehr and Hobbs, 1992).

Upon retreat of the Rainy lobe from the study area, the western one-third of the study area was glaciated by the northwestern-source Koochiching lobe (Martin and others, 1989). The deposits of the Koochiching lobe are easily distinguished from Rainy lobe deposits. Koochiching lobe till is calcareous, dark gray in color and is predominantly clay loam to silt loam in texture, and generally stone-poor (Meyer, 1993). The advancing Koochiching lobe was not as effective at eroding older deposits since its advance was shorter-lived than that of the Rainy lobe. However, the Koochiching lobe was also bordered by a glacial lake and its deposits reflect extensive incorporation of proglacial lake sediment (Meyer, 1993). The eastern extent of Koochiching lobe till is approximately the St. Louis County line (Martin and others, 1989), however Koochiching lobe lake sediments extend along lowlands as far east as Tower, Embarrass, and Basswood Lake.

MINERAL DEPOSIT MODELS

There are at least three mineral deposit models appropriate for this geologic terrane. The three models are: 1. Archean lode gold deposits; 2. Gold deposits hosted by iron formations, and; 3. Volcanogenic Massive Sulfide (VMS) deposits. The three models of these deposits are described below:

Sims, P.K. and Day, W.C., 1992 p. M1, describe the gold potential of the area "An occurrence model largely based on known parameters of gold mineralization in Canada suggests that the greenstone-granite terranes of the Wawa and Wabigoon subprovinces in the United States are favorable for important gold deposits. The deposits should be hosted at a regional, district, and deposit scale in or adjacent to transcurrent faults, such as the Vermilion fault system in northeastern Minnesota and its smaller splays. --- The model suggests that gold mineralization took place during or later than the transcurrent faulting and that it took place contemporaneously with emplacement of silica-undersaturated intrusions.---Extensive, intense alteration comprising carbonitization, silicification, and sulfidization accompanied the gold mineralization."

Canadian, Archean gold deposits are found in two models, mesothermal lode-gold deposits as described by Hodgson (1993) and iron formation hosted gold deposits described by Kerswill (1993). "Mesothermal lode-gold deposits are mostly quartz-vein-related, gold-only deposits with associated carbonatized wall rocks. They occur in low-to medium-grade metamorphic terranes of all ages, but only in those that have been intruded by granitoid batholiths.---Commonly associated minerals include pyrite (less commonly pyrrhotite), the common base-metal sulphides, arsenopyrite, tourmaline and molybdenite. Mineralization may occur in any rock type and ranges in form from veins, to veinlet systems, to disseminated replacement zones. Most mineralized zones are hosted by and always related to steeply dipping reverse-or oblique-slip brittle-fracture to ductile-shear zones.---At a regional scale, the deposits occur in prograding arc-trench complexes in association with major transcrustal fault zones---, (Hodgson, 1993 p. 635)."

"Banded iron-formation (BIF)-hosted gold deposits have several important common features but can be usefully divided into stratiform and non-stratiform types on the basis of empirical (non-genetic) characteristics. In stratiform deposits, much of the gold is uniformly disseminated in laterally continuous units of cherty, well-laminated sulphide BIF that are conformably interlayered with gold-poor silicate and (or) carbonate BIF. In non-stratiform deposits, gold is restricted to late structures (quartz-rich veins and shear zones) and (or) sulphide BIF immediately adjacent to such structures. In non-stratiform ores, ubiquitous replacement textures as well as the very close spatial association between late structure and sulphide BIF, clearly indicate that these deposits are epigenetic products of localized sulphidation reactions in structurally and chemically favorable host rocks. Although the genesis of stratiform ores is controversial, much of the available evidence is consistent with syngenetic concentration of gold and sulphur during sea floor deposition of sulphide BIF. This evidence includes not only the stratiform character of the ore but also the apparent lack of consistent correlation between gold-rich sulphide BIF and late veins, shear zones or fold hinges, the absence of oxide BIF, the lack of sulphidation textures, and the abundance of textures that indicate sulphide BIF has undergone both deformation and metamorphism prior to formation of the late structures (Kerswill, 1993 p. 171)."

Boyle (1979, pp. 46-47) displays a table "Gold and silver content of Canadian Precambrian and Paleozoic iron-formations" which has some fairly high gold contents particularly where there are pyritic bands or pyritic interflows. "The various data on iron-formations are interesting in the light of the common occurrence of commercial gold deposits in or near these formations in a number of places in the Canadian Shield." Boyle (1979, p. 47). All iron formations in prospective areas should be investigated.

In addition to the two models of gold deposits there is also the possibility of volcanic-associated massive sulphide deposits described by Franklin, 1993. "At the "bottom" of VMS-producing systems are subvolcanic intrusions, which represent focussed heat sources that provided the energy for circulating hydrothermal fluids and leaching reactions. Immediately above these intrusions, the strata have undergone extensive high-temperature alteration, including metal depletion, extreme alkali modification, and silicification, Modern hydrothermal fluids have compositions consistent with water-rock reactions at about 400°C. In the immediate area of VMS deposits, major units of diachronous epiclastic breccia are evidence of local growth faults; these faults may be either rift-boundary master faults (in extensional regimes) or caldera-collapse ring faults. They were the principal conduits for high-temperature hydrothermal fluids. Alteration pipes that developed in the portions of these faults that immediately underlie the deposits are dominated by minerals formed through progressively heated, locally advected seawater. The zone where high-temperature metalliferous fluids reacted with the immediate substrata is limited to the cores of most pipes. The composition of the sulphide precipitates was controlled by water depth. Cooling through "boiling" caused the fluids to fractionate; those that emerged onto the sea floor in shallower water (<1500m) have precipitated copper in the zone of ascent, making them more zinc rich and, after extreme cooling, lead rich. Such shallow-water systems are also unusually gold and silver rich. Finally, "conservative" elements, such as barium and manganese, were precipitated distally to the deposits only in those oceans where bottom water was oxidizing. Chemosynthetic bacteria have always been important in fixing distal silica. (Franklin, 1993 p. 315)"

Some of the analytical samples contain anomalous cobalt. Most of the anomalous cobalt analysis are combined with other elements indicating volcanogenic massive sulfides. Franklin (1993) p. 321 describes some deposits in which sedimentary rocks are important, such as those at Sherridon, Manitoba. Some of this "group of deposits, such as Windy Craggy, have high (~1000ppm) Co contents."

RESEARCH METHODS USED

Field Sampling Introduction

"Ore-bearing clasts in till are undisputable evidence of bedrock mineralization" (Parent, 1996 p. 124). Where there is good drift exposure such as numerous gravel pits and/or road cuts, collection of mineralized clasts and analysis is a very cost effective method of evaluating area mineral potential. "Dispersal trains are produced when a glacier erodes and entrains clasts from a distinctive bedrock source, and then transports and deposits these debris over distances ranging from a few centimeters to several hundred kilometers. The significance to mineral exploration is that dispersal trains are several times larger than the ore bodies from which they derive and are thus much easier targets to recognize (Parent 1996, p. 124, quoting Shilts, 1976; DiLabio, 1989)."

While sampling clasts in shallow till with single episodes of glaciation has proven effective, mineral deposits under deeper till which have been subjected to more than one glacial advance are more difficult to detect. The eastern part of the study area has shallow till of the Rainy Lobe which advanced from the northeast. In the western part of the study area the till is deeper and has been subjected to the Rainy Lobe advance from the northeast, followed by the Koochiching Lobe from the northwest (Mooers, 1996). This is an ideal area to compare how mineralized clasts survive more than one glacial advance with those from a single glacial advance. It is also a good area to study the second dispersion effects on determining mineralized bedrock location.

A good description of this problem is provided by Saarnisto (1990) p. 9. He is quoting DiLabio (1988) "Debris eroded glacially from a distinctive source forms a dispersal train-an elongated cluster of clasts or till lens that is enriched in the distinctive component relative to the till underlying or enclosing it. Dispersal trains can be investigated with regard to their three-dimensional shapes and structure. Many trains are very thin in comparison to their length and width, so that T.W.L. ratios of the order of 1:200:1000 are common. The following characteristics can be helpful for the prospector. Firstly dispersal trains are much larger than their bedrock sources, making them easier targets to find. Secondly, they are usually straight and oriented parallel to the direction of ice flow, so they can be followed up-ice to the source. Thirdly, they climb gently (1° to 3°) in the down-ice direction. Fourthly, they are often very thin, which forces geologists to sample sections and drill cores at short intervals. ---

In a horizontal direction, boulder fans, the classic example of dispersal trains, characteristically coincide in orientation with the last or most pronounced direction glacial flow, occupying a sector of approximately 10° according to Salonen (1986), although this angle may be considerably wider if the fan is a product of a number of ice flows of varying orientation. Thus fans opening up to angles of as much as 90° have been described in eastern and northern Finland in particular."

To help identify the source of mineralized rock in the sample sites, a random sample of 100 pebbles was collected at each site by a mining aide. These were classified and generally combined to compare with the 1996, Geologic Map of Minnesota, Bedrock Geology, compiled by G.B., Morey.

Field Sampling Procedure

After obtaining permission to enter and sample the site a mining aide collected 100 pebbles or small cobbles about one inch in diameter for the lithologic sample. These samples were marked with the lithology sample numbers, noted in the field book and also entered on the site sample record. The location and description of the site was recorded in the field book and latter copied to field site sample records numbered 3180200001 to 3180200144. For the first sixty-five sample sites (1995 field season) the location was taken from U.S.G.S. 7.5 minute topographic maps. After that (1996 field season) a Global Positioning System, without differential corrections, was used for location. At least one picture was taken of the sample site that would present information on site size, depth of excavation and vegetation cover within the sample site. A second picture was taken displaying the size of clasts in site glacial deposits.

The site was searched for altered and mineralized rock. If found, a mineralized clast sample was collected. The mineralized samples were numbered consecutively one number for each site with mineralized rock. These mineralized sample numbers were entered in the field book and on site sample records. For each mineralized sample a description was written on the field site sample record or analytical sample records and open filed. After sample site sixty-five pictures were taken of the mineralized samples (this included a few earlier sites revisited in the 1996 field season). We learned that these pictures provide valuable support for the analytical work. Alteration and evidence of structure were written in the field book. At a number of pits a picture was taken displaying alteration or other unusual features. These pictures are open filed at the DNR, Division of Minerals, office in Hibbing, Minnesota. They are in a notebook titled PROJECT 318 Pictures of Gravel Pits.

A paper by Hattori (1987) suggests that magnetic felsic intrusions may be associated with Canadian Archean gold deposits. "Whereas felsic intrusive rocks, underlying large parts of Archean terrains, have generally low magnetic susceptibilities compared with surrounding mafic and ultramafic rocks, felsic intrusions associated with Archean gold mineralization are abnormally magnetic." The paper was disputed by Wahl (1988) and supported by Hattori in a comment and reply. If there is a spacial relationship between gold mineralization and elevated magnetic susceptibility in granites or silicification and depressed magnetic susceptibility in mafic volcanics this relationship might be observed by taking magnetic susceptibility measurements on boulders and correlating the data with analytical results. This data could then be combined with airborne magnetic surveys and might provide information on mineral deposit locations. Magnetic susceptibility measurements were taken on dominant lithologies particularly granites and mafic volcanics where available. The measurements were done with an Exploranium KT-5 magnetic susceptibility meter. At most sample sites several readings (ten or more were taken) usually two on each boulder. These were also recorded in the field book and numbered consecutively from 3180500001 to 3180500380. The table of magnetic susceptibilities for granites and mafic volcanics is included as Paradox digital file P318MAGS.

Sample Administration

The DNR Minerals Division, Mineral Potential and Information Services Sections use a ten digit number to classify various kinds of samples. The first three digits are the project number. The fourth and fifth digits are the sample type, the sixth through the tenth digits are the sequence number. The following descriptions explain the sample numbers used for Project 318:

3180000001-3180000115; (318) indicates the project number, (00) indicates mineralized clasts found at this site and sampled, (00001-00115) indicates the sequence of mineralized samples. Of the 144 sites investigated 115 had mineralized rock. The sample number was written on mineralized clast sample bags, included on site sample sheet, shown on pictures of mineralized clasts and written on analytical sample sheets.

3180100001-3180100165; (318) again indicates the project number, (01) indicates an analytical sample cut from mineralized clasts, (00001-00165) indicates 165 analytical samples were submitted for analysis including samples of mineralized clasts and reference samples. This sample record provides related sample numbers, the sample date, location information, U.S.G.S. quadrangle Map, the surface ownership, the site description, and a description of the sample that was analyzed.

3180200001-3180200144; (02) indicates sample site records, (00001-00144) The sample record describes the other sample numbers related to this site, the date when the sample was taken, the location, the U.S.G.S. quadrangle map where the site was found, the surface owner, the lithologies and alteration observed, the mineralized sample description if available and the site description. If mineralized clasts were found and sampled most of the information on this record is duplicated on the other records. Where no mineralized clasts were found the field book, lithologic sample record and this record are the sources of this information.

3180300001-3180300144; (03) indicates a lithologic sample, (00001-00144) indicates sequence of lithologic samples. The sample number was written on the sample bag and entered on the site sample record. Note only 140 of these samples were used because two of the samples were in the Boundary Waters Canoe Area Wilderness Mineral Management Corridor and two of the sample bags tore open and the sample pebbles were mixed.

3180400001; (04) indicates a thin section sample sheet for project (318) this sequence was left open for thin sections or other analytical methods and was not used.

3180500001-3180500380; (05) indicates magnetic susceptibility measurements. These measurements were entered in the field book and compiled into tables for the report.

Sampling for Analysis

Mineralized clast samples were broken up in the laboratory using a hammer or hydraulic core splitter. Analytical samples were composed of fragments most likely to contain economic minerals based on visual examination. For many samples (particularly those cut in 1996) the analytical sample was cut from a single boulder or mineralized lithology. About half of the analytical samples (particularly those cut in 1995) were taken from several mineralized rocks (up to five), and combined into one analytical sample. For each analytical sample a descriptive sample record has been compiled and open filed. If there was enough rock, samples of the mineralized rock were marked with the analytical sample number and the sample site number and also open filed. Analytical samples collected and cut in 1995 were not photographed. Analytical samples collected and cut in the 1996 field season were photographed. These photographs help determine whether the analysis was likely diluted by more than one kind of mineralization. In addition to the photographed analytical samples collected in 1996 a few samples from sites revisited, mineralized rock found in lithologic pebbles and attempts to duplicate some assay results were also photographed and sent for analysis. The photographs of the analytical samples are also on open file at the DNR, Division of Minerals, office in Hibbing, Minnesota. They are in a notebook titled PROJECT 318 ASSAY SAMPLES.

The 1995 samples were analyzed by Bondar Clegg, Inchcape Testing Services, Ottawa, Ontario, Canada. They were analyzed for twenty-one elements; gold, platinum, palladium, silver, lead, zinc, iron, barium, aluminum, titanium, manganese, vanadium, chromium, nickel, cadmium, copper, cobalt, arsenic, zirconium, yttrium and niobium. These elements, the analytical methods used, the reported units and detection limits are shown on Table 1. The sample analysis done by Bondar Clegg included samples 3180100001 - 3180100043, with 3180100032, 3180100042 and 3180100043 being reference samples supposedly containing 695, 145 and 300 ppb gold. Nine of the assays were duplicate, more than one analytical sample was cut from the mineralized sample taken from a sample site. This was done to confirm high metal content at a sample site and/or test another mineralized rock type. All the results are presented in Paradox digital files P318BC1 and P318BC2.

For 1996 another contract was bid and ACTLABS Incorporated of Wheat Ridge, Colorado did the analytical work. They analyzed for the

TABLE 1. BONDAR CLEGG NINETEEN ELEMENT ANALYTICAL PACKAGE PLUS PLATINUM AND PALLADIUM				
ELEMENT NAME	METHOD[1]	UNITS	LOWER DETECTION LIMIT	UPPER DETECTION LIMIT
Au	FA-30	PPB	5	10000
Ag	ICP	PPM	0.2	50
Pb	ICP	PPM	2	10000
Zn	ICP	PPM	1	20000
Fe	ICP	PCT	0.01	10
Ba	ICP	PPM	1	2000
Al	ICP	PCT	0.01	10
Ti	ICP	PCT	0.001	99.999
Mn	ICP	PPM	1	20000
V	ICP	PPM	1	20000
Cr	ICP	PPM	1	20000
Ni	ICP	PPM	1	20000
Cd	ICP	PPM	0.2	1000
Cu	ICP	PPM	1	20000
Co	ICP	PPM	1	20000
As	ICP	PPM	5	2000
Zr	XRF	PPM	1	20000
Y	XRF	PPM	1	20000
Nb	XRF	PPM	5	10000
Pd	FADCP	PPB	1	10000
Pt	FADCP	PPB	5	10000

FA-30 = Fire Assay 30 gram sample, ICP = Inductively Coupled Plasma Emission, XRF = X-ray Florescence (Fusion), FADCP = Fire Assay Direct Current Plasma Emission

following twenty-two elements and compounds; titanium oxide, aluminum oxide, iron oxide, manganese oxide, magnesium oxide, sodium oxide, potassium oxide, vanadium, chromium, cobalt, nickel, copper, zinc, barium, arsenic, antimony, molybdenum, cadmium, tungsten, lead, gold and silver. These elements, the analytical methods used, the reported units, lower detection limits and precision are shown on Table 2. The samples analyzed by ACTLABS are 3180100044-3180100164. These were sent in two groups: The first group are samples 3180100044-3180100159. Reference samples are 3180100153 (145 ppb Au), 3180100154 (145 ppb Au), 3180100155 (68 ppb Au), 3180100156 (68 ppb Au), 3180100157 (68 ppb Au), 3180100158 (145 ppb Au) and 3180100159 (145 ppb Au). In the sequence to be analyzed the reference samples were samples 1, 19, 40, 61, 82, 103 and 122. In the second group submitted for analysis there were five samples 3180100160-3180100164 with 3180100164 (the last sample) being a reference sample, 145 ppb gold. All the analytical results for Project 318 from ACTLABS are presented in PARADOX file P318AL1, P318AL2 and P318AL3. There is also digital file P318MCA and Table 3 in the report which display selected element analysis from both Bondar Clegg and ACTLABS that were used to help define Mineralized Clast Areas.

Nineteen pulps returned from Bondar Clegg were selected for analyses by ACTLABS for comparison of results. Both analytical package (Table 2) and Lead Fire Assays were used. These results are in digital files CABC&AL and CBC&ALFA. A random sample comparison of thirty-five assay results indicate ACTLABS analysis are forty-one percent higher than Bondar Cleggs. Sample 3180100024 had repeat gold contents of 5,365 and 5,040 ppb indicating no nugget effect.

Location of the Source of Mineralized Rock

Approximate location of the source of mineralized samples is indicated by: 1. Development of mineralized-altered boulder dispersal trains. Mapping mineralized-altered glacial clasts has been an important exploration tool in Canada and Finland. The book Glacial Indicator Tracing edited by Kujansuu and Saarnisto (1990) provides an excellent description of these methods. 2. The amount of mineralized rock at the sample site. 3. Definition of mineral deposit models from sample lithology, alteration, minerals and analytical data and comparison of the model lithology and structure with mapped geology up ice from anomalous samples. 4. Study of megascopically determined pebble lithology frequency distribution for randomly collected samples of 100 pebbles from each site which are grouped to match lithologic units so that they can be compared with mapped bedrock lithology (Morey 1996).

Inferred Geologic-Mineral Potential Maps in Preparation

Under contract with the Department of Natural Resources, the Minnesota Geological Survey is making an inferred geologic - mineral potential map from geophysical interpretations, 1:62,500

TABLE 2. ACTLABS INC. ACTIVATION LABORATORIES LTD, TWENTY-TWO ELEMENT ANALYTICAL PACKAGE NUMBER THREE				
ELEMENT NAME	METHOD[1]	UNITS	LOWER DETECTION LIMIT	PRECISION
TiO2	ICP	PERCENT	0.01%	15%
Al2O3	ICP	PERCENT	0.01%	15%
Fe2O3	ICP	PERCENT	0.01%	15%
MnO	ICP	PERCENT	0.01%	15%
MgO	ICP	PERCENT	0.01%	15%
Na2O	ICP	PERCENT	0.01%	15%
K2O	ICP	PERCENT	0.01%	15%
V	ICP	PPM	2 PPM	15%
Cr	INAA	PPM	5 PPM	15%
Co	INAA	PPM	1 PPM	15%
Ni	ICP	PPM	1 PPM	15%
Cu	ICP	PPM	1 PPM	15%
Zn	ICP	PPM	1 PPM	15%
Ba	ICP	PPM	5 PPM	15%
As	INAA	PPM	0.5 PPM	15%
Sb	INAA	PPM	0.2 PPM	15%
Mo	ICP	PPM	1 PPM	15%
Cd	ICP	PPM	0.5 PPM	15%
W	INAA	PPM	1 PPM	15%
Pb	ICP	PPM	2 PPM	15%
Au	INNA	PPB	2 PPB	15%
Ag	ICP	PPM	0.5 PPM	15%

[1]ICP = Inductively Coupled Plasma Emission, INNA = Instrumental Neutron Activation Analysis

scale, covering twenty-six contiguous townships in the western part of the study area (T60N-T63N, R21W-R26W, plus T64N, R25W-R26W). The area covered by this map is shown on Figure 1, The Index of Studies.

