



Special Report 08

A Study of Potential Co-Product Trace Elements Within the Clear Hills Iron Deposits, Northwestern Alberta

Published as Alberta Geological Survey Special Report 08

**A STUDY OF
POTENTIAL CO-PRODUCT TRACE ELEMENTS
WITHIN THE CLEAR HILLS IRON DEPOSITS,
NORTHWESTERN ALBERTA**

Prepared for

Research and Technology Branch, Alberta Energy

Prepared by

APEX Geoscience Ltd.
(Project 97213)

In cooperation with

The Alberta Geological Survey, Energy and Utility Board

And

Marum Resources Ltd.

February, 1999

R.A. Olson
D. R. Eccles
C.J. Collom

A STUDY OF POTENTIAL CO-PRODUCT TRACE ELEMENTS WITHIN THE CLEAR HILLS IRON DEPOSITS, NORTHWESTERN ALBERTA

TABLE OF CONTENTS

<u>SECTION</u>	<u>PAGE</u>
ACKNOWLEDGMENTS AND DISCLAIMER	vi
1.0 SUMMARY	1
2.0 INTRODUCTION	3
2.1 Preamble.....	3
2.2 Location, Access, Physiography, Bedrock Exposure	4
2.3 Synopsis of Prior Scientific Studies of the Clear Hills Iron Deposits, and the Stratigraphically Correlative Bad Heart Formation	4
2.4 Synopsis of Prior Exploration of the Clear Hills Iron Deposits	6
3.0 GEOLOGY	7
3.1 Introduction	7
3.2 Regional Stratigraphic Relationships in the Peace River Region	8
3.2.1 Peace River Group	8
3.2.2 Shaftesbury Formation	8
3.2.3 Dunvegan Formation	8
3.2.4 Smoky Group	10
3.2.4(a) Kaskapau Formation	10
3.2.4(b) Cardium Formation.....	10
3.2.4(c) Muskiki Formation	11
3.2.4(d) Bad Heart Formation	11
3.2.5 (e) Puskwaskau Formation	12
3.2.5 Wapiti Formation	12
3.2.6 Glacial Deposits	12
3.3 Regional Structural Setting.....	13
3.3.1 Introduction.....	13
3.3.2 Peace River Arch.....	13
3.4 Geology of the Bad Heart Formation.....	14
3.4.1 Historical Background.....	14
3.4.2 Regional Geology, Stratigraphy and Paleontology	16
3.4.3 The Ferruginous Oolitic Ironstone	18

TABLE OF CONTENTS (Cont.)

<u>SECTION</u>	<u>PAGE</u>
3.5 Geology of the Clear Hills Iron Deposits	19
3.5.1 Introduction.....	19
3.5.2 Description of the Known Iron Deposits.....	20
3.5.2(a) Southern Clear Hills, including Worsley Deposits.....	22
3.5.2(b) Rambling River, Whitemud River and South Whitemud River Iron Deposits.....	26
3.5.2(c) Smoky River Section	29
3.6 Possible Correlative Ferrous Deposits in the Western Canada Sedimentary Basin	29
3.7 Correlative Iron Deposits Worldwide	30
4.0 CHARACTERISTICS OF THE CLEAR HILLS IRON DEPOSITS	32
4.1 Ore Mineralogy, Petrology and Petrography of the Iron Deposits	32
4.2 Physical Characteristics of the Iron Deposits	34
4.3 Chemical Characteristics of the Iron Deposits From Prior Studies.....	36
5.0 SUMMARY OF SOME ECONOMIC AND BENEFICIATION ASPECTS FOR FUTURE EXPLOITATION OF THE CLEAR HILLS IRON DEPOSITS.....	38
5.1 Estimated Ore Reserves and Grades	38
5.2 Synopsis of Prior Beneficiation Studies.....	38
5.3 Availability of Fuel and Other Raw Materials Needed for Processing the Clear Hills Iron Deposits	42
5.4 Synopsis of Prior Marketing Studies	42
6.0 RESULTS FROM CURRENT STUDY OF POTENTIAL CO-PRODUCT TRACE ELEMENTS IN THE CLEAR HILLS IRON DEPOSITS.....	43
6.1 Summary of Samples and Their Locations.....	43
6.2 Sample Preparation and Analytical Methodology.....	43
6.3 Geochemical Results	49
6.3.1 Introduction.....	49
6.3.2 Precious Metals (Gold, Silver, Platinum Group Elements)	52
6.3.3 Base Metals and Selected 'Pathfinder Elements'	54
6.3.4 Uranium Thorium, Rare Earth and Related Elements	61
6.3.5 Rock Forming and Related Elements	64

TABLE OF CONTENTS (Cont.)

<u>SECTION</u>	<u>PAGE</u>
7.0 DISCUSSION.....	67
7.1 Possible Sedimentological Depositional Setting of the Bad Heart Formation, and Genetic Origin of the Clear Hills Iron Deposits	67
7.2 Discussion of Results From the Current Study With Respect to Potential Economic Development of the Clear Hills Iron Deposits	69
8.0 CONCLUSIONS AND RECOMMENDATIONS	70
8.1 Conclusions With Respect to Potential Co-product Trace Elements in the Clear Hills Iron Deposits	70
8.2 Recommendations for Future Studies	72
9.0 REFERENCES	74
10.0 CERTIFICATION FOR SENIOR AUTHOR OF REPORT	87

TABLES

<u>TABLE</u>	<u>PAGE</u>
I UPPER CRETACEOUS REGIONAL STRATIGRAPHIC COMPARISONS, NORTHWEST ALBERTA	9
II AVERAGE PERCENTAGE OF TEXTURAL ELEMENTS IN OOLITIC IRON STONE AT RAMBLING RIVER.....	34
III BULK CHEMICAL COMPOSITION OF THE CLEAR HILLS IRON DEPOSITS	37
IV SUMMARY OF CLEAR HILLS IRON ORE RESOURCES	40
V CHEMICAL ANALYSES OF THE ORE AFTER UPGRADING	41
VI SUMMARY OF SAMPLES USED, CLEAR HILLS IRON DEPOSIT STUDY	44
VII SUMMARY OF ANALYTICAL METHODS USED, CLEAR HILLS IRON DEPOSIT STUDY	50
VIII SUMMARY OF ELEMENTS AND DETECTION LIMITS, CLEAR HILLS IRON DEPOSIT STUDY	51

TABLES (Cont.)

<u>TABLE</u>	<u>PAGE</u>
IX SUMMARY OF RESULTS FOR RARE EARTH AND RELATED OTHER ELEMENTS	62
X GEOCHEMICAL RESULT HIGHLIGHTS FROM CURRENT STUDY	71

APPENDICES

<u>APPENDIX</u>	<u>PAGE</u>
I SYNOPSIS OF CHEMISTRY AND DESCRIPTION FOR MINERALS WITHIN THE CLEAR HILLS IRON DEPOSITS	AT END
II GEOCHEMICAL RESULTS FROM CURRENT STUDIES	
II.1 Certificates of Analysis from Activation Laboratories Ltd.	AT END
II.2 Digital Copy of Results on CD-ROM Disk	AT END
III.3 Master Summary Table of Results	AT END
III SYNOPTIC STATISTICAL ANALYSIS BY MAJOR SAMPLING AREA	AT END
IV COMPARATIVE RESULTS OF DUPLICATE SAMPLE PAIRS	AT END
V COMPARATIVE RESULTS BETWEEN THE INAA AND FIRE ASSAY OR ICP METHODS FOR GOLD (Au), SILVER (Ag), MOLYBDENUM (Mo), NICKEL (Ni), ZINC (Zn) AND CALCIUM (Ca)	AT END
VI GEOCHEMICAL DISTRIBUTION HISTOGRAMS FOR SELECTED ELEMENTS, CLEAR HILLS IRON DEPOSITS	AT END
VI.1 Precious Metals and Platinum Group Elements	AT END
VI.2 Base Metals and Pathfinder Elements	AT END
VI.3 Uranium, Thorium, Rare Earths and Related Elements	AT END
VI.4 Rock Forming and Related Trace Elements	AT END

FIGURES

<u>FIGURE</u>	<u>PAGE</u>
1 LOCATION AND REGIONAL GEOLOGY OF THE BAD HEART FORMATION, INCLUDING SAMPLE SITES FOR THIS STUDY	5
2 BEDROCK GEOLOGY AND SCHEMATIC CROSS SECTION OF THE CLEAR HILLS AREA	15

FIGURES (Cont.)

<u>FIGURE</u>	<u>PAGE</u>
3 BIOSTRATIGRAPHIC ZONATION AND GEOCHRONOLOGY FOR CARDIUM AND WAPIABI FORMATION EQUIVALENTS IN THE PEACE RIVER ARCH REGION OF ALBERTA AND BRITISH COLUMBIA	17
4 LOCATION OF PRIOR DRILLING IN THE CLEAR HILLS IRON DEPOSITS.....	23
5 SUMMARY DRILL SECTIONS, WORSLEY DEPOSIT AREA.....	24
6 LITHOLOGY OF THE WORSLEY DEPOSIT	25
7 LITHOLOGY OF THE RAMBLING RIVER DEPOSIT	27
8 VERTICAL VARIATION IN PETROGRAPHIC TEXTURAL ELEMENTS IN THE RAMBLING RIVER OOLITIC IRON DEPOSIT.....	35
9 VERTICAL VARIATIONS IN IRON CONTENTS WITHIN THE CLEAR HILLS OOLITIC IRON DEPOSITS	39

PLATES

<u>PLATE</u>	<u>PAGE</u>
1 BAD HEART FORMATION OOLITIC FACIES, RAMBLING RIVER DEPOSIT, ALBERTA.....	21

ACKNOWLEDGMENTS AND DISCLAIMER

The authors would like to thank several individuals who assisted with the preparation of this report. These individuals include Mr. R. Boulay, President of Marum Resources Inc. (Marum) who provided many of the samples used in this study. Mr. Tom Bryant, consultant prospector to Marum who provided both samples and geological data. Mr. W. Hamilton, Senior Research Scientist with the Alberta Geological Survey (AGS), who assisted in identifying the samples on file with the AGS, and also shared his knowledge about the Clear Hills iron deposits. Mr. John D. Scott, the project co-manager appointed by Alberta Energy, who assisted with overall project planning and supervision. Finally, several individuals at APEX Geoscience Ltd., including Mr. C. Buchanan and Ms. Sollie Balzer, assisted in either data manipulation or other aspects of preparation of the final project report. All this assistance, without which this study would not have been possible, is greatly appreciated. However, any errors or omissions in the final project report, are solely the responsibility of the authors.

This also acknowledges that the research project for which this report is submitted was funded (in part) by the Government of Alberta through the Alberta Department of Energy. However, this report and its contents, the project in respect of which it is submitted, and the conclusions and recommendations arising from it, do not necessarily reflect the view of the Government of Alberta, its officers, employees or agents. Specifically, the Government of Alberta, its officers, employees or agents make no warranty, express or implied, representation or otherwise, in respect of this report or its contents. For greater certainty, the Government of Alberta, its officers, employees and agents are exempted, excluded and absolved from all liability for damage for injury, howsoever caused, to any person in connection with or arising out of the use by that person for any purpose of this report or its contents.

A STUDY OF POTENTIAL CO-PRODUCT TRACE ELEMENTS WITHIN THE CLEAR HILLS IRON DEPOSITS, NORTHWESTERN ALBERTA

1.0 SUMMARY

The Clear Hills iron deposits (also known as the Peace River iron formation) comprise an oolitic iron- and silica-rich facies of the Bad Heart Formation sandstone of Late Cretaceous (late Coniacian) age in northwestern Alberta. The oolitic iron deposit crops out along the southern and northeastern flanks of the Clear Hills. The iron deposit is up to about 9 m thick in the northeast, but reportedly thins to zero metres thickness to the west.

The iron deposit was initially discovered in 1924, and attracted considerable development interest during the late 1950's into the 1960's. At that time a large amount of exploratory and feasibility work was done because the Clear Hills deposit is the only potentially economic iron ore deposit in the Prairies region of western Canada. Total resources in the 'proven', 'probable' and 'possible' categories have been estimated at over 1 billion tonnes grading about 32 to 35 per cent (%) iron and 20% silica. However, the relatively low iron grade, and the complex ore mineralogy, have prevented development to date.

In general, there is consensus that the oolitic iron formation was deposited in a wave-agitated shallow marine environment, but the exact origin of the high concentrations of iron and silica in the late Coniacian sea water is less certain. Some workers have suggested these elements were derived from normal weathering processes from a nearby land mass or masses. However, Olson *et al.* (1994) speculated that the genetic origin of the Clear Hills iron deposits may in some way be related to an igneous fumarolic event that debouched iron, silica and possibly other metals into the shallow waters which existed during Bad Heart Formation time. If so, then there might be potential for the existence of elevated base- or precious-metal concentrations, or even ore deposits, to exist within portions of the Clear Hills iron deposits. Subsequently, reconnaissance exploration for gold in the Clear Hills iron deposits identified some sites that produce rock samples assaying locally up to 25 grams gold per tonne (Boulay, 1995, 1996). Thus, the current lithogeochemical study of 151 samples, which are from a suite of archived Bad Heart Formation samples, was undertaken to evaluate the potential for selected elements to exist in sufficiently high concentrations to be important as co-products during possible future iron exploitation.

Results from the current lithogeochemical study indicate that elements with elevated concentrations in the iron-rich portion of the Bad Heart Formation oolitic ironstone comprise: gold (typically 10 ppb to 36 ppb Au), antimony (typically 8 ppm up to 75 ppm Sb), arsenic (typically 150 ppm up to 1,000 ppm As), cobalt (typically 30 ppm up to 210 ppm Co), chromium (typically 140 ppm up to 180 ppm Cr), lead (typically 45

ppm up to 59 ppm Pb), manganese (typically 500 ppm up to 1,661 ppm Mn), molybdenum (typically 10 ppm up to 92 ppm Mo), nickel (typically 50 ppm up to 250 ppm Ni), vanadium (typically 800 ppm up to 1,633 ppm V), zinc (typically 300 ppm up to 808 ppm Zn), plus some REE (Eu up to 4.4 ppm, Lu up to 1.03 ppm, Nd up to 53.0 ppm, Sm up to 14.0 ppm, Tb up to 3.6 ppm, Y up to 152.0 ppm, and Yb up to 7.9 ppm). However, none of these elements exist in concentrations that, in themselves, are economically mineable at the few areas where the archived samples are from. Nonetheless, their elevated character indicates at some places within the Clear Hills iron deposits they may exist in sufficient concentration such that one or more of them could be an important co-product during any future mining of iron. Further work is needed to evaluate this conclusion.

Of possible particular interest is the Rambling River area, where samples in this study tend to have higher mean, median and modes for As, Co, Cr, Mo, Mn, Ni, Pb, Sb, V, W, Fe and possibly P, and lower amounts of Al, Ca and K. Vanadium is of particular interest as a potential co-product because in places its content is equivalent to about 0.22% V_2O_5 . Thus, vanadium could be a significant co-product if the Rambling River iron deposit is, in future, mined. As well, the elevated contents of As, Mo, Sb and W at this area, indicate that there is potential for discovery of important auriferous zones associated with the Clear Hills iron deposits. In addition, because fumarolic hydrothermal activity appears to have been important at least locally during Bad Heart Formation time, potential exists for base- and precious-metal massive sulphide deposits. Finally, the presence of 'diamond indicator mineral grains' in places in the Bad Heart Formation and some other Late Cretaceous strata in northwestern Alberta, indicates potential exists for the discovery of diamondiferous ultramafic diatremes.

With respect to further geoscientific studies, there is a need for more extensive sampling and analytical work of the Clear Hills iron deposits, and the Bad Heart Formation. This work should better evaluate the regional variations in lithochemistry of the Bad Heart Formation oolitic ironstone, and particularly whether some elements, other than iron, have potential to be important co-products in places. Because elevated contents of Fe, As, Co, Cr, Mo, Mn, Ni, Pb, Sb, V and W exist at the Rambling River area, future studies should perhaps be initially focused at and near this area. Further work on the Clear Hills iron deposits will require drilling to obtain core or, less desirably, cuttings on some selected systematic regional basis due to the fact that most of the Clear Hills iron deposit is covered by Late Cretaceous or younger sedimentary units, or by Quaternary to Recent till and other surficial sediments. Further work also is required to understand the regional stratigraphy and paleogeographic setting, including contemporaneous intra-basinal faulting, of the Bad Heart Formation and other Late Cretaceous strata in northwestern and northern Alberta. Such work would provide data as to the potential for contained base- and precious-metal deposits to exist within the Bad Heart Formation, and would assist in identifying sites favourable for the emplacement of ultramafic diatremes which currently are an important focus of diamond exploration in northern Alberta. Finally, to ensure any future work is done to professional geoscientific standards, such work should be done by, or under the supervisory auspices of, the Alberta Geological Survey.

2.0 INTRODUCTION

2.1 Preamble

The Clear Hills iron deposits (also known as the Peace River iron formation) comprise an oolitic iron- and silica-rich facies of the Bad Heart Formation sandstone of Late Cretaceous (Coniacian) age in northwestern Alberta. The oolitic iron deposit is known to crop out along the southern and northeastern flanks of the Clear Hills, and is essentially flat-lying to very shallowly easterly dipping, and may extend under all or a major portion of the Hills. The iron deposit reaches up to about 9 m thick in the zero metres thickness to the west (Hamilton, 1980).

The deposit was initially discovered in 1924 by homesteader's in the Peace River area, but the deposit held little economic interest at that time, and was all but forgotten until the early 1950's when it was 're-discovered' during exploratory oil well drilling (Kidd, 1959). The iron deposit attracted considerable development interest during the late 1950's into the 1960's, and a large amount of exploratory and feasibility work were done because the Clear Hills are the only potentially economic iron ore deposit in the Prairies region of western Canada (Hamilton, 1980). Total resources in the 'proven', 'probable' and 'possible' categories have been estimated at over 1 billion tonnes grading about 32 to 35 per cent (%) iron and 20% silica (Kidd, 1959; Bertram and Mellon, 1975). However, the relatively low iron grade, and the complex ore mineralogy, have prevented development to date (Hamilton, 1980).

In 1994 (Olson *et al.*, 1994) speculated that the genetic origin of the Clear Hills iron deposits may in some way be related to some igneous or volcanic fumarolic event that debouched iron, silica and possibly other metals into the shallow waters which existed during Bad Heart Formation time. If so, then there might be potential for the existence of precious or base metal concentrations, or even deposits, to exist within portions of the Clear Hills iron deposits. Subsequently, reconnaissance exploration for gold in the Clear Hills iron deposits identified some sites that produced rock samples assaying from about 3.0 grams gold per tonne (g Au/t, or 0.0886 oz Au/T¹), up to 25.03 g Au/t (Boulay, 1995, 1996). However, exploration indicated that "*while ubiquitous, the finely disseminated gold is present in quantities that are too small to be economically mined by themselves*" (Boulay, 1996.).

Thus, the current study was undertaken to assess whether elevated concentrations of gold, other precious or base metals, or any other 'trace elements', exist within the Clear Hills iron deposits. If some elements do exist locally in sufficiently high concentrations, then they might be potentially economic 'co-products' to assist in the feasibility of developing the iron deposits.

¹Note: 1.0 ounces gold per short ton (oz. Au/T) equals 34.286 grams gold per tonne (g Au/t).

2.2 **Location, Access, Physiography, Bedrock Exposure**

The Clear Hills iron deposits underlie all or much of the Clear Hills in northwestern Alberta, which are about 80 km northwest of the town of Peace River, Alberta, and about 480 air-kilometres northwest of Edmonton (Figure 1). The deposits are primarily within National Topographic System (NTS) map-areas 84D and 84E.

The southern parts of the Clear Hills iron deposits are accessible by gravel road extending northerly from the small community of Worsley. Farther north, the deposits which crop out along Rambling River (formerly called Swift Creek) are accessible by foot from the dry weather, gravel road that extends to the Notikewin forestry tower and airstrip. In general, other than these locales, access to other places in the Clear Hills is best done by helicopter, or in winter by skidoo along several seismic lines which transect this area. The iron deposits extend at least 40 km to the east and 35 km to the north from the Worsley Pit, which is the southernmost exposures of the Clear Hills iron deposits and is located about 10 km northeast of the community of Worsley, (Figure 1).

The rolling Prairie topography in the vicinity of the Clear Hills has an average elevation of about 700 m. The Clear Hills form a gently sloping upland that rises from east to west, reaching elevations that locally reach up to almost 1,100 m near their southwestern margin and to the north along Halverson Ridge. Local relief is about 300 m along the souther margins of the Clear Hills, but to the north and east the hills slope gradually into the wide glaciated valleys of the the Notikewan and Whitemud Rivers and their tributaries. The terrain within the Clear Hills is rolling and thickly wooded, with the dominant species being spruce on the uplands, poplar on the slopes, and willow along the rivers and creeks; muskeg only covers small areas of the upland (Kidd, 1959). The Clear Hills originated as post-Cretaceous monadnocks, which subsequently were modified by Pleistocene glaciation. The Hills are underlain by nearly flat-lying sandstone and shale units of Late Cretaceous age, and these are overlain by unconsolidated glacial and alluvial deposits of variable thickness that locally reach up to 35 m thick. As a result, bedrock exposures are scarce, commonly discontinuous and, as a result, the Clear Hills iron deposits crop out mainly along stream margins. In general, the oolitic iron-bearing unit is best exposed along Rambling River (Swift Creek), North and South Whitemud River, and in creeks along the south flank of the Clear Hills north of Worsley (Figure 1).

2.3 **Synopsis of Prior Scientific Studies of the Clear Hills Iron Deposits, and the Stratigraphically Correlative Bad Heart Formation**

The geology of the Bad Heart Formation has not, in general, been subjected to extensive, detailed study until recently (Donaldson, 1991, 1997; Donaldson *et al.*, 1998; Collom, 1997a,b,c, 1999; Collom and Krouse, 1997). Selected older references of particular interest include Stott (1960, 1961, 1963 and 1967), Green and Mellon (1962), Plint *et al.* (1990), and Leckie *et al.* (1994). A discussion of the regional geology of the Bad Heart Formation, and the overlying and underlying stratigraphy, and a more extensive list of pertinent scientific references, is given in Section 3.0 herein.



Geology Legend

- Wapiti Formation
- Smoky Group (undifferentiated)
- Puskaskau Formation
- Bad Heart Formation
- Kaskapau Formation
- Dunvegan Formation
- Shaftesbury Formation
- Peace River Group

After Green and Mellon (1962)

Sample Locations

- ① Worsley Deposit: pit samples (Boulay, 1995 and Eccles, 1995)
- ② Worsley Deposit: core samples (Boulay, 1996)
- ③ Swift Creek Deposit: trench samples (Hamilton, 1974)
- ④ Smoky River outcrop samples (Collom, 1990)

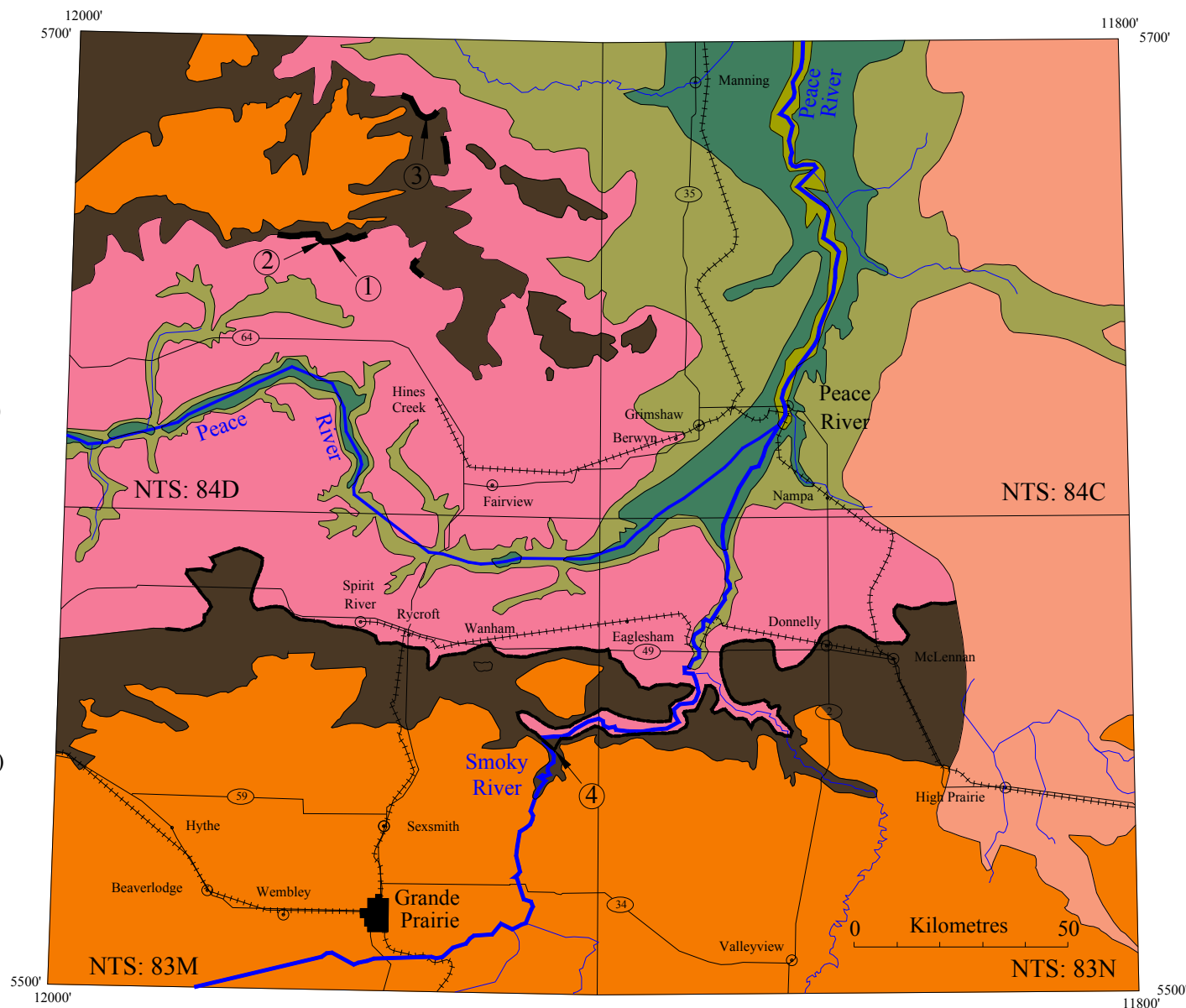


Figure 1. Location and Regional Geology of the Bad Heart Formation, Including Sample Sites for this Study.