RESULTS

Interpretation of Analytical Results and Development of Mineralized Clast Areas (MCAs)

In geochemical work there is the need to develop threshold values for the various elements analyzed that provide a significant indication of mineral potential. Where there has been enough local sampling background values can be defined. The following example from Perrault, et al., 1984, p. 227, describes auriferous halos associated with the gold deposits at Lamaque Mine, Quebec. "The distribution of gold in host rocks on the Lamaque property (area 10 km^2) has been established with 141 samples. In about 10 percent of the area, the host rocks contain less than 3 ppb Au; this corresponds to normal gold contents in unmineralized greenstone belt igneous rocks (0.6-1.7 ppb Au). The 3 ppb Au contour line encloses a broad area believed to represent an ore field halo;--- The 10-ppb Au contour line envelops all known ore zones and defines ore-zone halos." This provides an idea of how analytical data in an area where detailed sampling has taken place and background values are established might help the exploration geologist. All the analytical samples collected for this project were altered mineralized rock. Therefore, none of the assays represent what might be considered background. For lode gold deposit models the work done by Perrault, et al., 1984 suggests that a gold content greater than 3 ppb in altered rock favorable for lode gold probably has enough significance to indicate more work is warranted. Because we are analyzing mineralized glacial clasts these values cannot be thought of as enclosing ore zones although they might represent an ore zone halo somewhere up-ice from the sample site.

Another approach is to use published data that describes abundances of elements in common rock types and consider analysis above the upper range of these abundances as significant. Two publications that describe these abundances are Rose, et. al. (1979) p. 549-581 and Govett, editor (1983, pp. 390-393). Table 3, (page 19) summarizes the upper range (the threshold) of these abundances for some elements commonly used to define lode gold, iron formation hosted gold and VMS deposits. These thresholds are combined as much as possible to correlate with the lithologic units and structures mapped in the study area Morey (1996). Three or four sites with analysis below these thresholds were included as Mineralized Clast Areas if they had elevated mineral content, favorable alteration, lithology and/or structure.

Combined anomalous analysis of pathfinder minerals, descriptions of observed alteration and local bedrock geology are used to make random groupings of sample sites called Mineralized Clast Areas. These areas should provide a reasonable basis for comparing this area's mineral potential with other areas which might be explored. Figure 3, page 20 displays the mineralized clast areas (MCAs) and Table 4, pages 21-24 lists the results used to describe mineralized clast areas. The digital file for this table is Paradox table P318MCA. Complete analytical results are found in Paradox digital files: P318BC1; P318BC2; P318AL1; P318AL2 and P318AL3. All of the analyzed samples are altered and many show structural deformation. Observed alteration minerals include: Sulfides; pyrite, pyrrhotite and chalcopyrite; Carbonate; both calcite and ankerite; Silicification, mostly quartz veining; Sericite; biotite, and

Table 3. PROJECT 318 THRESHOLD VALUES FOR SIGNIFICANT ANALYTICAL RESULTS, Rose, et al. (1979) Govet (Editor, 1983)

Element	Mafic Volcanics	Mixed Meta Volcanics	Mafic Intrusive	Granite	Metamorphic Mica Schist
Au ppb	3.2	4.5	3.2	2.3	
Ag ppm	0.1	0.2	0.005	0.05	0.3
Pt ppb	30	8.2	30	8.2	
Pd ppb	21	2	21	2	
Pb ppm	18	56.1	10.2	31.2	30
Zn ppm	120	89	154	85	
Ba ppm	675	830	613	1,870	1,000
Ni ppm	15.8	16	530	5.1	50
Cu ppm	160	34	50	12	30
Co ppm	43	7	50	6	20
As ppm	2.5	4.8	2.5	2	

albite. Observed structural features include folding, brecciation and shearing. Anomalous gold values ranged up to 3,598 ppb, usually with arsenic values up to 1,900 ppm. High base metal values include zinc to 2,899 ppm, copper to 14,944 ppm, nickel to 3,126 ppm and lead to 248 ppm. Barium ranged to 1,980 ppm. It is likely that many of the analyzed samples represent mineralized halos around ore deposits and one sample 3180100024, Site 57, MCA-3, 3,598 ppb Au, might represent an ore zone, we think the mineralization in this sample was diluted by combining mineralized clasts from the sample site.

Discussion Mineralized Clast Areas (MCAs) 1, 2, 8 and 17

These MCAs are in the eastern part of the study area. Glacial drift

Figure 3 MINERALIZED CLAST AREAS

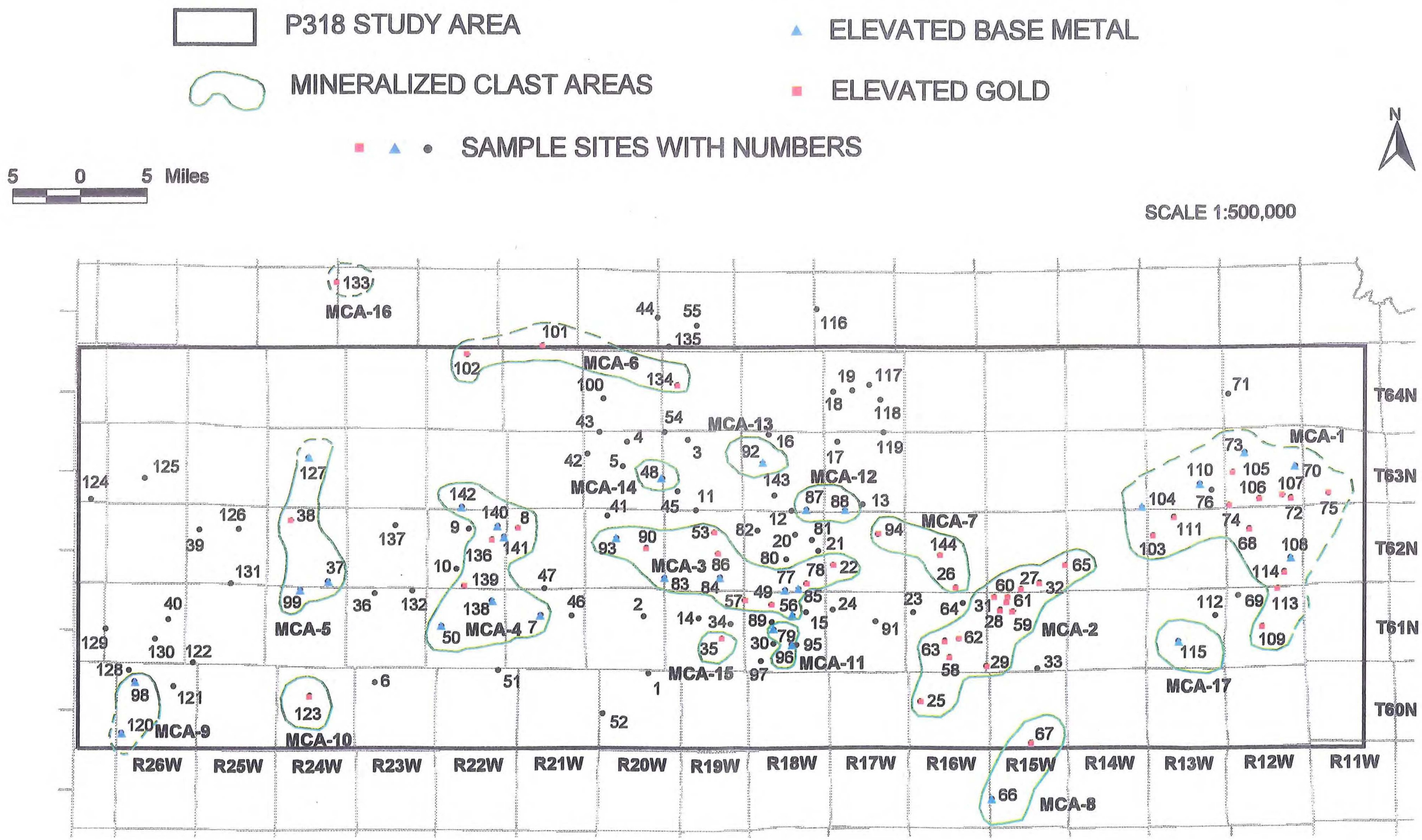


Table 4. PROJECT 318 MINERALIZED CLAST AREAS FROM ALTERATION AND ANALYSIS

MCA #	Site #	Alteration	Sample id	Au ppb	Pt ppb	Pd ppb	Ag ppm	Pb ppm	Zn ppm	Fe pct	Ba ppm	Mn pct	Ni ppm	Cd ppm	Cu ppm	Co ppm	As ppm
1	68	Qtz-Py	3180100051	82			2.4	-2	-1	14.26	93	0.25	9	-0.5	240	34	47
1	68	Py	3180100052	-2			-0.5	-2	63	15.98	70	0.24	21	-0.5	767	35	2
1	68	Py	3180100053	-2			-0.5	3	22	9.17	92	0.25	9	-0.5	21	13	11
1	70	Qtz-Py	3180100054	15			-0.5	21	2624	7.28	238	0.04	7	5.4	445	20	9
1	70	Qtz-C-Py	3180100055	13			-0.5	5	-1	11.22	80	0.11	14	-0.5	48	22	12
1	72	Qtz-Sul	3180100056	7			-0.5	23	2899	19.44	-5	0.53	12	3.7	223	160	1.4
1	72	Sul-Ars	3180100057	100			6.0	123	268	31.89	52	0.02	29	0.6	418	81	150
1	72	Qtz-Py	3180100058	-2			-0.5	-2	72	6.08	49	0.06	3	3.6	418	3	4.1
1	72	Qtz-Py	3180100059	6			-0.5	3	-1	4.61	-5	-0.01	8	0.9	283	14	96
1	73	Py	3180100060	23	16.8	19.1	-0.5	-2	303	14.52	151	0.30	62	-0.5	509	54	0.5
1	73	Qtz-Py	3180100061	7			-0.5	-2	120	23.44	-5	0.39	15	-0.5	61	8	4.2
1	74	Ars-Py	3180100062	60			-0.5	26	-1	13.99	-5	0.31	8	0.6	117	10	99
1	74	Hem-Py	3180100063	-2			-0.5	-2	192	9.02	50	0.19	12	-0.5	466	28	4.7
1	75	Hem-Py	3180100064	3			-0.5	16	-1	26.43	-5	0.03	6	-0.5	41	25	74
1	75	Qtz-CuS	3180100065	33			2.4	-2	91	17.72	113	0.06	59	-0.5	4254	64	26
1	103	Qtz-C-Py	3180100101	50			0.8	18	9	10.58	18	-0.01	13	7.6	26	14	280
1	103	Qtz-CuS	3180100102	6			-0.5	-2	50	19.79	99	0.18	48	-0.5	2114	190	3.5
1	103	Qtz-Py	3180100103	5			-0.5	6	54	27.14	79	0.21	7	-0.5	626	170	5.6
1	104	Qtz-C-Py	3180100104	6			-0.5	-2	75	6.71	1476	0.12	35	4.8	65	24	150
1	105	Qtz-CuS	3180100105	6	7.9	6.7	-0.5	-2	173	9.52	213	0.15	52	-0.5	338	53	-0.5
1	105	Qtz-Py	3180100106	17			2.0	31	96	12.10	130	0.18	13	-0.5	92	45	17
1	106	Qtz-Fe	3180100107	57			-0.2	11	91	9.59	23	0.03	12	0.8	76	11	30
1	107	Ars-CuS	3180100108	80			4.8	134	135	28.67	5	0.02	155	4.1	298	190	190
1	107	Qtz-Py	3180100109	31			-0.5	4	85	20.02	11	0.05	11	-0.5	183	14	19
1	107	Qtz-CuS	3180100110	304			2.0	16	75	25.38	11	1.06	26	-0.5	181	36	25
1	107	Qtz-Py	3180100111	47			-0.5	11	3	5.68	7	-0.01	1	1.8	52	4	68
1	108	Py-Ars	3180100112	99			2.8	72	750	22.95	8	0.01	19	3.6	275	320	150
1	109	Py	3180100113	13			1.5	14	45	16.18	44	0.20	6	-0.5	23	6	30
1	110	Qtz-Py	3180100114	-2			-0.5	10	109	5.32	774	0.07	33	-0.5	136	22	-0.5
1	110	Qtz-CuS	3180100115	7			-0.5	17	345	14.04	185	0.09	133	-0.5	690	110	3
1	110	Py	3180100116	23			-0.5	78	127	45.27	16	0.25	134	-0.5	128	49	24
1	110	Qtz	3180100117	-2			-0.5	2	15	1.07	131	0.02	5	-0.5	288	2	0.5
1	111	Py	3180100118	-2			-0.5	-2	22	2.69	272	0.02	20	-0.5	56	17	20
1	111	Qtz-Sul	3180100119	75			1.2	66	189	12.30	51	0.01	15	2.0	136	23	100
1	111	Qtz-Sul	3180100120	33			2.0	-2	133	12.49	86	0.33	26	0.8	189	23	47
1	111	CuS	3180100121	2	13	12.8	-0.5	-2	24	17.62	-5	0.08	-1	-0.5	2	58	2.6
1	113	Qtz-Py	3180100123	20			-0.5	-2	50	10.13	172	0.11	294	-0.5	332	4	16
1	114	Qtz-Py	3180100124	-2			-0.5	-2	5	9.27	7	-0.01	-1	-0.5	-1	38	7.2
1	114	Fe-Py	3180100125	6			-0.5	2	33	10.86	37	0.01	-1	-0.5	131	2	6.7
2	25	Qtz-Py	3180100008	39	-5	-1	5.7	56	10	0.70	29	0.01	20	-0.2	131	5	-5
2	27	Qtz-Py	3180100010	49	-5	-1	0.5	16	42	+10.00	15	0.02	11	-0.2	14	8	99
2	28	Qtz-Py	3180100011	5	-5	-1	0.7	105	70	5.63	9	0.03	19	-0.2	23	7	23
2	28	Qtz-Py	3180100012	116	-5	-1	0.3	7	26	7.88	11	-0.01	5	0.3	29	1	497
2	28	Qtz-Py	3180100033	19	-5	-1	.6	6	16	2.74	6	-0.01	27	-.2	32	12	23
2	29	Qtz-Py	3180100013	35	-5	2	0.8	9	41	7.47	16	0.02	25	-0.2	491	6	12
2	31	Qtz-Py	3180100015	34	-5	-1	2.5	13	26	6.80	3	-0.01	28	-0.2	53	4	46
2	32	Qtz-Py	3180100016	15	-5	-1	0.7	17	26	+10.00	10	0.10	20	-0.2	45	12	86
2	32	Qtz-Py	3180100047	29			0.8	8	363	9.60	12	0.02	9	4.3	228	28	380
2	58	Qtz-Py	3180100025	9	-5	-1	0.5	4	12	4.27	13	0.03	12	-0.2	342	12	-5
2	59	Qtz-Py	3180100026	15	-5	-1	1.0	13	26	8.04	6	0.02	31	-0.2	33	9	41

Alteration: Secondary Quartz-Qtz, Copper Sulphides-CuS, Pyrite-Py, Hematite-Fe, Carbon (Ankerite)-C, Arsenopyrite-Ars, Suphides Mixture (Pyrite & Chalcopyrite)-Sul, Muscovite or Sericite-K

Table 4. PROJECT 318 MINERALIZED CLAST AREAS FROM ALTERATION AND ANALYSIS

MCA #	Site #	Alteration	Sample id	Au ppb	Pt ppb	Pd ppb	Ag ppm	Pb ppm	Zn ppm	Fe pct	Ba ppm	Mn pct	Ni ppm	Cd ppm	Cu ppm	Co ppm	As ppm
2	60	Qtz-Sul	3180100027	56	-5	-1	0.5	13	51	+10.00	8	0.03	34	-0.2	33	10	39
2	61	Qtz-Ars	3180100028	131	-5	-1	1.8	21	28	+10.00	8	-0.01	61	-0.2	90	18	78
2	61	Qtz-Py	3180100039	35	-5	-1	1.6	19	187	8.58	5	0.02	65	-.2	63	19	45
2	62	Qtz-Sul	3180100029	472	-5	1	1.8	11	54	7.92	22	0.07	79	-0.2	43	22	-5
2	62	Qtz-C-Py	3180100040	246	-5	1	2.2	9	37	7.06	20	0.05	37	-.2	32	15	-5
2	63	Qtz-Py	3180100030	13	-5	-1	-0.2	18	35	6.65	28	0.07	44	-0.2	103	26	26
2	65	Qtz-CuS	3180100031	30	-5	1	1.6	26	85	+10.00	4	0.04	30	-0.2	2262	77	15
2	65	Qtz-CuS	3180100043	60	-5	1	3.4	41	62	+10.00	4	0.03	48	-.2	2359	122	16
3	22	Qtz-C-Py	3180100006	-1	-5	-1	-0.2	7	21	1.38	61	0.03	8	-0.2	54	4	40
3	49	Qtz-C-Py	3180100021	408	-5	-1	1.5	12	50	2.80	57	0.08	37	-0.2	31	13	18
3	49	Qtz-C-Py	3180100036	183	-5	-1	1.4	12	63	3.66	108	0.08	48	-.2	31	17	17
3	53	Qtz-Py	3180100022	11	-5	-1	-0.2	15	48	2.20	55	0.12	38	-0.2	30	11	-5
3	56	Qtz-C-Py	3180100023	-1	-5	-1	-0.2	7	19	1.28	39	0.06	16	-0.2	252	7	-5
3	57	Qtz-Ars	3180100024	3598	-5	14	116	30	61	7.39	40	0.03	16	-0.2	72	10	13
3	57	Qtz-Py	3180100037	8	8	1	.3	11	55	3.04	120	0.03	31	-.2	72	14	-5
3	57	Mn	3180100038	3	-5	-1	.6	9	28	8.47	454	0.62	44	-.2	34	26	32
3	77	Qtz-Py	3180100066	-2			-0.5	3	-1	3.70	-5	0.01	32	-0.5	14944	3	1.4
3	77	Py	3180100067	-2			-0.5	-2	19	6.26	738	0.06	35	-0.5	138	20	3
3	78	Qtz-Py	3180100068	-2			-0.5	-2	-1	3.41	494	0.02	14	-0.5	41	9	7
3	78	Qtz-C-Py	3180100069	6			-0.5	4	25	8.57	29	0.02	21	-0.5	119	4	32
3	78	Qtz-Py	3180100070	-2			-0.5	-2	58	5.24	140	0.14	44	-0.5	109	11	-0.5
3	83	Qtz-C-Py	3180100074	-2			-0.5	14	50	5.45	459	0.07	84	-0.5	170	36	-0.5
3	83	Qtz-C-Py	3180100075	5			-0.5	-2	14	3.55	1980	-0.01	11	3.1	9	5	110
3	84	Qtz-Py	3180100076	-2			-0.5	75	154	11.09	518	0.12	72	0.8	153	35	-0.5
3	85	Qtz-Py	3180100077	-2			-0.5	6	63	10.97	238	0.14	38	-0.5	517	17	9.6
3	86	Qtz-Py	3180100078	13			-0.5	159	57	9.31	52	0.03	25	0.9	94	46	80
3	86	Qtz-Py	3180100079	-2			-0.5	28	35	2.67	213	0.02	33	-0.5	36	7	4.5
3	90	Qtz-Py	3180100083	9			-0.5	13	82	4.79	713	0.12	41	-0.5	28	14	38
3	93	Qtz-Py	3180100086	68			-0.2	-2	36	3.79	348	0.02	25	-0.5	18	7	-0.5
3	93	Qtz-Py	3180100087	-2			-0.5	-2	43	4.86	971	0.23	36	-0.5	51	12	-0.5
4	7	Qtz-Py	3180100001	3	-5	-1	0.5	11	38	7.30	16	0.10	30	-0.2	379	25	-5
4	8	Qtz-Py	3180100002	3	-5	-1	-0.2	11	52	+10.00	14	0.10	46	-0.2	85	39	-5
4	8	Qtz-Sul	3180100003	51	-5	-1	0.3	3	6	4.28	4	-0.01	10	-0.2	544	44	-5
4	8	Qtz-Py	3180100034	47	-5	1	.7	4	7	4.28	5	-0.01	13	-.2	94	44	-5
4	50	Qtz-Py	3180100046	-2			-0.5	-2	-1	2.44	685	-0.01	7	0.7	30	8	3.2
4	136	Qtz-Py	3180100139	9			-0.5	-2	231	10.97	44	0.16	457	-0.5	122	45	4.3
4	138	Qtz-CuS	3180100140	9			-0.5	102	168	2.28	809	0.03	170	1.8	21	61	-0.5
4	139	Qtz-CuS	3180100141	12			-0.5	248	41	37.76	12	-0.01	549	4.1	610	24	73
4	140	Py	3180100142	10			-0.5	2	171	11.61	448	0.11	193	-0.5	261	27	-0.5
4	141	Qtz-Sul	3180100143	-2			-0.5	59	850	11.67	59	0.07	329	0.8	791	72	7.2
4	141	Qtz-CuS	3180100148	31			2.4	5	174	17.43	119	0.41	91	-0.5	638	92	-0.5
4	142	Qtz-Py	3180100149	-2			-0.5	9	157	27.18	21	0.01	82	-0.5	116	23	18
5	37	Qtz-Py	3180100018	2	-5	-1	-0.2	13	1292	9.87	33	0.08	18	4.5	133	28	-5
5	37	Qtz-Py	3180100035	12	-5	1	.8	15	901	9.13	48	0.07	24	3.4	156	25	-5
5	37	Py	3180100160	-2			-0.5	33	43	11.90	310	0.03	99	3.2	96	40	-0.5
5	37	Qtz-C-Py	3180100161	63			3.3	119	22	3.70	170	-0.01	7	1	32	2	57
5	37	Qtz-Py	3180100162	5			-0.5	20	364	13.47	200	1.76	20	8	78	12	23
5	37	Qtz-C-Py	3180100163	14			7.6	17	70	7.72	112	0.16	16	2	244	19	2.4
5	38	Qtz-Sul	3180100133	17			-0.5	4	15	5.13	447	0.01	197	-0.5	21	29	47

Alteration: Secondary Quartz-Qtz, Copper Sulphides-CuS, Pyrite-Py, Hematite-Fe, Carbon (Ankerite)-C, Arsenopyrite-Ars, Suphides Mixture (Pyrite & Chalcopyrite)-Sul, Muscovite or Sericite-K