With respect to the scientific literature dealing directly with the Clear Hills iron deposits, after their re-discovery in the early 1950's, there were a number of studies from the late 1950's to about 1980 that discussed various aspects about their geology, petrography, mineral and chemical compositions, reserves and grades, and their possible genesis. Chronologically, from oldest to youngest, selected scientific references about the Clear Hills iron deposits include: Lenz (1956), Colborne (1958), Kidd (1959), Mellon (1962), Bertram and Mellon (1975), Petruk (1976, 1977), Petruk, Farrell *et al.* (1977), Petruk, Klymowsky and Hayslip (1977), and Hamilton (1974, 1980). In general, these studies provided information about the geology of the oolitic iron deposits within the clear hills, the textural characteristics of the oolitic units, the bulk chemistry of the potential iron resource and a summary of the iron resources present. As well, some research was directed towards the metallurgical reduction of the oolitic iron ore (e.g., Samis and Gregory, 1962; Hamilton, 1974, 1980). The results of these prior scientific studies of the Clear Hills iron deposits are discussed in greater detail in Section 4.0 herein.

Because this studies focuses on the trace element composition of selected parts of the Clear Hills iron deposits, and mineralogy is important to understanding the chemistry of the deposits, Appendix I provides a brief description of each mineral discussed or referred to herein.

2.4 **Synopsis of Prior Exploration of the Clear Hills Iron Deposits**

Interest in the Clear Hills iron deposits as a potential iron resource was sparked with the discovery of "*oolitic hematite*" in the Phillips Petroleum Company Phil C No. 1 well drilled in 1953 within Lsd. 8, Sec. 23, Tp. 90, R. 5, W. 6th Mer.¹, which is directly south of Rambling River (Swift Creek), about 5 km southwest of the Notikewin tower (Kidd, 1959). As well, similar ferruginous material was recorded in two other nearby wells (McDougall, 1954). Subsequently, a total of about 245 holes were cored between 1954 and 1965 to test the Clear Hills iron deposits (McDougall, 1954; Edgar, 1960, 1961, 1962, 1963, 1964a,b,c,d,e, 1965). This work identified four separate ore reserve blocks (named Rambling River, North Whitemud River, South Whitemud River, and Worsley) that, in total, contained net recoverable reserves of 206 million tonnes proven, and 814 million tonnes probable and possible combined. The results of this evaluation work up to the early 1960's, indicated that the ore deposit was not economically developable because of its low grade and its resistance to conventional upgrading methods (Hamilton, 1980).

Little further activity occurred until 1974, when a joint research program was undertaken by the governments of Alberta and Canada to reassess the economic potential of the Clear Hills iron deposits in the light of more advanced metallurgy. To provide a large sample of the representative unweathered potential ore material for this program, a 135 tonne bulk sample was mined from beneath 15 m of overburden in the

¹Note: Lsd. is Legal Subdivision"; Sec. is Section ; Tp. is Township; R. is Range, W. is West; and Mer. is Meridian.

Rambling River portion of the deposit (Hamilton, 1974). This bulk sample was used for studies of various ore dressing, mineralogy and mineability aspects (Krupp, 1975). As well, CANMET conducted a thorough investigation of the ore mineralogy (Petruk *et al.*, 1974, 1977a,b; Petruk, 1976, 1977). The results of this reassessment of the geology and economic potential of the Clear Hills iron deposits, are summarized in Hamilton (1980), and in Sections 4.0 and 5.0 herein.

Following the work in the 1970's, little or no evaluation of the Clear Hills iron deposits was done until the mid 1990's, when the deposit was again evaluated by Marum Resources Inc. (Marum) of Calgary, Alberta for its iron potential, as well as for potential co-product elements such as gold or other metals. During 1995 and 1996, Marum excavated and sampled a trench at the Worsley area, and drilled 11 holes that penetrated to a maximum depth of 70 feet [21.34 m], with 9 of the 11 holes intersecting oolitic ironstone (Boulay, 1995, 1996). Marum also conducted a proprietary iron ore market study (MT Environmental Systems Inc., 1996). The results of this exploration are summarized in Sections 4.0 and 5.0 herein.

3.0 GEOLOGY

3.1 Introduction

During the Late Cretaceous (100 Ma to 69 Ma ago), the foreland basin associated with the Cordilleran/Sevier Orogeny along the length of the North American Rocky Mountains was flooded by an epicontinental seaway. This body of marine water extended from the Gulf of Mexico to the Arctic Ocean, and had shorelines (in Canada) near the present British Columbia - Alberta and Manitoba - Ontario provincial boundaries. Numerous sea level transgressions and regressions occurred during the 30 million years the Western Interior seaway was present over Alberta. Normally, the drops in relative sea level resulted in the eastward progradation of coastal 'wedges' of clastic sediments (siltstone, sandstone, and conglomerate). Large hydrocarbon accumulations are often found in these Cretaceous sandstones, such as the Cardium Formation (Pembina oil field), which has produced over a billion barrels of oil during the past three decades.

This trace element study focuses on unique sandstone strata of the Bad Heart Formation in the Peace River area of northwestern Alberta (Figure 1). However, unlike most Upper Cretaceous clastic wedges in western Canada, the Bad Heart Formation: (1) is associated with anomalous iron concentrations, particularly in abundant oolite-rich layers, (2) is not associated with hydrocarbons, (3) may bear evidence of syn-depositional tectonic activity involving the Precambrian basement, and (4) contains evidence of syn-depositional hydrothermal venting which affected biota and some other litho-stratigraphic characteristics.

The surface and subsurface stratigraphy of the Bad Heart Formation was the subject of Ph.D. research by Donaldson (1997; Donaldson *et al.*, 1998). More recently, the paleontology and surface stratigraphy of the Bad Heart Formation is the subject of

Ph.D. research by Collom (1999 in preparation). Both Donaldson's (*Ibid*) and Collom's (*Ibid*) published work, are summarized herein.

3.2 **Regional Stratigraphic Relationships in the Peace River Region**

The Peace River region is underlain mainly by nearly flat-lying units of late Early to late Late Cretaceous age, which are covered in most places by unconsolidated glacial deposits of variable thickness (Kidd, 1959; Green and Mellon, 1962; Irish, 1965). The exposed Cretaceous rocks range in age from Early Cretaceous Albian (about 105 Ma) to Late Cretaceous Campanian (about 74.5 Ma), and form a sequence of alternating marine and nonmarine sandstone, with mudstone or shale. Table I shows the regional stratigraphic relationships proposed by various workers, and that used in this study. Brief lithological descriptions of the Cretaceous units follow.

3.2.1 **Peace River Group**

The oldest rocks in the region comprise late Early Cretaceous (Albian) Peace River Group, which is within the Fort St. John Supergroup. The Peace River Group is a sequence of shale (near the base) to sandstones (at the top).

3.2.2 **Shaftesbury Formation**

The Shaftesbury Formation (late Albian to Cenomanian) is the uppermost unit within the Fort St. John Supergroup, and underlies the lowlands adjacent to the Chinchaga River (Figure 1). The Shaftesbury Formation increases in thickness towards the east in the Clear Hills area, from approximately 450 m to 290 m (Green and Mellon, 1962), and consists of dark grey marine shales with laminated siltstone interbeds that increase near the top of the sequence. The Shaftesbury Formation has been subdivided into the Westgate, Fish Scales and Belle Fourche formations (Bloch *et al.*, 1993). The Fish Scales Formation comprises a bone bed and abundant fish scales, which can be traced throughout the Western Canada Sedimentary Basin (WCSB) and is useful as a datum for subsurface well-log correlations.

3.2.3 **Dunvegan Formation**

The Dunvegan Formation (Cenomanian) underlies the lower slopes of the Chinchaga and Milligan highlands, and much of the lowlands adjacent to the Chinchaga and Notikewan Rivers. The Dunvegan Formation rises gently to the northeast where it forms the caprock of part of the Naylor Hills, attains thicknesses of about 150 m to 235 m (Green and Mellon, 1962), and forms a thick wedge of carbonaceous, medium- to coarse-grained, cross bedded sandstone with interlayered siltstone and mudstone. The Dunvegan Formation is interpreted as a stacked series of deltaic depositional systems (Battacharya and Walker, 1991). Both the upper and lower boundaries of the Dunvegan Formation, with the overlying Smoky Group and the underlying Shaftesbury Formation, are best characterized as interfingering and somewhat diachronous.

NORTHERN REGION							This Study		
STOTT 1967	STELCK 1955	GLEDDIE 1949	McLEARN & KINDLE 1950	McLEARN 1926	McLEARN 1919	DAWSON 1881			
BRAZEAU	WAPITI	WAPITI	WAPITI	WAPITI	WAPITI	WAPITI	Wapiti		
SMOKY GROUP	Wapiabi formation	Wapiabi formation	Wapiabi fm.	"Upper shale" formation	Upper shale	Upper shale	Puskwaskau		
								Nomad	
								Chungo	
								Hanson	
								Thistle	
								Dowling	
								Marshy-bank	
	Cardium formation	Cardium formation	Cardium formation	Cardium formation	Kaskapau formation	Smoky River formation	Smoky River formation	Bad Heart	
									Muskiki
									Sturrock
									Leyland
									Moose-hound
									Ram
									Opabin
									Haven
Kaskapau fm.	Kaskapau fm.	Kaskapau	Kaskapau	Kaskapau	Smoky River formation	Smoky River formation	Lower shale		
								Vimy	
								Sunkay	
Dunvegan fm.	Dunvegan	Dunvegan	Dunvegan	Dunvegan	Dunvegan	Dunvegan	Dunvegan		
"Ft. St. John"	FORT ST. JOHN GROUP	FORT ST. JOHN GROUP	FORT ST. JOHN GROUP	St. John fm.	St. John fm.	Ft. St. John	Ft. St. John Group		
Mtn. Park fm?									
							Shaftesbury		
							Peace River Group		

Table 1. Upper Cretaceous Regional Stratigraphic Comparisons, Northwest Alberta.

3.2.4 Smoky Group

The Smoky Group (late Cenomanian to early Campanian) comprises a thick, predominantly marine sequence of fine-grained strata that underlies a large area in the Peace River district of Alberta and British Columbia. Southwest of the Clear Hills, towards the Rocky Mountain Foothills, the Smoky Group is coeval with the Alberta Group, which is divided into three formational units: the Blackstone, Cardium and Wapiabi (Stott, 1963). East of the Smoky River region, along the Athabasca River, the Smoky Group is represented by undifferentiated mudstones of the Lea Park Formation (Wickenden, 1949). The Smoky Group in the Clear Hills area consists of the Kaskapau, Cardium, Muskiki, Bad Heart and Puskwaskau formations.

3.2.4(a) Kaskapau Formation

The Kaskapau Formation (late Cenomanian to late Turonian) underlies the slopes of the Clear Hills, Chinchaga Hills and Milligan Hills. The formation comprises a series of five northeast-trending, shingled (back stepping), shallow-marine sandstone bodies that are encased in marine mudstone (Wallace-Dudley and Leckie, 1993). In the northern Rocky Mountains and Foothills of Alberta, Stott (1967) assigned the following members to the Kaskapau Formation: Sunkay Member (including the Doe Creek, Pouce Coupe and Howard Creek sandstones), Vimy Member (including Tuskoola and Wartenbe sandstones), Haven Member and Opabin Member. However, these members were also all traditionally used for the heterogeneous lithological units of the Blackstone Formation of the south-central Rocky Mountains and Foothills. Therefore, because little more than the individual sandstone beds of the Kaskapau Formation can readily be identified in outcrop in northwestern Plains of Alberta, it is suggested the member names for the Blackstone Formation should not be used in the Peace River district. Thus, the age of the revised Kaskapau Formation in the northwest Plains of Alberta extends from latest Cenomanian, through all of the Turonian, into possibly late Early Coniacian.

Locally, the Kaskapau comprises a sequence of dark grey to black mudstone with rusty weathering sideritic concretions, and this sequence is intercalated between the predominant sandstone of the underlying Dunvegan and the overlying Cardium to Bad Heart Formations. Subsurface data in the vicinity of the Clear Hills indicate that the Kaskapau Formation ranges from 60 m to 120 m thick (Green and Mellon, 1962), whereas the coeval Blackstone Formation attains a maximum thickness of up to 675 m in the Foothills west of Dawson Creek (Stott, 1961, 1963).

3.2.4(b) Cardium Formation

The Cardium Formation (late Turonian) in the Alberta Foothills is well defined and has been studied in detail by numerous authors (see Braunberger, 1994 for a summary), due in large part to the vast petroleum reserves of the Pembina field associated with the Cardium. In the southern and central Alberta Foothills, the Cardium Formation is subdivided from base to top into the Ram, Moosehound/Kiska, Cardinal,

Leyland, and Sturrock members, whereas in the northern Alberta Foothills the Cardium comprises only the Ram and Moosehound members, with the Moosehound being coeval to the Kiska to Sturrock members which exist to the south (Krause *et al.*, 1994). Along the Alberta – British Columbia border, the Cardium consists of the Ram, Moosehound and, topmost, Baytree members. However, in the northwestern Plains of Alberta over the Peace River Arch (PRA), the fine-grained sediments that are correlative with the Cardium Formation, are poorly understood. As a result, stratigraphic correlation errors made by Gleddie (1949, 1954), Stelck (1955), and Stott (1967) in the area between the Athabasca and Peace rivers have greatly confused the exact definition of "Cardium" in outcrops and subsurface of the PRA region.

Paleontological age control, in the form of biostratigraphic index macro- and micro-fossils, of the this interval in the PRA region have determined that the marine mudstones and chert pebble marker bed(s) previously assigned to the "Cardium" of the Peace River Plains (e.g., Gleddie, 1949; Plint *et al.*, 1990) are Late Turonian to late Early Coniacian age, and are equivalent to the Cardinal, Leyland, and Sturrock members of the Rocky Mountain Foothills. The fossil-bearing facies in these two tectonically varied areas (i.e., the PRA and Foothills) are, not surprisingly, significantly different. Because both the Bad Heart Formation and Baytree Member are not correlative with true Cardium Formation of the Foothills (Stelck, 1955; Collom, in preparation), and the Ram, Cardinal, and Sturrock sandstones are represented by little more than condensed, thin silty horizons or chert pebble beds in the PRA region, it is recommended that the term "Cardium Formation" be abandoned in the Smoky River region, north of Township 75.

3.2.4(c) Muskiki Formation

The Muskiki Formation (early to late Coniacian) is a marine, non-calcareous, dark mudstone that commonly contains fossiliferous, siderite concretions. These marine facies have been interpreted as a transgressive systems tract, characterized by retrogradational parasequence stacking patterns which culminate in a thin condensed section (Battacharya, 1991). Plint *et al.* (1990) measured Muskiki Formation thicknesses of 40 m from Well A-23-A, 93-1-16, which is at Mistanusk Creek, British Columbia, and 7 m from well 7-5-67-6W6, which is south of Grande Prairie.

3.2.4(d) Bad Heart Formation

The Bad Heart Formation (middle to late Coniacan, or deposited between about 86.0 and 85.5 Ma), which is the focus of this trace element study, is a rather peculiar oolitic ironstone. The Bad Heart Formation separates the Kaskapau/Muskiki and Puskwaskau mudstones as a thin mappable unit, and crops out principally on the slopes of the Chinchaga and Clear Hills. At its type locality, about 65 km south of the Clear Hills on the Smoky River, the Bad Heart consists of an argillaceous quartzose sandstone, approximately 6.0 m to 8.0 m thick, that is capped by a laterally-persistent ironstone layer, 0.3 to 0.6 m thick (McLearn, 1919; Wall, 1960). Because the Bad Heart Formation, or "Peace River iron deposit", is the stratigraphic host of the ferruginous

oolitic ironstone facies within the Clear Hills, it is discussed in greater detail in sections 3.4 and 3.5.

3.2.4(e) Puskwaskau Formation

The Puskwaskau Formation (Santonian to middle Campanian) underlies the upper slopes of the northwestern highland terrains, particularly the northeast area of the Chinchaga Hills. The Puskwaskau Formation is comprised of dark grey mudstone and lesser calcareous mudstone of marine origin, which commonly is silty, and is estimated to be about 90 m to 180 m thick in the Clear Hills area (Green and Mellon, 1962). The Puskwaskau Formation is subdivided, from base to top, into the Dowling, Thistle, Hanson, Chungo and Nomad members, and typically is siltier in the upper members. The basal shales of the formation crop out above the Bad Heart Formation oolitic sandstone exposures that are north of Worsley Creek and at Rambling River within the Clear Hills.

3.2.5 Wapiti Formation

The highest parts of the uplands in the northwestern Plains are capped by nonmarine sandstones and shales of the Wapiti Formation (middle Campanian to Maastrichtian). The southern portion of the Clear Hills is capped by the Wapiti Formation, where the unit probably attains a maximum thickness of 120 m, and is overlain unconformably by unconsolidated gravels and glacial deposits (Green and Mellon, 1962). The lower Wapiti Formation is composed of light grey, fine-grained, argillaceous, carbonaceous sandstone with interbedded siltstone, silty mudstone, thin layers of coal and bentonite, and locally is conglomeritic. The sandstone beds range in thickness from very thin to thick (greater than 5 m), with some channel deposits being up to 30 m in thickness. The sandstones grade, fining-upwards, into siltstone and mudstone sequences (McMechan and Dawson, 1995).

3.2.6 Glacial Deposits

The Clear Hills, which extends between the Peace River on the south and east and the British Columbia border on the west, originated as post-Cretaceous monadnocks that subsequently were modified by Pleistocene glaciation (Hamilton, 1980). The nearly flat-lying Cretaceous strata which underlies the hills, are now mantled by unconsolidated glacial and alluvial deposits, but preserve the expression of a former dissected upland. Glacial deposits are prevalent throughout the area and consist largely of pebbly clay till in ground moraine or hummocky disintegration moraine, or as lacustrine clay with sparse pebbles (Green and Mellon, 1962). These deposits range in thickness from zero to 20 m. Glacial and Recent outwash and fluvial deposits of well-sorted sands, up to 35 m thick, with layers of gravel, are present in valleys cut by the Notikewin and Whitemud Rivers.

3.3 **Regional Structural Geology**

3.3.1 Introduction

The sedimentary strata in the Clear Hills form a gently undulating homocline, with regional dips generally to the southwest, although local reversal of dips locally result in variable dip directions (Green and Mellon, 1962). In general, the regional dips are extremely low and rarely exceed 5 m per 1 km. However, structure contours on the top of the Bad Heart Formation show that within the Clear Hills this unit is mainly shallowly east-dipping (Figure 2).

3.3.2 Peace River Arch

The Peace River Arch (PRA) is a deeply buried structural feature that has had a complex tectonic history extending from the Late Proterozoic until at least the Late Cretaceous. This east-northeasterly trending structure extends from the Rocky Mountain Front Ranges in northeastern British Columbia, across north-central Alberta and has a total length of at least 750 km. In northwestern Alberta, the PRA has created a wide zone of structural disturbance; in the west near the British Columbia border (120° W Longitude) it is approximately 260 km wide (as defined by its north and south boundaries near 57°00' N Latitude and 55°00' N Latitude respectively), but it narrows to the east to about 140 km wide near the Sixth Meridian (118° W Longitude). At the Alberta-British Columbia border the PRA includes uplifted Precambrian basement rocks that stand approximately 1,000 m above the regional basement elevation which exists to the north and south. This basement elevation decreases towards the east along the axis of the PRA, and is approximately 500 m at the Fifth Meridian (116° W Longitude) in central Alberta, and less than 50 m near the Fourth Meridian (114° W Longitude) in eastern Alberta.

It appears that the PRA in the Phanerozoic developed upon a pre-existing structural zone that may have been active as early as the Late Proterozoic (O'Connell *et al.*, 1990; Ross, 1990). At present, the oldest expression of the PRA consists of uplifted and truncated Upper Proterozoic and Lower Cambrian sediments that are exposed in the Cordillera (McMechan, 1990). O'Connell *et al.* (1990) have suggested the possibility that Precambrian fault zones in the Peace River region have been reactivated throughout the Phanerozoic and that several major basement terrane contacts are coincident with: (1) trends of Devonian and Carboniferous grabens, (2) emplacement of Late Devonian dolomite occurrences, and (3) a linear Cretaceous erosional feature.

What is clear is that several episodes of crustal extension have been focussed in the northwestern Alberta region throughout the Phanerozoic, and this has influenced facies distribution and depositional architecture in northwestern and north-central Alberta (Barclay *et al.*, 1990; Hart and Plint, 1990). For a complete regional syntheses of the PRA, the reader is referred to publications by Cant (1988), O'Connell *et al.* (1990), and O'Connell (1994).

Recently, the surface traces of PRA faults have been recognized on high-resolution aeromagnetic surveys (Peirce *et al.*, 1997). As well, the outcrops of the Bad Heart Formation along the Smoky River and in the Clear Hills are associated with well-known faults (e.g., Rycroft Fault) or fault-bounded structures (e.g., Hines Creek Graben). In short, there is increased evidence that movement along Precambrian basement faults, and their structural manifestations in the Phanerozoic, may have been a significant factor in the observed variations in lithologies and iron content of the Bad Heart Formation. Although the faults themselves may have done little to directly affect the overall deposition of the Bad Heart Formation, it is postulated that upward movement of hypersaline brines and related hydrothermal fluids (supersaturated in respect to iron, aluminum and silica) along PRA faults may have resulted in the local deposition of the ferruginous oolitic facies (Rostron *et al.*, 1995; Collom, 1999 in preparation). The precipitated products of these brines can be investigated via stable isotope geochemistry. For example, Collom and Krouse (1997) reported that Bad Heart Formation outcrops that are proximal to basement-controlled PRA faults (as suggested from Peirce *et al.*, 1997), contain anomalous amounts of sulfide minerals (e.g. pyrite and pyrrhotite), nontronite/berthierine ooids and have relatively enriched sulfur isotopic signatures (up to +68.3‰) indicative of a brine source.

3.4 **Geology of the Bad Heart Formation**

3.4.1 **Historical Background**

Oolitic sandstones of the Bad Heart Formation were initially described by McLean (1919) from exposures along the Smoky River, where the unit separated "upper" and "lower" shales of the Smoky Group. The name "Kaskapau" was subsequently applied to the underlying marine mudstones (McLearn, 1926), and the overlying mudstones were termed "Puskwaskau Formation" by Wall (1960). During the 1950's, several conflicting studies were published on the stratigraphic relations of the Bad Heart and Cardium sandstones (Gleddie, 1954; Stelck, 1955; Harding, 1955; MacDonald, 1957), until Stott (1960, 1961) clearly separated the Cardium Formation from the overlying Bad Heart Formation. Stott (1967) addressed the entire Smoky Group and suggested that the Marshybank Member of the Wapiabi Formation in the Foothills region was correlative with the Bad Heart sandstone of the Smoky River region. Along the Smoky River and its tributaries (Bad Heart River, Kakut Creek) the Bad Heart strata are prone to slumping and bedrock exposures are scarce and discontinuous.

Recently, Plint *et al.* (1990) restricted the term Bad Heart Formation to the variable package of oolitic sandstone, silty sandstone and sandy siltstone that is present in the northwestern Plains, with the type locality along the Smoky River. In contrast, the approximately coeval Marshybank Member is restricted to the Rocky Mountain Foothills of Alberta and British Columbia. Although these two lithological units are coeval, their internal facies, thickness, and geographic distribution are sufficiently different to merit separate names. The lithostratigraphic terms applied to the Bad Heart Formation and associated mid to upper Cretaceous strata, are summarized in Table I.

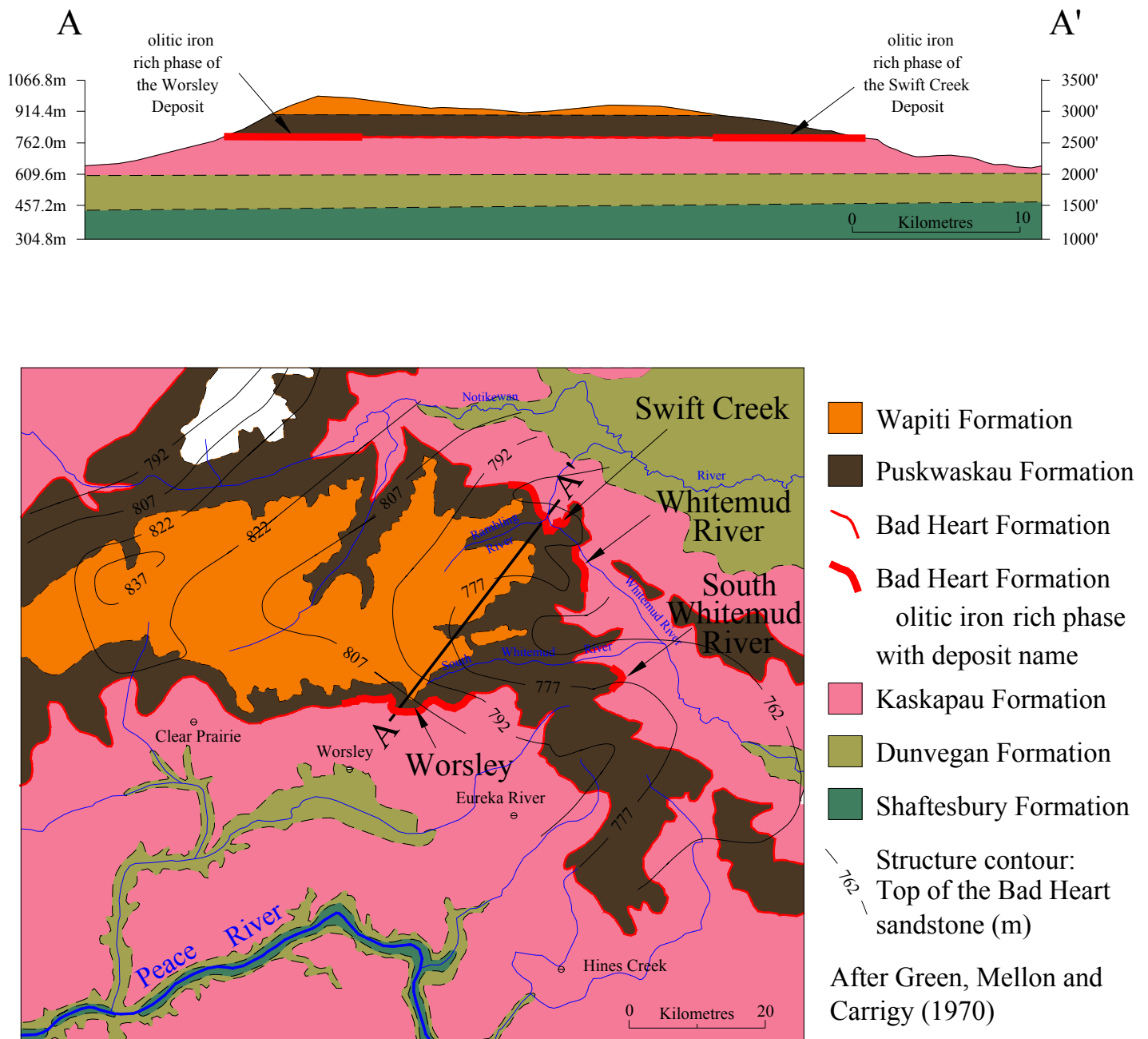


Figure 2. Bedrock geology and schematic cross section of the Clear Hills area, with contours representing the top of the Bad Heart Formation sandstone and oolite iron rich deposit locations.

3.4.2 Regional Geology, Stratigraphy and Paleontology

Paleontological and biostratigraphic studies of Upper Cretaceous strata of the Peace River district are few (McLearn, 1926; Wall, 1960; Wall and Germundson, 1963; Braunberger, 1994). The preliminary study of fossil *Inoceramid* bivalves from western Canada by McLearn (1943) remains the only study addressing Cretaceous molluscan macrofauna occurring in the Smoky River region. Stott (1967) listed numerous invertebrate fossils he found during his field investigations on the Smoky River and its tributaries, and concluded from these and data from previous work (Stott, 1963) that: (1) the Bad Heart Formation was Late Coniacian in age, and (2) the Marshybank Member and Bad Heart Formation were coeval, and both deposited during the *Scaphites depressus* Zone. [Note: all the paleontological identifications listed in Stott's various publications were made by the late G. Jeletzky of the Geological Survey of Canada, Ottawa]. The Ph.D. dissertation by Collom (1999 *in preparation*) provides detailed definitions of the ammonite and inoceramid bivalve biozones from the Middle Coniacian (Muskiki Formation) to Early Campanian (Puskwaskau/Wapiti transition) in Alberta (Figure 3). The Bad Heart Formation is Late Coniacian (*Scaphites depressus* / *Volviceras involutus* Zone), as initially recognized by Stelck (1955), and is thought to have been deposited in less than 300,000 years, between about 86.0 and 85.5 million years ago (Collom, 1999 *in preparation*).

Donaldson (1997) recognized nine facies in the Bad Heart Formation, which in general from base to stratigraphic top, comprise: (A) chert and phosphate pebble conglomerate, (B) laminated mudstone, (C) *Thalassinoides*-burrowed silty sandstone, (D) ooidal ironstone, (E) bioturbated silty sand, (F) thinly – bedded sandstone, (G) ooidal muddy sandstone, (H) *Skolithos*-burrowed silty sandstone, and (I) phosphatic ooidal silty sandstone. Donaldson *et al.* (1998) noted that the Bad Heart Formation is, in places, up to 32 m thick. However, in the Clear Hills, Donaldson (1997) stated the ooidal ironstone (Facies D) reaches a maximum thickness of about 6.7 m, overlies Facies C with gradational contact, and is overlain with sharp contact by either Facies E or F. In some places, the ooids disappear abruptly above the overlying contact, whereas in others they gradually fade away through the first few centimetres of Facies E. Finally, Donaldson (1997) suggested the Bad Heart Formation in the Smoky River region comprises two allomembers bounded by three discontinuities. Allomember 1 includes Facies A to D, and Allomember 2 includes Facies C to H, with the bounding discontinuities occurring at the base and top of Allomember 1, and at the top of Allomember 2 where it is overlain by Facies I. However, Donaldson (*Ibid*) noted that the “*sedimentological record of the Bad Heart Formation in the Clear Hills is incomplete compared to that available on the Smoky River*”. In the Clear Hills, Donaldson (*Ibid*) postulated that only Facies C and D are present, with possibly some Facies E and F at the Rambling River (Swift Creek) section.

Recently, Collom (1997a,b,c, 1998, and 1999) has been studying the paleontology and paleoenvironments of the Bad Heart Formation for his Ph.D. research being conducted at the University of Calgary. He has reported some very interesting results, including: (a) “*shoals of oolitic nontronite ... up to 8.0 m thick, massive sulfide*

AGE (Myrs.)	SUBSTAGE	STRATIGRAPHY	AMMONITE ZONES
88.0 85.5 82.0	Upper Tur.	Kaskapau Formation	<i>Scaphites corvensis</i> <i>Baculites yokoyamai</i>
	Lower Coniacian		<i>Scaphites preventricosus</i> <i>Baculites sweetgrassensis</i>
	Middle Coniacian	Muskiki Fm.	<i>Scaphites ventricosus</i>
	Upper Coniacian	Marshybank — Bad Heart	<i>Scaphites depressus</i> <i>Baculites codyensis</i>
	Lower Santonian	Puskwaskau Formation	<i>Clioscaphtes saxitonianus</i>
	?		<i>Baculites ovatus</i>
	Upper Santonian		<i>Scaphites novimexicanus</i> <i>Desmoscaphtes erdmanni</i>
	?		First White Specks interval (~84.0 Myrs.)
	Lower Cmp.	Wapiti Fm.	<i>Baculites aquilaensis</i> <i>Holcoscaphtes leei</i> III
			?

Figure 3. Biostratigraphic zonation and geochronology for Cardium and Wapiabi Formation equivalents in the Peace River Arch region of Alberta and British Columbia. Note that the Marshybank Member and Bad Heart Formation are coeval, both deposited within the *Scaphites depressus* Zone (Late Coniacian).

deposits (pyrite and pyrrhotite), glauconite ... and anomalous $d^{34}S$? isotopic values”, and (b) anomalous concentrations and types of selected benthic fauna. Collom (*Ibid*) attributed these phenomena to the presence hydrothermal seeps, such as the “Black Smokers” that exist in places in modern environments. He (*Ibid*) further suggested that the hydrothermal seeps may have been controlled by faults that were active during Bad Heart Formation deposition.

3.4.3 The Ferruginous Oolitic Ironstone

A principal lithological dissimilarity of the Bad Heart Formation to the underlying Marshybank Member, aside from stratigraphic thickness, is the presence of abundant ferruginous ooids. These sedimentary indicators of shallow-water deposition (Young, 1989) are distributed throughout the Bad Heart Formation. Ooids also occur at the base of the Cardium and Muskiki formations, although in thin chert pebble beds that probably represent regression lags. In contrast, the Bad Heart Formation which is exposed on the Smoky River locally comprises beds with up to 15% iron ooids, whereas at the Worsley and Rambling River deposits in the Clear Hills, the ooids often comprise 60 to 70% of the rock in the upper part of the unit and decrease to only 20 to 25% toward the base. As well, in a few places at the Clear Hills, some beds in the Bad Heart contain up to 90% ferruginous ooids (Hamilton, 1980).

The ooids, which locally form a single massive bed, are approximately 0.4 to 0.5 mm in diameter, have tangential layers (commonly concentric), and are comprised of goethite and quartz that alternate in concentric shells of variable width (Kidd, 1959). An average oolite consists of about 45 wt% goethite ($Fe_2O_3 \cdot H_2O$), 45 wt% nontronite [$(Fe,Al)_2O_3 \cdot 3SiO_2 \cdot nH_2O$], 5 wt% quartz and 5 wt% amorphous phosphate (Petruk, 1977). The phyllosilicate clay mineral, nontronite, is a low-temperature alteration product of berthierine (Fe^{2+}, Fe^{3+}, Mg) $_{2-3} \cdot (Si,Al)_2O_5 \cdot (OH)_4$ and a 1:1 type layer silicate of the serpentine group (Brindley, 1982). The oolites are closely packed, but mostly separated by a matrix of ferruginous opal and clastic material; the clastic material consists of illite and nontronite cemented by ferruginous opal (Petruk, 1977).

Hamilton (1980) observed that the oolitic facies seems to form a series of elongated northwest-trending bodies, the exact limits and thicknesses of which remain to be determined. On the Smoky River the ooids fill vertical *Skolithos* and *Diplocraterion* burrows, and even show evidence of reworking by the burrow-forming organisms. In the Clear Hills, however, the Bad Heart oolitic 'shoals' are lens-shaped to tabular bodies up to 10 m thick (similar to modern Bahamian carbonate ooid shoals), and have no bioclastic debris or internal evidence of bioturbation. The main outcrops of oolitic ironstone are on the southern and eastern slopes of the Clear Hills, and typically are best exposed along small creeks which form a radial drainage pattern around the hills. In general, the 'oolitic lenses' range from 3 to 6 m in thickness in the vicinity of Rambling River and north of Worsley, but in places some outcrops along Rambling River reach thicknesses of up to 9 m. These scattered exposures represent the thickest iron-rich deposits in the area, and appear to be correlative with thinner oolitic phases of the Bad Heart to the north and west (Kidd, 1959; Green and Mellon, 1962).

Observations from extensive shallow drilling by Premier Steel Mills (Edgar, 1960, 1961, 1962, 1963a,b, 1964a,b,c,d,e, and 1965) to test the grade and extent of the iron deposit, in combination with petroleum drilling, indicate that: (1) the ferruginous oolitic facies of the Bad Heart Formation sandstone is relatively widespread; and (2) argillaceous sandstone fragments are associated with the oolitic material, becoming more abundant towards the west at the expense of oolitic sandstone. Thus, although the Bad Heart Formation proper is present in the western part of the Clear Hills, the ferruginous oolite phase becomes more prevalent eastward, forming locally thick deposits, such as those at Worsley and Rambling River (Green and Mellon, 1962).

3.5 **Geology of the Clear Hills Iron Deposits**

3.5.1 Introduction

Interest in iron in the Clear Hills started with the discovery of oolitic "hematite" in the Phillips Petroleum Company Phil C No. 1 well, which was drilled in 1953 (Petroleum and Natural Gas Conservation Board, 1955). Follow-up exploration, between 1953 and 1957, outlined two separate ferruginous deposits, the Rambling River and the Southern Clear Hills deposits, that each contain from 500 million to 1 billion tons of ferruginous ironstone with a grade averaging about 33% iron (Kidd, 1959). In this study, the Clear Hills iron deposits are referred to with respect to their best exposures, which from north to south are the Rambling River, Whitemud River, South Whitemud River and Worsley deposits (Figure 2). Because this large resource is the only potentially economic iron ore deposit in the Prairies region of Alberta, the Clear Hills iron deposits have attracted development interest periodically over the past 40 years.

McDougall (1954) first noted that the Peace River iron ore contains a higher percentage of silica in the form of quartz and opaline material than other oolitic iron deposits, such as the Clinton type iron ore in New York State and Alabama, United States of America. The nuclei of many Bad Heart ooids, particularly in the Clear Hills, are highly angular fragments of crystal-clear quartz and/or glass, which range from about 0.40 mm to 4.0 mm in longest dimension (Collom, 1999, in preparation; Plate 1). The quartz grains that comprise the sandstones of the laterally equivalent Marshybank Member tend to be well-sorted and semi-rounded, as a result of more than 100 km of transport from the hinterland to the west. Thus the question then with respect to the Bad Heart Formation, is how did the 'quartz' grains in the core of many ooids apparently avoid mechanical erosion and rounding during such apparent lengthy fluvial and shallow marine transport? The most direct answer at this time, considering the relatively limited extent of the Bad Heart ferruginous oolites in the Clear Hills area and the common presence of angular quartz nuclei in ooids, is that these grains are predominantly 'locally derived' volcanic glass shards, rather than being quartz derived from the exposed Precambrian basement which was then rising and being eroded to the west in the Cordillera. In short, the Bad Heart quartz grains underwent minimal water-borne transportation, and instead may have been derived from volcanic airfall on the seaway.

The light-coloured mud-size fraction (less than 0.004 mm grain size) which probably composed the bulk of the volcanic ash beds, was inhibited from deposition by persistent wave energy in the PRA region, and/or was incorporated into the ooid laminations that grew around the glass shards and other small condensation nuclei (e.g., fecal pellets, lithic fragments or sulfide minerals). The presence of numerous bentonites in: (1) the Kevin Shale Member, Marias River Formation of northern Montana; (2) the Upper Coniacian Kanguk Formation of the Northwest Territories; and (3) in west-central Alberta, where mid- to Late Cretaceous bentonites have been postulated to occur from localized intra-basin volcanic events (Dufresne *et al.*, 1996; Eccles *et al.*, 1998; Dufresne *et al.*, 1999), indicates that there was sufficient volcanic activity in the Western Interior to account for the observed petrology of the Bad Heart in the Clear Hills.

Petruk *et al.* (1975, 1977) was the first to describe the unusual iron and silica mineralogy of the Bad Heart ooids (see Appendix I). He (*ibid.*) made comparisons of the Upper Cretaceous Bad Heart deposits with Recent hydrothermal nontronite deposits in Africa, South America and the Red Sea, but he did not clearly suggest that the Bad Heart ooids were formed via a similar hydrothermal or brine-related mechanism. However, there is now mounting evidence that many, if not a majority, of the berthierine-bearing ooid deposits of the Phanerozoic (most being Ordovician or Jurassic in age) may be directly related to seepage of brines on the seafloor (Bhattacharya, 1989; Heikoop *et al.*, 1995; Kimberly, 1989, 1994). The saturation of these fault and fracture-transported fluids and gases with respect to methane, iron, hydrogen sulfide, and other compounds attracts a very diverse association of benthic marine invertebrates, particularly chemosymbiotic species (Haymon and Koski, 1985; Postgate, 1979). This is considered a primary reason for the extensive shell beds and fossil accumulations within the Bad Heart Formation, and other similar stratigraphic units deposited in the Late Cretaceous seaway elsewhere in western North America (Kauffman *et al.*, 1996). As well, this type of seafloor seep system also provides the raw material for the formation of ferruginous and siliceous ooids, such as those in the Bad Heart Formation. Additionally, ash from volcanic eruptions which may have occurred near, or even within, the seaway and PRA may have been a source of the elements that form the goethite (and minor chamosite) in Bad Heart ooids (Sturesson, 1992; Collom, 1998).

3.5.2 Description of the Known Iron Deposits

Hamilton (1980) described the Clear Hills iron deposits as “*an oolitic iron-rich facies of the Bad Heart Sandstone ... The deposit crops out on the southern and northeastern flanks of the Clear Hills in northwestern Alberta, and is essentially flat-lying and extends back from outcrop to underlie a large area of the Hills.*”

Lithologically, the deposit consists of dark brown and green to black, ferruginous oolite, forming a bed up to 10 m thick. The ore bed is thickest in the northeast (Rambling River) segment of the deposit, thinning westward to zero as the oolitic facies passes into siltstone and argillaceous sandstone. It is overlain and underlain by grey

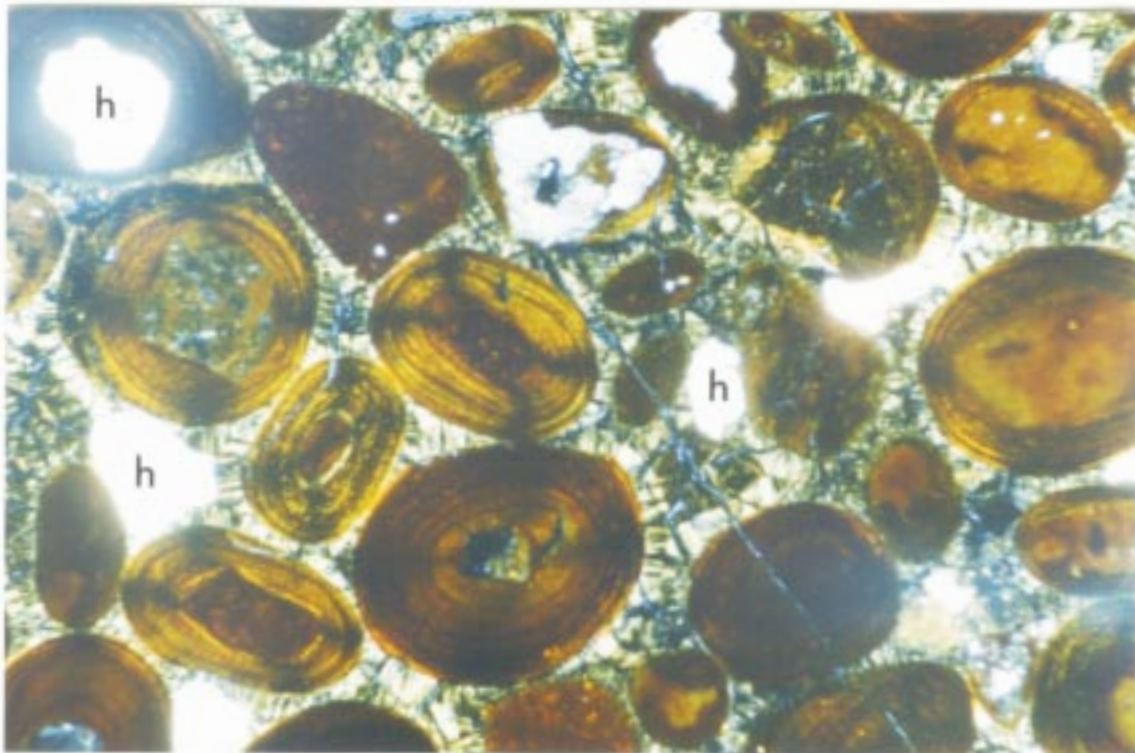
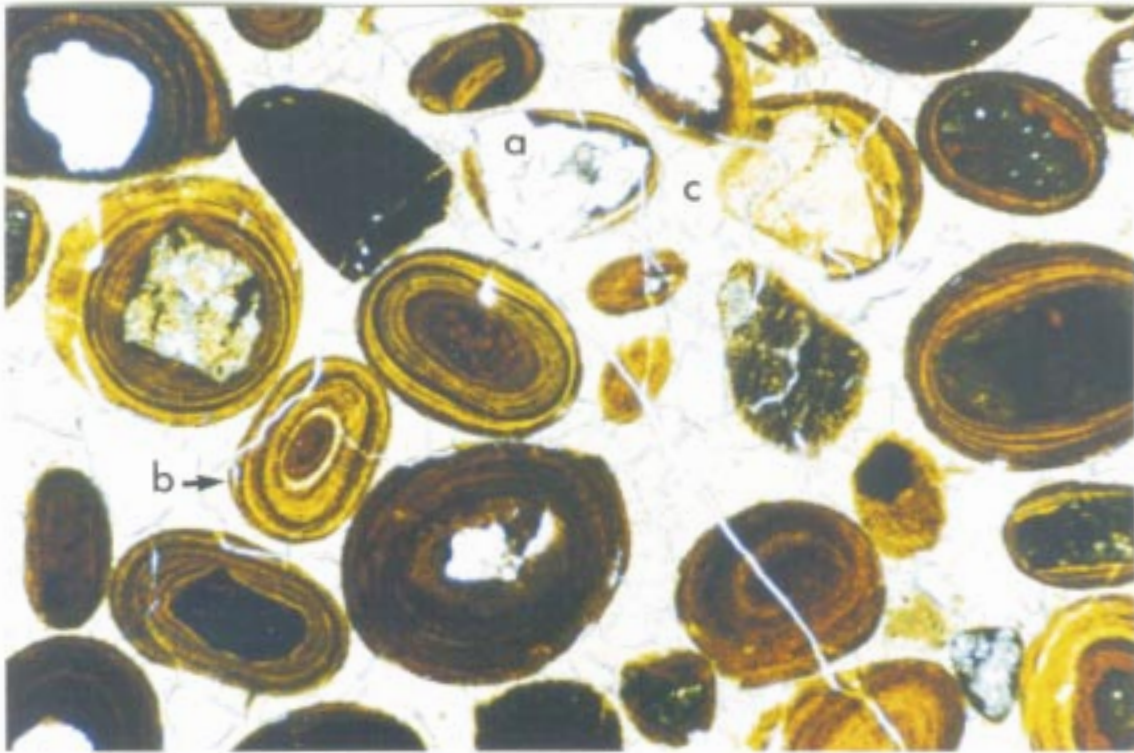


PLATE 1: Bad Heart Formation Oolitic Facies, Rambling River Deposit, Alberta.

Thin section, with both areas showing same area of slide: (1) top microphotograph in plain polarized light; (2) bottom microphotograph in crossed nicols; both at magnification about 60x. Ooids are up to 1.5 mm in diameter and are composed of tangential layers of varying composition around nuclei. Nuclei comprise: "a" are angular quartz grains or possibly volcanic glass fragment; "b" are ooid with goethite/chamosite core; "c" are ferruginous opal cement; and "h" are holes in the thin section. Note that the opaline matrix has a 'bird's eye extinction', with radial patterns oriented perpendicular to the outer surface of the ooids.

marine shales of the upper and lower Smoky Group. ... In gross lithology the iron formation consists of dark brown and green to black oolitic ironstone, with thin lenses and interbeds of hard sideritic ironstone and greenish grey mudstone. Near the outcrop margin the oolite has been oxidized to form a soft, compact, reddish brown aggregate with harder carbonate cemented lenses. The oolites, about 0.4 mm in diameter, form 60 to 70 per cent of the rock in the upper part of the bed and decrease in amount toward the base, to only 20 to 25 per cent. The detrital mudstone, with forms the matrix throughout the oolite bed, thus becomes the dominant lithologic fraction at the base.

The oolite [unit] appears to be a single massive bed. In unweathered exposures stratification is only vaguely defined. There are no distinct bedding plan surfaces or sedimentary structures to be seen within the unit. The upper contact with the Puskwaskau Formation is sharp; however, in most places on the flanks of the Clear Hills the Puskwaskau shale has been stripped back by glaciation and the iron formation lies in direct contact with glacial till. The lower contact generally is gradational into dark silty shales of the Kaskapau Formation, although in the Rambling River sampling pit it was observed to be fairly sharp.” Although Hamilton (1974) suggested the lower contact was gradational, at least in places, more recent work has shown that the base of the Bad Heart Formation is a regional disconformity to, in places, unconformity (Leckie et al., 1994).

3.5.2(a) Southern Clear Hills, including Worsley Deposits

The Worsley Deposit area is known as a result of the exposures in a 1960 bulk sampling pit (Samis and Gregory, 1962), drilling of 105 test holes along a strike length of about 17 km completed by Premier Steel Mills in the early 1960's (Figure 4), an exploration trench excavated in 1995 near the 1960's pit, and by a series of series of 10 holes which were drilled in 1996 by Marum Resources Inc. (Figure 5; Boulay, personal communication, 1996). These data were used to prepare a composite sequence of the Bad Heart strata at the Worsley area (Figure 6).

Friable, red-weathering ferruginous sandstones are traceable in more than 15 outcrops along the southern slopes of the Clear Hills for approximately 60 km at elevations ranging from about 795 m to 830 m asl (Kid, 1959). In places, the exposures of oolitic ferruginous sandstones reach thicknesses of greater than 9 m, and typically average more than 2 m. Most of the sandstone exposures are less than 30 m long, hence the continuity between outcrops is uncertain. There may be erosional or depositional gaps between the outcrops, and hence the subsurface continuation of the ferruginous oolitic sandstone may be a relatively continuous sedimentary bed, or may comprise several lenses.