Table 4. PROJECT 318 MINERALIZED CLAST AREAS FROM ALTERATION AND ANALYSIS

MCA #	Site #	Alteration	Sample id	Au ppb	Pt ppb	Pd ppb	Ag ppm	Pb ppm	Zn ppm	Fe pct	Ba ppm	Mn pct	Ni ppm	Cd ppm	Cu ppm	Co ppm	As ppm
5	99	Qtz-C-Py	3180100092	-2			-0.5	-2	43	2.48	103	0.08	23	-0.5	99	8	1.6
5	99	Qtz-Py	3180100093	-2			-0.5	-2	52	8.15	712	0.06	15	0.6	218	37	13
5	99	Py	3180100094	-2			-0.5	4	168	7.10	518	0.10	51	0.5	63	16	8.3
5	127	Qtz-Py	3180100134	2	-0.1	-0.1	-0.5	-2	93	10.46	209	0.06	1073	-0.5	545	12	3.3
6	101	Qtz-Py	3180100098	-2			-0.5	-2	90	10.96	455	0.06	43	-0.5	328	40	-0.5
6	102	K	3180100099	-2			-0.5	12	13	0.57	51	0.01	-1	-0.5	7	-1	0.8
6	102	Qtz-Py	3180100100	-2			-0.5	-2	99	7.11	633	0.08	11	-0.5	1339	24	-0.5
6	134	Py	3180100138	3			-0.5	12	787	6.65	57	0.06	473	-0.5	83	11	-0.5
7	26	Qtz-Sul	3180100009	13	-5	-1	-0.2	4	12	1.10	48	0.02	19	-0.2	11	10	-5
7	94	Qtz-C-Py	3180100088	12			-0.5	-2	57	7.87	90	0.16	59	28.9	237	19	1900
7	144	Qtz-Py	3180100150	-2			-0.5	-2	10	5.09	-5	-0.01	6	1.5	29	4	100
7	144	Qtz-Py-K	3180100151	98			1.2	5	33	9.52	271	0.02	35	1.5	75	22	120
8	66	Qtz-Sul	3180100044	-2			-0.5	-2	76	14.31	113	0.11	34	-0.5	321	59	2
8	66	Qtz-Py	3180100045	3			-0.5	-2	18	15.11	22	0.02	4	-0.5	34	3	6.7
8	66	Qtz-C-Py	3180100048	2			-0.5	12	-1	7.01	16	-0.01	7	-0.5	29	3	15
8	66	Qtz-Py	3180100049	7			-0.5	8	-1	9.13	373	0.06	16	-0.5	211	35	7.3
8	67	Qtz-Py	3180100050	-2			-0.5	11	-1	15.60	-5	0.36	11	-0.5	321	9	1.5
8	67	Py-CuS	3180100152	22			2.0	-2	69	9.77	129	0.10	9	-0.5	2023	22	5.9
9	98	Qtz-CuS	3180100090	-2			-0.5	-2	83	10.17	90	0.10	36	-0.5	921	24	-0.5
9	98	Qtz-Py-K	3180100091	-2			-0.5	13	85	12.15	314	0.21	102	-0.5	203	40	5.7
9	98	Qtz-K	3180100095	-2			2.7	44	70	1.57	108	0.02	19	-0.5	53	-1	1.1
9	120	Py	3180100129	-2			-0.5	-2	150	2.48	369	0.06	-1	-0.5	-1	15	81
9	120	Qtz-Py	3180100130	-2			-0.5	127	221	10.40	105	0.16	144	2.7	22	7	5.3
10	123	Qtz-Sul	3180100131	28			1.2	-2	151	6.94	392	0.11	272	5.1	57	19	130
10	123	Qtz-Py	3180100132	229			1.6	11	71	24.18	21	0.11	510	1.3	90	30	260
11	79	Qtz-Py	3180100071	3			-0.5	-2	41	12.58	557	0.18	11	-0.5	123	5	2.1
11	79	Qtz-Py	3180100072	7			-0.5	-2	33	3.36	227	0.07	49	-0.5	95	8	2.6
11	96	Qtz-Py	3180100089	7			-0.5	-2	39	1.73	765	0.01	20	-0.5	34	4	1.8
12	87	Qtz-Py	3180100080	-2			-0.5	-2	22	4.47	1212	-0.01	63	-0.5	12	3	-0.5
12	88	Py	3180100081	-2			-0.5	-2	98	5.98	527	0.06	66	-0.5	15	20	2
12	88	Qtz-Py	3180100082	-2			-0.5	12	105	3.55	290	0.03	48	-0.5	146	19	1.9
13	92	Qtz-C-Py	3180100084	-2			-0.5	22	57	3.07	480	0.04	85	-0.5	74	11	3.5
13	92	Qtz-CuS	3180100085	-2			-0.5	16	122	8.22	363	0.10	158	-0.5	104	41	-0.5
14	48	Qtz-C-Py	3180100144	-2			-0.5	52	232	4.61	273	0.04	413	-0.5	41	20	1.8
14	48	C-Py	3180100145	-2			-0.5	-2	53	6.40	37	0.02	-1	-0.5	18	25	-0.5
14	48	Qtz-Py	3180100146	20	15.6	21.7	-0.5	-2	295	17.95	33	0.29	3126	-0.5	354	70	1
14	48	Qtz-Py	3180100147	122			-0.2	-2	-1	3.05	41	-0.01	5	0.7	15	6	1.7
15	35	Qtz-Py	3180100017	7	-5	-1	0.7	33	37	+10.00	16	0.04	44	-0.2	261	23	9
16	133	Qtz-Sul	3180100137	-2			-0.5	6	37	3.67	1724	0.03	102	0.5	54	10	-0.5
17	115	Qtz-Py	3180100127	4			-0.5	10	26	1.49	583	0.02	-1	-0.5	28	2	8.7

Alteration: Secondary Quartz-Qtz, Copper Sulphides-CuS, Pyrite-Py, Hematite-Fe, Carbon (Ankerite)-C, Arsenopyrite-Ars, Suphides Mixture (Pyrite & Chalcopyrite)-Sul, Muscovite or Sericite-K

Table 4. PROJECT 318 MINERALIZED CLAST AREAS FROM ALTERATION AND ANALYSIS

MCA #	Site #	Alteration	Sample id	Au ppb	Pt ppb	Pd ppb	Ag ppm	Pb ppm	Zn ppm	Fe pct	Ba ppm	Mn pct	Ni ppm	Cd ppm	Cu ppm	Co ppm	As ppm
	10	Qtz-Py	3180100004	4	-5	-1	-0.2	26	48	2.95	37	0.11	22	-0.2	18	7	6
	14	Qtz-C	3180100005	-1	-5	-1	-0.2	4	10	0.61	8	0.01	8	-0.2	12	3	-5
	23	Sul	3180100007	-1	-5	-1	-0.2	10	49	5.78	29	0.05	19	-0.2	21	5	-5
	43	Qtz-Py	3180100019	1	-5	-1	-0.2	4	10	1.27	44	-0.01	8	-0.2	19	4	-5
	45	Qtz-Py	3180100020	2	-5	4	-0.2	11	56	5.20	41	0.04	56	-0.2	52	69	-5
	45	Qtz-Py	3180100020	-1	-5	3	-0.2	12	58	5.53	45	0.04	60	-0.2	42	73	-5
	82	Qtz-Py	3180100073	-2			-0.5	-2	36	4.74	108	0.22	65	-0.5	58	4	2.3
	100	Py	3180100096	3			-0.5	24	38	2.94	59	0.02	10	-0.5	83	6	-0.5
	100	Qtz-Py	3180100097	-2			-0.5	-2	121	7.14	144	0.77	7	-0.5	76	10	-0.5
	112	Qtz-Py	3180100122	-2			-0.5	-2	88	4.96	124	0.09	-1	-0.5	41	2	-0.5
	115	Qtz-Sul	3180100126	-2			-0.5	-2	20	8.84	26	0.08	-1	-0.5	4	7	1.2
	119	Qtz-Py	3180100128	-2			-0.5	65	18	29.23	12	-0.01	421	1.2	-1	3	1.7
	128	Qtz-Py	3180100135	-2			-0.5	-2	96	7.35	289	0.09	113	-0.5	96	46	-0.5
	132	Qtz-Py-K	3180100136	-2			-0.5	3	16	4.55	100	0.02	-1	-0.5	84	18	12

Alteration: Secondary Quartz-Qtz, Copper Sulphides-CuS, Pyrite-Py, Hematite-Fe, Carbon (Ankerite)-C, Arsenopyrite-Ars, Suphides Mixture (Pyrite & Chalcopyrite)-Sul, Muscovite or Sericite-K

is shallow in this area (Olsen and Mossler, 1982 and Southwick, 1993). The glacial till is from the Rainy Lobe (Mooers, 1996) which traversed the area from the northeast to the southwest (Lehr and Hobbs, 1992). An overlay of faulting in the area (Morey, 1996) shows a close relationship between mineralized sample site locations and northeast-southwest trending faults, although there is boulder train dispersal in the pattern. In his description of the Soudan Mine Klinger, (1956, p. 132-134) writes, "The ore is cut by faults and fractures and in places is brecciated. At least one of these post-ore faults is mineralized by pyrite." Project 265 Soudan Mine Sampling Project, (Dahlberg, et al., 1989) sampled core from the Soudan Mine. They reported a number of assays with gold pathfinder element contents similar to those found in this project. Their descriptions of lithologies and alteration are also similar to those of gold deposit models. There are numerous mineralized rocks in the northern part of area MCA-1 indicating short travel distance to bedrock mineralization. In the southern part fewer mineralized rocks were found possibly indicating a longer travel distance.

Mineralized Clast Area 1 (MCA-1) Figure 3 and Table 4 is the largest area of contiguous sample sites displaying mineralized clasts. Many of the samples have analysis suggesting lode gold model characteristics while others indicate VMS deposits. For several sites both models would be appropriate. Site 104 is labeled a VMS site based on the high barium analysis, but this could be a lode gold site from faulting in granites to the north, Boyle (1979, p. 125). There are also some anomalous nickel assays in the area considering mapped lithologies where the samples were taken. However, they might result from mafic intrusions (dikes) and therefore would not be anomalous. There are complex structures in MCA-1 and many of the sample sites correlate with these structures and favorable lithologies. Some of the sites probably relate to Rainy Lobe boulder trains which would help in finding bedrock sources of the mineralization. Site 114 is analytically weakly anomalous and is located between sites which are clearly anomalous and is therefore included in MCA-1.

Mineralized Clast Area 2 (MCA-2) could be an extension of the northwest limb of MCA-1, T62N-R14W was not sampled because there were active leases in this township. Northeast of the mineralized sample sites of MCA-2 are the folded, faulted, Archean, Ely greenstone (Amv) which includes the Soudan Iron Formation. The Vermilion Fault and Mud Creek Shear zone traverse the area. The lithologies, structures and described alteration are very similar to those hosting Canadian lode gold deposits. MCA-2 is composed of mineralized samples with analytical results indicating lode gold deposits, also observed alteration and descriptions are characteristic of lode gold mineralization models. The shape and trend of the mineralized clast area suggests a boulder train with a dispersal pattern following the course of the Rainy Lobe till. The axial orientation of MCA-2 (N45°E) coincides with the orientation of the Waasa fault in T60-61N, R13-14W. It also coincides with the mineralized footwall of the Duluth Complex, T59-62N, R11-15W (Severson and Hauck, 1994). If the boulder train is following a fault there may be mineralization along the fault contributing to the boulder train. The picture of the mineralized boulder on page 32, Pictures of Gravel Pits, sample site 61, is typical of observed alteration and mineralization in this MCA.

MCA-17, Site 115 has elevated Au, As and Ba analysis although not anomalous by the criteria listed in Table 3. It is included as an MCA because sample 3180100127 is described as a cherty iron formation with disseminated sulfides. The axial trend of MCA-8 appears to follow that of MCA-2 and these sites are also in Rainy Lobe glaciation. The mineral sample picture for site 67 analysis, (3180000052) page 35 shows brecciated, silicified rock. In working with the lithologic sample rocks a fine grained diorite shot with sulfides, pyrite and some chalcopyrite was found and assayed. This is analytical sample 3180100152, it has a Cu value of 2,023 ppm and Au 22 ppb.

Mineralized Clast Areas 3, 7, 11, 12, 13, 14 and 15

Northwest of MCA-2 there is a change in the orientation of the mineralized clast areas. There is probably considerable influence from the direction of ice movement of the Kootchiching Lobe, northwest to southeast. The orientation also appears to be related to local geology particularly the northwest-southeast and east-west strike of dominant faulting: the Mud Creek Shear Zone, Vermilion Fault and the Bear River Fault correlate with many anomalous sample sites. The location of a number of granitoid intrusions; the Rice River Pluton, Cook Airport Pluton, Lost Lake Pluton and Daisy Bay Pluton are also related to area mineralization. Also there are Favorable lithologic units for mineralization; felsic tuffs, flows and volcanoclastics, mafic volcanics in fault contact with metasediments (Morey, 1996, Jirsa, et al., 1991 and Southwick, 1993). In MCA-3 and MCA-7 the sites with anomalous gold appear related to: The small pluton on the Bear River Fault; The Mud Creek Shear Zone with associated Rice River Pluton; The Cook Airport Pluton and Daisy Bay Pluton and associated Mud Creek Shear Zone. Sample 3180100024, Site 57, MCA-3, assayed 3,598 ppb gold with the sample site two miles south of the Cook Airport Pluton and about 1.25 miles south of the Mud Creek Shear Zone. In the southern part of MCA-3 and MCA-11 the base metal anomalies appear related to the felsic tuffs and volcanics of the lft unit (Southwick, 1993). MCAs 12, 13 and 14 are base metal anomalies although MCA-14 could easily be classed as a gold anomaly (sample 3180100147 Au 122 ppb). MCA-12 has elevated, although not above threshold barium and copper. The three samples display deformation and alteration with silicification and sulfides and would fit the VMS model. There doesn't appear to be much glacial dispersion even though MCAs 3, 14 and 15 were glaciated by both the Rainy Lobe and Koochiching Lobe.

On Mooers Landform Assemblage Map there is a thin band of Rainy Lobe glacial deposits which follows the edge of the "Scoured Bedrock Uplands" unit. To the southwest are Koochiching Lobe glacial deposits. This band has about the same attitude as major faults in the area. An overlay of the Mineralized Clast Areas map on Mooers Landform Assemblage Map shows MCAs 7, 12, 13 and the two eastern sites of MCA-6 are on or very close to this feature. Site 87 of MCA-12 has elevated barium but does not meet the threshold criteria listed in Table 3. Sample 3180100080 is described as a quartz diorite porphry with pyritic quartz veins and disseminated pyrite which indicates it is of interest.

Mineralized Clast Areas 4, 5, 9 and 10

These MCAs are in the western part of the study area. There is a north-south trend to mineralized clast areas. In these Mineralized Clast Areas most of the site anomalies are base metal anomalies although some of the sites like 37 could be either base metal or gold. It is likely that base metal MCAs would be related to felsic centers rather than structure. MCA-4 is closely related to the Linden and Morcom Plutons with sedimentary and felsic volcanic units (Southwick, 1993 and Morey, 1996). The Deer Creek and Bear River Faults would provide favorable structure for indicated gold deposits. Site 141, MCA-4 is shown as a base metal site because of high copper and zinc, but one sample contains 31 ppb gold, and the site is just south of the Deer Creek Fault jmv/jms mafic volcanics/sedimentary and felsic volcanics contact, where the fault hits the Linden Pluton (Southwick, 1993). For MCA-5, site locations near the Coon Lake and Effie Pluton, along with the Deer Creek Fault probably determine the location of the gold anomalies. The base metal anomalies are located in favorable lithologic units except for Sites 98 and 120 which are located on the mapped Bello Lake Pluton. It is possible these clasts were moved onto the pluton by Rainy Lobe and Koochiching Lobe ice. It is likely the shape and orientation of MCA 4 and 5 would change if there were more sample sites available. Again Site 50 does not have analytical criteria that would indicate an MCA. It does have elevated barium and sample 3180100046 is described as dacite shot with quartz veins and sulfides and is therefore included in the MCA.

Mineralized Clast Areas 6 and 16

The sample sites are all north of the Vermilion Fault. Three of the sites are on Morey's Agm unit which is granite-rich migmatite with one site on paragneisses and schist-rich migmatite Asm. At MCA-16 there is 1,724 ppm Ba without base metal support. The analytical sample is described as a "Brecciated dacite porphyry with vugs and veinlets filled with fine and medium sulfides, pyrite, chalcopyrite, and arsenopyrite, also brecciated quartz veins, with fine gray sulfides." The analysis shows 3.67% Fe which suggests pyrite and 54 ppm Cu which indicates some chalcopyrite. Boyle, (1979, p. 125) describes barium as a pathfinder for hypogene gold deposits particularly where the veins occur in intermediate igneous rocks (syenite, granodiorite).

Anomalous elements for the three sites of MCA-6 are barium, copper, zinc and potassium oxide. The sample for Site 101 (3180100098) is described as "A sheared metamorphosed mafic volcanic (basalt) with large biotite crystals infused with quartz and thin veinlets of sulfides." The description for Site 102, (3180100100) with anomalous base metals has a similar description without the pegmatitic biotite crystals. For Site 134, (3180100138) the rock description is "Dacite porphyry and andesite with fine disseminated pyrite, some concentration along shears and fractures." With these descriptions it is questionable whether the sampled lithologies had a local source. Boyle, (1979, p. 125) writes that "Zinc is a nearly universal associate of gold in all types of hypogene gold deposits---. " On p. 118 Boyle describes the elements commonly associated in hypogene and supergene gold deposits as including copper. None of the sites in MCA-6 display significant gold or arsenic values, but they contain elements that are commonly associated with gold deposits, and the local lithologies are similar to the gold deposits at Kirkland Lake and Red Lake, Ontario (Boyle, 1979, p. 125). They are not similar to the lithologies that Franklin (1993) describes for VMS deposits. A mylar print of the Mineralized Clast Areas is also provided as Plate 2 at a scale of 1:750,000 designed to overlay the other plates or figures in the text.

Pebble Counts

To help identify the source of rock in the sample sites a random sample of 100 pebbles was collected at each site by a mining aide. Lithologies were megascopically determined and grouped according to units recognized on the Geologic Map of Minnesota, Bedrock Geology, compiled by G.B., Morey (1996). Table 5. PROJECT 318 LITHOLOGY PEBBLE COUNT shows the sample site number, location in UTMs and frequency distribution in sample sites by lithology. To make maps of pebble count lithology distribution the information was arranged in Table 6. PROJECT 318 PEBBLE COUNT FREQUENCY DISTRIBUTION BY LITHOLOGY which displays the lithologic classifications and distribution of pebbles by increments of five pebbles for 140 sample sites. The PEBBLE COUNT FREQUENCY DISTRIBUTION BY LITHOLOGY table was used to construct histograms of pebble count frequency in samples sites. The histograms determined the increments of sample site pebble counts displayed on the maps. The histograms for making plates 3-12 are on the pages following lithology pebble count maps. For most lithologies the pebble count increased within the lithologic units as compiled by Morey (1996) or down ice from the mapped units. Increased counts also appear to be associated with or somewhat down ice from mapped faults in Morey's mapped lithologic units. Exceptions to Morey's compilation are: 1. Quartzite pebbles were separated from metasediments. This was done because quartzites are often difficult to distinguish from silicified tuffs using a hand lens or binocular microscope, and tuffs provide marker

Table 5. PROJECT 318 LITHOLOGY PEBBLE COUNT

SITE#	UTM EAST	UTM NORTH	GRANITE	GNEISS-SCH	MAFIC INT	METASEDS	QUARTZITE	FELSIC VOL	MAFIC VOL	VEIN QTZ	IRON FM	LIME ST	SAND ST	COUNT
1	511112	5284410	31	9	1	14	13	8	32	6	0	0	0	101
2	510515	5291310	36	50	3	1	1	2	3	5	0	0	0	100
3	515820	5312665	40	18	4	0	0	17	14	5	0	0	0	98
4	508420	5312405	53	17	10	0	0	11	6	2	0	0	0	99
5	507945	5309455	31	26	5	0	0	18	15	5	0	0	0	100
6	478050	5283340	31	5	4	21	4	8	31	1	0	0	0	101
7	498010	5291505	42	14	2	5	2	8	22	7	0	0	0	100
8	495290	5302035	45	12	0	21	1	12	10	0	0	0	0	101
9	489360	5301930	30	8	22	12	1	7	18	3	0	0	0	100
10	487860	5297085	36	19	19	8	5	4	12	1	2	2	0	101
11	516830	5304175	39	14	4	0	0	0	39	4	0	0	0	100
12	528395	5304080	59	6	2	5	5	6	18	3	0	0	0	100
13	536905	5304800	53	8	1	1	1	17	15	4	0	0	0	99
14	517195	5291105	20	12	1	19	5	18	25	5	0	0	0	100
15	530160	5291800	14	3	0	29	29	44	10	0	0	0	0	100
16	525625	5313280	43	42	3	1	1	4	7	0	0	0	0	100
17	533830	5312360	72	14	0	1	0	6	3	4	0	0	0	100
18	533320	5318410	63	26	0	0	0	3	9	0	0	0	0	101
19	535610	5318550	68	20	2	2	2	2	6	0	0	0	0	100
20	528790	5301140	57	21	0	3	0	7	12	0	0	0	0	100
21	531575	5299220	57	13	0	5	0	11	13	0	0	0	0	99
22	533360	5297515	26	9	0	18	0	3	42	1	1	0	0	100
23	542970	5291805	19	17	1	37	16	19	6	3	0	0	0	102
24	533310	5292110	40	8	4	16	10	22	5	5	0	0	0	100
25	543890	5281060	18	10	3	0	0	25	42	3	0	0	0	101
26	548100	5294860	22	17	1	21	0	16	20	3	0	0	0	100
27	555890	5294645	9	9	0	23	21	30	18	3	7	0	0	99
28	553450	5292120	19	43	0	16	7	11	3	4	5	0	0	101
29	551795	5285350	26	24	13	11	2	11	12	3	0	0	0	100
30	526280	5288040	36	11	5	13	13	22	11	2	0	0	0	101
31	552730	5293670	24	10	2	18	1	26	12	3	6	0	0	101
32	558080	5295410	8	6	0	12	4	18	21	7	27	0	0	99
33	557840	5285035	23	1	1	15	10	27	31	2	0	0	0	100
34	521040	5290390	16	6	2	15	13	30	31	0	0	0	0	100
35	519980	5288675	29	13	8	11	10	10	28	1	0	0	0	100
36	477980	5294090	41	12	7	5	3	2	30	4	0	0	0	101
37	472395	5295560	34	3	0	11	2	16	34	1	2	0	0	101
38	468010	5302940	36	12	3	16	2	13	14	2	0	4	0	100
39	456960	5301825	50	7	13	6	1	4	14	2	0	1	0	97
40	453250	5290995	44	16	0	2	0	15	22	0	0	2	0	101
41	506065	5303490	40	11	1	10	0	18	19	1	0	0	0	100
42	503660	5310980	30	36	3	0	0	6	19	7	0	0	0	101
43	505100	5313590	66	14	4	2	0	4	6	4	0	0	0	100
44	512105	5327430	64	19	6	2	1	0	9	0	0	0	0	100
45	514565	5306420												
46	501800	5291405	30	16	14	7	0	1	30	2	0	0	0	100
47	498490	5294705	35	4	1	14	0	11	32	3	0	0	0	100
48	512700	5308020	45	17	0	2	0	12	24	0	0	0	0	100
49	525990	5292780	26	55	3	8	2	0	1	8	0	0	0	101
50	486095	5290200	38	7	6	9	2	6	34	0	0	0	0	100
51	492960	5284835	39	4	0	6	4	8	42	1	0	0	0	100