Kidd (*Ibid*) described the Southern Clear Hills – Worsley iron deposits as follows. “The upper part of the sandstone contain up to 75 per cent oolites in a matrix of calcite and siderite. The oolites are 0.4 mm to 0.6 mm across and consist of quartz and reddish-brown goethite, with greenish tinges here and there. The decrease in amount toward the bottom where the sandstone contains up to 85 per cent angular detrital

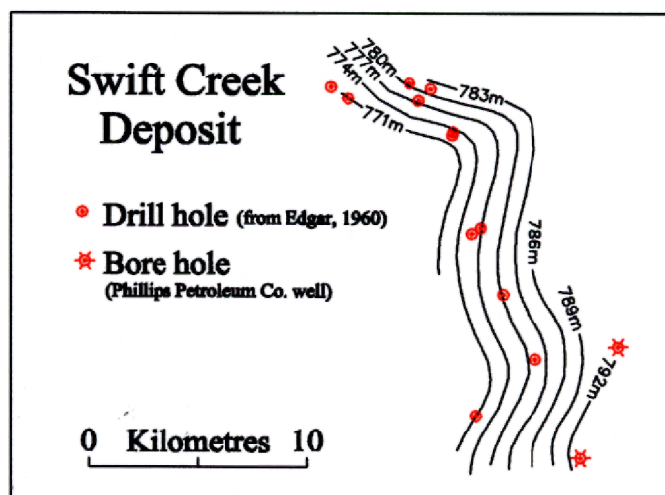
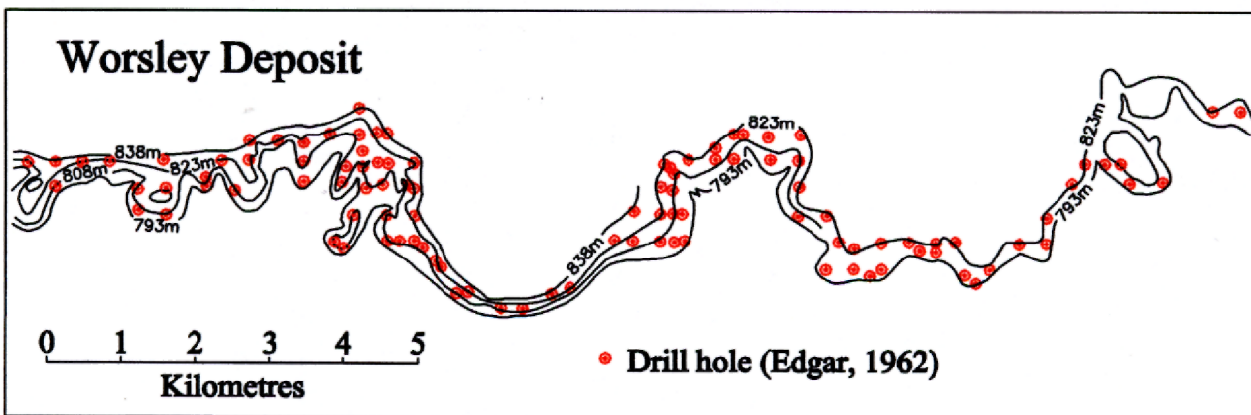
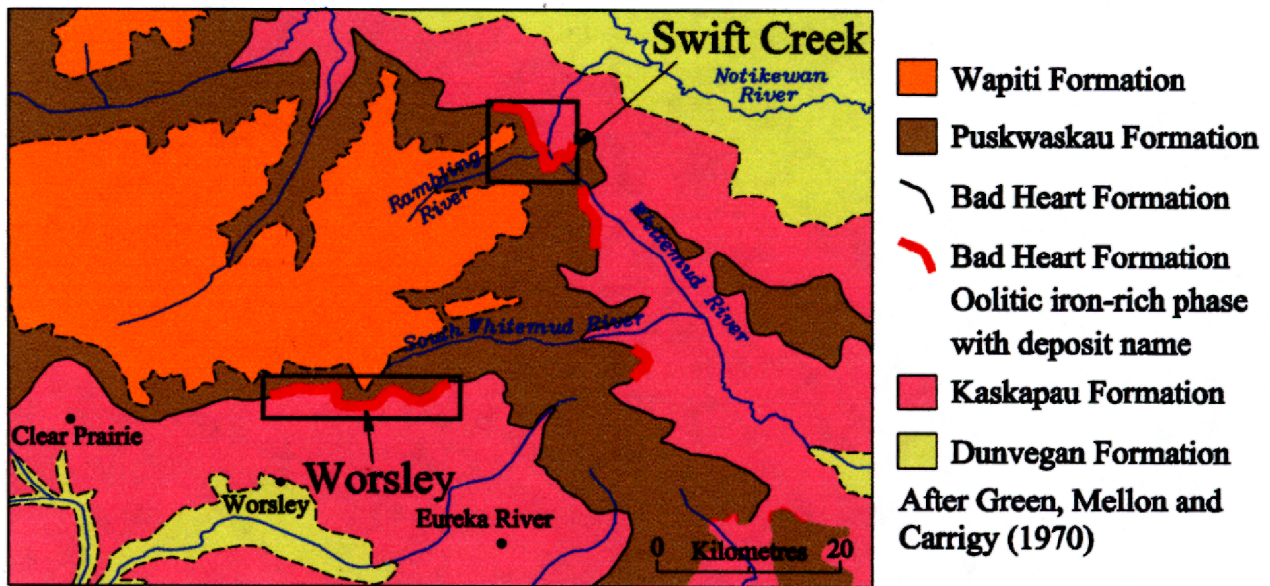


Figure 4. Location of prior drilling in the Clear Hills Iron Deposits.

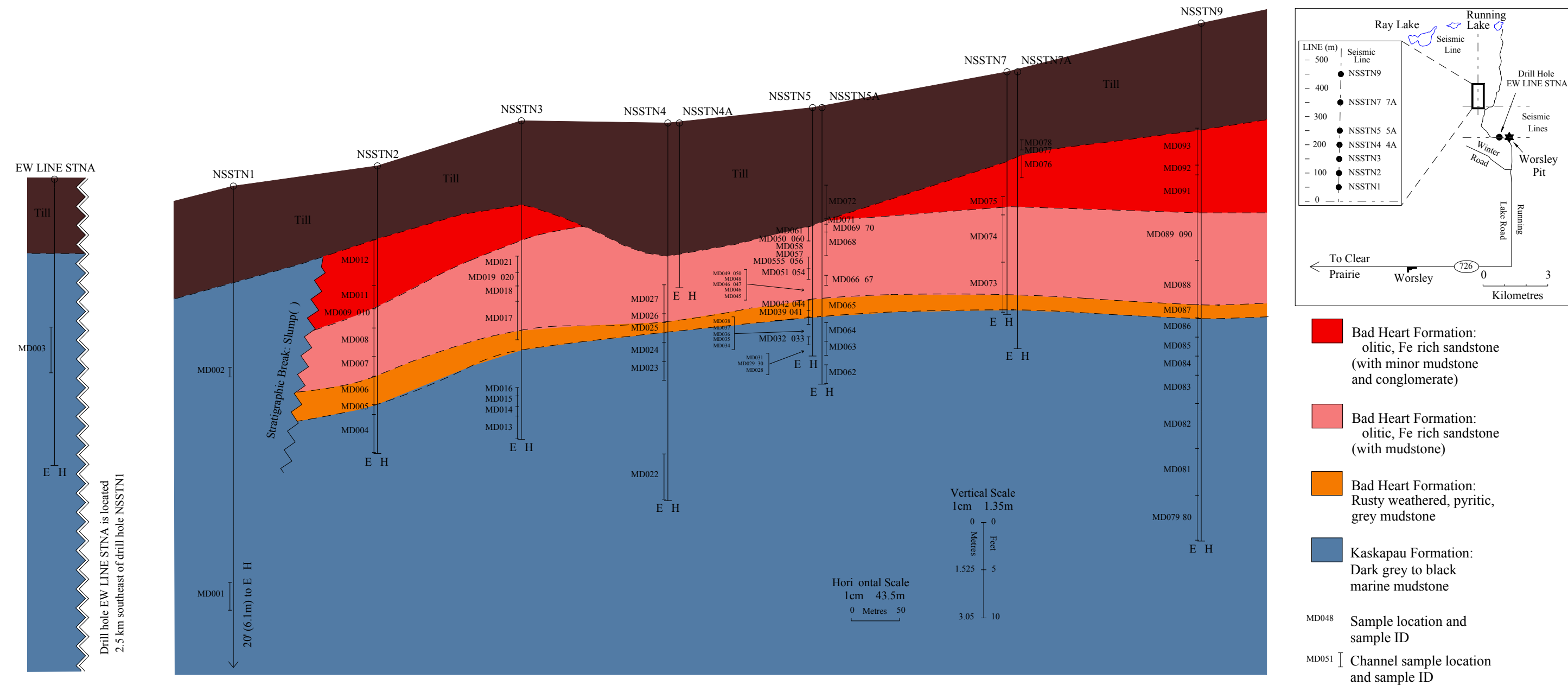


Figure 5. Summary drill sections, Worsley Deposit area.



Figure 6. Lithology of the Worsley Deposit (Green and Mellon, 1962 Eccles, unpublished field notes), with sample locations from this study.

grains, about 0.2 mm across, and less than 1 per cent feldspar grains in a matrix of calcite and siderite. The sandstone also contains up to 15 per cent of green chamosite-like grains, 20 per cent micro-sphrilitic carbonate, and 8 per cent siderite grains. The ground mass comprises 5 to 65 per cent of the rock."

In general, the Worsley iron formation consists of dark brown and green to black oolitic sandstone, with chert pebbles and thin clasts and lenses of hard sideritic ironstone and greenish grey mudstone. The top part of the section contains two distinct conglomeritic layers, 15 cm and 30 cm thick. The oolites are 0.4 mm to 0.6 mm in diameter and decrease from about 65+% near the top, to about 20% near the base of the section. The detrital mudstone, which forms the matrix throughout the oolite bed, thus becomes the dominant lithologic fraction towards the base.

The contact at the base of the Bad Heart at the Worsley area is not as sharp as that at the Rambling River Deposit. Instead, at Worsley, the Bad Heart appears gradational into dark silty shale of the Kaskapau Formation (Hamilton, 1980). The transition to Kaskapau shales occurs over a 30 cm interval, where a rusty weathered clay in direct contact with the oolitic sandstone, changes gradationally to a buff-yellow-grey clay with quartz and black cherty particles thought to resemble bentonite, and finally, into a grey clay thought to represent the Kaskapau Formation (Dufresne *et al.*, 1999).

3.5.2(b) Rambling River, Whitemud River and South Whitemud River Iron Deposits

The Rambling River deposit is known from exposures along the river and the nearby Clear Hills, from 12 holes which were drilled in 1954 (Figure 4), and from a bulk sampling program that excavated approximately 15 m of overburden and sampled about 50 tonnes of the Bad Heart Formation over an interval of 8.25 m during the early 1970's (Hamilton, 1974). These data were used to prepare a composite sequence of the Bad Heart strata at the Rambling River area (Figure 7).

Along Rambling River, a ferruginous oolitic bed crops out as a weathered seam along both sides of the stream for nearly 1.2 km, at an elevation of about 780 m asl (Kidd, 1959). At least 8 m of the bed are exposed, but the base is covered. In 1974, Hamilton (1974) reported that the unit was 8.2 m thick in a large trench, but the top was erosional, hence the original thickness would have been somewhat more. The bed thins towards and is absent 14.5 km south-southwest of the Rambling River outcrop. To the northwest, there is a reported (Kidd, *Ibid*) outcrop about 1.2 km northwesterly of the most northerly exposure on Rambling River. However, the northern limit of the bed is at least about 10 km northwesterly, based on drill core data, and the upper contact is erosional beneath overlying Quaternary sediments (Hamilton, 1980; McDougall, 1954).

To the southeast, exposures are limited, but the oolitic iron formation is believed to extend to south of South Whitemud River (Figure 2). "*Southeast of Swift Creek [Rambling River] the oolitic iron sandston is approximately 20 feet [6 m] thick as*

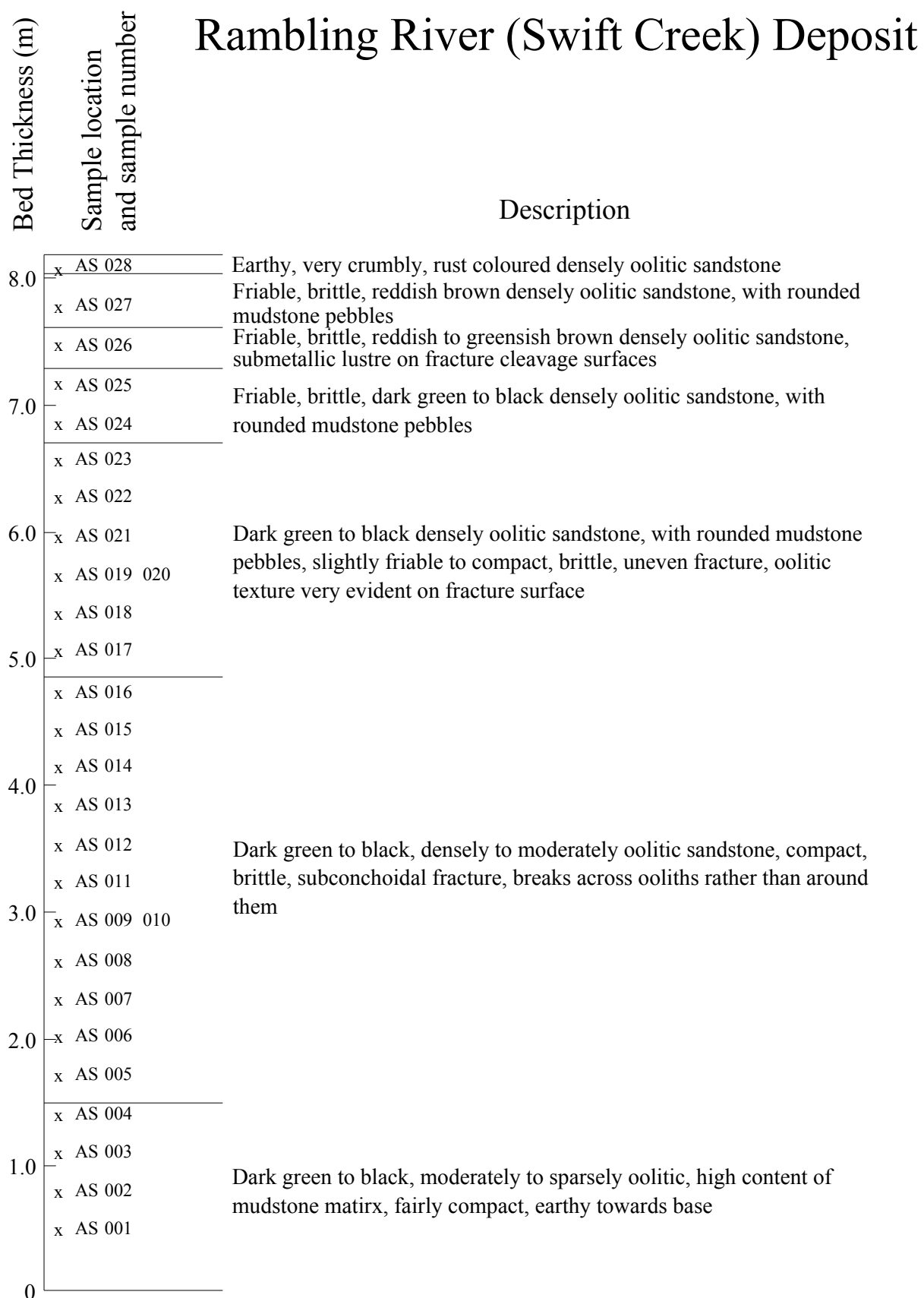


Figure 7. Lithology of the Rambling River Deposit (Hamilton, 1974), with sample locations from this study.

determined from the most easterly holes drilled by McDougall (*Ibid*). Towards the southwest the thickness decreases to 12 feet [3.7 m] at core hole 3A (Figs. 5, 6 in Kidd, 1959) and oolitic material is absent 9 miles [14.5 km] to the south-southwest in Phil. A No. 1 well. From the core-hole data, McDougall (1954) calculated that the deposit underlay an area of 42.9 square miles [110 km²], and in the vicinity of Swift Creek [Rambling River] the beds dip south-southwest at 10 feet to the mile [about 1.9 m/1 km]” (Kidd, 1959). In contrast, Hamilton (1980) stated the Rambling River oolitic iron deposit is virtually flat-lying and undisturbed, except for two distinct sets of vertically-dipping joint planes with average strikes of 310° (N50W) and 060° (N60E) (Hamilton, 1980).

At Rambling River, Kidd (1959) stated “the oolitic sandstone bed is olive-green to greyish-green at the base, brown to reddish-brown with white weathering patches in the middle, and reddish brown in the upper 10 to 15 feet [3.0 to 4.6 m]. The middle beds contain horizontal lenticles of greyish-green oolitic sandstone more than 6 feet [1.8 m] long and up to 10 inches [0.25 m] thick” (Kidd, *Ibid*).

In the trench excavated near Rambling River, Hamilton (1974) broadly divided the Bad Heart at Rambling River into three intervals. (1) A top section, about 0.75 m thick, that comprises reddish-brown, oxidized, oolitic iron-rich sandstone with conspicuous rounded pebbles of greenish clay material. The bottom 30 cm of this topmost interval records a transition from thoroughly oxidized, reddish-brown material to non-oxidized reddish- to greenish-brown oolitic sandstone. (2) A middle section, about 2.5 m thick, where the oolitic iron-rich sandstone becomes distinctly dark green, almost black in colour and increasingly is more massive. Lastly, (3) a bottom interval, about 5 m thick, in which the oolite content declines gradually towards the base of the Bad Heart. He (*Ibid.*) further described the Rambling River iron formation as being “for the most part massive, showing only vaguely defined stratification within its upper and lower boundaries. The unit is topped by a highly oxidized zone generally less than 6 inches [0.15 m] thick, consisting of earthy, very crumbly, rust-coloured material, which rests upon comparatively hard, slabbly, oxidized oolitic iron-rich sandstone extending over an interval of 2 ½ feet [0.75 m]. The sandstone, reddish brown in colour, containing conspicuous rounded pebbles of greenish clayey material, is fairly friable and brittle ... The bottom foot of this interval records a transition from the thoroughly oxidized material above to essentially unoxidized material of identical rock-type below. ... Below this 2 ½ - foot [0.75 m] oxidized interval, the oolitic iron-rich sandstone becomes distinctly dark green, almost black in colour. For the next 2 feet [0.6 m] the material remains somewhat friable and brittle ... [but] from here downward it becomes increasingly harder, more dense ... Moreover, in this interval the formation lacks any well developed bedding separation planes or horizontal cleavage planes ... To the depth of about [3.35 m], the iron formation retains a rather dull, granular appearance, with the oolitic texture very evident on broken surfaces, but below this the rock becomes more uniformly hard within its textural framework and tends to break across the oolite grains rather than around them, giving a subconchoidal aspect to fracture surfaces. ... From here to the base of the bed at 27 feet [8.23 m] the rock shows little change in gross physical characteristics, notwithstanding ... the oolite content declines gradually from about 60

per cent near the middle of the bed (and throughout the upper half) to about 20 per cent at the base, with a concomitant increase in the content of the mudstone matrix and decrease in the ferruginous cement. One noticeable change, however, is the earthy appearance that the rock acquires in the lower 5 feet [1.5 m] or so, reflecting the increased mudstone content (to about 50 per cent at the base). ... The base of the iron formation [at the Rambling River excavation] is marked by a change from the dark green to black oolitic iron-rich mudstone to a medium to dark bluish grey clay. The contact is fairly sharp, but forms an irregular surface.” The Bad Heart succession is underlain by dark, bluish-grey marine clays of the Kaskapau Formation.

3.5.2(c) Smoky River Section

The Bad Heart Formation crops out south of the Peace River in a series of discontinuous exposures that extend from west of Spirit River in the west near the British Columbia – Alberta border, easterly along the Bad Heart and Smoky Rivers, to as far east as near Kimiwan Lake, which is about 40 km northwesterly of the town of High Prairie (Green and Mellon, 1962, 1970). *“The thickness increases from about 15 feet [4.5 m] at Spirit River to 25 feet [7.6 m] on the Smoky [River] ... The ridge-forming sandstone is medium- to coarse-grained, porous and characteristically dark-red weathering ... [At this locale] the Bad Heart contains ironstone concretions, glauconite and some interbedded sandy shale, and a few bands of chert pebbles. Along the Smoky River, the Bad Heart is capped by a hard limy ironstone ledge at least one foot [0.3 m] thick. ... The Bad Heart sandstone at Spirit River is similar petrographically to the lower part of the ferruginous sandstone in the Clear Hills. It contains up to 85 per cent detrital quartz grains, 0.3 mm or less across, and locally up to 10 per cent oolites, probably of goethite. The groundmass is calcite and siderite. In well samples the sandstone contains pyrite and glauconite.”* (Kidd, 1959)

3.6 **Possible Correlative Ferrous Deposits in the Western Canada Sedimentary Basin**

Hamilton and Olson (1994) summarized the metallic and industrial mineral occurrences, prospects and deposits known at that time within the Western Canada Sedimentary Basin, and Olson *et al.* (1994) summarized the existing information pertaining to iron deposits, and other metallic and diamond indicator minerals, in Alberta. In total, Hamilton and Olson (*Ibid*) reported only six known ferrous metal prospects or deposits in Phanerozoic rocks in the Western Canada Sedimentary Basin. Five of these six ferrous metal prospects exist in Upper Cretaceous Sedimentary strata; three are in Alberta, and one each exists in Saskatchewan and Manitoba.

In Alberta, the best known and largest ferrous occurrence in Cretaceous strata is the Clear Hills iron deposits in northwestern Alberta. The other two ferrous occurrences are in southwestern Alberta, but these comprise palaeoplacer detrital magnetite in Late Cretaceous Belly River Formation. In addition, to these three occurrences reported by Hamilton and Olson (*Ibid*), at the “Zep iron deposit” in the Highwood River area of southwest Alberta there is reported to be a sedimentary bed up to about 3 m thick that

comprises phosphorous siderite, ferrous dolomite, calcite and collophane which, in places, has an oolitic texture (Norman, 1957; Bruce, 1958; Anonymous, 1958). The deposit has produced samples averaging about 35% total iron (as Fe_2O_3). The exact stratigraphic position of the Zep iron deposit is uncertain, but it is believed to be in either Triassic Spray River Formation, Jurassic Fernie Group or Lower Cretaceous Kootenay Formation or overlying Blairmore Group. If so, then the Zep deposit is considerably older than Late Cretaceous Bad Heart Formation. Interestingly, Anonymous (1958) reported that finely oolitic siderite occurs in a lenticular bed in the Blairmore Group within a few kilometres of the Zep deposit. He (*Ibid.*) also stated that the “*the same siderite horizon [as that at the Zep deposits exists] in a northern part of the Rockies around the Nordegg and Jasper areas*” in west central Alberta.

In central Saskatchewan at Pasquia Hills, nodular concretions rich in manganese and iron occur in siltstone and shale of the basal 100 m of Riding Mountain Formation; the resource is reported to be up to about 6 million tonnes of nodules averaging 17% Mn and 20% Fe (Beck, 1974). The Riding Mountain Formation is stratigraphically equivalent to the upper part of Campanian Lea Park Formation which exists in northeast and central Alberta, and hence the Pasquia Hills iron-manganese deposit may be a few million years younger than the Bad Heart Formation.

In Manitoba, the manganiferous siderite concretions exist in Upper Cretaceous Pierre Formation shale (Price, Hamilton and Olson, 1999). Pierre Formation is approximately age-equivalent to the Colorado Group, hence was deposited between about 97.5 Ma and 84 Ma, and encompasses the time period during which the Bad Heart Formation was deposited.

3.7 Correlative Iron Deposits Worldwide

Gross (1965) defined “*iron formation*” as “*all stratigraphic units of layered, bedded, or laminated rocks that contain 15 per cent or more iron*”. Based on this definition, the Clear Hills iron deposits are iron formation because they contain on average somewhat more than 30% iron. Gross (*Ibid.*) subdivided bedded iron formations into six main types based on their depositional environment. Four of the six types are primarily chemical precipitates, whereas two are clastic sediments, and for the chemical precipitates, two are predominantly siliceous, whereas the other two are predominantly aluminous. Three of the chemical precipitates were deposited in shallow-water environments and in these oolitic textures are common. In summary, the six iron formation types comprise:

- (1) **Algoma type cherty iron formation** with hematite and magnetite being the primary iron minerals. This type was deposited mainly in a eugeosynclinal environment, and typically exhibit a close relationship spatially and genetically with vulcanism.
- (2) **Superior type cherty iron formation** with hematite – goethite being the primary iron minerals. This type was deposited mainly in a shallow water, continental

shelf environment, and typically is associated with dolomite, quartzite, red and black ferruginous shale. However, volcanic rocks are not always directly associated with the iron formations, although they tend to occur somewhere in the succession. Oolitic textures are common.

- (3) **Clinton type iron formations** are typically deep red to purple, massive beds with oolitic textures, that are composed primarily of intimate mixtures of hematite, chamosite and siderite. Chert, however, is absent. They typically contain about 51% iron, and are typically have a higher phosphorus content than the Superior type iron formations. They are associated with carbonaceous shale, sandy shales, dolomite and limestone, and formed along the margins of continents or continental shelves.
- (4) **Minette type iron formations** are oolitic textured rocks comprised of siderite, and iron silicates such as chamosite or iron chlorites. In many places, clastic debris is present, and the typically are associated with black carbonaceous shale, mudstone and sandy shale which formed in marine or brackish water in shallow basins. Gross (1965) stated that the Minette type iron deposits are *“particularly important and widespread in Europe, but the only Canadian examples known are the iron-formations of the Peace River area, Alberta”*. The iron content of the Minette type iron formations is usually less than 40%, with the lime content from 5 to 20%; and the phosphorus content being higher than the cherty Superior and Algoma types.
- (5) **Non-oolitic iron formations** are lithologically diverse, but most consist of lenticular beds of siderite or sideritic mudstone, siderite-hematite, or massive hematite, and limonite. Bedding tends to be poorly developed or lacking, and massive units are typical. Most units of this type contain less than 25 per iron, and tend to be siliceous and high in alumina or lime. In places, manganese can be present up to 15%.
- (6) **Clastic iron formations** may be composed of various iron minerals, but magnetite is the most common, and typically exists in placers or paleo-placers which form in beach- or fluvial-environments. Alberta examples include the Burmis and Dungarvan deposits in Late Cretaceous (Campanian) Belly River Formation sandstone in southwestern Alberta.

With respect to the Minette type iron formations, European examples include the sideritic or chamositic ironstones of northern England, the classical minette ores of the Lorraine district of France and Western Germany, the Salzgitter ores of Lower Saxony in Germany, and many other deposits in northern Europe (Gross, 1965). They tend to be most common in Mesozoic and Tertiary rocks, and typically are closely associated with black carbonaceous shale, mudstone and sandy shale which frequently were deposited in marine or brackish water in shallow basins.

The Minette type iron formations have many features in common with the Clinton type iron formations, but they tend to have a higher silica and lower iron content, the ferric oxides are usually brown and limonitic rather than red hematite, and siderite is more abundant. In general, the Minette type iron formations have a higher silica, ferrous iron (Fe^{2+}), alumina, calcium and magnesium contents, with small amounts of TiO_2 , Cr_2O_3 , V_2O_5 , and As. Correspondingly, the total iron content tends to be 10 to 15% less in the Minette type versus the Clinton type iron formations. Finally, most Minette type iron formations are of limited areal extent and were apparently deposited in shallow bays and restricted arms of the sea where the water was agitated by wave or current action, and this facilitated the deposit of oolites. The source of the iron in the Minette type deposits is speculative, but Gross (*Ibid*) postulated that it was derived from a weathered landmass by sedimentary processes.

The Clear Hills iron deposits *“have textures and chemistry (including high P_2O_5) similar to other minette-type deposits throughout the world (Rohrlich, 1974). However, the Peace River deposits contain nontronite and opal as the the main silicate minerals, whereas chamosite, chlorite, kaolinite, etc. predominate in other worldwide deposits such as Ramin, Israel ..., Hussigny, Lorraine [in France and Germany] ..., Raasay [and] ... Loch Etive, Scotland ..., Northampton [, Great Britain] ... On the other hand, nontronite is the major silicate in ... Tunisia oolitic iron deposits ...”* and in some other Recent oolitic iron deposits (Petruk, 1977).

4.0 CHARACTERISTICS OF THE CLEAR HILLS IRON FORMATIONS

4.1 Ore Mineralogy, Petrology and Petrography of the Iron Deposits

The ore mineralogy, petrology and petrography have been described by Mellon (1962), Petruk (1976, 1977) and Petruk *et al.* (1977a, b), and is summarized in Hamiltion (1980).

“The Clear Hills ore is a minette-type oolitic ironstone, comprising densely packed ooliths, rounded rock fragments and angular grains of quartz and siderite in a soft earthy matrix. The ooliths consist of concentric layers of goethite and nontronite, commonly with a mineral grain nucleus. They constitute from 30 to 70 per cent of the rock mass, increasing upward from the base of the ore bed and averaging about 60 per cent for the whole.

The matrix consists of illite and nontronite imbedded in a ferruginous opal cement. It averages about 25 per cent of the rock mass. Minor components of the oolite include rock fragments, quartz grains, siderite and amorphous phosphate. Rock fragments occur commonly as well rounded ‘pebbles’ up to 1 cm in size, composed of matrix-like ferruginous material. They constitute about 10 per cent of the rock. The quartz is found mainly as the cores of ooliths, but also in the matrix. Siderite occurs as authigenic crystals in the matrix. Phosphate is confined to ooliths, as a diffuse impurity in the goethite and nontronite layers and rarely as grains in the cores. ...

The oolite content is highest in the upper part of the bed (about 70 per cent), decreasing progressively towards the base [to less than about 25%]. The oolites range in size from 0.05 to 1.0 mm but are well sorted and are mostly about 0.4 mm in diameter. They consist of concentric layers of goethite and nontronite, normally enclosing a mineral grain nucleus (Petruk, 1977). These nuclei are principally quartz, but may also be amorphous phosphate, massive goethite, broken oolite fragments, or rock fragments. The average composition of the oolites is about 45 per cent goethite, 45 per cent nontronite, 5 per cent quartz and 5 per cent amorphous phosphate. However, the composition varies to the extent that some oolites are largely goethite, others almost wholly nontronite ... The goethite-rich oolites are most abundant at the top of the iron bed, whereas the nontronite oolites are found only at the base.

The interstitial 'matrix' [to the oolites] consists of the clay minerals, illite and nontronite imbedded in a ferruginous opal cement ... [which forms] a dark green, earthy material. The matrix averages about 25 per cent by volume throughout the ore bed thickness, but it varies inversely with the oolite content and toward the base it increases to a maximum of about 50 per cent.

Rock fragments constitute about 10 per cent by volume of the ore and are fairly constant in amount throughout the ore bed. ... Many of the fragments occur as well rounded, polished 'pebbles' up to 1 cm in size, conspicuously larger than the more abundant oolites. The fragments are composed largely of ferruginous, silty shale aggregates similar in composition to the interstitial matrix of the oolite, showing all gradation between unaltered, dark green aggregates to completely oxidized, dark brown limonitic aggregates. ...

Other minor components of the oolite bed are quartz, siderite, and amorphous phosphate, [plus small quantities of chalcedony and pyrite]. The quartz is detrital, found mainly as the cores of the oolites but also [occurs] as discrete, uncoated grains scattered throughout the matrix. Siderite is authigenic and is present mainly as intergranular crystals in the matrix, occupying portions of the voids in the oolite not completely infilled by matrix material. The phosphate is confined to oolites, as rare discrete grains in the cores and also as a diffuse impurity in the goethite and nontronite layers. The phosphate is largely amorphous but one grain gave a weak x-ray diffraction pattern of apatite (Petruk, 1977). Quartz and siderite each constitute about 5 per cent of the rock, phosphate about 3 per cent." (Hamilton, 1980).

With respect to the quartz nuclei at many oolite centers, Dufresne (*personal communication*, Oct. 1997) suggested that much of the quartz nuclei represent volcanic glass shards.

Mellon (1962), from a core drilled about 0.4 km west of the oolitic iron deposit exposed in outcrop at Rambling River, estimated from point counts the percentages of the different textural elements in eleven samples which were collected from the lower part of the oolite bed. The averages given by Mellon (*Ibid*) are summarized in Table II.

Table II shows that the oolites are the most common constituent by volume of the oolitic ironstone, and they tend to become increasingly more abundant stratigraphically upwards, ranging from about 24 volume per cent near the stratigraphic base, to almost 60% at the top (Figure 8). The increase in oolite content coincides with a concomitant decrease in the amount of matrix. However, ferruginous cement also increases upward, and in the uppermost sample studied by Mellon (*Ibid*), oolites and ferruginous opal cement comprise almost 90 volume per cent of the oolitic ironstone.

TABLE II
AVERAGE PERCENTAGE OF TEXTURAL ELEMENTS
IN OOLITIC IRON STONE AT RAMBLING RIVER

Textural Element	Average Percentage (i.e., for a composite across the entire oolitic ironstone unit)
Oolites	46.0
Matrix	22.3
Ferruginous cement	13.5
Rock fragments	9.9
Carbonate (mainly siderite)	5.6
Quartz grains	2.7
Grand Total	100.0

4.2 **Physical Characteristics of the Iron Deposits**

The physical properties of the Clear Hills iron deposits are largely dependent on the degree of oxidation from Recent and Pre-glacial weathering.

"Unweathered, completely unoxidized ore is dark green to black in colour, moderately hard, compact and brittle. The [fresh] rock is uniformly hard ... and tends to break across the ooliths, rather than around them, giving a subconchoidal aspect to the fracture surfaces. ... The lower part of the ore bed (lower 2 m or so) is somewhat softer than the main part, due to the higher mudstone content and the decline in the oolitic framework component. ... The ore bed as a whole is massive. It lacks any well developed bedding separation planes or horizontal cleavage ... Specific gravity determinations of the unweathered ore vary from 2.5 (Edgar, 1961) to 2.82 (Krupp, 1975). Petruk et al. (1977a) measured specific gravities for the mineral end-members of the ore as follows: for goethite 3.8, for siderite 3.8, for nontronite 2.6 and for ferruginous opal 2.0. For an average goethite[, specific gravity] was calculated as 3.1 and for an average oolith as 2.8. ... No determinations have been made of compressive or shear strengths, or seismic velocity of the ore material." (Hamilton, 1980)

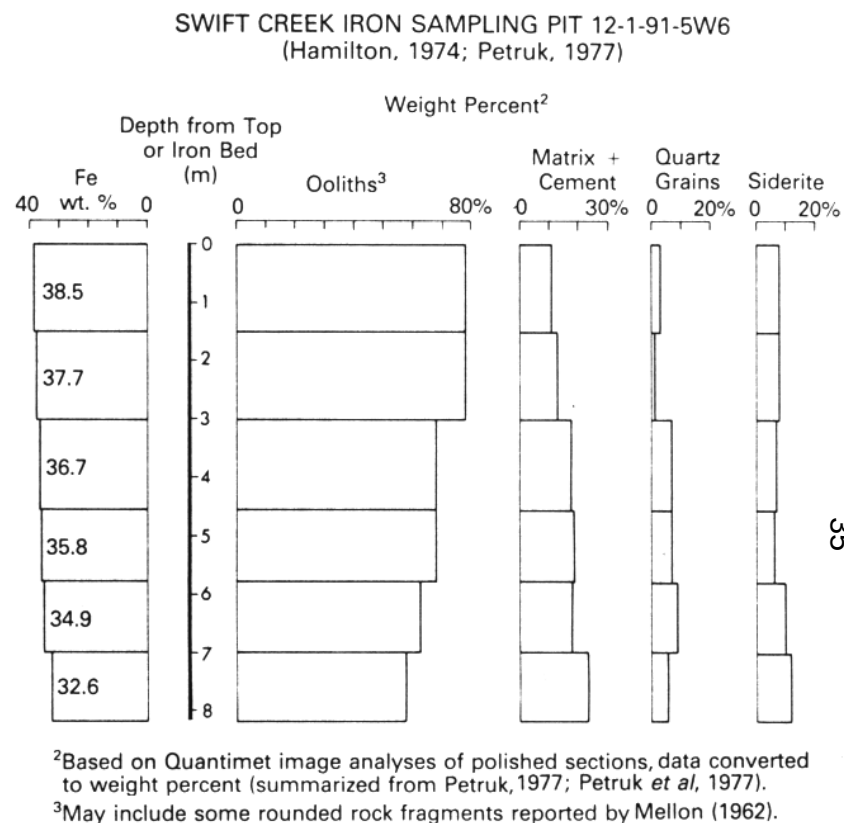
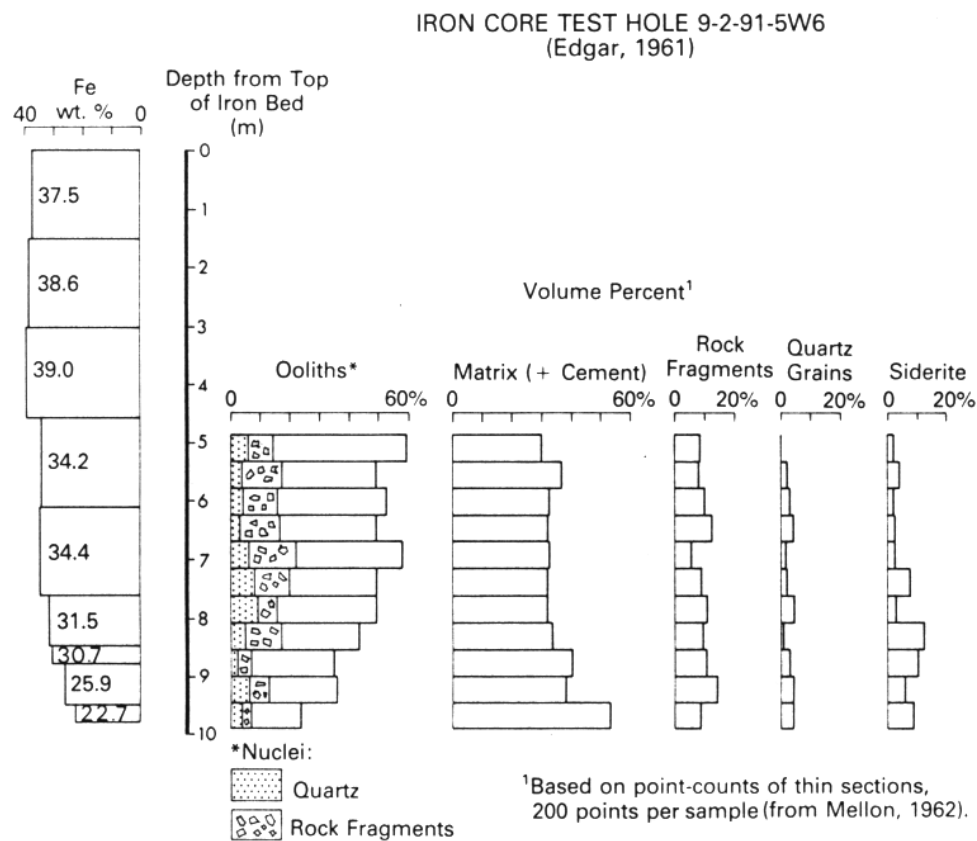


FIGURE 8: Vertical Variation in Petrographic Textural Elements in the Swift Creek Oolitic Iron Deposit.
(After Hamilton, 1980)

In most places where the iron deposits are now exposed at Rambling River and near Worsley, the deposits are overlain by glacial and other drift, and the oolitic iron deposits typically are extensively to at least somewhat oxidized. *“The depth and intensity of the oxidation is variable from place to place in the deposit. In the Worsley area the ore bed has been exposed to surficial weathering from preglacial time to the present and intense oxidation extends throughout the bed. In the Swift Creek [Rambling River] area, where the ore bed was exposed only for a time following preglacial erosion, the ore is unoxidized except for the upper 2 or 3 m of the bed. It is now covered by thick till. Where the ore bed is overlain by bedrock (i.e., where it was not preglacially exposed) it is entirely unoxidized. ... Where the ore bed has been exposed to such prolonged weathering, the material on the surface is oxidized to a reddish coloured, soft and friable earthy material. The highly oxidized zone normally extends less than 1 m into the bed, below which the effects of less intense oxidation may be evident for a further 2 or 3 m. In this sub-weathering zone the rock resembles unoxidized ore, is dark green to black in colour, but is less hard and dense. The rock tends to break around the oolites ... This seems to reflect a weakening of the matrix material, caused by the loss of absorbed water from ferruginous opal on exposure to atmospheric conditions”* (Hamilton, 1980).

4.3 **Chemical Characteristics of the Iron Deposits From Prior Studies**

The main iron-bearing minerals in the Clear Hills iron deposits are goethite, nontronite, ferruginous opal and siderite (Appendix I). These minerals comprise both the oolites and the matrix and ferruginous cement between oolites. In the past, the Clear Hills iron deposits have been mainly analyzed for their iron content, and some related rock-forming elements (e.g., Kidd, 1959; Bertram and Mellon, 1975; Petruk *et al.*, 1977; Hamilton, 1980). Table III summarizes the bulk chemistry for the deposits, which are derived from averaged analyses of samples from numerous boreholes.

Salient observations from the data in Table III include.

1. The average total iron content ranges from 33 to 36%, being highest at the Rambling River segment of the iron deposits. The data in Hamilton (1980) shows that most of the iron is present as ferric (Fe^{3+}) versus ferrous (Fe^{2+}), with the average of four analyses being 47.5% Fe_2O_3 and 5.4% FeO .
2. The silica content is high, averaging about 25%, and alumina is low, averaging less than 6%.
3. the calcium content ranges from 1.9% at Rambling River, to about 4% at the Worsley segment. Hamilton (1980) speculated that the higher CaO content at Worsley is the result of the deeper surface oxidation at this locale, which caused siderite (FeCO_3) to oxidize to goethite ($\text{Fe}_2\text{O}_3 \cdot \text{H}_2\text{O}$) and calcite (CaCO_3). Lastly,

TABLE III
BULK CHEMICAL COMPOSITION
OF THE CLEAR HILLS IRON DEPOSITS¹

Constituent		Deposit						Average
Description	Element	Rambling River		Rambling River – Whitemud River ³	Worsley			
		Bertram & Mellon (1975)	Hamilton (1980) ²		Bertram & Mellon (1975)	Hamilton (1980) ⁴	Mikhail et al (1996) ⁵	
Iron	Fe	35.4	36.0	33.0	32.7	33.7	33.6	34.1
Silica	SiO ₂	26.5	25.4	29.3	25.7	19.3	23.5	25.0
Alumina	Al ₂ O ₃	5.0	5.2	5.5	5.5	8.4	5.7	5.9
Calcium	CaO	1.9	2.0	N.A.	3.3	4.5	1.4	2.6
Magnesia	MgO	1.0	1.1	1.6	1.3	2.3	0.8	1.4
Manganese	MnO	0.2	0.8	N.A.	0.2	0.1	Tr ⁶	0.3
Sodium	Na ₂ O	N.A. ⁶	0.2	N.A.	N.A.	0.1	Tr	0.2
Potassium	K ₂ O	N.A.	0.5	N.A.	N.A.	0.7	0.7	0.6
Phosphorous	P	0.7	1.7 (P ₂ O ₅)	0.5	0.7	0.8 (P ₂ O ₅)	1.3 (P ₂ O ₅)	1.0
Sulfur	S	0.1	0.03	N.A.	0.1	0.1	Tr	0.1
Vanadium	V	N.A.	0.2	N.A.	N.A.	N.A.	N.A.	0.2
Loss on Ignition (H ₂ O and CO ₂)	LOI	13.8	10.2	11.9	14.4	12.1	18.8	13.5
Totals		84.6 ⁷	83.3	81.8	83.9	82.1	85.1	84.9 ⁷

¹Modified after Table 1 in Bertram and Mellon (1975), and Table 5 in Hamilton (1980).

²Average of six Canmet analyses in Table 5 Hamilton (1980).

³From Table 1 in Bertram and Mellon (1975)

⁴Average of two Worsley samples in Table 5 in Hamilton (1980).

⁵After data in Mikhail et al. (1996).

⁶"Tr" denotes Trace, and "N.A." denotes Not Available.

⁷Total does not equal 100% due to weights not accounting for oxygen tied up with Fe, P, S, V and other elements.

4. the high Loss on Ignition (LOI) may be due to water in the abundant opaline silica that is present.

With respect to the vertical variation in the iron content, Figure 9 demonstrates that there is a clear variation in the iron content from almost 40 weight per cent iron near the top of the oolitic ironstone unit, decreasing to about 25 weight per cent near the base of the unit. This decrease in overall iron content downwards correspond to a similar decrease in the percentage of oolites from between about 60 volume per cent or more near the top of the ironstone unit, to less than 30 volume per cent near the base of the unit. That is, because the oolites are comprised of about 85 weight per cent of ferruginous minerals (goethite, nontronite, ferruginous opal and siderite; see Table 6 in Petruk, 1977), hence a volumetric decrease in the amount of oolites results in an overall lower iron content.

5.0 SUMMARY OF SOME ECONOMIC AND BENEFICIATION ASPECTS FOR FUTURE EXPLOITATION OF THE CLEAR HILLS IRON DEPOSITS

5.1 Estimated Ore Resources and Grades

Hamilton (1980) stated “reserves are defined in four main segments, or ‘blocks’ of the Clear Hills iron deposit. These are referred to as Worsley (block A), Swift Creek [Rambling River] (block B), Whitemud River (Block C) and South Whitemud River (block D) (Figure 2). In blocks A and B the reserves are essentially proven, by extensive test drilling [which was done in the late 1950’s and early 1960’s, whereas] ... Blocks C and D reserves are only roughly outlined. Block B, the Swift Creek [Rambling River] segment, is the most likely site for future mine development. The ore bed is thickest here and has the best potential mineability. The reserves underlie less than 40 m of overburden, with an average stripping ratio of 3:1, and are ample to sustain a major steel plant.”

Table IV summarizes the iron ore resources estimated by Hamilton (1980). In total, there exist over 1 billion tonnes grading about 34.0% Fe.

5.2 Synopsis of Prior Beneficiation Studies

“It was early apparent to Premier Steel Mills that the Peace River iron ore was unsuitable as a blast furnace feed and the company [, and subsequently the Alberta Research Council,] began investigating various methods of processing [the] low-grade [iron] ores” (Samis and Gregory, 1962). The various possible beneficiation methodologies for the Clear Hill iron resources have been discussed by Samis and Gregory (*Ibid.*), Bertram and Mellon (1975) and, most recently, by Marum Resources Inc. (R. Bouley, Personal Communication, 1997). The beneficiation methods discussed in these reports include: (a) magnetic separation, (b) the ‘R-N process’, (c) acid leaching, (d) flotation, (e) and some experiments conducted by the Alberta Research Council involving drying, crushing, magnetizing roasting, oxidative roasting, magnetic

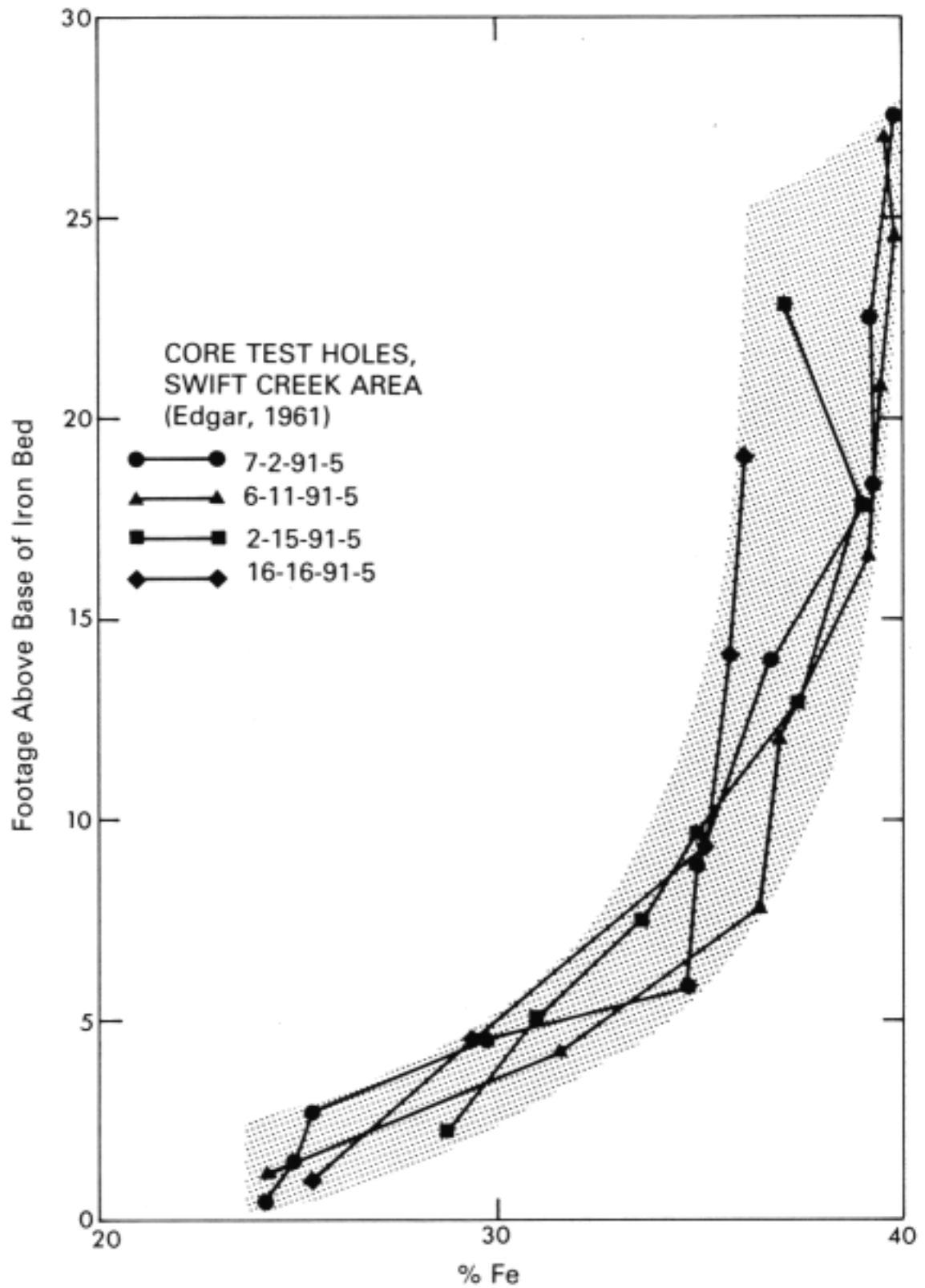


FIGURE 9: Vertical variation in iron content within the Swift Creek oolitic iron deposit (After Hamilton, 1980)

separation (wet and dry), high-intensity dry magnetic separation, electrostatic separation, and solution-type recovery processes (Bertram and Mellon, *Ibid.*).