Table 5. PROJECT 318 LITHOLOGY PEBBLE COUNT

SITE#	UTM EAST	UTM NORTH	GRANITE	GNEISS-SCH	MAFIC INT	METASEDS	QUARTZITE	FELSIC VOL	MAFIC VOL	VEIN QTZ	IRON FM	LIME ST	SAND ST	COUNT
52	505560	5279600	37	14	5	7	2	11	22	4	0	0	0	100
53	519030	5301480	44	0	4	2	0	5	42	3	0	0	0	100
54	512980	5313580	50	16	8	1	1	7	16	2	0	0	0	100
55	516860	5326480	66	22	0	0	0	1	9	1	0	0	0	99
56	528505	5291420	26	12	4	8	1	27	18	5	0	0	0	100
57	522800	5293280	31	47	0	8	4	0	0	12	2	0	0	100
58	547385	5286405	31	13	2	19	3	13	22	0	0	0	0	100
59	554920	5291920	18	8	0	24	14	25	16	3	8	0	0	102
60	554345	5293640	9	14	1	35	1	11	28	5	0	0	0	103
61	554200	5293000	15	37	0	32	21	3	3	5	6	0	0	101
62	548480	5288630	19	7	0	5	0	22	46	2	0	0	0	100
63	546780	5288390	17	8	0	19	15	16	39	1	0	0	0	100
64	548950	5292940	10	12	0	45	35	13	21	0	0	0	0	101
65	561205	5297455	40	11	5	16	3	18	3	0	8	1	0	102
66	552521	5269334	46	7	10	3	0	2	28	3	0	0	0	99
67	557120	5276097	45	7	2	7	1	5	27	4	3	0	1	100
68	583326	5301866	49	0	6	6	0	4	35	0	0	0	0	100
69	582004	5293827	66	1	1	6	0	5	18	2	0	0	0	100
70	588822	5309352												
71	580731	5318164												
72	588317	5305568	34	17	0	13	3	6	28	2	0	0	0	100
73	582723	5311083												
74	580877	5304750	45	6	9	4	0	10	18	0	8	0	0	100
75	592843	5306076	44	4	3	13	1	6	15	6	9	0	0	100
76	578756	5306582	35	5	36	1	0	0	23	0	0	0	0	100
77	527615	5294511	47	17	2	4	0	1	17	13	0	0	0	101
78	530167	5295277	29	8	6	23	2	6	21	7	0	0	0	100
79	526267	5289781	58	7	5	9	4	13	7	1	0	0	0	100
80	527737	5298247	66	11	4	3	0	1	14	1	0	0	0	100
81	530847	5300495	69	6	7	2	0	2	15	0	0	0	0	101
82	524326	5301703	64	5	1	2	0	0	24	2	0	0	0	100
83	513012	5296002	43	17	7	9	2	1	19	4	0	0	0	100
84	519723	5296060	36	22	4	12	0	4	16	7	0	0	0	101
85	529210	5294640	13	8	1	16	0	17	42	3	0	0	0	100
86	519497	5298956	44	16	4	9	1	2	18	7	0	0	0	100
87	530158	5304199	44	5	0	0	0	33	15	3	0	0	0	100
88	534776	5304067	44	19	12	0	0	1	20	4	0	0	0	100
89	526032	5290638	33	6	0	11	10	40	8	1	1	0	0	100
90	510789	5299610	42	3	4	8	0	2	37	4	0	0	0	100
91	538469	5290634	26	6	8	11	5	40	10	1	0	0	0	102
92	524913	5309868	43	28	6	0	0	5	17	1	0	0	0	100
93	507167	5300769	23	12	0	11	0	5	38	11	0	0	0	100
94	538710	5301202	18	3	0	12	0	23	42	2	0	0	0	100
95	529017	5287863	34	10	1	3	2	27	24	1	0	0	0	100
96	528431	5287912	25	11	3	27	21	15	14	5	0	0	0	100
97	524760	5285935	23	3	2	34	31	18	20	0	0	0	0	100
98	449161	5283502	22	13	4	0	0	11	42	4	0	4	0	100
99	469091	5294541	44	7	0	1	0	8	34	3	0	3	0	100
100	505560	5317655	25	50	7	4	2	9	2	3	0	0	0	100
101	498199	5324086	66	7	3	2	2	0	10	3	0	9	0	100
102	489113	5323012	45	33	3	1	0	0	15	2	0	2	0	101
103	571690	5301072	38	5	3	5	0	0	49	0	0	0	0	100

Table 5. PROJECT 318 LITHOLOGY PEBBLE COUNT

SITE#	UTM EAST	UTM NORTH	GRANITE	GNEISS-SCH	MAFIC INT	METASEDS	QUARTZITE	FELSIC VOL	MAFIC VOL	VEIN QTZ	IRON FM	LIME ST	SAND ST	COUNT
104	570320	5304452	57	12	3	0	0	7	18	3	0	0	0	100
105	581353	5308708	62	7	4	2	0	7	18	0	0	0	0	100
106	584510	5305498	61	2	2	2	2	2	18	1	12	0	0	100
107	587294	5305912	24	2	4	12	0	6	42	3	7	0	0	100
108	588268	5298325	89	3	1	0	0	1	5	1	0	0	0	100
109	584940	5290077	93	0	0	1	0	2	2	2	0	0	0	100
110	577301	5307350	67	12	8	0	0	3	7	4	0	0	0	100
111	574184	5303323	34	6	12	14	0	5	27	1	1	0	0	100
112	579242	5291400	83	1	3	2	0	4	8	0	0	0	0	101
113	586751	5294610	94	0	1	0	0	3	2	0	0	0	0	100
114	587562	5296673	86	4	3	0	0	0	5	1	1	0	0	100
115	574794	5288324	95	1	0	0	0	3	2	0	0	0	0	101
116	531321	5328404	55	22	1	0	0	13	8	1	0	0	0	100
117	537653	5319217	83	10	1	2	1	0	4	0	0	0	0	100
118	538941	5317456	87	11	0	0	0	1	1	0	0	0	0	100
119	539353	5313524	78	16	3	0	0	2	0	1	0	0	0	100
120	447619	5277322	23	0	3	1	1	3	4	1	0	65	0	100
121	453884	5282902	50	6	3	1	0	4	16	1	0	18	1	100
122	456253	5285796	41	5	10	1	1	5	30	2	0	6	0	100
123	470236	5281752	34	10	16	1	0	3	34	2	0	0	0	100
124	443863	5305508	20	5	6	1	1	2	9	0	0	57	0	100
125	450365	5308055	38	11	5	1	0	1	5	0	0	40	0	101
126	461674	5301913	57	12	4	2	0	1	13	2	0	9	0	100
127	470042	5310502	53	16	3	2	0	4	19	3	0	0	0	100
128	448482	5284844	57	8	9	2	1	1	13	2	0	8	0	100
129	445710	5289860	32	6	16	3	0	3	37	2	0	0	10	100
130	451631	5288615	54	4	1	2	2	8	17	0	0	14	0	100
131	460708	5295349	63	8	8	2	1	4	13	3	0	0	0	101
132	482521	5294437	55	6	6	3	1	3	26	4	0	0	0	100
133	473434	5331773	65	12	8	2	1	5	5	1	0	2	0	100
134	514485	5319284	57	34	3	0	0	1	5	0	0	0	0	100
135	513475	5323940	64	27	2	0	0	0	9	0	0	0	0	102
136	492175	5300642	67	3	8	0	0	1	20	1	0	0	0	100
137	480470	5302291	62	6	3	2	0	3	23	1	0	0	0	100
138	492137	5293255	38	16	4	0	0	4	38	1	0	0	0	101
139	488812	5295064	42	4	8	8	2	3	32	3	0	0	0	100
140	492808	5302238	52	16	10	2	0	3	13	1	0	0	0	100
141	493562	5300966	55	9	21	3	0	1	9	2	0	0	0	100
142	488495	5304590	44	14	5	9	0	1	24	3	0	0	0	100
143	526287	5305953	23	41	5	0	0	1	29	1	0	0	0	100
144	546166	5298731	32	24	4	8	1	4	13	14	1	0	0	100

Table 6. PROJECT 318 PEBBLE COUNT FREQUENCY DISTRIBUTION BY LITHOLOGY

Number of Sites With Lithology Pebble Count by Increments of Five

LITHOLOGY	0-5	6-10	11-15	16-20	21-25	26-30	31-35	36-40	41-45	46-50	51-55	56-60	61-65	66-70	71-75	76-80	81-85	86-90	91-95
GRANITE	0	4	3	10	11	10	15	16	21	6	8	8	9	9	1	1	2	3	3
GNEISS-SCHIST	31	39	29	20	6	4	2	2	3	3	1	0	0	0	0	0	0	0	0
MAFIC INTRUSIVES	104	25	5	3	2	0	0	1	0	0	0	0	0	0	0	0	0	0	0
METASEDIMENTS	78	20	19	10	6	2	3	1	1	0	0	0	0	0	0	0	0	0	0
QUARTZITE-TUFF?	123	5	5	1	3	1	2	0	0	0	0	0	0	0	0	0	0	0	0
FELSIC VOLCANICS	72	22	17	13	6	6	1	2	1	0	0	0	0	0	0	0	0	0	0
MAFIC VOLCANICS	21	20	22	25	14	11	11	6	8	2	0	0	0	0	0	0	0	0	0
VEIN QUARTZ	127	9	4	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
IRON FORMATION	130	8	1	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0
LIMESTONE	131	4	1	1	0	0	0	1	0	0	0	1	1	0	0	0	0	0	0

horizons for some massive sulfide deposits. 2. Pebbles bearing quartz veins were logged as vein quartz to help determine areas of alteration even though vein quartz might not be the dominant lithology in the assemblage. If there was another recognized lithology they were also counted for that lithology. 3. Iron formation is separated from other metasediments because it is the host rock for a number of world class gold mines. 4. There is no limestone or sandstone mapped as bedrock in the study area. However, Mooers, 1996, Landform Assemblage Map shows much of the western half of the Project 318 area is Koochiching Lobe which probably carried these sediments into the area from bedrock to the northwest. These units would be Phanerozoic, Jurassic or Cretaceous sediments and there could be small outliers of these lithologies beneath the glacial till which have not been mapped. This would explain the localized patterns of distribution.

The total number of granite pebbles is 6,020. Plate 3 shows the granite pebble counts. All sample sites have high granite counts. The granites appear to be very resistant as compared with other lithologies. Nine sites have 71-95 granite pebbles, of these seven sites are in Agr units of the Vermillion and Giants Range granites, mostly clustered along faults. Two sites are in the Asm unit paragneisses and schist-rich migmatite about two miles from granite. Thirty-four sites are in the 51-70 granite pebble group. Twenty of these sites are within or touching mapped granites. Three of the sites are within a mile of mapped granite. Six sites are within two miles of mapped granite. One site is within three miles of mapped granite and the rest are further than three miles. Fifty-eight sites have 31-50 granite pebbles. Sixteen of these sites are on or touching mapped granite. The rest of these sites are estimated to be evenly distributed in areas not mapped as being granite with an average distance to granite bedrock of three miles. Thirty-nine sites have 0-30 granite pebbles. Six of these sites are on mapped granites, the others seem to be concentrated in the Ams, metasedimentary rocks with an average distance from granite of about ten miles. While a few granite pebbles have traveled some distance it is apparent most of these pebbles are near a mapped bedrock source.

The total count for gneiss and schist is 1,792. Eleven sites have more than 30 pebbles, nine sites have 21-30, the other sites have 0 to 20 pebbles. The bulk of these sites are in or close to Ams metasediments intruded by granitic plutons, or Asm paragneisses, or in Agm granites and migmatites. There also appears to be a correlation between the gneiss-schist pebbles and faulting. In retrospect this group should have been divided into course and fine grained classes. That would have probably separated those associated with intrusives from the paragneisses and fine grained volcanic-sedimentary schists. There are 594 mafic intrusive pebbles. Most of these are probably from Proterozoic diabase dikes which are not shown on the geologic map (Morey, 1996). Only one site with more than 10 pebbles is on a granite or granitoid intrusion. Most sites with more than 10 pebbles are in the Ams metasediments. Probably the dikes are more resistant to weathering than metasediments, therefore they formed topographic highs in sediments and were subjected to more glacial erosion than dikes intruded into granitic rocks or volcanics. There is an interesting concentration of mafic intrusive pebbles in T62N-R22W. Three of the sites with 16-36 mafic intrusive pebble counts are within or very near MCA-4. Five of the sample sites in MCA-4 have elevated nickel values although not above the threshold of what would be expected from a mafic intrusive.

There are 1,058 metasediment pebbles. As expected there is a very strong correlation with the Ams metasediments, particularly near fault zones or down ice from faulted metasediments. Only one site with more than 20 pebbles is on an Agd granitoid intrusion. There are 396 quartzite pebbles. These were broken into two groups; five or less pebbles, and greater than five pebbles. All the sites with more than five pebbles are grouped along the southern side of the Ams metasediments or just down ice from the metasediments. Again many of the sites are on or near faults. There is also a strong correlation between quartzite pebbles and the other metasediments.

There are 1,221 felsic volcanic pebbles. Sample sites were broken into three groups; 0-10, 11-30 and 31-44. Many of the sites with more than 11 felsic volcanic pebbles are in or near the lft felsic tuff-dacite unit Map M-79 compiled by Southwick (1993). Further west more than 11 pebble count sites correlate with Southwick's jms sedimentary and felsic volcanic rock unit. Most of the remaining plus 11 count are on or near Agd granitic plutons or Agm granites and are also at or near faults. Overall there appears to be a good correlation with more detailed geologic maps. There is also a very good correlation between gold anomalies in MCAs 2, 7 and 3 with both quartzite, meta sediments without quartzite and felsic volcanics.

There are 2,622 mafic volcanic pebbles. These were also divided into three groups; 0-20, 21-30 and 31-49 pebbles. Quite a few of the 21-30 and 31-49 groups are on or not too far down ice from the Amv mafic metavolcanic units and Amm mixed metavolcanic rocks. Other sites with these plus 21 counts again correlate with mafic volcanic units on the MGS more detailed map. There are probably a few sites that are five or six miles from a mafic volcanic unit. Most of the mapped iron formations are in mafic volcanics and that is why these sediments are include in this paragraph about volcanic units. Sites with iron formation pebbles were divided into two groups: 0-10 and 11-27. Two sites had more than 11 iron formation pebbles. One site is in Amv just south of mapped iron formation, this site is also in MCA-2. The other site is on Amv mafic volcanics about two miles west of Ely in MCA-1.

Sites with vein quartz are divided into two groups; those with 0-10 vein quartz pebbles and those with 11-14 vein quartz pebbles. Four sites are in the 11-14 class, two of these are on the Amv unit near fault zones and two are on Ams near faulting and granitoid plutons. One of these sites is in MCA-7 and the other three in MCA-3.

In the western part of the study area 247 limestone pebbles and twelve sandstone pebbles were found. Since there is no mapped limestone or sandstone in the study area or near it, although these Phanerozoic units would be above the Archean bedrock, it is impossible to estimate how far the Kootchiching Lobe might have moved these pebbles. Excluding the possibility of boulders traveling a great distance then breaking up there might be a local bedrock source which has not yet been mapped.

The conclusions from the pebble count part of the study are: A few rocks might have traveled some distance, but most of the rock found has a local source probably not more than one or two miles from the sample site. This is particularly true where there is an abundance of rock of one lithologic class, or a lot of mineralized rock. Generally pebble lithologies are on or near mapped bedrock lithologies. Faulting increases the numbers of faulted lithology pebbles in or down ice from the fault. At the reconnaissance scale of mapping many of the MCAs are on or near favorable lithologies and structures. However, there are mineralized boulder trains helpful to an exploration effort.

Results of Magnetic Susceptibility Readings

To test whether magnetic susceptibility readings on boulders would provide meaningful exploration data, correlation coefficients were done on the samples where Bondar Clegg did the analysis. Using the average readings at the sites for granite and the Bondar Clegg gold analysis there is a correlation coefficient of 0.162. This included Site 57 (3,598 ppb gold). The correlation coefficient becomes minus 0.0071 if the gold content for Site 57 is reduced to 500 ppb to eliminate nugget affect. For the same group of assays the correlation coefficient is 0.0002 comparing average mafic volcanic readings with gold content. This means there is essentially no correlation and the method did not work. There is a digital file P318MAGS which lists the sample site, the total magnetic susceptibility for granite and mafic volcanics, the average magnetic susceptibility for granites and mafic volcanic observations, and the number of observations taken.

RECOMMENDATIONS

The study provides strong indications of gold and volcanogenic massive sulfide base metal mineralization. Although none of the analytical work directly indicates ore grade mineralization, combined with observed alteration it certainly indicates that ore forming geologic processes took place. Observed lithologies, structural features, alteration and an abundance of mineralized rock indicate a prospective area comparable with many areas where world class mineral deposits are found.

If such deposits exist a careful study of DNR General Exploration Files and publications particularly, Report 231, (Martin 1985) "A compilation of ore mineral occurrences, drill core, and testpits in the State of Minnesota." would be very helpful. Another DNR publication that provides background information on the Soudan Mine Area is "Drill core repository sampling projects: A Minerals Diversification Project." Dahlberg, et al. (1989). More geochemical work especially better definition of boulder trains would also indicate areas for more detailed studies.

LIST OF DIGITAL FILES

P318RPT.WP This is a Wordperfect file containing the text of the report.

P318BC1 Project 318 Paradox analytical data file for the first shipment of samples to Bondar Clegg. The sample numbers for this group are 3180100001 - 3180100031. Sample 3180100032 is a reference sample for this group with certified values listed in the reference sample file.

P318BC2 Project 318 Paradox analytical data file for the second shipment of samples to Bondar Clegg. The sample numbers for this group are 3180100033 - 3180100043. Sample 3180100042 is a reference sample for this group with certified values listed in the reference sample file.

P318AL1 Project 318 Paradox analytical data file for the first shipment of samples to ACTLABS. The sample numbers for this group are 3180100044 - 3180100152. Samples 3180100153 - 3180100159 are reference sample for this group with certified values listed in the reference sample file.

P318AL2 Project 318 Paradox analytical data file for the second shipment of samples to ACTLABS. The sample numbers for this group are 3180100160 - 3180100163. Sample 3180100164 is a reference sample for this group with certified values listed in the reference sample file.

P318AL3 Project 318 Paradox analytical data file for the third shipment of samples to ACTLABS. The minimum detection limit for silver with the method used for the first two shipments is 0.5 ppm. A lower selection limit is desirable particularly for samples with high gold values. Twenty-two samples with high gold were resubmitted, also one reference sample, to be done with an Aqua Regia extraction ICP package having 0.2 ppm detection limit. The results of this analysis are incorporated into the table P318MCA.

P318MCA Project 318 Paradox analytical data file of selected assay data from the files listed above which is used to make the mineralized clast area map.

P318REF Project 318 Paradox analytical data file of reference sample certified assay data values for reference samples (3180100032), (3180100042), (3180100153 - 3180100159) and (3180100164).

P318MAGS Paradox file for Project 318 magnetic susceptibilities for granite and mafic volcanic boulders. Because there was a very low correlation coefficient between magnetic susceptibility readings for boulders and mineralization they are not included in the report. However, they might be used as a data base for later reference.

P318PEB This table lists: the site number; UTMs; lithologies with number of pebbles in each lithology and total pebble count in sample.

P318PEBD This table lists the distribution of lithologies by sites using increments of five. The table was used to make histograms for each lithology.

CABC&AL This table lists nineteen samples analyzed by Bondar Clegg that were also analyzed by ACTLABS for comparison of results. There is also a reference sample that was certified to contain 18 ppb gold.

CBC&ALFA This table lists the same nineteen samples as the previous file with the results of analysis for platinum group elements and gold.

PROJECT COST

Thirty-eight days in the field were required for a geologist and mining aide to collect samples and data. Field expenses and sample analysis are the major cost items.

Estimated Project Expenses

We estimate 7,000 miles traveled in van and fwd
utility vehicles, cost excluding fleet charges.....$560.00
Field expenses lodging and food..........................600.00
Analytical work (note ACTLABS gave a 50% reduction
on 116 samples because of time delay).............3,094.79
Shipping samples and return of pulps (estimated).........300.00
Printing report, for 100 copies........................3,008.50
Total.........................$7,563.29

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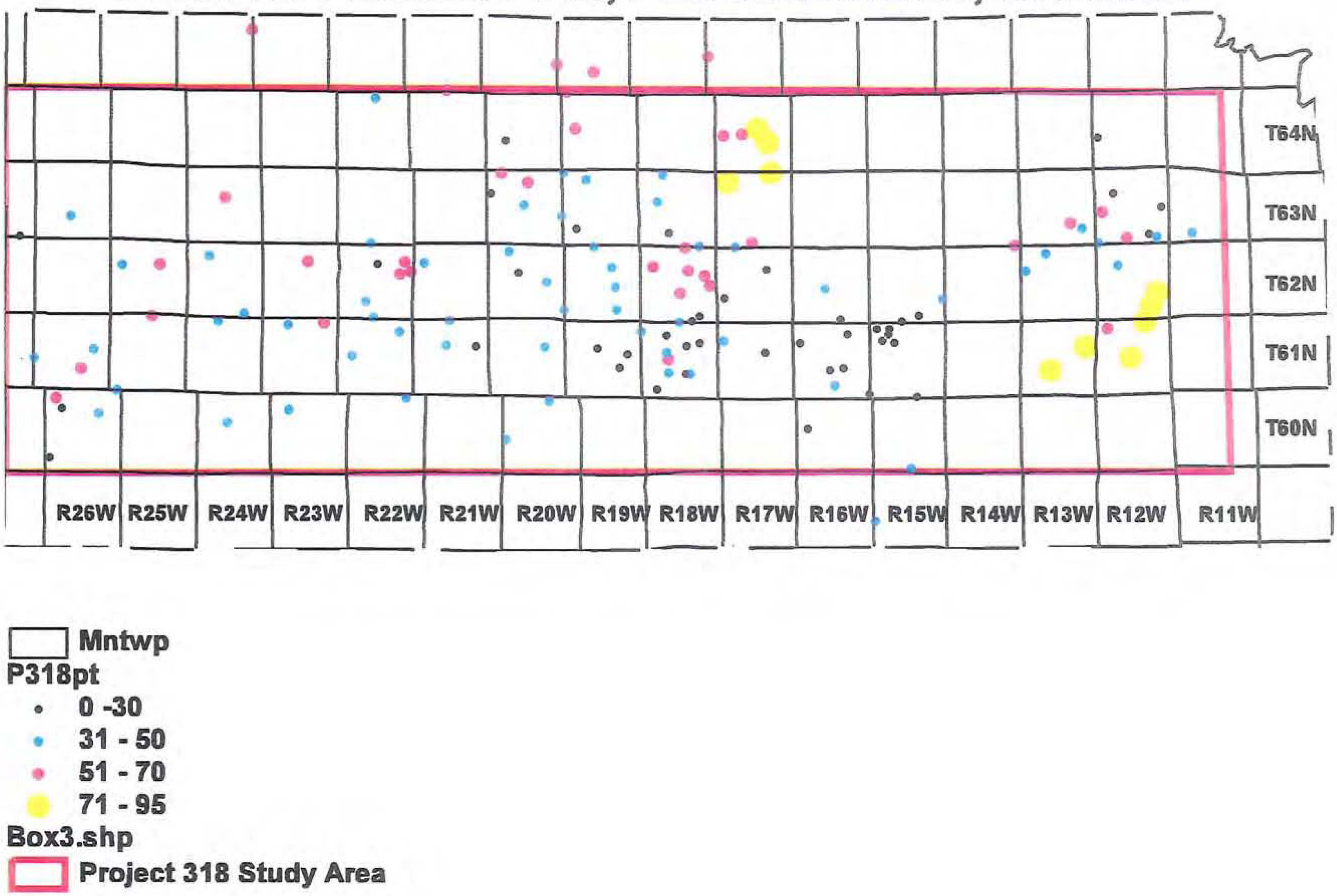
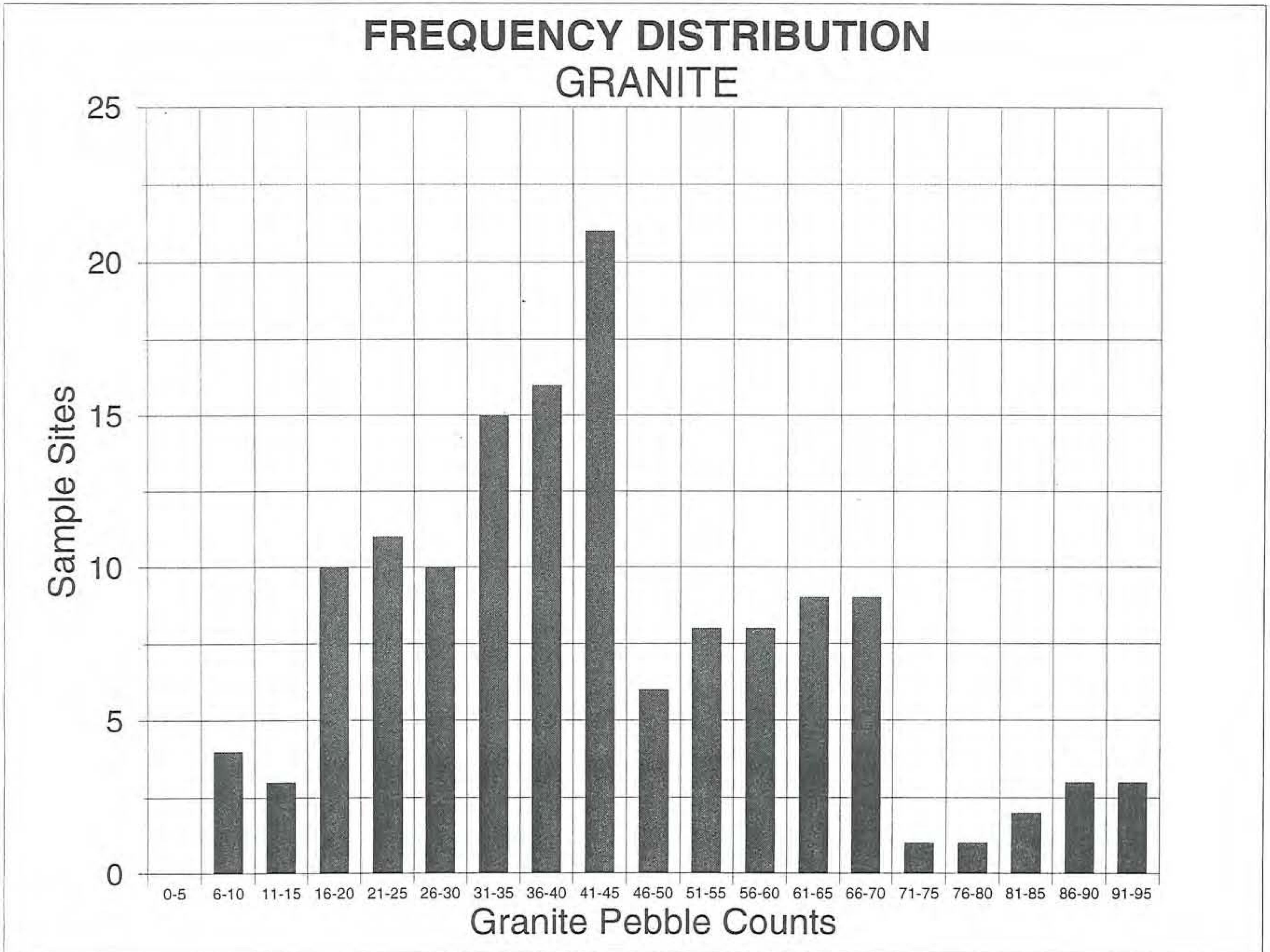
PLATE 3. PROJECT 318, PEBBLE COUNT, GRANITE





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10
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Sample Sites
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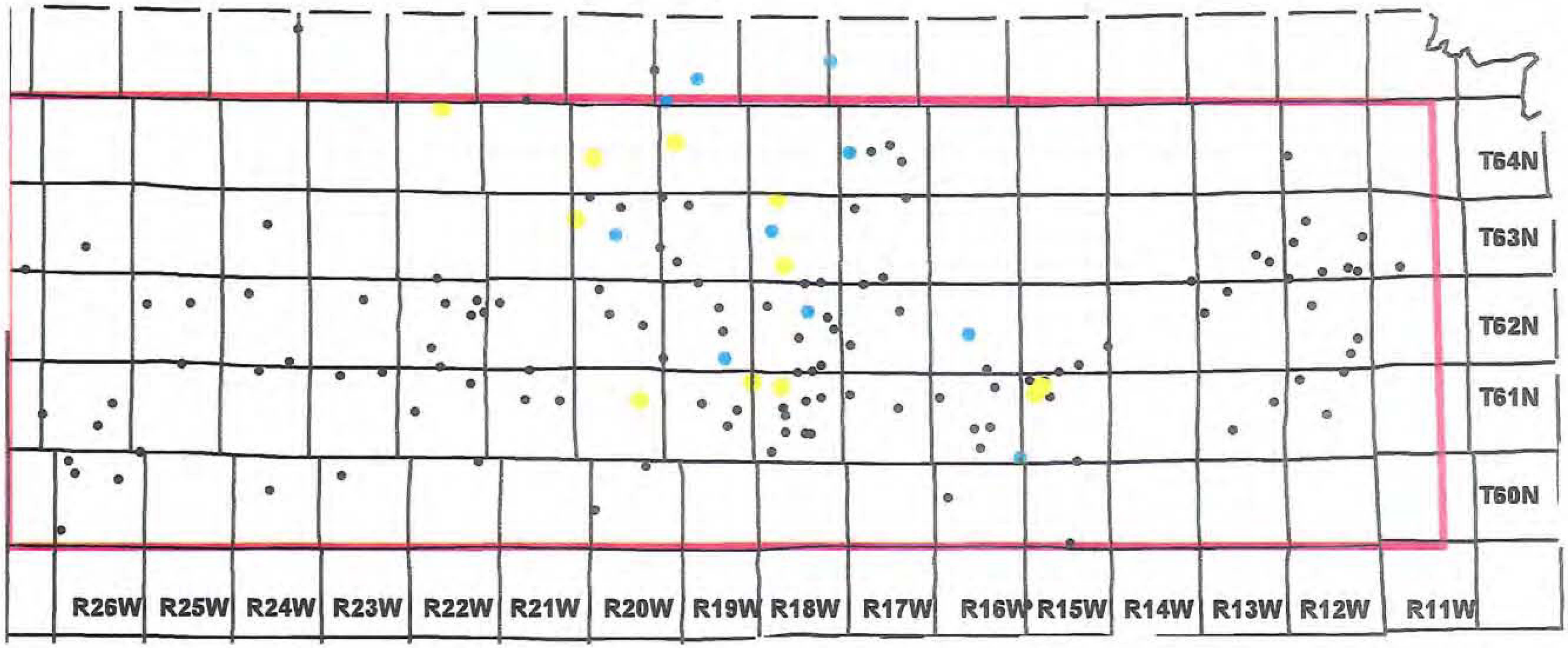
6-10
11-15
16-20
21-25
26-30
31-35
36-40
41-45
46-50
51-55
56-60
61-65
66-70
71-75
76-80
81-85
86-90
91-95
Granite Pebble Counts

PLATE 4. PROJECT 318, PEBBLE COUNT, GNEISS AND SCHIST



Mntwp
P318pt
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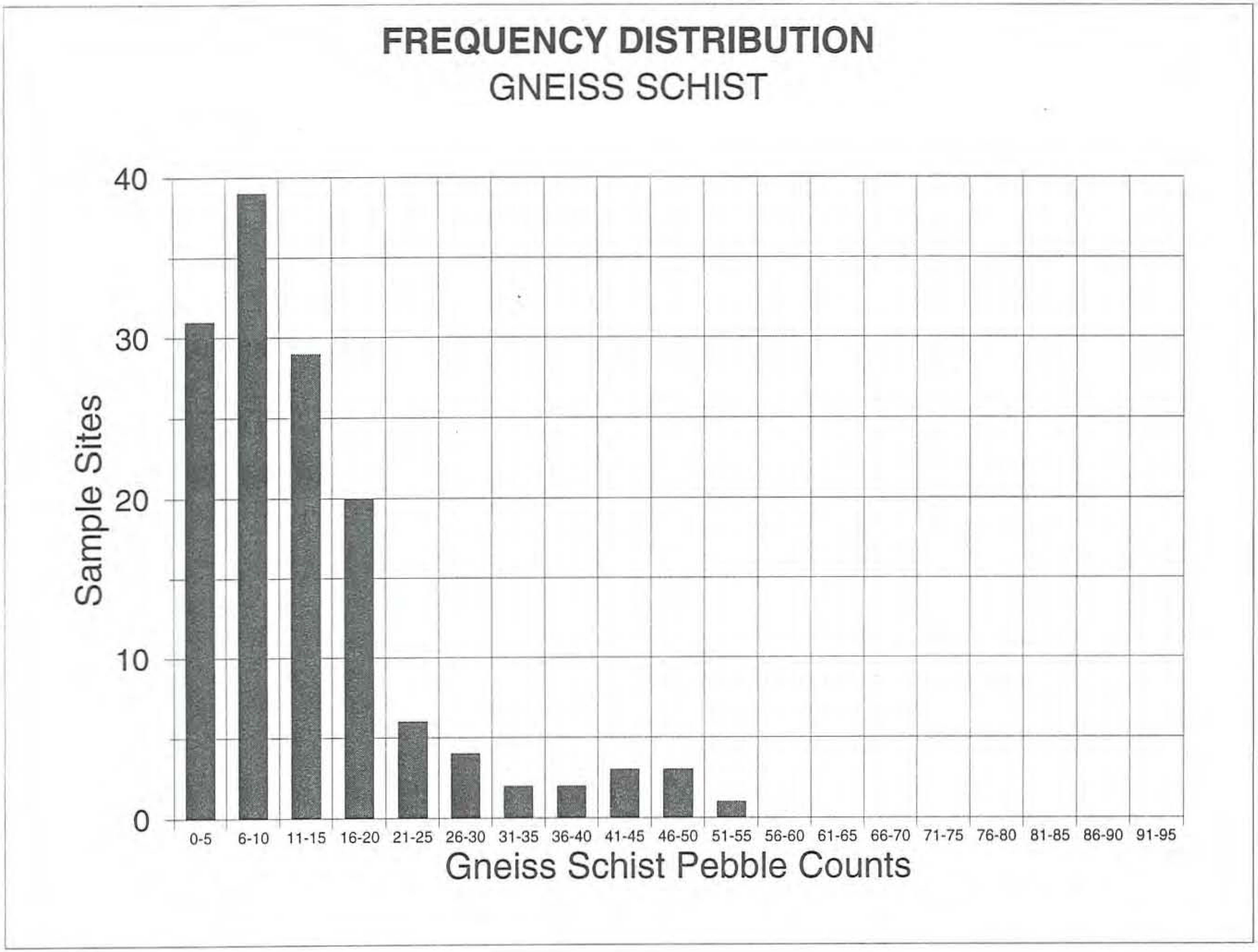
- 21 - 30
- 31 - 55

Box3.shp
Project 318 Study Area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GNEISS SCHIST
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30
20
10
0
Sample Sites
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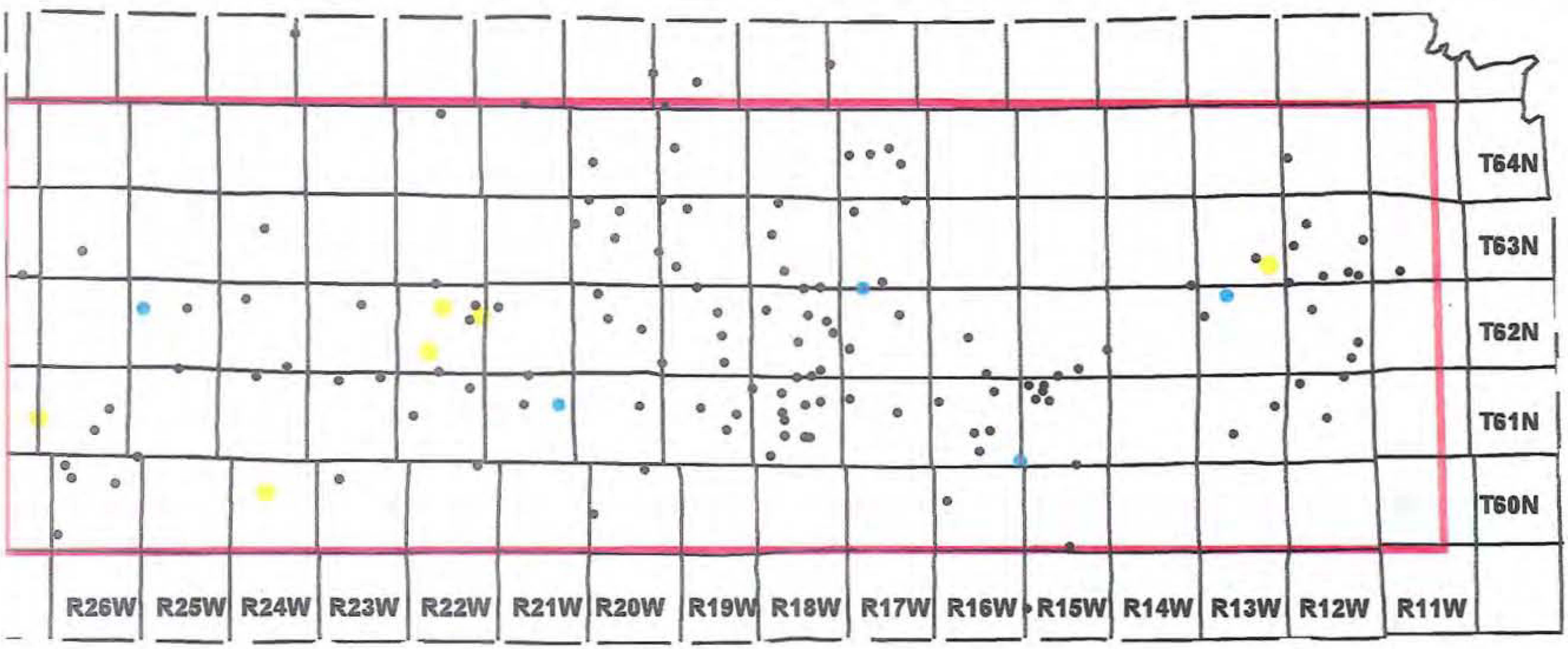
6-10
11-15
16-20
21-25
26-30
31-35
36-40
41-45
46-50
51-55
56-60
61-65
66-70
71-75
76-80
81-85
86-90
91-95
Gneiss Schist Pebble Counts

PLATE 5. PROJECT 318, PEBBLE COUNT, MAFIC INTRUSIVES



Mntwp
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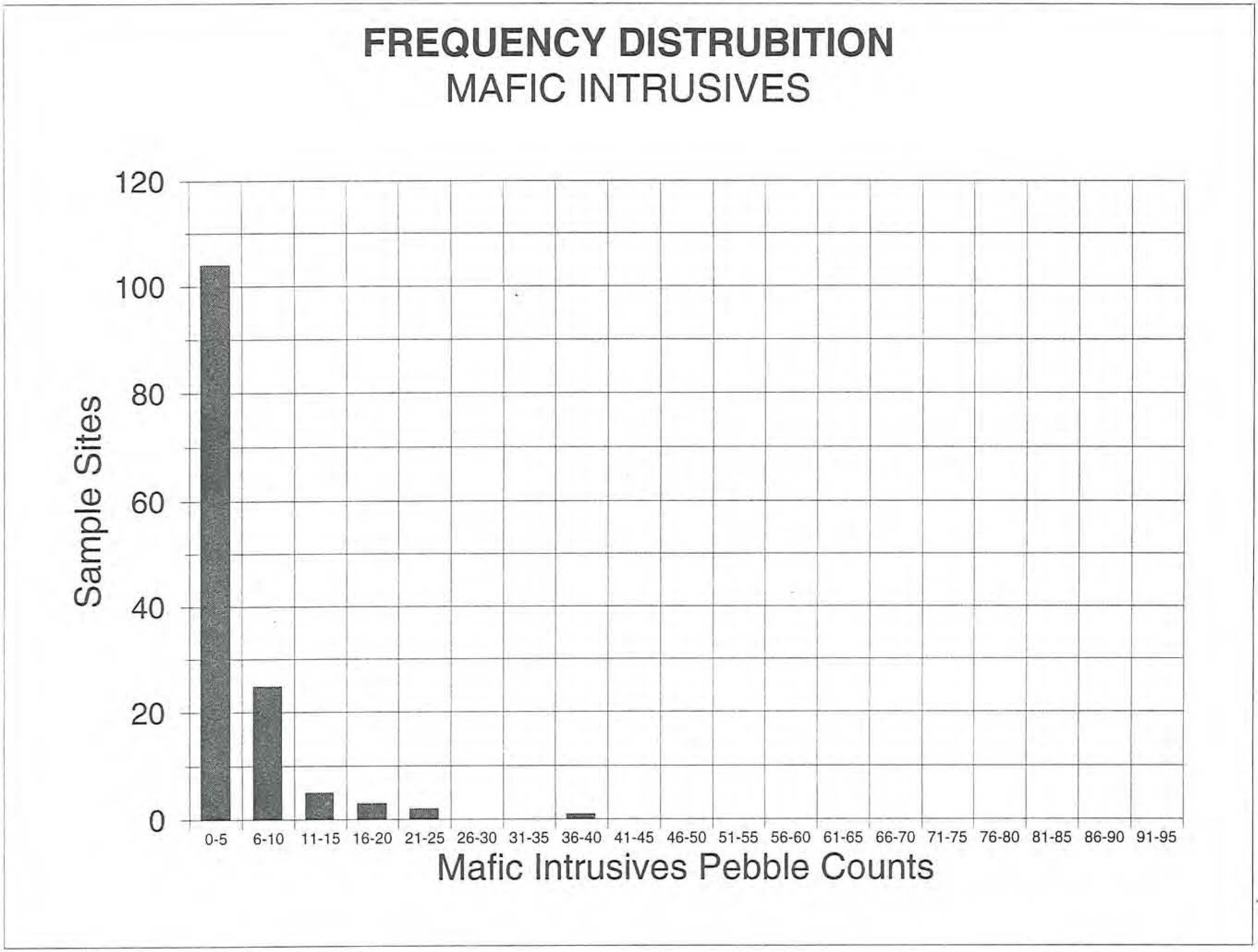
0 - 10
11 - 15
16 - 36
Box3.shp
Project 318 Study Area