Bertram and Mellon (1975) concluded that *“the best procedure for treating the Peace River ore appears to be either:*

- (1) *a mild reductive roast followed by crushing and grinding to to yield a magnetic concentrate, or*
- (2) *intensive reduction of the ore to an iron-metal product followed by magnetic beneficiation of this product to remove the gangue constituents.*

Either procedure will be relatively expensive when one considers the value of the products. The mild reductive roast procedure may be better in that a wider range iron- and steel-making procedures can be used on the upgraded product.” They (*Ibid.*) concluded by recommending that additional beneficiation research be carried out.

More recently, Marum Resources Inc. had CANMET in Ottawa conduct a preliminary metallurgical evaluation of a 50 kg sample from the Worsley Pit at the southern end of the Clear Hills iron deposit (Mikhail et al., 1996). The Mikhail et al. (1996) study included: (a) characterization of the ore as received by X-Ray Diffraction (XRD) analysis, (b) upgrading tests of the ore, and (c) reduction and smelting tests of the concentrate. The XRD analysis indicates the Worsley Pit material is mainly goethite with minor amounts of quartz and trace amounts of muscovite and other mica-type material. However, they (*Ibid.*) also noted that mineral components in amounts less than a few per cent, may not be detected by XRD. Thermal analysis showed that on heating the ore in air to temperatures below 600°C resulted in a 15% decrease in the mass through loss of water, mainly from goethite, and evolution of CO₂, mainly from reduction of iron carbonate (e.g., possibly siderite). Chemical analysis of the Worsley sample by Mikhail et al. (1996) are listed in Table III. The results after upgrading are summarized in Table V, which shows that after grinding, screening magnetic separation and roasting, total iron content had increased from 33.6% in the ‘as received ore’ to 40.0% in the ‘upgraded ore’, with the conversion of goethite mainly to hematite. After smelting of the concentrate, including the mixture of graphite and lime, the yield was only 1.2 kg from 8 kg of concentrate, or about 38% of what was expected (Table V). As a result, Mikhail et al. (1996) concluded that the *“preliminary qualitative study indicated that the reduction/smelting of the Clear Hills iron ore to produce metallic iron is technically feasible. [However,] due to the physical and chemical nature of the ore, ... high material losses and low metallic yield are expected.”* They (*Ibid.*) recommended that further extensive research and development is required if the iron recovery process for the Clear Hills iron ore is to be optimized.

TABLE IV**SUMMARY OF CLEAR HILLS IRON ORE RESERVES***

Block	No. of Drillholes	Reserves (million tonnes)			Average Grade (% Fe)	Average Thickness (m)	Maximum Overburden Thickness (m)
		Proven	Probable	Possible			
A – Worsley	120	23.36	7.46		32.6	2.4	20
B – Rambling River	115	182.340 (or 144.240)			33.9 (or 35.4)	6.7 (or 5.3)	40
C – Whitemud River	8		620.300		34.0	5.2	60
D – South Whitemud River	2			186.0	34.0	3.4	60
Subtotals	245	205.7			33.75		
			627.76		34.0		
				186.0	34.0		
Grand Total		1,019.46			33.9		

*After Table 8 in Hamilton (1980), with drillholes after Table 2 in Bertram and Mellon (1975).

TABLE V
CHEMICAL ANALYSES OF THE ORE AFTER UPGRADING¹

Chemical Constituent	As Received Ore From Worsley Pit (%)	After Upgrading ² (%)	After Smelting of Concentrate (%)
Total Fe	33.6	40.0	24.1
SiO ₂	23.5	28.3	33.5
Al ₂ O ₃	5.7	6.9	8.8
CaO	1.4	2.4	12.7
MgO	0.8	1.1	1.5
P ₂ O ₅	1.3	1.9	No data
K ₂ O	0.7	0.8	No data
LOI	18.8	3.2	No data
C	No data	No data	17.0
Totals	85.8	84.6	97.6

¹After data in Mikhail et al. (1996), combination of his Tables 1 and 2.

²Upgrading included grinding, screening, magnetic separation and roasting.

³Result is the slag of Melt II, in which 8 kg of concentrate was mixed with 3 kg of graphite and 1 kg of lime. The metal yield in this test was about 1.2 kg, which was significantly less than the 3.2 kg indicated by the calculated yield. However, they concluded that the results indicate *"the reduction/smelting of the Clear Hills iron ore to produce metallic iron is technically feasible"*.

5.3 **Availability of Fuel and Other Raw Materials Needed for Processing the Clear Hills Iron Deposits**

Hamilton (1980) noted that the raw materials, including coal, calcium chloride, limestone and natural gas, required for processing the Clear Hills iron ore, existed in *'good supply in northwestern Alberta'*. Although this statement was made almost 20 years ago, it is as true today, or truer, than when made in 1980.

5.4 **Synopsis of Prior Marketing Studies**

Bertram and Mellon (1975) suggested: (a) the possible value of a 'medium grade concentrate' (i.e., assumes Peace River iron ore can be upgraded to about 60% Fe, 20% SiO₂, 0.3% P and 2% CaO), would be between about \$13 to \$19.00 per tonne (in 1975 dollars Canadian), and (b) that the cost to process the Clear Hills iron ore to metal might range between \$55Cdn to \$72Cdn per tonne of iron, assuming the ore can be made available in the form of self-fluxing pellets grading 52% Fe. They (*Ibid.*) also noted that *"a slight change in costs for any item can lead to large changes in the costs of converting iron ore to iron metal [and that] ... the scale of the process has a large bearing on determining the ultimate costs of conversion"*.

More recently, MT Environmental Systems Inc. (1996) stated that *“the iron and steel industry is in a period of brisk sales and strong growth in certain areas after a long period of stagnation. Explosive economic growth ... in Asia has challenged feedstock production and absorbed all surplus scrap world wide. To meet these demands, a number of very large iron ore mining projects have been announced ... If all the announced projects are successfully funded and come on stream as planned, there will still be a shortfall in [iron] ore production by the end of the century.”* They (*Ibid.*) concluded, however, that although the markets were good for magnetite and high quality pig iron ingots, that the iron ore trade is not attractive for the Clear Hills iron deposits because the relatively low ore grades and long hauls to tidewater *“make entry into this market unattractive”*. With respect to the demand for pig iron, they (*Ibid.*) stated that eight mills in Western Canada represent a demand for at least 30,000 tonnes of pig iron per year, possibly more, and that all the mills were dissatisfied with their supplier, who currently enjoys a monopoly supply position.

6.0 RESULTS FROM CURRENT STUDY OF POTENTIAL CO-PRODUCT TRACE ELEMENTS IN THE CLEAR HILLS IRON DEPOSITS

6.1 Summary of Samples and Their Locations

A total of 138 samples were obtained for this study: (a) 26 contiguous samples from the AGS from the Rambling River (Swift Creek) excavated pit, (b) 12 contiguous samples from the AGS from the Worsley Pit, (c) 12 samples from Marum Resources or Mr. T. Bryant from the Worsley Pit, (d) 84 samples from drilling conducted by Marum Resources near the Worsley Pit (which includes 2 duplicate sample pairs), and (e) 4 samples provided by Mr. C. Collom from an outcrop along the Smoky River (Table VI). These 138 original samples were rebagged with new sample identifiers, and 13 selected samples were subdivided to provide additional duplicate sample pairs for comparative analyses. As a result, a total of 151 samples were submitted for geochemical analysis, including a total of 15 duplicate sample pairs (Table VI).

6.2 Sample Preparation and Analytical Methodology

All 151 samples were sent to Activation Laboratories Ltd., Ancaster, Ontario (‘ActLab’) for sample preparation and analysis. In summary;

1. All 151 rock samples were crushed using ActLab’s ‘Code RX2’ mild steel sample preparation method.
2. All 151 samples were analyzed for gold (Au) plus 47 other selected elements by ActLab’s ‘Code 1H’ combination Instrumental Neutron Activation Analysis (INAA) or Total Digestion-Induction Coupled Plasma Spectrometry (ICP) methods.

TABLE VI

SUMMARY OF SAMPLES USED CLEAR HILLS IRON DEPOSIT STUDY

(APEX Project 97213)

Peace River Iron Study Sample No.	Dupl.	Original Sample Identifiers		Approximate Sample Weight				Colour (where known)	Remarks (after AGS descriptions)
		Sample No.	Interval (feet)	<0.2 kg	0.2-1 kg	1-2 kg	>2 kg		
RAMBLING RIVER (SWIFT CREEK) SAMPLES WHICH WERE COLLECTED BY THE ALBERTA GEOLOGICAL SURVEY (also see Figure 7)									
AS028		1	0 - 1		x			"Rust" to reddish brown	Sampled below overlying glacial till. Earthy, very crumbly to friable brittle; rippable with bulldozer
AS027		2	1 - 2		x			Reddish brown	Friable, brittle, densely oolitic with rounded mudstone pebbles; rippable with bulldozer
AS026		3	2 - 3		x			Reddish to greenish	Friable, brittle, densely oolitic; rippable with bulldozer
AS025		4	3 - 4		x			Dark green to black	Friable, brittle, densely oolitic with rounded mudstone pebbles; rippable with bulldozer
AS024		5	4 - 5		x			Dark green to black	Friable, brittle, densely oolitic with rounded mudstone pebbles; rippable with bulldozer
AS023		6	5 - 6	x	199g			Dark green to black	Slightly friable to compact, densely oolitic with rounded mudstone pebbles; difficult to rip with
AS022		7	6 - 7	x	199g			Dark green to black	Slightly friable to compact, densely oolitic with rounded mudstone pebbles; difficult to rip with
AS021		8	7 - 8	x	116g			Dark green to black	Slightly friable to compact, densely oolitic with rounded mudstone pebbles; difficult to rip with
AS020	D	9	8 - 9		x			Dark green to black	Slightly friable to compact, densely oolitic with rounded mudstone pebbles; difficult to rip with
AS019	D	9	8 - 9		x			Dark green to black	Slightly friable to compact, densely oolitic with rounded mudstone pebbles; difficult to rip with
AS018		10	9 - 10	x	116g			Dark green to black	Slightly friable to compact, densely oolitic with rounded mudstone pebbles; difficult to rip with
AS017		11	10 - 11		x			Dark green to black	Slightly friable to compact, densely oolitic with rounded mudstone pebbles; difficult to rip with
AS016		12	11 - 12	x	121g			Dark green to black	Compact, brittle, densely to moderately oolitic; cannot be ripped with bulldozer
AS015		13	12 - 13	x	177g			Dark green to black	Compact, brittle, densely to moderately oolitic; cannot be ripped with bulldozer
AS014		14	13 - 14	x	179g			Dark green to black	Compact, brittle, densely to moderately oolitic; cannot be ripped with bulldozer
AS013		15	14 - 15	x	150g			Dark green to black	Compact, brittle, densely to moderately oolitic; cannot be ripped with bulldozer
AS012		16	15 - 16	x	129g			Dark green to black	Compact, brittle, densely to moderately oolitic; cannot be ripped with bulldozer
AS011		17	16 - 17		x			Dark green to black	Compact, brittle, densely to moderately oolitic; cannot be ripped with bulldozer
AS010	D	18	17 - 18	x	147g			Dark green to black	Compact, brittle, densely to moderately oolitic; cannot be ripped with bulldozer
AS009	D	18	17 - 18	x	170g			Dark green to black	Compact, brittle, densely to moderately oolitic; cannot be ripped with bulldozer
AS008		19	18 - 19		x			Dark green to black	Compact, brittle, densely to moderately oolitic; cannot be ripped with bulldozer
AS007		20	19 - 20		x			Dark green to black	Compact, brittle, densely to moderately oolitic; cannot be ripped with bulldozer
AS006		21	20 - 21		x			Dark green to black	Compact, brittle, densely to moderately oolitic; cannot be ripped with bulldozer
AS005		22	21 - 22	x	127g			Dark green to black	Compact, brittle, densely to moderately oolitic; cannot be ripped with bulldozer
AS004		23	22 - 22		x			Dark green to black	Fairly compact, moderately to sparsely oolitic, high mudstone content in matrix
AS003		24	23 - 24		x			Dark green to black	Fairly compact, moderately to sparsely oolitic, high mudstone content in matrix
AS002		25	24 - 25	x				Dark green to black	Fairly compact, moderately to sparsely oolitic, high mudstone content in matrix
AS001		26	25 - 26	x				Dark green to black	Fairly compact, moderately to sparsely oolitic, high mudstone content in matrix, earthy towards base

NOTE: Samples are listed from top of section, downwards to base of section.

With respect to duplicates, "D" refers to duplicate pairs prepared during this study, whereas "MD" refers to duplicate pairs prepared by Marum Resources.

Peace River Iron Study Sample No.	Dupl.	Original Sample Identifiers		Approximate Sample Weight				Colour (where known)	Remarks (after AGS or Marum descriptions)
		Sample No.	Interval (feet)	<0.2 kg	0.2-1 kg	1-2 kg	>2 kg		
WORSLEY PIT SAMPLES WHICH WERE COLLECTED BY THE ALBERTA GEOLOGICAL SURVEY (also see Figure 6)									
AW013		95SH-47-012			x			Dark brown	Densely oolitic, with greenish clay partings; sampled over 30 cm.
AW012		95SH-47-011			x			Dark brown	Conglomerate, between 3.85 and 4.0 m from base, with 12 - 14 mm pebbles of shale and siderite
AW011		95SH-47-010			x			Greenish brown	Oolitic sandstone with greenish clay partings in interval from 3.6 to 3.85 m above base.
AW010	D	95SH-47-009			x			Dark brown	First conglomerate at 3.3-3.6 m above clay, with grey and greenish-grey siderite and shale.
AW009	D	95SH-47-009			x			Dark brown	First conglomerate at 3.3-3.6 m above clay, with grey and greenish-grey siderite and shale.
AW008		95SH-47-008			x			Dark brown	Massive densely oolitic; 3.7 m above Kaskapau clay
AW007		95SH-47-007			x			Dark brown	Massive densely oolitic; 2.2 m above Kaskapau clay
AW006		95SH-47-006			x			Dark brown	Massive densely oolitic; 1.7 m above Kaskapau clay
AW005		95SH-47-005			x			Orange	Oolitic sandy claystone 1.1 m above Kaskapau clay, with scattered ironstone nodules
AW004		95SH-47-004			x			Orange	Oolitic sandy claystone 70 cm above Kaskapau clay, with scattered ironstone nodules
AW003		95SH-47-003			x			Orange	Oolitic sandy claystone immediately above Kaskapau clay, with pebbles up to 0.3 mm
AW002		95SH-47-002			x			Buff - yellow	Rusty- to buff weathered clay (bentonite?) with quartz and black cherty grains
AW001		95SH-47-001			x			Grey	Kakaskapu Formation clay
WORSLEY PIT SAMPLE WHICH WAS COLLECTED BY MARUM RESOURCES LTD. (also see Figure 6)									
MW001		Lower Bad					x	Light brown	
WORSLEY PIT SAMPLES WHICH WERE COLLECTED BY T. BRYANT ON BEHALF OF MARUM RESOURCES LTD. (intervals after Bryant, personal communication, 1997)									
BW011		TS-14	0 - 1'8"				x		"Top oolite"; good oolite, some sedimentary layers, some mudstone
BW010		TS-11	3'6" - 4'4"				x		Coarse mudstone; iron poor with few oolites; "Au noted" by screening
BW009		TS-10	4'4" - 4'10"				x		"Top 6 inches" of dense oolite zone
BW008		TS-9	4'10" - 8'4"				x		Heavy oolite zone
BW007		TS-7	9'10" - 10'4"				x		Bottom of dense oolite zone
BW006		TS-6	10'4" - 11'2"				x		Top of clay shale unit in contact with overlying oolitic unit
BW005		TS-5	11'2" - 11'6"				x	Earth yellow to dark red brown to black	"First foot" of iron shale"; white crusts in fractures; some iridescent patches;very few oolites
BW004		TS-4	11'6" - 14'2"				x		"Second foot of iron shale"; oolite poor; iron rich shale in patches
BW003		TS-3	14'2" - 14'8"				x		"Third foot of iron shale" to base with clay shale
BW002		TS-1	15'10" - 16'5"				x	Yellowish	Yellow clay - rust stained layers, very sticky
BW001		grey base	16'5" - ?				x	Bluish grey	Blue clay base (Kaskapau Formation)

Peace River Iron Study Sample No.	Dupl.	Original Sample Identifiers		Approximate Sample Weight				Colour (where known)	Remarks (after Marum drill logs)
		Hole No.	Interval (feet)	<0.2 kg	0.2-1 kg	1-2 kg	>2 kg		
DRILL CUTTINGS FROM HOLES NEAR WORSLEY PIT WHICH WERE COLLECTED BY MARUM RESOURCES LTD.									
MD093		NS 9	11'-15'				x	Light brown	Ironcap and mudstone.
MD092		NS 9	15'-16'			x		Light brown	Ironcap and mudstone.
MD091		NS 9	16'-20'				x	Light brown	Highly oolitic Ironcap.
MD090	D	NS 9	20'-25'					Light brown	Transitional - oolitic Ironcap to blue shale.
MD089	D	NS 9	20'-25'				x	Light brown	Transitional - oolitic Ironcap to blue shale.
MD088		NS 9	25'-29'6"				x	Light grey	Pyritic blue shale; crumbly.
MD087		NS 9	29'6"-31'				x	Light grey	Pyritic blue shale; crumbly.
MD086		NS 9	31'-33'			x		Medium grey	Blue shale; plastic texture.
MD085		NS 9	33'-35'				x	Light grey	Pyritic blue shale; crumbly.
MD084		NS 9	35'-37'				x	Medium grey	Blue shale; plastic texture.
MD083		NS 9	37'-40'				x	Medium grey	Pyritic blue shale; crumbly.
MD082		NS 9	40'-45'				x	Medium grey	Semi-plastic blue shale.
MD081		NS 9	45'-50'				x	Medium grey	Semi-plastic blue shale.
MD080	D	NS 9	50'-55'					Medium grey	Semi-plastic blue shale.
MD079	D	NS 9	50'-55'				x	Medium grey	Semi-plastic blue shale.
MD078		NS 7A	7'-8'				x	Light brown	Glacial deposit.
MD077		NS 7A	8'-8'4"		x			Light brown	Transitional - glacial to Ironcap.
MD076		NS 7A	8'4"-11'3"				x	Light brown	Dense oolitic Ironcap.
MD075		NS 7	9' - 13'				x	Moderate brown	Dense oolitic Ironcap.
MD074		NS 7	15'-20'				x	Light brown	Dense oolitic Ironcap.
MD073		NS 7	20'-25'				x	Light brown	Slightly oolitic Ironcap.
MD072		NS 5A	8'-12'7"				x	Moderate brown	Glacial deposit; sandy mudstone, quartzite bebbles, coal?
MD071		NS 5A	11'3"-12'1"			x		Light brown	Transitional - glacial to oolitic Ironcap.
MD070	D	NS 5A	12'7"-13'					Light brown	Dense oolitic Ironcap.
MD069	D	NS 5A	12'7"-13'		x			Light brown	Dense oolitic Ironcap.
MD068		NS 5A	13'-15'6"				x	Light brown	Dense oolitic Ironcap.
MD067	MD	NS 5A	17'6"-18'6"; 1 of 2				x	Light brown	Transitional - Ironcap to blue shale.
MD066	MD	NS 5A	17'6"-18'6"; 2 of 2				x	Medium brown	Transitional - Ironcap to blue shale.
MD065		NS 5A	21'2"-21'4"		x			Light brown	Blue shale.
MD064		NS 5A	22'4"-24'6"				x	Medium grey	Pyritic blue shale; some plastic texture.
MD063		NS 5A	24'6"-26'				x	Medium grey	Slightly pyritic blue shale.
MD062		NS 5A	27'-29'				x	Medium grey	Slightly pyritic blue shale.

Peace River Iron Study Sample No.	Dupl.	Original Sample Identifiers		Approximate Sample Weight				Colour (where known)	Remarks (after Marum drill logs)
		Hole No.	Interval (feet)	<0.2 kg	0.2-1 kg	1-2 kg	>2 kg		
DRILL CUTTINGS FROM HOLES NEAR WORSLEY PIT WHICH WERE COLLECTED BY MARUM RESOURCES LTD. (Cont.)									
MD061		NS5	12' 6"-14'				x	Light brown	Ironcap.
MD060	D	NS5	14'-14' 6"					Light brown	Ironcap with fine mudstone.
MD059	D	NS5	14'-14' 6"				x	Light brown	Ironcap with fine mudstone.
MD058		NS5	14' 6"-15'	x				Light brown	Ironcap with trace mudstone.
MD057		NS5	15'-15' 10"		x			Light brown	Oolitic Ironcap with quartzite pebbles.
MD056		NS5	14'6"-15' 10"				x	Light brown	Oolitic Ironcap.
MD055		NS5	15' 10-17' 2				x	Light brown	Oolitic Ironcap.
MD054		NS5	17'2"-17' 8"	x				Light brown	Oolitic Ironcap.
MD053		NS5	17'8"-18' 8"			x		Light brown	Slightly oolitic Ironcap.
MD052		NS5	17'-18'				x	Light brown	Oolitic Ironcap.
MD051	D	NS5	17'2"-18'8"				x	Light brown	Oolitic Ironcap.
MD050	D	NS5	17'2"-18'8"				x	Light brown	Oolitic Ironcap.
MD049		NS5	18' 8"-19'		x			Light brown	Slightly oolitic Ironcap.
MD048		NS5	19'-19' 6"			x		Light brown	Ironcap with trace mudstone.
MD047		NS5	19' 6"-19' 10"		x			Light brown	Slightly oolitic Ironcap; plastic texture.
MD046		NS5	19' 10"-20'	x				Light brown	Ironcap with trace mudstone.
MD045		NS5	20'-20' 4"		x			Light brown	Ironcap with trace mudstone; hard and crumbly.
MD044		NS5	20' 4"-20' 10"		x			Light brown	Ironcap with trace mudstone; hard and crumbly.
MD043		NS5	20' 10"-21' 4"		x			Moderate brown	Transitional - iron stained blue shale.
MD042		NS5	20' 4"-21' 4"				x	Moderate yellowish brown	Transitional - Ironcap to blue shale.
MD041		NS5	21' 4"-22'		x			Moderate yellowish brown	Transitional - Ironcap to blue shale.
MD040	D	NS5	21' 4"-22' 6"					Moderate olive brown	Transitional - Ironcap to blue shale.
MD039	D	NS5	21' 4"-22' 6"				x	Moderate olive brown	Transitional - iron stained blue shale.
MD038		NS5	22"-22' 6"		x			Light grey	Ironstained blue shale; fossiliferous.
MD037		NS5	22' 6"-22' 10"		x			Moderate yellowish brown	Ironstained blue shale; fossiliferous.
MD036		NS5	22' 10"-23' 1"	x				Medium grey	Blue shale; crumbly
MD035		NS5	23' 1"-23' 3"	x				Light grey	Blue shale; crumbly; plastic texture.
MD034		NS5	23' 3"-23' 9"		x			Light grey	Blue shale; crumbly
MD033	MD	NS5	23' 9"-24' 7"; 2 of 2			x		Medium grey	Pyritic blue shale
MD032	MD	NS5	23' 9"-24' 7"; 1 of 2				x	Light grey	Pyritic blue shale
MD031		NS5	24' 7"-24' 8"	x				Medium grey	Pyritic blue shale; hard and crumbly.
MD030	D	NS5	24' 7"-26'					Medium grey	Pyritic blue shale.
MD029	D	NS5	24' 7"-26'				x	Medium grey	Pyritic blue shale.
MD028		NS5	26'-26' 6"				x	Medium grey	Pyritic blue shale.

Peace River Iron Study Sample No.	Dupl.	Original Sample Identifiers		Approximate Sample Weight				Colour (where known)	Remarks (after Marum drill logs)
		Hole No.	Interval (feet)	<0.2 kg	0.2-1 kg	1-2 kg	>2 kg		
DRILL CUTTINGS FROM HOLES NEAR WORSLEY PIT WHICH WERE COLLECTED BY MARUM RESOURCES LTD. (Cont.)									
MD027		NS4	17'-20'			x		Moderate brown	Highly oolitic Ironcap.
MD026		NS4	20'-21'				x	Moderate brown	Highly oolitic Ironcap.
MD025		NS4	21'-22'				x	Brownish grey	Transitional - Ironcap to blue shale.
MD024		NS4	23'-25'				x	Medium grey	Pyritic blue shale - crumbly.
MD023		NS4	25'-27'		x			Medium grey	Blue shale.
MD022		NS4	35'-40'				x	Medium dark grey	Pyritic blue shale - large crystals.
MD021		NS3	15' 6"-17'				x	Moderate brown	Oolitic Ironcap with trace mudstone.
MD020	D	NS3	17'-18' 6"					Moderate brown	Ironcap with coarse mudstone.
MD019	D	NS3	17'-18' 6"				x	Moderate brown	Ironcap with coarse mudstone.
MD018		NS3	18' 6"-20'				x	Moderate brown	Ironcap with coarse mudstone.
MD017		NS3	20'-24'				x	Moderate brown	Slightly oolitic Ironcap.
MD016		NS3	29'-30'				x	Medium grey	Pyritic blue shale.
MD015		NS3	30'-31'				x	Medium grey	Slightly pyritic blue shale.
MD014		NS3	31'-32'				x	Medium grey	Pyritic blue shale.
MD013		NS3	32'-35'		x			Medium light grey	Slightly pyritic blue shale.
MD012		NS2	8'-12'6"				x	Pale brown	Transitional - glacial to oolitic Ironcap; diamictite.
MD011		NS2	12'6"-15'				x	Light brown	Highly oolitic Ironcap.
MD010	D	NS2	15'-17'					Moderate brown	Oolitic Ironcap with trace mudstone.
MD009	D	NS2	15'-17'				x	Moderate brown	Oolitic Ironcap with trace mudstone.
MD008		NS2	17'-20'				x	Moderate brown	Ironcap - less oolitic.
MD007		NS2	20'-22'			x		Pale yellowish brown	Transitional - Ironcap to blue shale.
MD006		NS2	22'-25'				x	Light olive grey	Transitional - Ironcap to blue shale; salt crystals.
MD005		NS2	25'-26'			x		Medium grey	Pyritic blue shale.
MD004		NS2	26'-30'				x	Light olive grey	Slightly pyritic blue shale.
MD002		NS1	19'-20'			x		Moderate yellowish brown	Blue shale with quartz clasts.
MD001		NS1	42'-45'				x	Light grey	Blue shale.
MD003		EW STN A	15'-20'				x	Light grey	Blue shale.
Peace River Iron Study Sample No.	Dupl.	Original Sample Identifiers		Approximate Sample Weight				Colour (where known)	Remarks (after Collom and AGS descriptions)
		Collom	Interval (feet)	<0.2 kg	0.2-1 kg	1-2 kg	>2 kg		
SMOKEY RIVER SAMPLES WHICH WERE COLLECTED BY C. COLLOM									
CS005	D	HB-3			x				Top bed: rusty, fine-grained sandstone with chert pebbles
CS003	D	HB-3			x				Top bed: rusty, fine-grained sandstone with chert pebbles
CS004		No ID			x				10 cm thick sulphide rich silty sandstone between HB-2 and HB-3
CS002		HB-2			x				Middle Bed: rusty weathering similar to top bed; has fewer fossils than Lower Bed
CS001		HB-1			x				Lower Bed: grey, no rusty weathering, fine-grained sandstone;high percentage of macrofossils

3. Finally, a total of 125 selected samples were analyzed by ActLab's 'Code 1C' Research Lead Fire Assay for gold (Au), platinum (Pt) and palladium (Pd) method. The reason only 125 selected samples were analyzed for Au, Pt and Pd is because of project budgetary restraints.

Tables VII and VIII summarize the samples that were analyzed by each method, and the elements determined. As well, Table VIII lists the analytical detection limits for each element as reported by ActLab.

6.3 **Geochemical Results**

6.3.1 Introduction

ActLabs issued results to APEX in both hardcopy ("Certificate of Analysis") and digital format. Copies of the Certificates of Analysis from ActLab are included in Appendix II.1. In order to assist the reader, the geochemical data are tabulated in Appendix II.2, and have been broadly grouped in two ways:

- (a) firstly, by broad elemental class into:
 - (1) precious metals and platinum group elements;
 - (2) base metals and pathfinder elements;
 - (3) uranium, thorium, rare earth and selected other related elements; and
 - (4) rock forming and related trace elements;
- (b) then by major sampling area, comprising:
 - (1) Rambling River samples;
 - (2) Worsley Pit samples;
 - (3) cuttings from drilling done near the Worsley Pit; and
 - (4) Smoky River samples.

In Appendix II.2, and the other hardcopy tables of data herein, red numbers reflect those analytical results that are less than detection, hence the result shown in red is one-half way between the detection limit given in Table VIII and zero. Lastly, the digital data in Appendix II.2, as well as the digital data for selected other tables and figures, are included on a CD-ROM which is included herein as Appendix II.3.

Appendix III provides some synoptic 'statistical parameters', including the Mean, Median, Mode, Standard Deviation, Kurtosis, Skewness, Largest Analytical Result, and Smallest Analytical Result, are tabulated by major area of sampling. Note that the Mean, Median, Mode, Standard Deviation, Kurtosis and Skewness were all calculated by the program 'Microsoft Office 97 Excel', which assumes that the data are 'Normally Distributed'. That is, the calculations assume that the underlying geochemical distribution for each element closely approximates the Gaussian distribution, but this probably is not correct for all or the majority of the elements. Therefore, for this reason, and also because the sample numbers are small in some areas (e.g., at the Worsley Pit

TABLE VII

SUMMARY OF ANALYTICAL METHODS USED CLEAR HILLS IRON DEPOSIT STUDY

(APEX Project 97213)

Sample No.		Total No. of Samples	Preparation and Analytical Procedures		
From	To		Mild Steel Sample prep Code RX2 (# of Samples)	Au + 47 pkg by INAA & ICP Code 1H (# of Samples)	Lead Fire Assay for Au, Pt and Pd Code 1C - Research (# of Samples)
AS001	AS028	28	28	28	28
AW001	AW013	13	13	13	13
CS001	CS005	5	5	5	5
MW001		1	1	1	1
MD001	MD093	93	93	93	67 selected samples*
BW001	BW011	11	11	11	
Total Samples to be Analyzed		151	151	151	125

*Selected Samples from MD001 to MD093 Series That Were Lead Fire Assayed for Au, Pt and Pd.

Sample No.		Hole No.	Sample Interval		Total Samples in Series
From	To		From (feet)	To (feet)	
MD004	MD012	NS STA2	8'	30'	9
MD022	MD027	NS4	17'	40'	6
MD028	MD061	NS5	12'6"	26'6"	34
MD073	MD075	NS7	13'	25'	3
MD079	MD093	NS9	11'	55'	15
Total selected samples					67

TABLE VIII

SUMMARY OF ELEMENTS AND DETECTION LIMITS
CLEAR HILLS IRON DEPOSIT STUDY

Analytical Method	Element	Detection Level	Measured In
LEAD FIRE ASSAY			
(Code 1C - Reasearch)			
ICP	Au	1	ppb
ICP	Pd	0.1	ppb
ICP	Pt	0.1	ppb
Au + 47 COMBINATION			
INNA/TOTAL DIGESTION - ICP (Code 1H)			
ICP	Ag	0.5	ppm
ICP	Al	0.01	%
INAA	As	0.5	ppm
INAA	Au	2	ppb
INAA	Ba	50	ppm
ICP	Be	2	ppm
ICP	Bi	5	ppm
INAA	Br	0.5	ppm
ICP	Ca	0.01	%
ICP	Cd	0.5	ppm
INAA	Ce	3	ppm
INAA	Co	1	ppm
INAA	Cr	5	ppm
INAA	Cs	1	ppm
ICP	Cu	1	ppm
INAA	Eu	0.2	ppm
INAA	Fe	0.01	%
INAA	Hf	1	ppm
INAA	Hg	1	ppm
INAA	Ir	5	ppb
ICP	K	0.01	%
INAA	La	0.5	ppm
INAA	Lu	0.05	ppm
ICP	Mg	0.01	%
ICP	Mn	1	ppm
ICP	Mo	2	ppm
INAA	Na	0.01	%
INAA	Nd	5	ppm
ICP	Ni	1	ppm
ICP	P	0.001	%
ICP	Pb	5	ppm
INAA	Rb	5	ppm
INAA	Sb	0.1	ppm
INAA	Sc	0.1	ppm
INAA	Se	3	ppm
INAA	Sm	0.1	ppm
INAA	Sn	0.01	%
ICP	Sr	1	ppm
INAA	Ta	0.5	ppm
INAA	Tb	0.5	ppm
INAA	Th	0.2	ppm
ICP	Ti	0.01	%
INAA	U	0.5	ppm
ICP	V	2	ppm
INAA	W	1	ppm
ICP	Y	2	ppm
INAA	Yb	0.2	ppm
ICP	Zn	1	ppm

and at Smoky River), the calculated statistical parameters in Appendix III should not be treated with statistical confidence, but instead should only be used as a relative comparative guide between the various sampled areas.

Appendix IV summarizes the comparative results for the 15 duplicate sample pairs: 13 prepared during this study, plus the 2 prepared by Marum from the cuttings from 11 holes drilled near the Worsley Pit. Differences for each element are discussed below.

Appendix V tabulates a comparison of the results for six elements that were analyzed for by both INAA and by either Fire Assay (Au) or ICP (Ag, Mo, Ni, Zn and Ca). As expected, the INAA method generally produces a higher result than either the Fire Assay or ICP methods. This is because INAA should 'count' all atoms of the element present, whereas the Fire Assay and ICP techniques employ a selective extraction process which may or may not give a result that reflects the 'total abundance' of the element in the sample.

Finally, in Appendix VI there are a series of histograms that illustrate the frequency or number of results (Y axis) plotted against specific result ranges (X axis). The histograms were prepared for each element that has sufficient results above detection limit. The histograms are arranged alphabetically by element, but are subdivided into four elemental sets: (1) precious metals and platinum group elements; (2) base metals and pathfinder elements; (3) uranium, thorium, rare earth and selected other related elements; and (4) rock forming and related trace elements. The histograms provide a pictorial understanding of the shape and result range of the underlying geochemical distribution.

6.3.2 Precious Metals (Gold, Silver, Platinum Group Elements)

Gold: The highest gold (Au) results are 160 parts per billion (ppb) by INAA and 36 ppb by Fire Assay (Appendix III). The histograms in Appendix VI.1 show that the geochemical distribution for gold is truncated to the left because many samples returned less than detection, and that the gold results are highly positively skewed. Lastly the statistics for all samples in Appendix III show that the calculated arithmetic mean is about 3.7 ppb Au, whereas both the mode and median are 1.0 ppb Au, or less than detection. The comparative gold results for the 15 duplicate pairs in Appendix IV can be described as, at best, only 'fair'.

There are a total of 26 samples that contain 5 ppb Au or greater by INAA, and 21 samples that contain 5 ppb Au or greater by Fire Assay. In general, the correlation is poor between the higher gold results by INAA versus those by ICP (Appendix V). For example, sample BW002 which gave the highest INAA result of 160 ppb Au, gave only 12 ppb Au by Fire Assay, and sample MD054 which gave the highest Fire Assay result of 36 ppb Au, gave less than detection by INAA. With respect to where the higher gold results are located, the data in Appendix II.2 shows there are a few weakly to strongly auriferous samples at both Rambling River (up to 11 ppb Au by INAA) and at Worsley

Pit (up to 160 ppb Au by INAA). However, the most consistently auriferous intercept is in drill hole NS5 (9 samples contain from 5 ppb up to 12 ppb Au by INAA, and 13 samples contain from 5 ppb up to 36 ppb Au by ICP). In general, the higher gold results are associated with the oolitic ironstone, although the 160 ppb Au (INAA) result at the Worsley Pit samples from Mr. T. Bryant is from a rusty clay (sample BW002) that apparently is from the base of the Bad Heart Formation (Table VI).

Most of the gold results in this study are less than 5 ppb Au, which corresponds to the average crustal abundance for gold (Levinson, 1974; Turekian and Wedepohl, 1961). However, of particular interest are some comparative sampling results for the Worsley Pit area. That is, for the 12 samples which were collected by the AGS at Worsley Pit, the highest result is 8 ppb Au (INAA result for sample AW013). As well, the AGS superpanned four other samples of oolitic ironstone from the Worsley Pit, and did not obtain any visible gold grains or flakes. In contrast, sample BW002 from Bryant assays 160 ppb Au by INAA, and 12 ppb Au by FA. Also, Boulay (1995) reported for the Worsley Pit and drilling samples that *“initial laboratory investigations resulted in the determination that fine, particulate native gold occurred in most samples of the Bad Heart formation rocks”,* and that *“gold values vary dramatically, from traces to loosely extrapolated values of several ounces per ton”*. For, example, Boulay (*Ibid.*, his Appendix 2) reported gold results for 717 rock samples which were collected from various places within the Clear Hills iron deposits, and there are many samples that assay more than 3.4 grams gold per tonne (g Au/t) [0.1 oz Au/T]¹, with the highest assay being 25.03 g Au/t [0.73 oz Au/T]. Boulay (1996), however, concluded that *“while ubiquitous, the finely disseminated gold is present in quantities that are too small to be economically mined by themselves”*. At this time, the reason for the much lower gold results in the current study is unknown.

Silver: The highest silver (Ag) results are 5 parts per million (ppm) by INAA and 1.0 ppm by ICP (Appendix III), but almost all the silver results by INAA and over 70% of the results by ICP are below detection. That is, a total of 44 samples that contain 0.6 ppm Ag or greater by ICP. As for gold, the histogram for silver (ICP) in Appendix VI.1 show that the geochemical distribution is truncated to the left because most samples contain less than detection and the silver results are positively skewed. In general, Appendix II.2 shows there is poor correlation between the higher gold results and higher silver results, although sample MD034 with 12 ppb Au (Fire Assay) also has 5 ppm Ag (INAA). The comparative silver results for the 15 duplicate pairs in Appendix IV can be described as ‘good’, but this is largely a result of so many assays for silver being below detection.

Platinum, Palladium, Iridium: With respect to these three platinum group elements, the highest Pt results are 63 ppb Pt and the highest Pd results are 5.1 ppb Pd, with both results from the Research Lead Fire Assay (Appendix III). With respect to iridium (Ir), which was analyzed for by INAA, all the INAA results are less than detection of 5.0 ppb. The comparative results for the 15 duplicate pairs in Appendix IV can be described: (a) for Pt as ‘good’, with the assay pairs differing typically by 0.1 ppb Pt or

less, and (b) for Pd also as 'good', with the assay pairs differing typically by 0.2 ppb Pd or less (Appendix IV).

The histograms for Pt and Pd in Appendix VI.1 show that the geochemical distribution for both elements are unimodal, and positively skewed. The statistics for 'All Samples' in Appendix III show that for Pt the median and mode are both 0.4 ppb, whereas the arithmetic mean, as expected, is higher at 0.7 ppb Pt. Similarly for Pd, the median and mode are both 0.2 ppb, whereas the arithmetic mean is 0.62 ppb Pd.

With respect to the location of higher results, there are only 6 Pt results greater than 0.5 ppb, to 0.7 ppb, with only sample MD046 having a highly anomalous content of 63 ppb Pt. The reason for the highly anomalous result in sample MD046 in hole NS5 is unknown as most of the other results in this hole, including the samples immediately above and below MD046, contain 0.3 ppb Pt or less (Appendix II.2). Turning to Pd, the distribution of higher results is somewhat more interesting. That is, there are 48 samples with assays between 0.5 ppb and less than (<) 1.0 ppb Pd, and 12 samples with assays ranging from greater than (>) or equal to 1.0, up to 5.1 ppb Pd. Most of the higher Pt results occur near the bottoms of the drill holes or sections, and typically are associated with the basal pyritic sandstone to shale of the lower Bad Heart Formation or the underlying blue-grey shale of the Kaskapau Formation. The highest Pd results occur at the base of the Rambling River section where samples AS001 to AS009, which were collected over about 2.75 m, assay from 0.6 to 5.1 Pd (Appendix II.2).

6.3.3 Base Metals and Selected 'Pathfinder' Elements

Herein, the base metals are assumed to include cadmium (Cd), chromium (Cr), cobalt (Co), copper (Cu), lead (Pb), manganese (Mn), molybdenum (Mo), nickel (Ni), tin (Sn), vanadium (V) and zinc (Zn), and the 'pathfinder' elements are taken to include antimony (Sb), arsenic (As), barium (Ba), bismuth (Bi), mercury (Hg), selenium (Se), and tungsten (W). The base metals are discussed first, in alphabetic order, followed by the pathfinder elements.

Cadmium: All the cadmium results, except for 7 samples, assay less than detection of 0.5 ppm Cd. The highest assay is only 0.7 ppm Cd, hence this element is not discussed further.

These cadmium results are consistent with those for mid to upper Cretaceous shales in northern Alberta, which average about 0.4 ppm Cd with the 95th percentile being about 0.8 ppm Cd (Dufresne *et al.*, 1999).

Chromium: The results for chromium range from 10 ppm, up to 180 ppm (Appendix III). With respect to the comparative duplicate pairs in Appendix IV, there is 'good' consistency, with most results differing by 15% or less.

The histogram for chromium in Appendix VI.2 shows that the geochemical distribution is unimodal to possibly bimodal and, in contrast to most other elements, is

negatively skewed. In general the mean, median and mode are all about 120 ppm Cr, with perhaps a second mode at about 160 ppm. In general, the higher chromium results (>140 ppm Cr) tend to be associated with oolitic ironstone, with lower assays tending to be associated with either the clay-rich ironstone or the Kaskapau Formation claystone (Appendix II.2).

In northern Alberta the typical mid to upper Cretaceous black shale generally has a 95th percentile chromium content of 120 ppm Cr or less (Dufresne *et al.*, 1999). In contrast, the mean, median and mode for the oolitic ironstone is about 140 ppm Cr (Appendix III). However, the average shale in the Earth's crust contains about 100 ppm Cr (Levinson), and the average sandstone only about 35 ppm Cr (Turekian and Wedepohl, 1961). Thus, the chromium content of the Bad Heart Formation oolitic ironstone, which essentially is a sandstone, is highly 'anomalous' for chromium.

Cobalt: The results for cobalt range from 2.0 ppm, up to 210 ppm (Appendix III). With respect to the comparative duplicate pairs in Appendix IV, there is 'good' consistency, with most results differing by about 5 ppm Co or less.

The histogram for cobalt in Appendix VI.2 shows that the geochemical distribution is bimodal, with peaks at about 15 ppm and 45 ppm. In this case, the statistics in Appendix III are meaningless. The reason for the bimodal geochemical distribution for cobalt is lithological because in Appendix II.2 the higher cobalt results (i.e., greater than 30.0 ppm) are consistently related to oolitic ironstone, whereas cobalt contents less than 30.0 ppm tend to be associated with either the more clay-rich ironstone or the underlying Kaskapau Formation claystone. Interestingly, the mean, median and mode for the Rambling River samples are between about 45 ppm to 55 ppm Co, which is about 50% to 100% higher than the cobalt results from the other areas sampled during this study (Appendix III).

In northern Alberta, the mid to upper Cretaceous shales typically average about 9 ppm Co, with their 95th percentile being about 17 ppm Co (Dufresne *et al.*, 1999). Turekian and Wedepohl (1961) stated the average shale in the crust contains about 19 ppm Co, whereas the average sandstone contains only 0.3 ppm Co. Thus, the cobalt results for the Clear Hills oolitic ironstone are significantly elevated over the average cobalt content of most shales, and definitely in comparison to that for the average sandstone.

Copper: The results for copper range from 5.0 ppm, up to 38 ppm (Appendix III). With respect to the comparative duplicate pairs in Appendix IV, there is 'good' consistency, with most results differing by 1 ppm Cu or less.

The histogram for copper in Appendix VI.2 shows that the geochemical distribution appears truncated to the left and is positively skewed, with perhaps a second modal peak at about 27.5 ppm Cu. In contrast to cobalt, the higher copper results tend to be associated with either the more clay-rich ironstone or the underlying Kaskapau Formation claystone.

Lead: The results for lead range from less than detection (5.0 ppm Pb) up to 59.0 ppm Pb (Appendix III). With respect to the comparative duplicate pairs, in general there is a 'good' correlation, with most pairs differing by only a few ppm or less (Appendix IV).

The histogram for lead in Appendix VI.2 shows the geochemical distribution is bimodal, with peaks centered at about 25.0 ppm Pb and 45 ppm Pb. As for several other elements, the higher lead results (i.e., greater than 35 ppm Pb) tend to be associated with the oolitic ironstone, whereas the lower lead results tend to be associated with the lower more clay-rich ironstone or the underlying Kaskapau Formation claystone (Appendix II.2).

Manganese: The results for manganese range from 5.0 ppm to 1,782.0 ppm (Appendix III). With respect to the comparative duplicate pairs in Appendix IV, some pairs have "good" consistency, whereas some samples have widely divergent. Mn results (e.g., MD032 assayed 421 ppm Mn and MD033 assayed 162 ppm Mn).

The histogram for manganese in Appendix VI.2 shows that the geochemical distribution is bimodal, with one peak at about 100 ppm Mn and the other at about 900 ppm Mn. Excluding the lower peak, the distribution tends to appear symmetric, with the arithmetic mean, median and mode all lying in the range from about 720 ppm to 1,000 ppm Mn (Appendix III).

With respect to the location of the Mn results, most of the lower results (i.e., less than 400 ppm) tend to be associated with either the Kaskapau claystone or the lower clay-rich ironstone unit, whereas the higher Mn results (i.e., above 500 ppm) tend to be associated with the more oolitic ironstone. Perhaps this is not surprising considering the elemental affinity between iron and manganese (i.e., they are adjacent on the Periodic Table of Elements). Interestingly, however, some of the highest Mn results (e.g., 1,413 ppm in sample AS002, 1,445 ppm in BW005, 1,782 ppm in MD038, and 1,772 ppm in CS003) are in clay-rich ironstone or in the lower iron-rich claystone (Appendix II.2).

Molybdenum: The results for molybdenum range from less than detection (1.0 ppm Mo), up to 160 ppm Mo by INAA, and less than detection (2.0 ppm) up to 264.0 ppm Mo by ICP (Appendix III). With respect to the comparative results between the INAA and ICP methods for molybdenum, in general the INAA results tend to be from 10% to 50% or more higher than the comparative ICP result (Appendix V). In most cases, however, a higher Mo result by INAA corresponds to a higher ICP result (e.g., sample CS004 assayed 160.0 ppm Mo by INAA and 264.0 ppm Mo by ICP. With respect to the 15 comparative duplicate pairs in Appendix IV, there is 'poor' consistency for molybdenum by INAA, but by ICP the consistency tends to be 'fair' to 'good', with most results differing by a few ppm Mo or less. As well, there tends to be 'good' correlation between the higher Mo results by INAA and ICP (Appendix II.2).

The histogram for molybdenum in Appendix VI.2 shows that the geochemical distribution is unimodal and tending towards symmetric, with the mean, median and mode all being about 10 ppm Mo by INAA, and about 7 ppm Mo by ICP. In general, the higher molybdenum results (>10 ppm Mo) tend to be associated with oolitic ironstone, with lower assays tending to be associated with either the clay-rich ironstone or the Kaskapau Formation claystone (Appendix II.2).

Nickel: The results for nickel range from from 10.0 ppm up to 250.0 ppm Ni by INAA, and 10.0 ppm up to 215.0 ppm Ni by ICP (Appendix III). With respect to the comparative results between the INAA and ICP methods for nickel, in general the INAA results tend to be from about 5% to 40% or more higher than the comparative ICP result (Appendix V). In most cases, however, a higher Ni result by INAA corresponds to a higher ICP Ni result (e.g., sample AS005 contains 250.0 Ni by INAA and 215.0 Ni by ICP). In several cases, however, particularly where the INAA Ni result is below detection by INAA, the corresponding ICP Ni result is higher (Appendix II.2). With respect to the 15 comparative duplicate pairs in Appendix IV, there is 'poor' consistency for several of the INAA Ni pairs, but for ICP Ni the consistency tends to be 'fair' to 'good', with most pairs differing by a few ppm Ni or less.

The histogram for Ni by INAA in Appendix VI.2 shows there is a modal peak for results less than 25.0 ppm, and a second modal peak between 75 and 100 ppm Ni. Excluding the results below 25 ppm Ni by INAA, the geochemical distribution tends to be symmetric to somewhat positively skewed. With respect to the histogram for Ni by ICP, the geochemical distribution is bimodal, with peaks centered at about 37 ppm and 87 ppm Ni. The reason for this bimodal character of nickel may be explainable based on lithology because the higher Ni results (>100 ppm Ni), by both INAA and ICP, tend to be associated with the oolitic ironstone, whereas lower results are associated with the lower or underlying clay-rich horizons (Appendix II.2).

In crustal rocks, the average shale contains about 68 ppm Ni and the average sandstone about 2 ppm Ni (Turekian and Wedepohl, 1961). Thus, the nickel results for the Clear Hills oolitic ironstone are highly anomalous.

Tin: The results for tin are all below detection (<0.01 ppm Sn) and are not discussed further.

Vanadium: The results for vanadium range from 51.0 to 1,633.0 ppm V (Appendix III). With respect to the results for the comparative duplicate pairs, in general there is a 'good' correlation, with most pairs differing by only a few per cent or less (Appendix IV).

The histogram for vanadium in Appendix VI.2 shows the geochemical distribution is bimodal, with peaks centered on about 300 ppm V and 1,300 ppm V. In general, the vanadium content is lithologically controlled, with higher results (>800 ppm V) associated with oolitic ironstone, and lower results (<800 ppm V) associated with either the lower clay-rich ironstone or the underlying Kaskapau Formation claystone (Appendix

II.2). In particular, the average vanadium results for the samples from the Rambling River samples are elevated, with the mean, median and mode all being about 1,250 ppm V (Appendix III).

In crustal rocks, the average shale contains about 130 ppm V and the average sandstone about 20 ppm V (Turekian and Wedepohl, 1961). In northern Alberta, the vanadium content of the typical mid to upper Cretaceous shale has a median of about 118 ppm V, with the 95th percentile being about 205 ppm V (Dufresne *et al.*, 1999). Therefore, the vanadium results for the Clear Hills oolitic ironstone are highly anomalous, with vanadium ranging between 800 ppm and about 1,600 ppm V. At Rambling River, the results from this study indicate the average vanadium content is about 1,250 ppm V, which equates to about 0.22% V₂O₅¹. Therefore, for the Rambling River oolitic iron deposit, assuming an average grade of 0.2% V₂O₅ and a price of at least \$16.00Cdn/kg (about \$5.00US/lb² or \$7.50Cdn/lb), this equates to a value of about \$33.00Cdn/tonne if vanadium can be successfully extracted as a co-product and a market for the product exists.