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0-5
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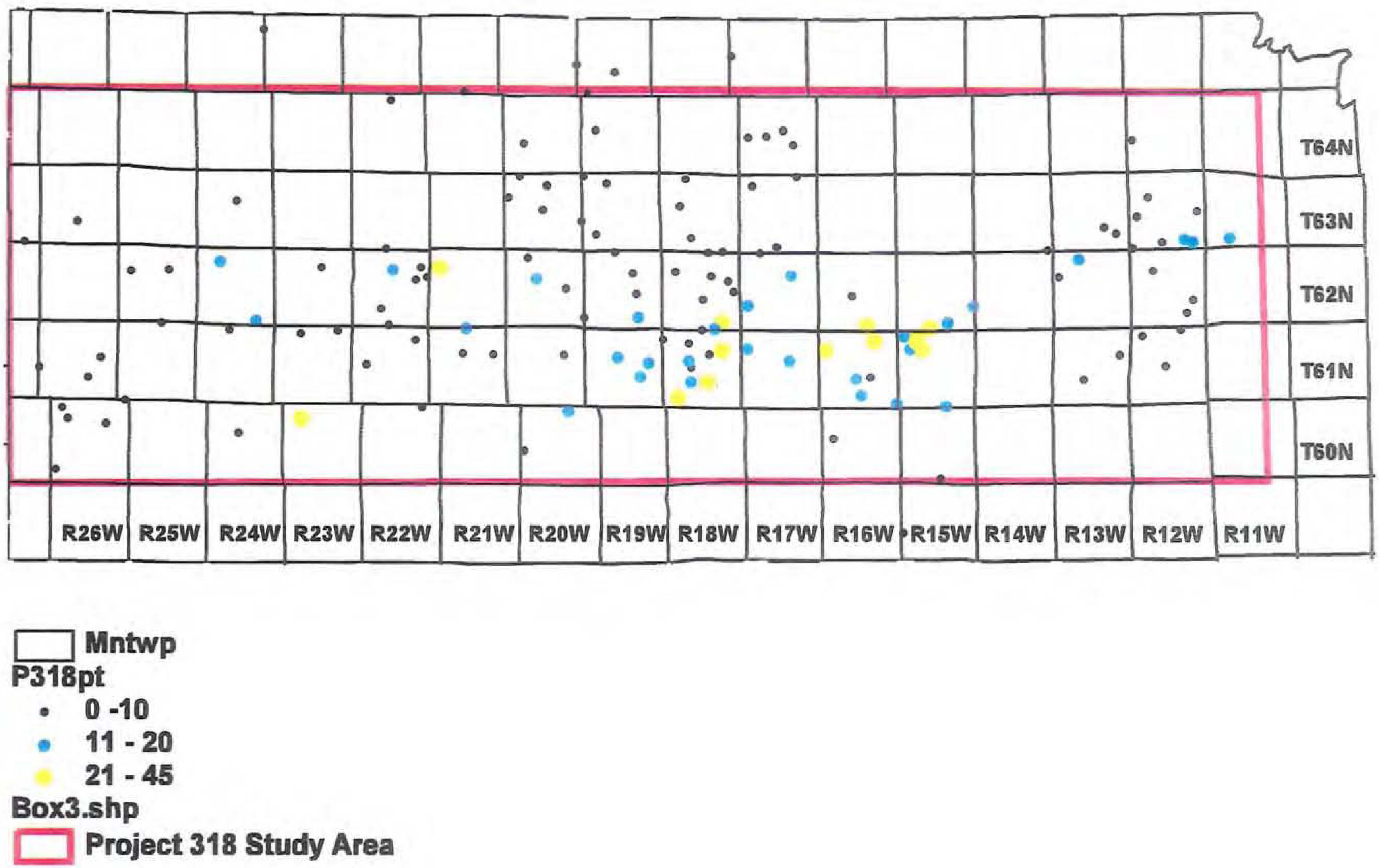
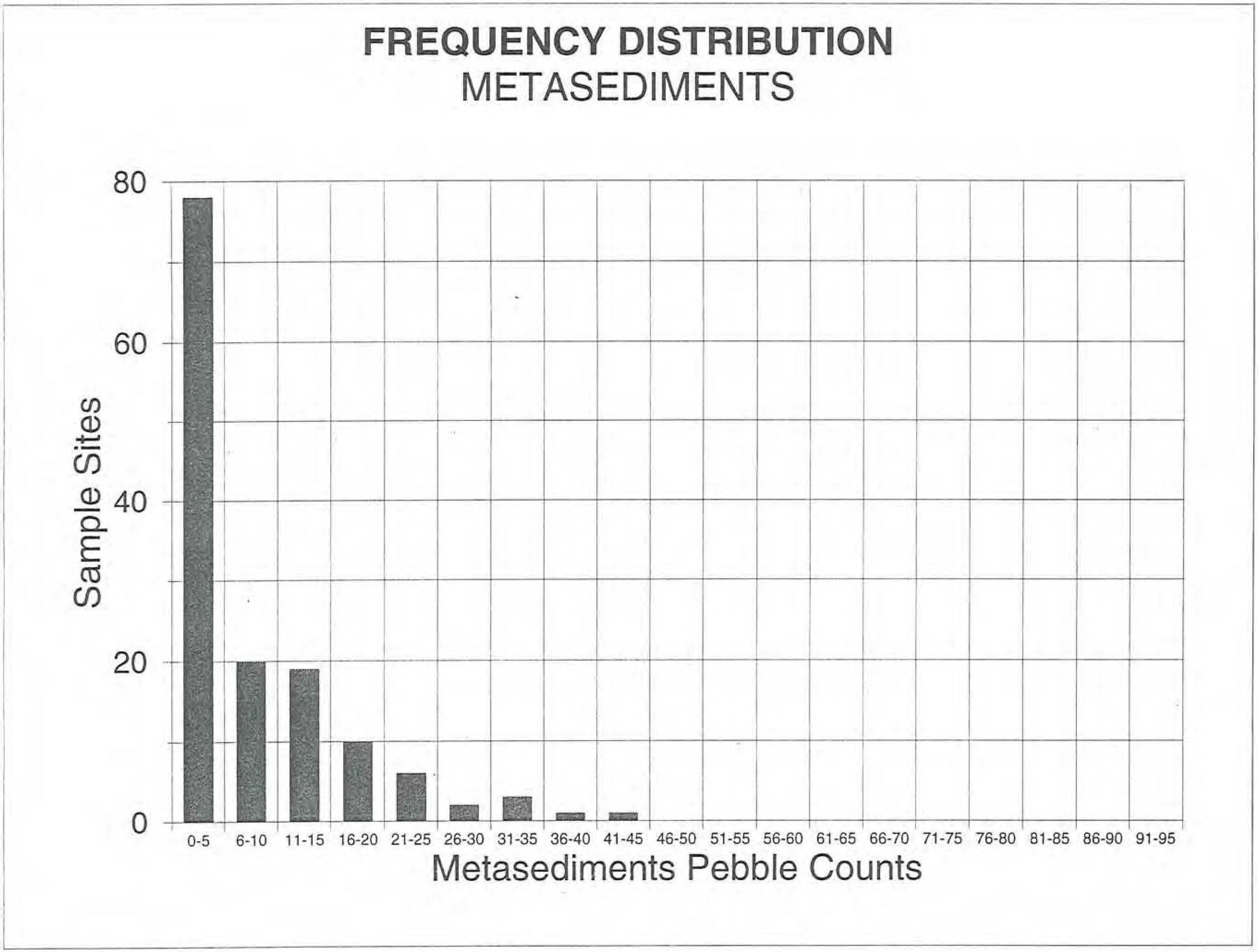
16-20
21-25
26-30
31-35
36-40
41-45
46-50
51-55
56-60
61-65
66-70
71-75
76-80
81-85
86-90
91-95
Mafic Intrusives Pebble Counts

PLATE 6. PROJECT 318, PEBBLE COUNT, META SEDIMENTS WITHOUT QUARTZITE





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Sample Sites
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6-10
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16-20
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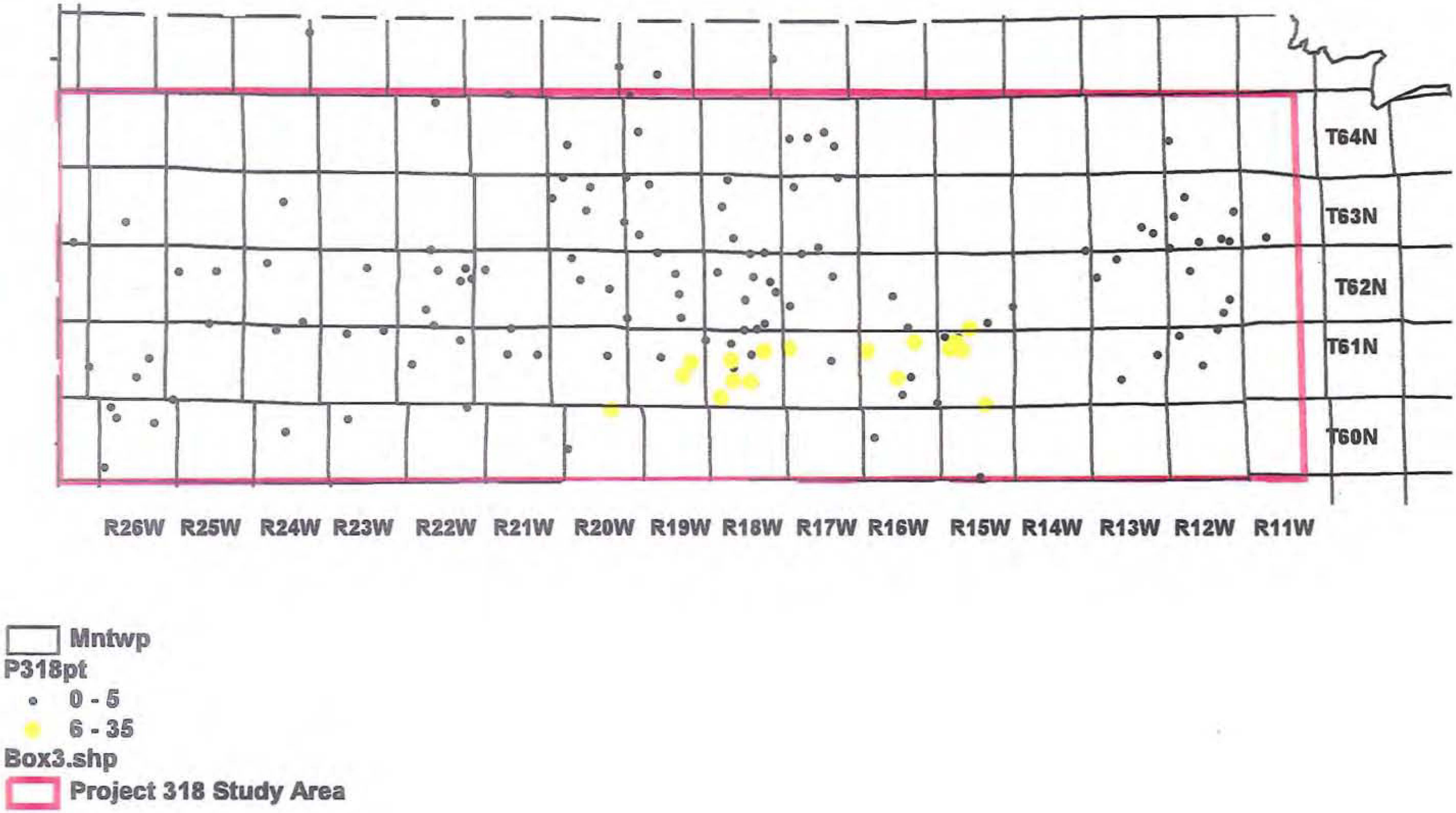
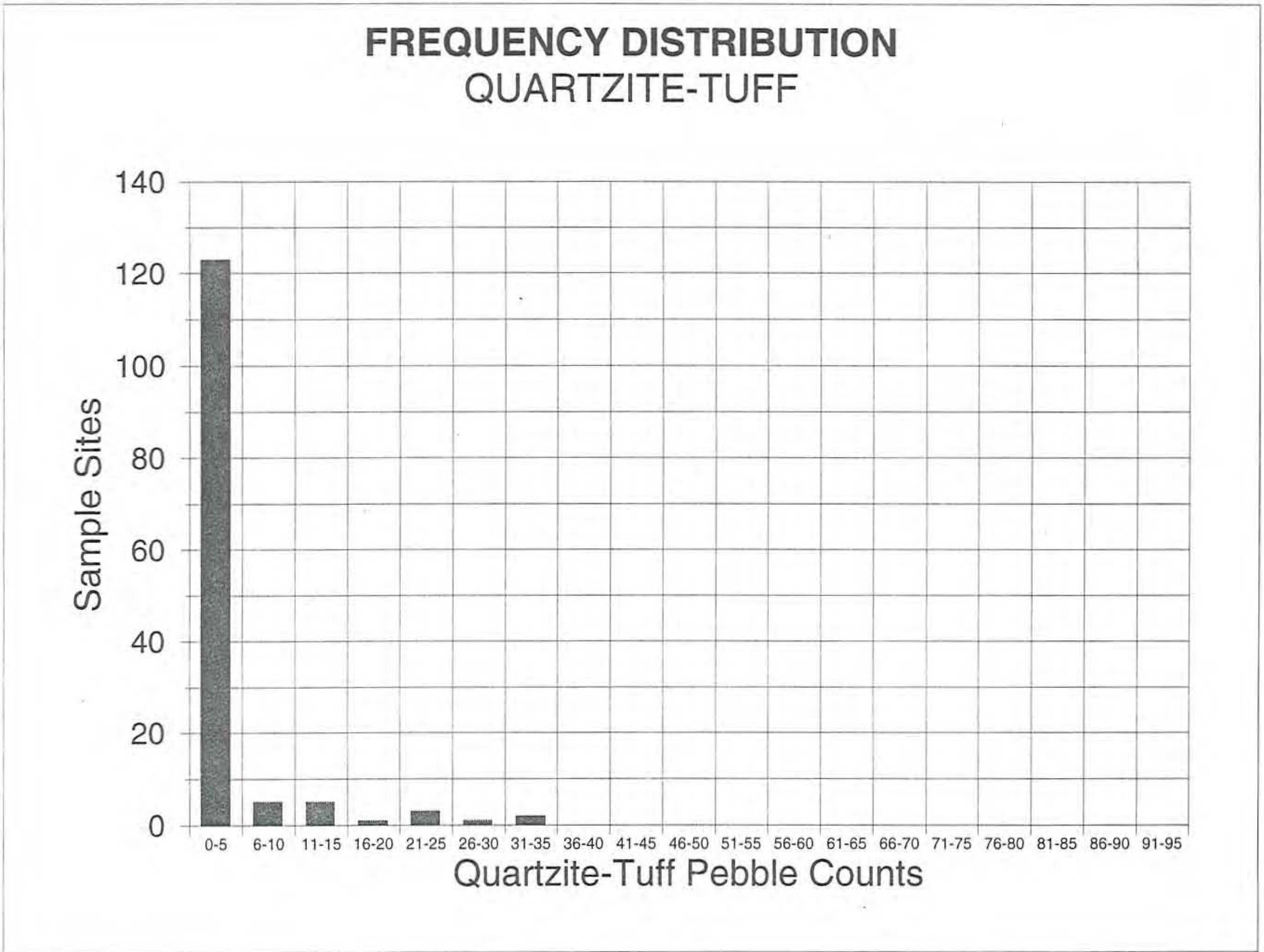
31-35
36-40
41-45
46-50
51-55
56-60
61-65
66-70
71-75
76-80
81-85
86-90
91-95
Metasediments Pebble Counts

PLATE 7. PROJECT 318, QUARTZITE - TUFF?

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QUARTZITE-TUFF
Sample Sites
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100
80
60
40
20
0
0-5
6-10
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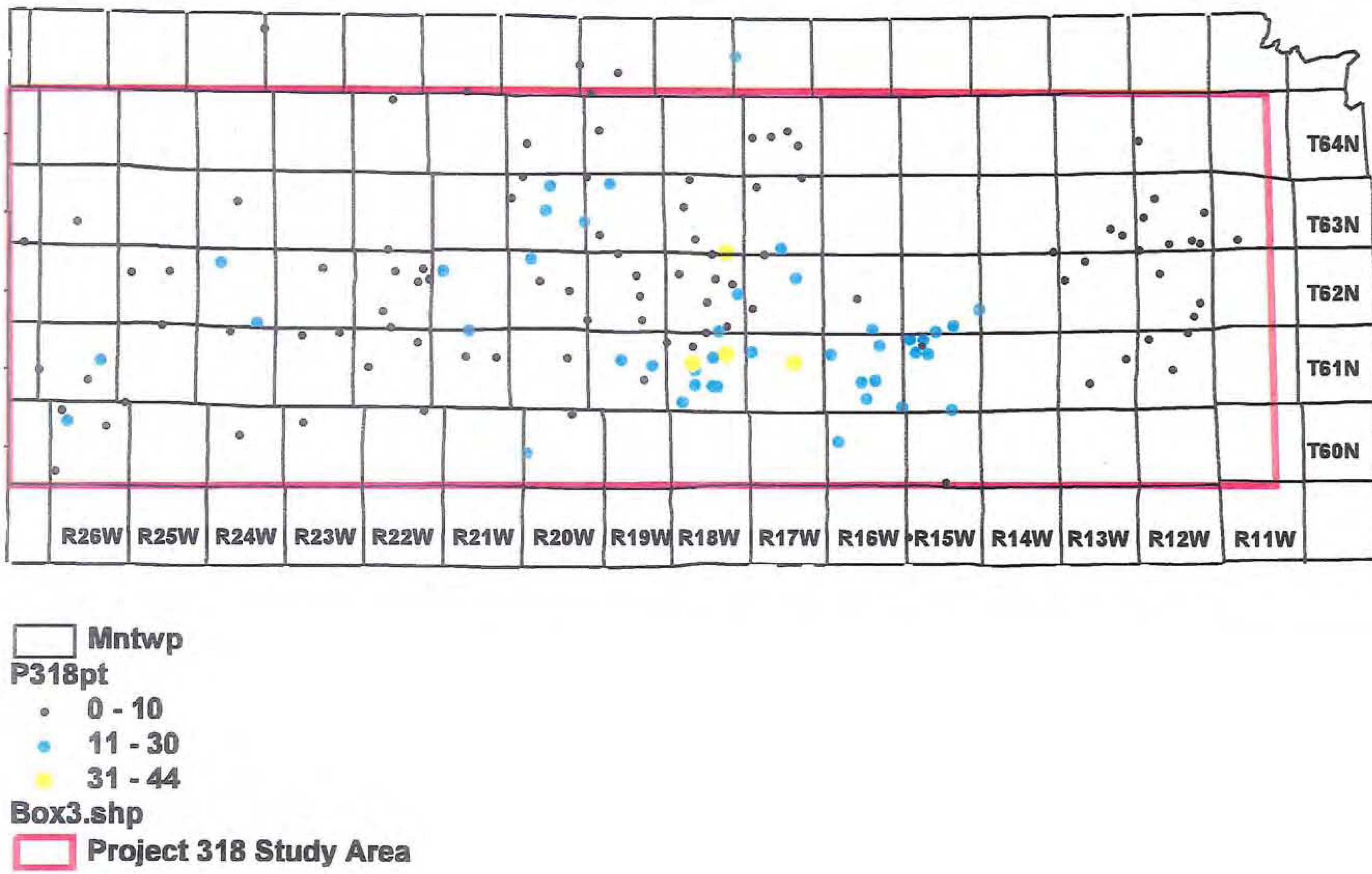
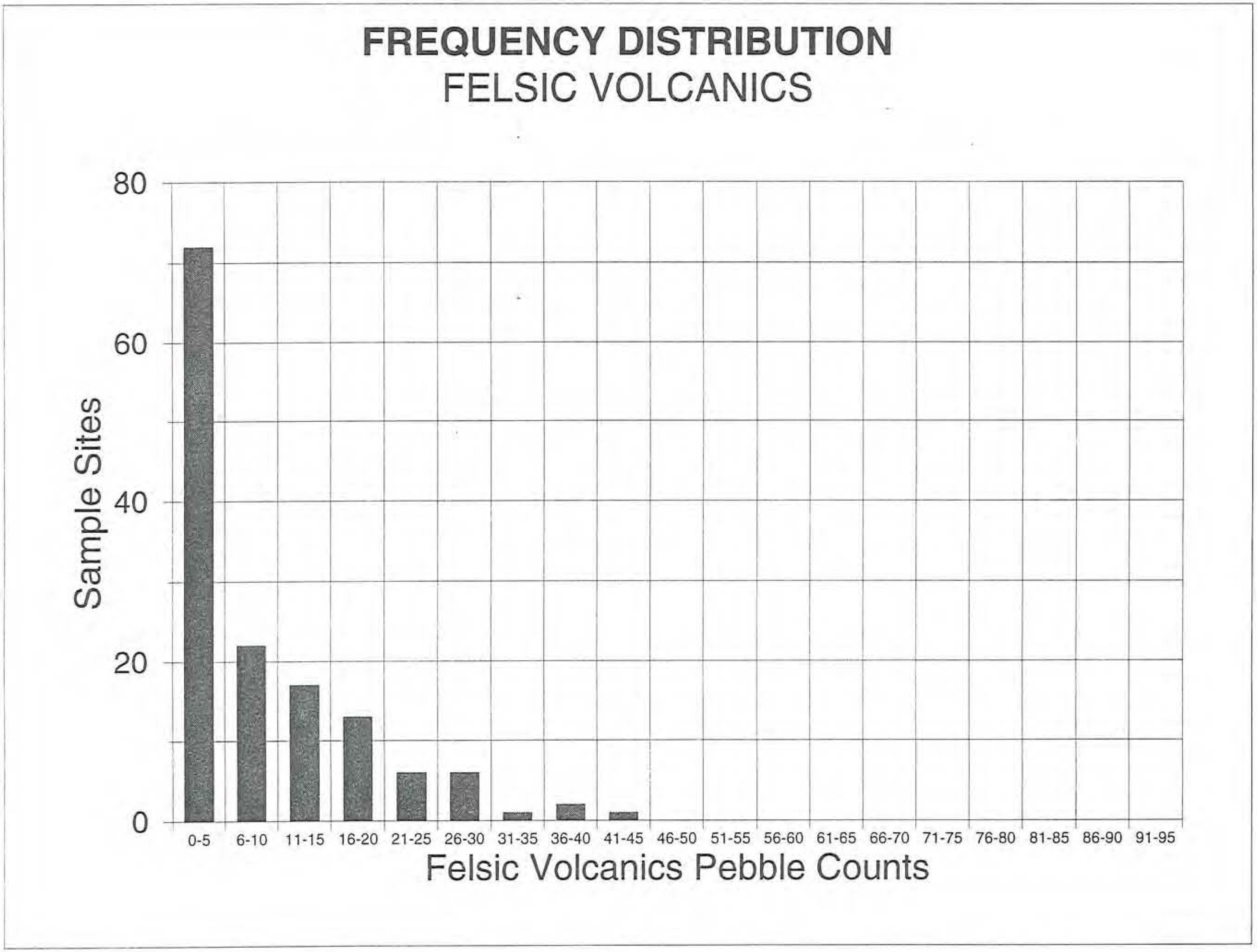
16-20
21-25
26-30
31-35
36-40
41-45
46-50
51-55
56-60
61-65
66-70
71-75
76-80
81-85
86-90
91-95
Quartzite-Tuff Pebble Counts

PLATE 8. PROJECT 318, PEBBLE COUNT, FELSIC VOLCANICS





FREQUENCY DISTRIBUTION
FELSIC VOLCANICS
Sample Sites
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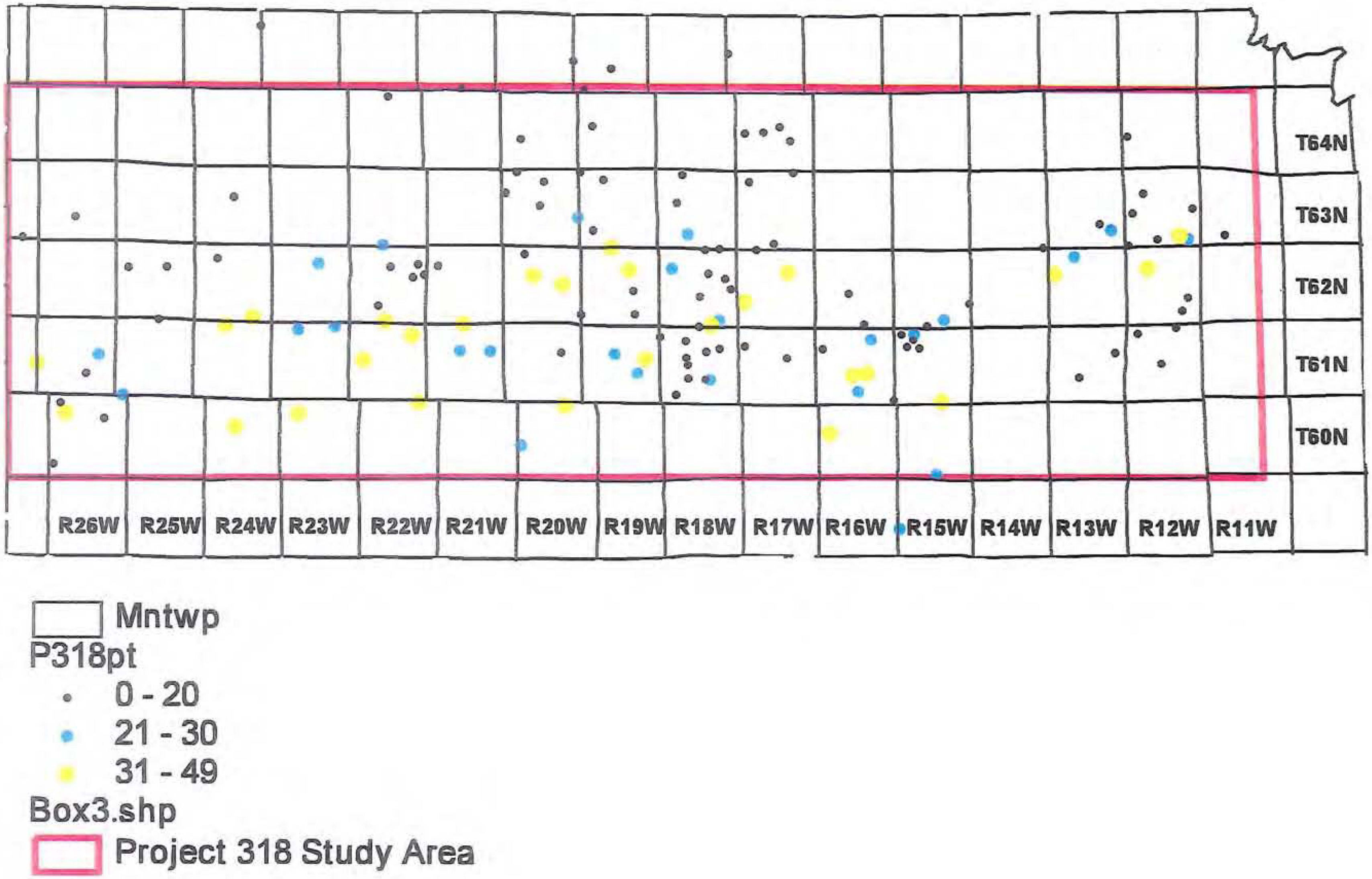
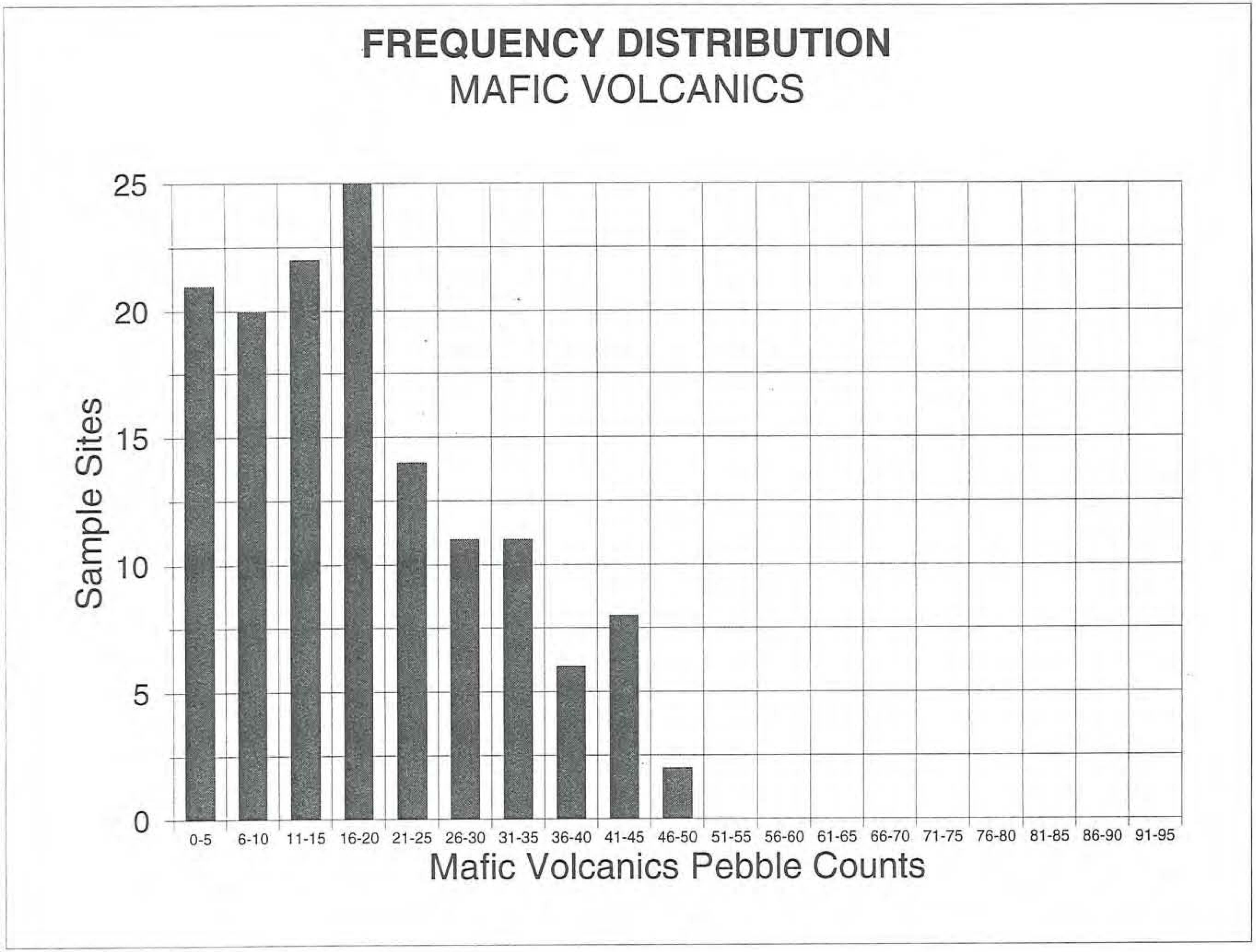
20
0
0-5
6-10
11-15
16-20
21-25
26-30
31-35
36-40
41-45
46-50
51-55
56-60
61-65
66-70
71-75
76-80
81-85
86-90
91-95
Felsic Volcanics Pebble Counts

PLATE 9. PROJECT 318, PEBBLE COUNT, MAFIC VOLCANICS




FREQUENCY DISTRIBUTION
MAFIC VOLCANICS
Sample Sites
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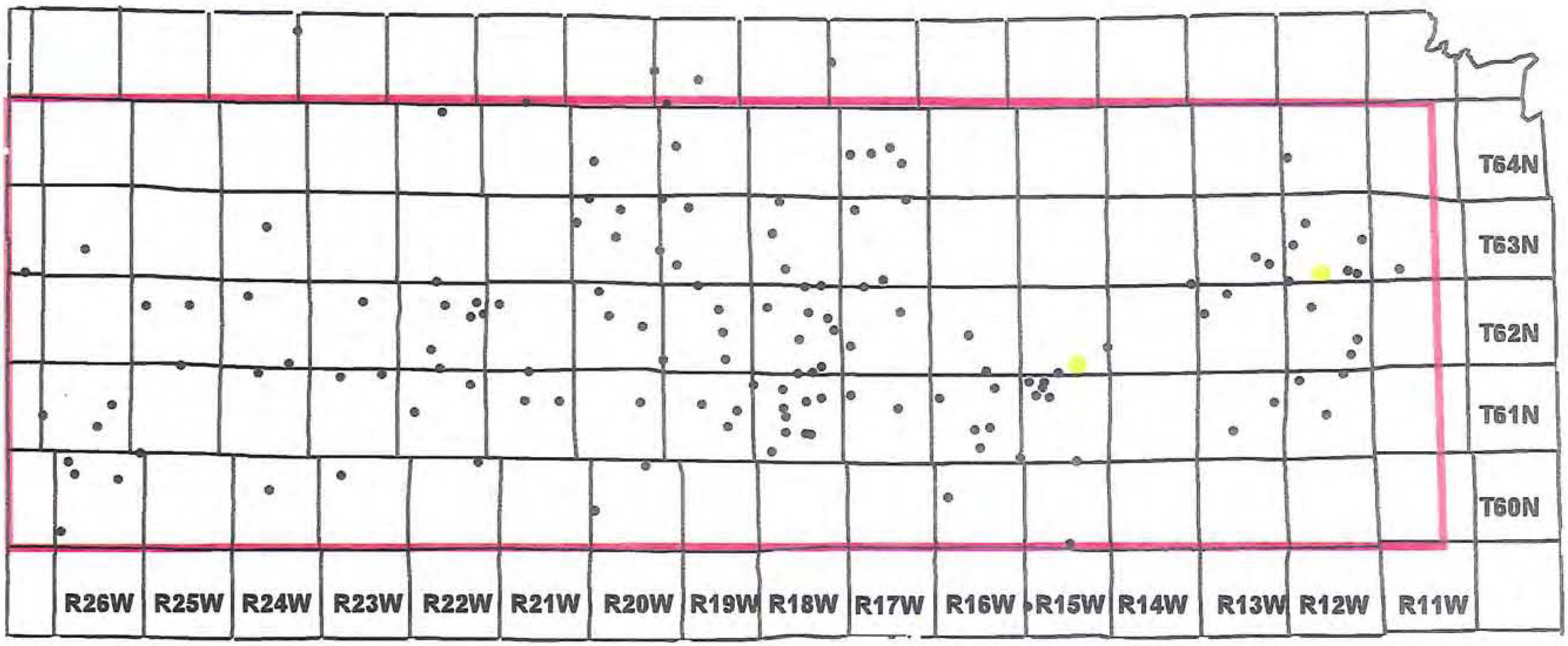
15
20
25
0-5
6-10
11-15
16-20
21-25
26-30
31-35
36-40
41-45
46-50
51-55
56-60
61-65
66-70
71-75
76-80
81-85
86-90
91-95
Mafic Volcanics Pebble Counts

PLATE 10. PROJECT 318, PEBBLE COUNT, IRON FORMATION



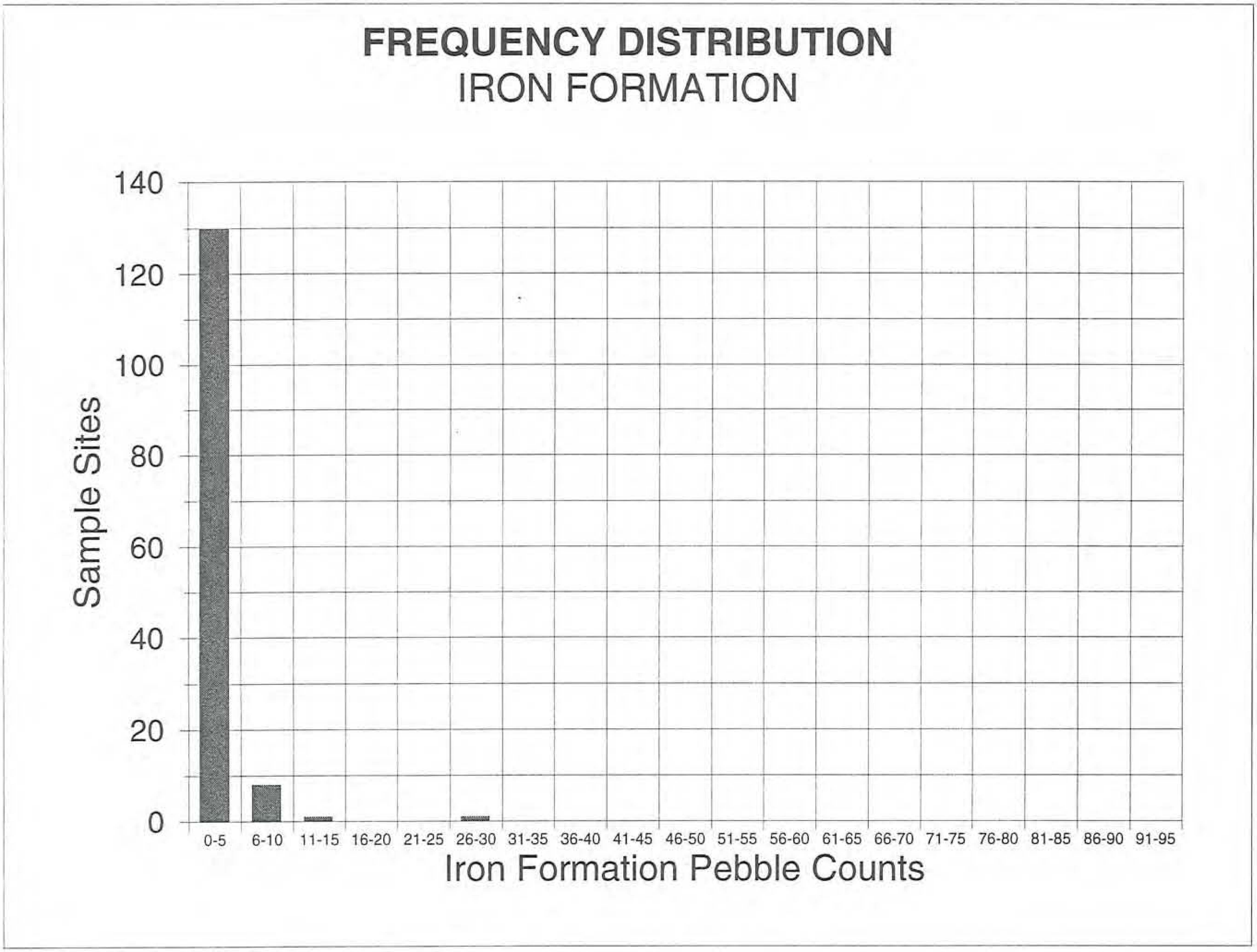
Mntwp

P318pt

- **0 - 10**
- **11 - 27**

Box3.shp

Project 318 Study Area


FREQUENCY DISTRIBUTION
IRON FORMATION
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Sample Sites
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6-10
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16-20
21-25
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31-35
36-40
41-45
46-50
51-55
56-60
61-65
66-70
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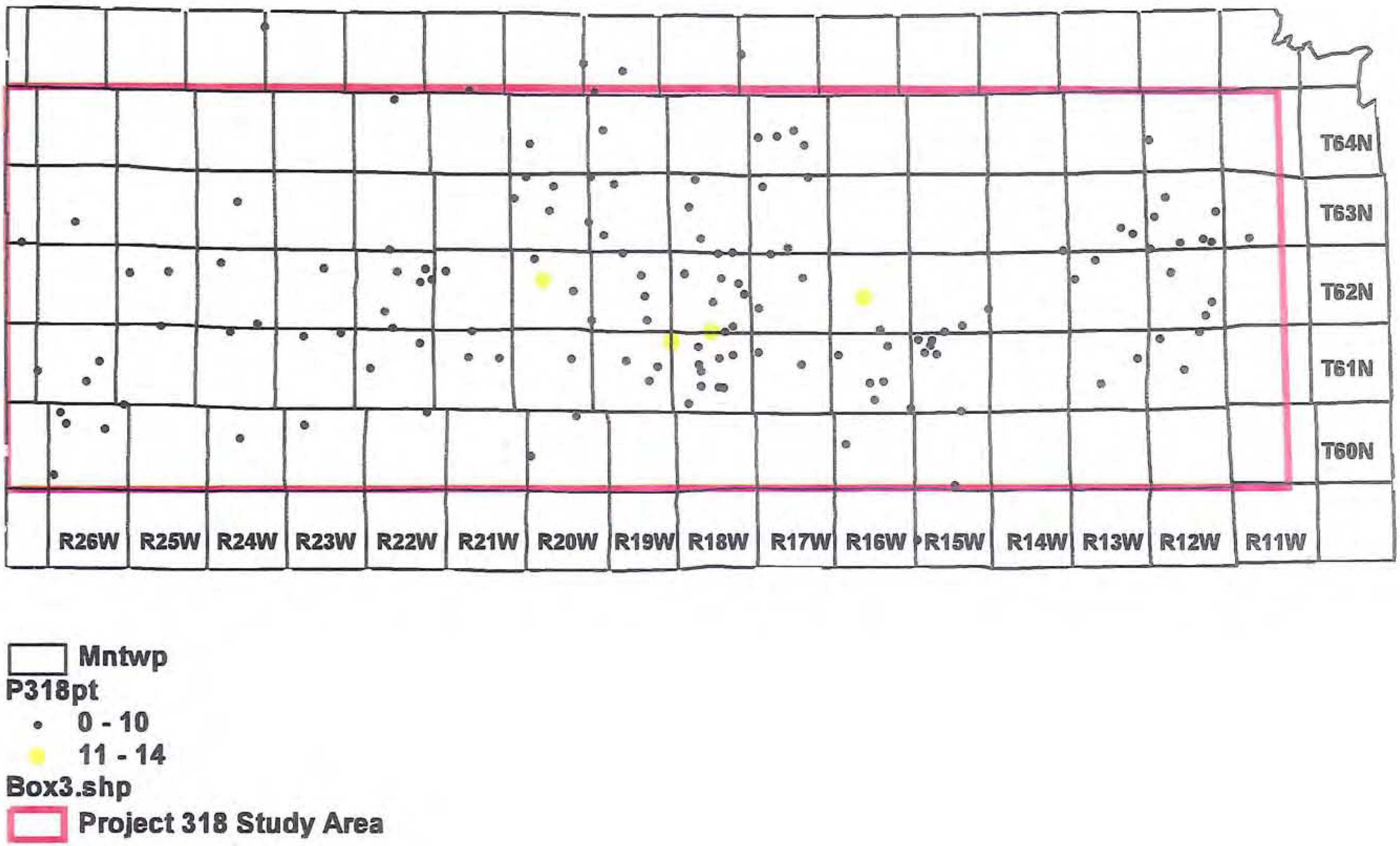
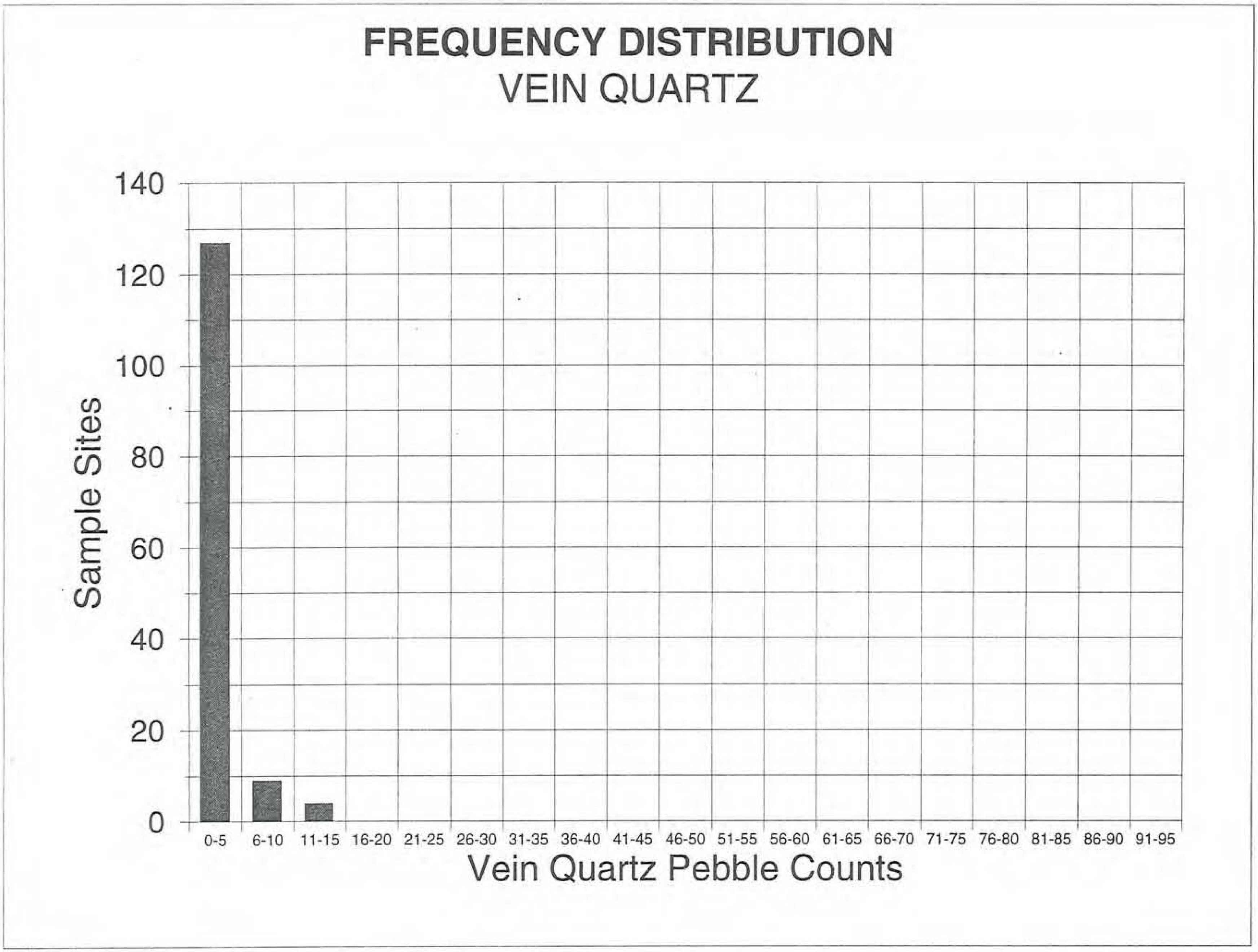
76-80
81-85
86-90
91-95
Iron Formation Pebble Counts

PLATE 11. PROJECT 318, PEBBLE COUNT, VEIN QUARTZ




FREQUENCY DISTRIBUTION
VEIN QUARTZ
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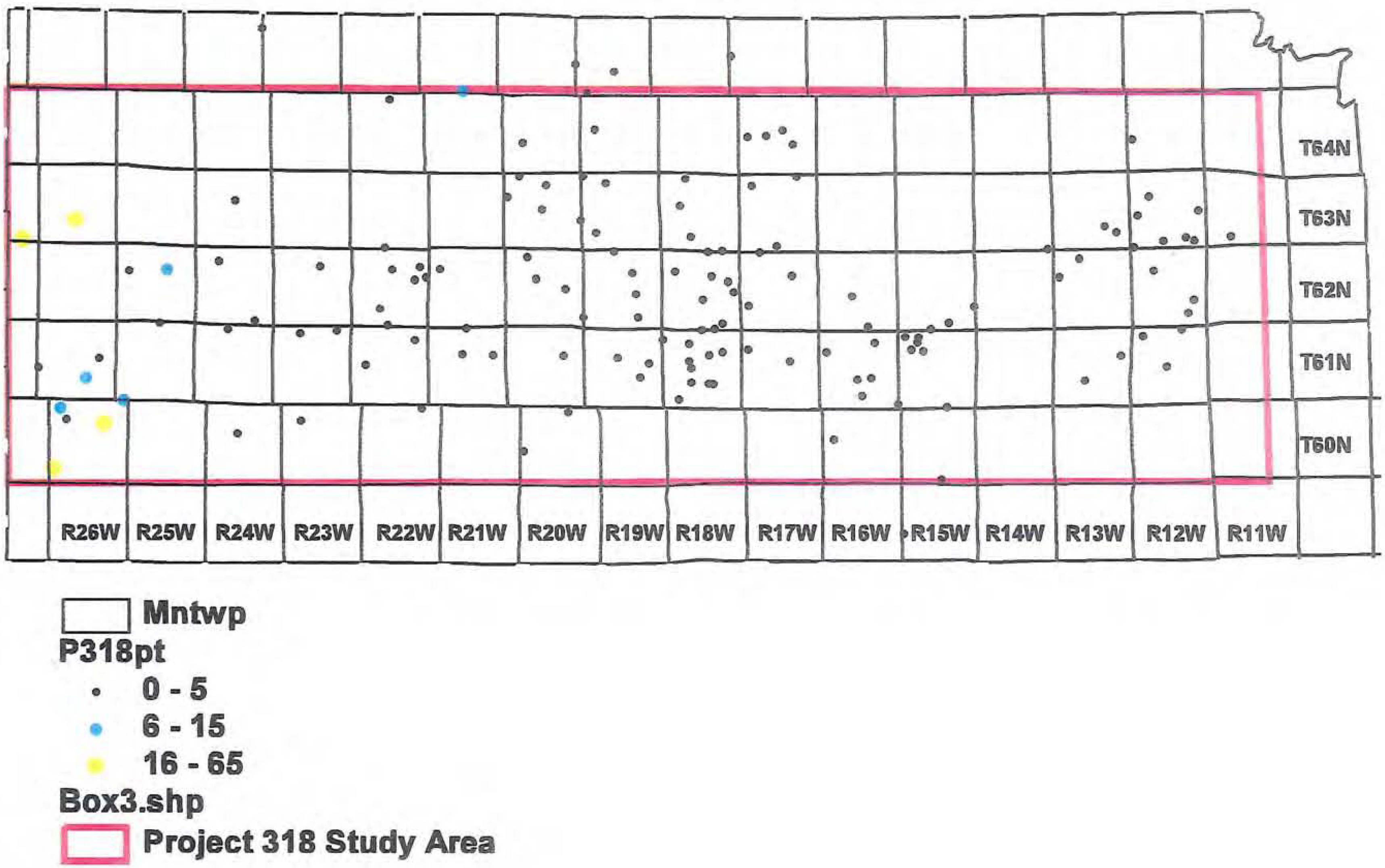
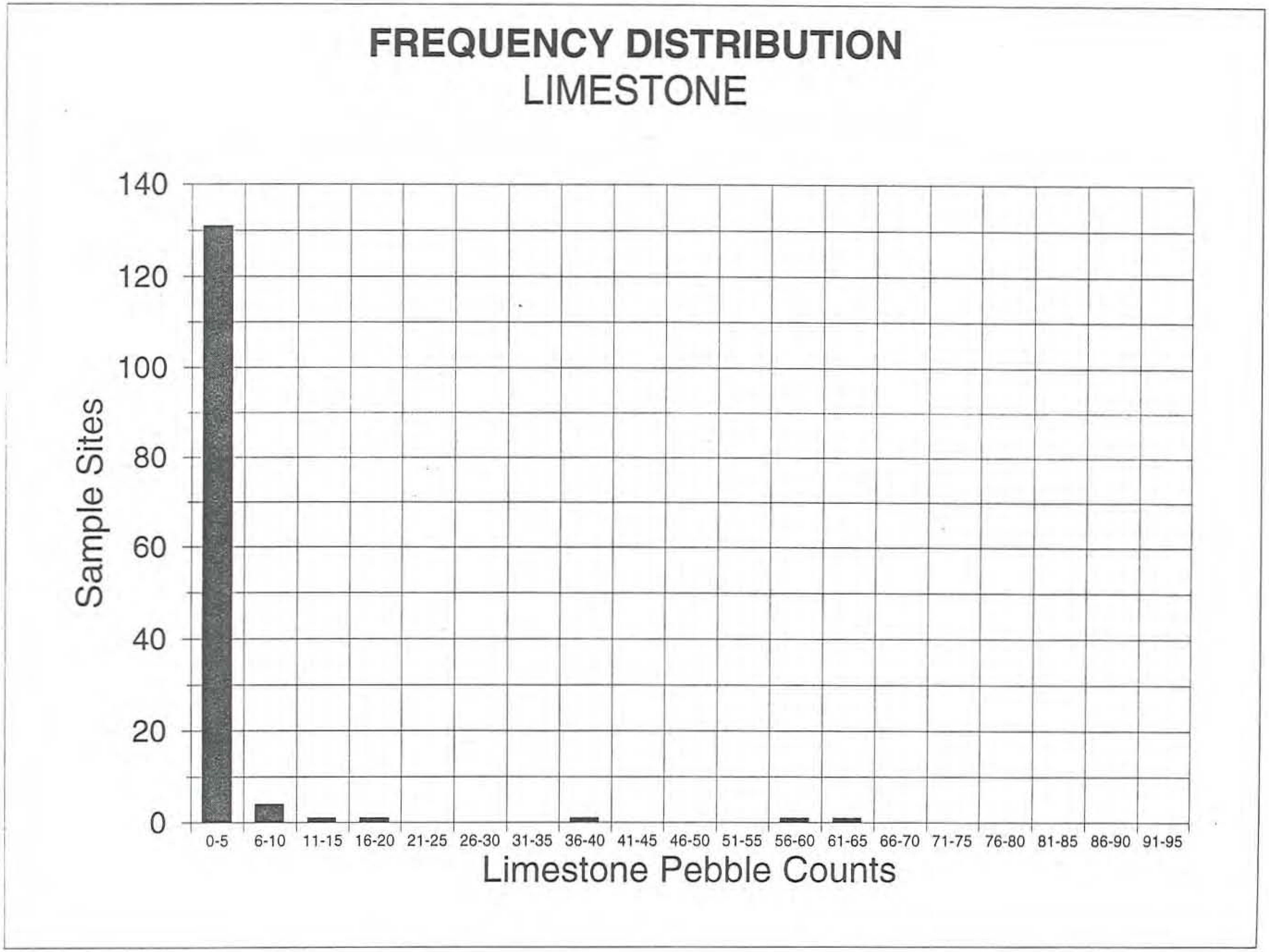
Vein Quartz Pebble Counts

PLATE 12. PROJECT 318, PEBBLE COUNT, LIMESTONE





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36-40
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51-55
56-60
61-65
66-70
71-75
76-80
81-85
86-90
91-95
Limestone Pebble Counts

PLATE 1 BEDROCK GEOLOGY ELY-BIGFORK STUDY AREA

PROJECT 318 STUDY AREA

FAULTS

MGS DESCRIPTION OF MAP UNITS [MODIFIED FROM MOREY 1996]

MIDDLE PROTEROZOIC

- **Pmgg** Granite and granophyric felsic rocks
- **Pmt** Intrusions of troctolitic and gabbroic rocks.
- **Pma** Anorthositic gabbro and related rocks.

EARLY PROTEROZOIC

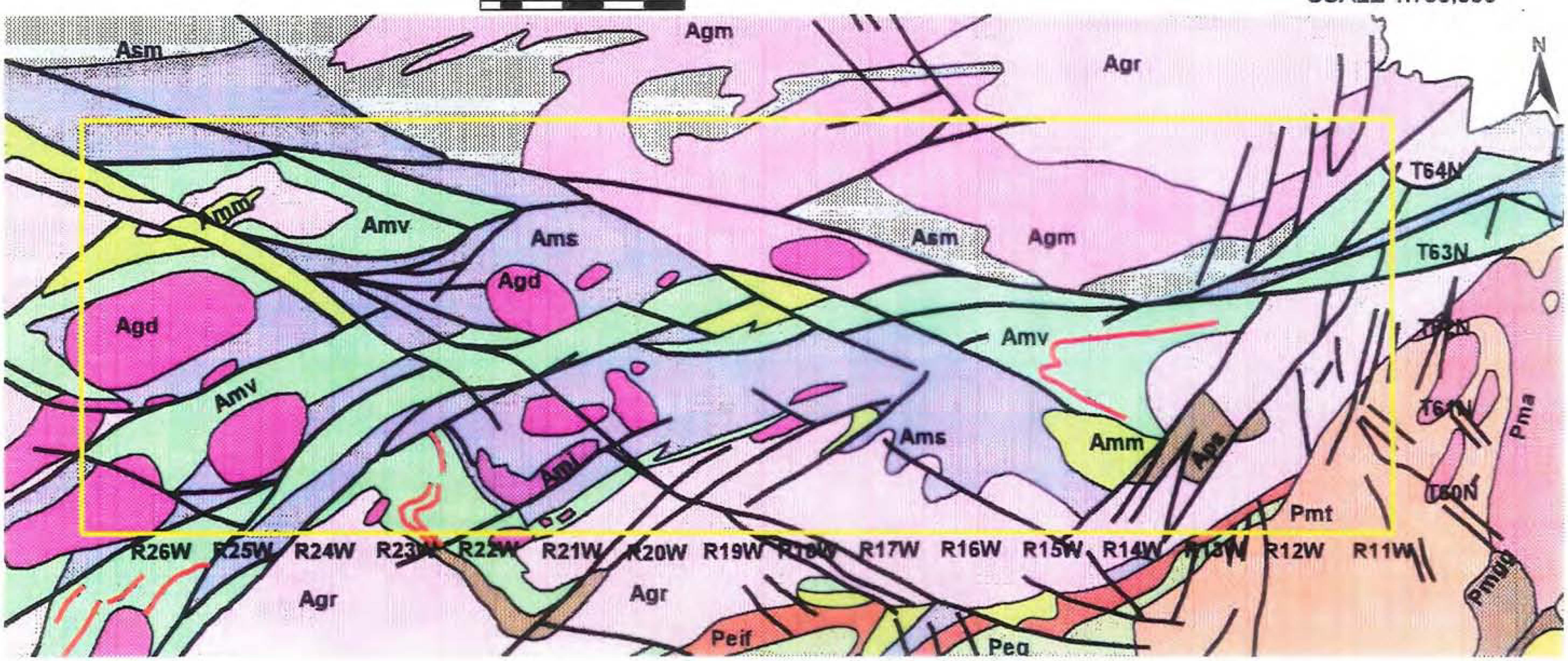
- **Peg** Shale, siltstone, feldspathic graywacke, and associated volcaniclastic rocks--Includes the Virginia Formation of Northern Minnesota
- **Peif** Iron-formation

LATE ARCHEAN

- **Ami** Post-tectonic mafic intrusions--Includes gabbro, peridotite, pyroxenite, and their metamorphic equivalents.
- **Agd** Post-tectonic to late-tectonic granitoid intrusions of the Algoman orogen--Includes multiphase intrusions of hornblend-pyroxene- and biotite-bearing monzonite, monzodiorite, diorite, and granodiorite.
- **Agr** Syntectonic to pre-tectonic granitoid rocks--Includes granite and granodiorite of the Vermilion Granitic Complex and Giants Range.
- **Agm** Granite-rich migmatite--Includes granitic gneiss, paragneisses, schist, and migmatite in the Vermilion Granitic Complex. Grades into granitoid rocks.
- **Asm** Paragneisses and schist-rich migmatite--Grades into metasedimentary rocks
- **Ams** Metasedimentary rocks, undivided--Includes graywacke, slate, local units of conglomerate,arenite, graphitic slate, fine-grained felsic volcanogenic and volcaniclastic rocks, and their metamorphic equivalents.
- **Amv** Mafic metavolcanic rocks--Unit is dominantly basalt but has thin units of sedimentary material, including iron-formation [shown in red].
- **Amm** Mixed metavolcanic rocks--Mafic to felsic volcanic sequences having variable amounts of felsic volcanogenic and volcaniclastic rocks and lean iron-formation [shown in red].
- **Aps** Paragneisses, schist, and amphibolite--Metamorphic equivalent of units Amv and Ams; may include components of unit Agr.

3 0 3 6 9 12 Miles

SCALE 1:750,000



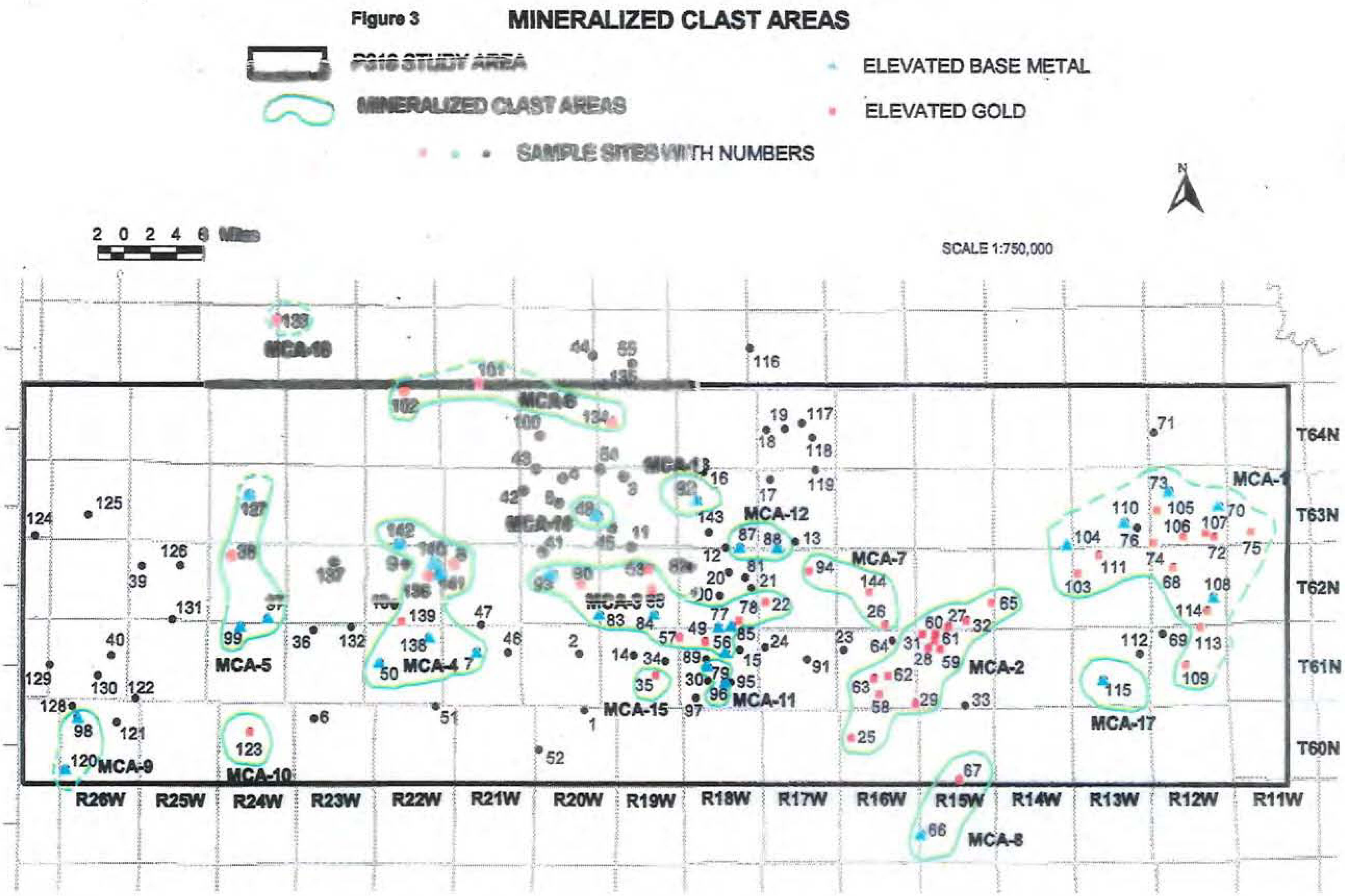


Figure 3
MINERALIZED CLAST AREAS
P316 STUDY AREA
MINERALIZED CLAST AREAS
SAMPLE SITES WITH NUMBERS
ELEVATED BASE METAL
ELEVATED GOLD
N
2 0 2 4 6 Miles
SCALE 1:750,000
MCA-1
MCA-2
MCA-4
MCA-5
MCA-6
MCA-7
MCA-8
MCA-9
MCA-10
MCA-11
MCA-12
MCA-13
MCA-15
MCA-17
T64N
T63N
T62N
T61N
T60N
R26W R25W R24W R23W R22W R21W R20W R19W R18W R17W R16W R15W R14W R13W R12W R11W