Zinc: The results for zinc range from <50 ppm to 808.0 ppm Zn by INAA, and 2.0 ppm up to 795.0 ppm Zn by ICP (Appendix III). With respect to the comparative results between the INAA and ICP methods for zinc, although the INAA results may on average be marginally higher, there is not a consistent trend as for some other elements (Appendix V). With respect to the 15 comparative duplicate pairs in Appendix IV, there is 'fair' to 'good' consistency for the INAA Zn pairs, and 'good' consistency for the ICP Zn pairs (averaging 10% or less deviation for both methods).

The histograms for lead in Appendix VI.2 show the geochemical distribution is bimodal for both the INAA and ICP results. Peaks for the INAA Zn data occur at about 150 ppm and 500 ppm, whereas for the ICP data peaks occur at 150 ppm and 450 ppm Zn. As for several other elements, the higher zinc contents (>300 ppm Zn) tend to be associated with oolitic ironstone, and lower zinc contents (<300 ppm Zn) are associated either with the lower clay-rich ironstone or the underlying Kaskapau Formation claystone (Appendix II.2). As is the case for vanadium, the zinc results for the Rambling River samples are elevated, with the mean, median and mode all falling between 475 and 500 ppm Zn (Appendix III).

In northern Alberta the mid to upper Cretaceous shales average about 102 ppm Zn with the 95th percentile being 180 ppm Zn (Dufresne *et al.*, 1999). In crustal rocks the average shale contains about 95 ppm Zn and the average sandstone about 12 ppm Zn (Turekian and Wedepohl, 1961). Thus, the zinc contents for the Clear Hills oolitic ironstone are highly anomalous.

¹Note: conversion from V in ppm to % V₂O₅ equals ppm V divided by 0.5602, hence 1,000 ppm V equals 1.785% V₂O₅.

²During early 1999, the spot price for V₂O₅ was about \$5.50US/lb.

Pathfinder Elements: Turning to the pathfinder elements (i.e., As, Ba, Bi, Hg, Sb, Se and W), these elements typically are associated with epithermal to mesothermal gold deposits and, in some cases, with volcanogenic-related massive sulphide deposits.

Antimony: The results for antimony range from 1.0 ppm to 22 ppm Sb, with one sample (CS004) containing 75 ppm Sb (Appendix III). With respect to the 15 comparative duplicate pairs in Appendix IV, the correlation of results typically is 'good', with the variation in most samples being a few per cent or less. The main exception is the duplicate pairs MD066 and MD067, which assay 4.4 ppm and 19.0 ppm Sb, respectively. The reason for the high variation in these two duplicate samples is uncertain.

The histogram for antimony in Appendix VI.2 shows that the geochemical distribution is unimodal, or possibly bimodal, with one peak at about 3.0 ppm Sb, and a possible second peak at about 11.0 ppm. As well, the histogram for antimony indicates the distribution is positively skewed. The pattern of result variation for antimony is similar to many other elements in that the highest results (>8.0 ppm Sb) tend to be associated with oolitic ironstone, intermediate results (3.0 to 7.0 ppm Sb) are associated with clay-rich ironstone, and the lowest results (<3.0 ppm Sb) are associated with the underlying Kaskapau Formation claystone (Appendix II.2).

In crustal rocks, the average content of antimony in shale is about 1.5 ppm Sb, and in sandstone is <1.0 ppm Sb (Turekian and Wedepohl, 1961). In northern Alberta, the mid to upper Cretaceous shales have a modal antimony content of 0.4 ppm Sb, and an average content of 1.1 ppm Sb (Dufresne *et al.*, 1999). In contrast, the Clear Hills oolitic ironstone has a mode of 11.0 ppm and a mean of 19.8 ppm Sb (Appendix III), hence the antimony content is highly anomalous.

Arsenic: The results for arsenic range from 25.0 to 1,000, plus a single highly anomalous result of 11,000.0 ppm As in sample CS004 (Appendix III). With respect to the 15 comparative duplicate pairs in Appendix IV, most pairs differ by a few tens of ppm As or less, although in a few cases the variation is high to extreme. For example, sample MD066 assays 74 ppm As by INAA, whereas its pair, MD067, assays 1,000 ppm As. These extreme differences are unexplained.

The histogram for arsenic in Appendix VI.2 show that the geochemical distribution is bimodal or possibly trimodal, with peaks at about 75 ppm, 225 ppm and 475 ppm As. In general, the higher arsenic results (>150 ppm As) tend to be associated with oolitic ironstone, whereas lower results (<150 ppm As) tend to be associated with either clay-rich ironstone or the underlying Kaskapau Formation claystone (Appendix II.2).

In crustal rocks, the average content of arsenic in shale is about 13.0 ppm As, and in sandstone is only about 1.0 ppm As. In northern Alberta, the mid to upper Cretaceous shales have a mode and arithmetic average of about 15 ppm As, and even some arsenic-rich shales such as the 'Second White Specks' have average contents of

55 ppm As, with the 95th percentile being 111 ppm As (Dufresne *et al.*, 1999). Therefore, because in the Clear Hills oolitic ironstone, the mean, median and mode for most arsenic results are between 110 and 150 ppm As, with that for the samples from Rambling River being about 450 ppm As, this shows the arsenic content of the Clear Hills ironstone is “*extremely high*” (Dufresne, *personal communication*, 1999).

Barium: The results for barium range from 220.0 ppm to 2,300 ppm Ba (Appendix III). With respect to the 15 comparative duplicate pairs in Appendix IV, the correlation of results typically is ‘good’ to ‘fair’, with the variation ranging from zero to, in a few cases, about 30% or higher. In some instances, there is ‘excellent’ correlation between the duplicate pairs (e.g., samples MD029 and MD030 both assay 1,200 ppm Ba, and samples MD032 and MD033 assay 970 ppm and 1,000 ppm Ba, respectively).

The histogram for barium in Appendix VI.2 shows that the geochemical distribution is unimodal, or possibly bimodal, with one peak at about 550 ppm Ba, and a possible second peak at about 750 ppm. The distribution tails off abruptly to the lowest result of 220 ppm Ba, and there are no lower results even though the detection level for barium is 50 ppm by INAA (Table VII). To higher results, the distribution for barium is or may be positively skewed. Interestingly, and in contrast to many other elements, the higher barium results (>700 ppm Ba) tend to be associated with either clay-rich ironstone or the underlying Kaskapau Formation claystone, whereas lower results (<700 ppm Ba) tend to be associated with oolitic ironstone (Appendix II.2). Perhaps this trend for barium is best observed in the samples from hole NS5, where the oolitic ironstone in samples MD061, at top, to MD043 assay from 360 ppm up to 710 ppm Ba, whereas the clay-rich ironstone and underlying Kaskapau Formation claystones in samples MD042 to MD028, at base, assay from 680 ppm up to 1,500 ppm Ba, with 8 of the 15 samples in this series containing over 800 ppm Ba.

Bismuth: The results for bismuth range from below detection (<5.0 ppm Bi) up to 17.0 ppm Bi (Appendix III). However, only 12% of the samples (18 of 151) assay 5.0 ppm Bi or greater (Appendix II.2). In general, the samples that assay between 5 ppm and 17 ppm Bi are from oolitic ironstone. Because so few bismuth samples assay above detection, no histogram was prepared for this element.

Mercury: The results for mercury are all below detection (1.0 ppm Hg), except for sample CS004 from the Smoky River section which assays 8 ppm Hg (Appendix II.2). This sample is from a highly pyritic silty sandstone (Table VI).

Tungsten: The results for tungsten range from less than detection (1.0 ppm W) up to 11.0 ppm (Appendix III). However, only 38 of the 151 samples (about 25%) assay above detection (i.e., equal to or greater than 1.0 ppm W). With respect to the comparative duplicate pairs in Appendix IV, 10 pairs both assay below detection, hence the correlation for these pairs is ‘good’. For the other five duplicate pairs, however, the correlation is ‘poor’.

No histogram was prepared for tungsten because only 25% of the results are above detection, and the range only extends up to 11.0 ppm. However, for those results at or above about 5.0 ppm W, they are predominantly associated with oolitic ironstone (Appendix II.2).

6.3.4 Uranium, Thorium, Rare Earth and Selected Other Related Elements

The uranium and thorium results are discussed first, then the rare earth and selected other elements.

Uranium: The results for uranium range from less than detection (0.5 ppm U) up to 20.0 ppm (Appendix III). With respect to the 15 comparative duplicate pairs, the correlation tends to be 'fair' to 'good' for most uranium pairs (Appendix IV).

The histogram for uranium in Appendix VI.3 shows the geochemical distribution is unimodal and positively skewed, with the mode, median and arithmetic mean all being between about 4.0 to 5.0 ppm U. With respect to the location of the higher uranium results (>8.0 ppm U), most tend to be associated with the oolitic ironstone.

Thorium: The results for thorium range from less than detection (0.2 ppm Th) up to 15.0 ppm. With respect to the 15 comparative duplicate pairs, the correlation tends to be 'good' for most thorium pairs (Appendix IV).

The histogram for thorium in Appendix VI.3 shows the geochemical distribution is unimodal and negatively skewed. The mode, median and arithmetic mean are all about 11.0 ppm Th. In general, the highest thorium results (>13.0 Th) tend to be associated with oolitic ironstone (Appendix II.2).

Rare Earth and Selected Other Related Elements: The rare earth (REE) and selected other related elements occur to the left portion of the Periodic Table of the Elements. In this study they include: beryllium (Be), cerium (Ce), cesium (Cs), europium (Eu), hafnium (Hf), lanthanum (La), lutetium (Lu), neodymium (Nd), scandium (Sc), samarium (Sm), tantalum (Ta), terbium (Tb), yttrium (Y) and ytterbium (Yb). The results for these elements are summarized in Table IX.

In general, none of the REE exist in very high concentrations. The highest concentrations are for cerium (up to 83.0 ppm), lanthanum (up to 66.0 ppm), neodymium (53.0 ppm) and yttrium (152.0 ppm). However, these elements have modes similar to the average crustal contents for shale or sandstone (Table IX). Finally, the REE are approximately evenly split between those having higher concentrations in the oolitic ironstone (e.g., Eu, Lu, Nd, Sm, Tb, Y and Yb), versus those having higher concentrations in the lower clay-rich ironstone or in the underlying Kaskapau Formation claystone (e.g., Ce, Cs, Hf, La, Sc and Ta).

TABLE IX**SUMMARY OF RESULTS FOR RARE EARTH AND RELATED OTHER ELEMENTS**

Element	Result Range ¹			Duplicate Pair Correlation	Geochemical Distribution	Remarks
	Low	Mode (Avg) ²	High			
Be	<2.0	1.0 (3.0)	3.0	'Good'	No histogram	Most results below detection. No consistent pattern to higher results
Ce	<3.0	55.0 (83.0)	83.0	'Fair' to 'Good'	Unimodal, symetric; mode about 55 ppm	Higher results (>60.0 ppm) are related to clay-rich ironstone or Kaskapau Fm. claystone. Crustal rocks average 59 ppm Ce in shale and 92 ppm Ce in sandstone ³
Cs	<1.0	2.0 (5.0)	9.0	'Fair'	Unimodal to possibly bimodal, positively skewed; main modal peak about 2.5 ppm, second about 7.5 ppm	Higher results (>6.0 ppm) are related to clay-rich ironstone or Kaskapau Fm. claystone
Eu	<0.2	1.4 (1.61)	4.4	'Fair' to 'Good'	Bimodal; one mode about 1.75 ppm, second about 3.25 ppm	Higher results (>2.5 ppm) are related to oolitic ironstone
Hf	<1.0	2.0 (3.0)	7.0	'Fair' to 'Good'	Bimodal; one mode about 2.5 ppm, second about 6.0 ppm	Higher results (4.0 ppm) are related mainly to Kaskapau Fm. claystone
La	2.0	34.0 (41.0)	66.0	'Good'	Unimodal, symetric; mode about 35 ppm	Higher results (>40.0 ppm) are related to clay-rich ironstone or Kaskapau Fm. claystone. Crustal rocks average 92 ppm La in shale and 30 ppm La in sandstone ³
Lu	<0.1	0.7 (0.61)	1.03	'Fair' to 'Good'	Unimodal, symetric; mode about 60.0 ppm	Higher results (>0.6 ppm) are related to oolitic ironstone

Element	Result Range ¹			Duplicate Pair Correlation	Geochemical Distribution	Remarks
	Low	Mode	High			
Nd	<5.0	27.0 (38.0)	53.0	'Fair'	Unimodal, symetric to positive skew; mode about 25.0 ppm	Higher results (>30.0 ppm) are related to oolitic ironstone. Crustal rocks average 24 ppm Nd in shale and 37 ppm Nd in sandstone ³
Sc	0.4	13.0 (15.0)	17.0	'Good'	Unimodal, negatively skewed; mode about 13.0 ppm	Highest (>14.0 ppm) results are related to Kaskapau claystone
Sm	0.2	11.0 (7.5)	14.0	'Good'	Bimodal; one mode about 5.0 ppm, second about 10.0 ppm	In general, higher results (>8.0 ppm) are related to oolitic ironstone
Ta	<0.5	0.3 (2.0)	1.7	'Fair' to 'Poor'	No histogram	Most results less than detection; results above detection (.0.5 ppm) are related to Kaskapau claystone
Tb	<0.5	0.3 (1.23)	3.6	'Fair'	Bimodal; one mode about 0.75 ppm; second about 2.25 ppm	Higher results (>1.5 ppm) are related to oolitic ironstone
Y	4.0	26.0 (25.0)	152.0	'Fair' to 'Good'	Bimodal; one mode about 30 ppm, second about 90 ppm	Higher results (>75.0 ppm) are related to oolitic ironstone. Crustal rocks average 26 ppm Y in shale and 40 ppm Y in sandstone ³
Yb	<0.2	5.1 (3.53)	7.9	'Good'	Bimodal; one mode about 3.5 ppm, second about 5.5 ppm	Higher results (>7.5 ppm) are related to oolitic iron stone

¹Note: From Appendix III

²Average concentrations of REE (ppm) in shales from North America, Europe and the Soviet Union, where given, in either Haskin and Haskin (1966), or in Levinson (1974)

³From Turekian and Wedepohl (1961)

6.3.5 Rock Forming and Related Elements

The rock forming and related elements include aluminum (Al), bromine (Br), calcium (Ca), total iron (Fe), potassium (K), magnesium (Mg), sodium (Na), phosphorous (P), rubidium (Rb), strontium (Sr) and titanium (Ti).

Aluminum: The results for aluminum range from 0.17% up to 7.80% (Appendix III). With respect to the duplicate pairs, in general the correlation is 'good' (Appendix IV).

The histogram for aluminum in Appendix VI.4 shows the geochemical distribution is bimodal, with one main peak at about 3.5%, and a second peak at about 7.5%. Interestingly, the distribution may be truncated at the high end. With respect to the distribution about the lower mode of 3.5%, and excluding results above 6.0%, the distribution is symmetric. As expected, aluminum results greater than 3.5%, and particularly those above 6.0%, are associated with the Kaskapau claystone, clay-rich ironstone or the overlying glacial till. In general, the oolitic ironstone contains 3.5% Al or less.

Bromine: The results for bromine range from less than detection up to 4.0 ppm Br (Appendix III). In general, about two-thirds of the bromine results are below detection (Appendix II.2). With respect to those samples with higher bromine contents (2.0 to 4.0 ppm Br), there is no consistent relationship with either the oolitic ironstone, or the more clay-rich lithologies.

Calcium: The results for calcium range from below detection up to 20% by INAA, and 17.4% by ICP (Appendix III). With respect to the comparison between the INAA and ICP results for calcium tabulated in Appendix V, in general the correlation is 'good'. However, although many of the INAA calcium results are below detection, all the calcium results by ICP are above detection. With respect to the 15 comparative duplicate pairs, the correlation for the INAA calcium results is 'fair' to 'poor', whereas for the ICP calcium results the correlation is 'fair' to 'good' (Appendix IV).

The histogram for calcium (INAA) in Appendix VI.4 indicates the underlying geochemical distribution is unimodal and somewhat positively skewed, with the modal peak at about 2.5% Ca (INAA). For calcium by ICP, the histogram also is unimodal and strongly positively skewed, with the modal peak being at about 1.0% Ca (ICP). In general, most of the higher calcium results (>3.0% Ca ICP) tend to be associated with oolitic ironstone. The highest calcium results (between 8.0% and 20.0% Ca ICP) occur in the lower most part of the Smoky River samples (Appendix II.2).

Iron: The results for iron range from 2.8% up to 39.90% Fe (Appendix III). With respect to the comparative duplicate pairs, in general there is 'good' correlation between the iron results (Appendix IV).

The histogram for iron in Appendix VI.4 indicates the underlying geochemical distribution is bimodal, with a lower modal peak at about 2.5% Fe, and an upper modal peak at about 35.0% Fe. As expected, the higher iron results (>15.0% Fe) are associated with the oolitic ironstone, with the more ferruginous ironstone containing between 25.0% to 35.0+% Fe. In contrast, the underlying Kaskapau Formation claystone tends to have an iron content less than about 10.0% Fe.

Potassium: The results for potassium range from 0.05% up to 2.27% K (Appendix III). With respect to the comparative duplicate pairs, the correlation is 'good' (Appendix IV).

The histogram for potassium in Appendix VI.4 indicates the underlying geochemical distribution is unimodal, with the lower mode at about 0.75%, or possibly weakly bimodal, with the upper mode at about 2.25%. In general, the higher potassium results (>1.0% K) are associated with the Kaskapau Formation claystone.

Magnesium: The results for magnesium range from 0.01% up to 1.43% Mg (Appendix III). With respect to the comparative duplicate pairs, the correlation is 'good' (Appendix IV).

The histogram for magnesium in Appendix VI.4 indicates the underlying distribution is unimodal and symmetric, with the modal peak at about 0.6% Mg. Although many of the higher magnesium results (>0.8% Mg) are associated with oolitic ironstone, there are also several higher Mg concentrations associated with clay-rich ironstone or the Kaskapau Formation.

Sodium: The results for sodium range from 0.07% up to 0.71% Na (Appendix III). With respect to the comparative duplicate pairs, the correlation is 'good' (Appendix IV).

The histogram for sodium in Appendix VI.4 indicates the underlying geochemical distribution is unimodal and positively skewed, with the modal peak at about 0.15% Na. There is a possibility the distribution may be bimodal, with a second lower modal peak at about 0.35% Na. The higher results (>0.25% Na) for sodium are associated with the Kaskapau Formation claystone. In general, the sodium content of the oolitic ironstone tends to be less than 0.25% Na, and commonly less than 0.15% Na.

Phosphorous: The results for phosphorous range from 0.01% up to 4.60% P (Appendix III). With respect to the comparative duplicate pairs, the correlation is 'good' to 'fair' (Appendix IV).

The histogram for phosphorous in Appendix VI.4 indicates the underlying geochemical distribution is bimodal, with the lower narrow peak centered at about 0.10% Na. The upper population ranges from about 0.3% P and up, with a modal peak at about 0.5% P and a symmetric to somewhat positively skewed distribution about this mode. Without question, the higher phosphorous contents (>0.5% P) are associated

with the oolitic ironstone, including seven samples that have phosphorous contents ranging from 1.0% up to 4.0% P. In contrast, the lower phosphorous contents (typically <0.2% P) are associated with the Kaskapau Formation claystone. These phosphorous results for the oolitic ironstone are consistent with results from prior sampling, which indicated the average phosphorous content of the ironstone was about 0.9% P (Table III).

In general, elevated contents of phosphorous reflect lithologies with an increased amount of vertebrate skeletal and teeth remains (Dufresne, *personal communication*, 1999). This in turn may reflect either a sedimentary process which accumulates such vertebrate remains, for example, a wave induced lag bed, or alternatively it could reflect a 'kill zone' whereby locally toxic water conditions have resulted in an increased death rate for those animals and plants not accustomed to these environmental conditions.

Rubidium and Strontium: Rubidium and strontium occur next to each other on the periodic table, and commonly substitute for one another in many minerals, hence they are discussed together.

The results for rubidium range from 7.50 ppm up to 150.0 ppm Rb (Appendix III). With respect to the duplicate sample pairs for rubidium, the correlation is 'fair' (Appendix IV).

The histogram for rubidium in Appendix VI.4 is trimodal, with a narrow lower mode centered at about 10 ppm Rb, a broader population ranging from 20 to about 100 ppm Rb with a mode about 60 ppm Rb, and an upper distribution with a modal peak at about 130 ppm Rb. The lowermost population (<20 ppm Rb) represents a group of samples that assay less than detection. The intermediate rubidium results (20 to 90 ppm Rb) are associated with oolitic ironstone, and the higher results (>90 ppm Rb) are associated with the Kaskapau Formation claystone.

Strontium was analyzed for by both INAA and ICP. The INAA results range from less than detection up to 0.13 ppm Sr, with only 12 strontium INAA results being above detection. For the ICP strontium results, the strontium contents range from 10.0 ppm up to 992.0 ppm Sr (Appendix III). With respect to the comparative duplicate pairs, the correlation is 'good' to 'fair' (Appendix IV).

The histogram for strontium (ICP) in Appendix VI.4 indicates the underlying geochemical distribution is unimodal, with the main peak centered at about 150 ppm Sr, and the distribution being truncated below about 100 ppm Sr. In general, the higher strontium contents (>150 ppm Sr) are associated with the oolitic ironstone, whereas the lower strontium contents (<150 ppm Sr) are associated with either the Kaskapau Formation claystone or clay-rich portions of the ironstone. Thus, although rubidium and strontium generally are considered 'chemically similar', the higher strontium results are associated with oolitic ironstone, whereas the reverse association is so for rubidium.

Titanium: The results for titanium range from 0.02 ppm up to 0.4 ppm Ti (Appendix III). With respect to the comparative duplicate pairs, the correlation is 'good' (Appendix IV).

The histogram for strontium in Appendix VI.4 indicates the underlying geochemical distribution is bimodal, with one modal peak centered at about 0.125 ppm Ti, and the second centered at about 0.375 ppm Ti. In general, the lower titanium results (<0.20 ppm Ti) are associated with oolitic iron formation, whereas higher results (>0.20 ppm Ti, and particularly >0.30 ppm Ti) are associated with the Kaskapau Formation claystone.

7.0 DISCUSSION

7.1 Possible Sedimentological Depositional Setting of the Bad Heart Formation, and Genetic Origin of the Clear Hills Iron Deposits

Donaldson (1997) and Donaldson *et al.* (1998) postulated that intra-basinal faulting was present and locally an important control on Bad Heart deposition. For example, Donaldson (1997) noted in the subsurface that there is an abrupt facies change from sand in the east to mud in the west, and Donaldson *et al.* (1998) noted that "*progressively older strata [of the Bad Heart Formation] subcrop against the basal erosion surface from southwest to northeast*". Donaldson *et al.* (*Ibid.*) postulated that the Bad Heart Formation was deposited in less than about 300,000 years during the late Coniacan (between about 88.85 to 87.5 Ma), "*sediment was derived primarily from the rising forebulge/Peace River Arch in the north and northeast*", and that the depositional facies were controlled or affected by a series of north-northwesterly and northeasterly trending block faults which formed horst and graben structures.

With respect to paragenesis of the ooid ironstone, Donaldson (1997) suggested: (a) during early to intermediate diagenesis, phosphate, a green authigenic clay, siderite (is most abundant mineral), pyrite, opal and calcite were more or less sequentially deposited, whereas (b) during late diagenesis and weathering, calcite, gypsum, jarosite and goethite formed. Donaldson (1997) suggested that the oolitic ironstone, his 'Facies D', was deposited in a "*well-oxygenated, very shallow marine setting (although the iron for the ooids was ultimately derived from a proximal, deeply weathered terrestrial iron source*". In short, Donaldson (1997) clearly attributed the iron, silica and phosphorous that exist in the Clear Hills oolitic ironstone to have been derived from a weathered continental source, and the original minerals were subsequently altered during diagenesis.

In contrast, Olson *et al.* (1994) suggested that although the oolitic character of the Clear Hills iron deposits indicate they were deposited under wave-agitated shallow marine conditions, perhaps the vast amounts of iron and silica which were in the seawater during Bad Heart Formation time, were derived from "*either igneous fumarolic activity or fumarolic deep-circulating hydrothermal basin fluids*". At the time Olson *et al.* (1994) completed their Metallogenic Evaluation of Alberta, there were no igneous

events of Coniacian age reported in Alberta. However, since then, to January 1999, at least 33 kimberlitic intrusions have been reported in northern Alberta (1 kimberlitic intrusion is about 100 km south-southwest of Peace River, at least 26 occur in the Buffalo Head Hills about 120 km northeast of Peace River, and at least 7 in the Legend Block which is about 185 km northeast of the Buffalo Head Hills kimberlites). U-Pb age dating of perovskite from some of the Buffalo Head Hills kimberlites indicates they were emplaced between 88 ± 5 and 86 ± 3 Ma (that is, during the Coniacian to early Santonian) (Carlson *et al.*, 1998). Interestingly, Collom (1998) reported that the nuclei of a significant portion of the ooids in the Clear Hills ironstone are mineral grains not normally found in the Western Canada Sedimentary Basin, including silicic volcanic glass, euhedral feldspar, $\exists$ quartz, eclogitic garnet, chromite, olivine, pyroxene and, apparently, even microdiamonds. Dufresne (*personal communication*, 1967) suggested that all these grains are indicator minerals for ultramafic diatremes (e.g., kimberlites, lamproites or minettes), and Collom (1998) stated that their presence within the ooids “*require the [diatreme emplacement] event(s) resulting in the distribution of these xenoliths to either shortly precede or be coeval to the Bad Heart Formation*”. Finally, Collom (*Ibid.*) speculated that at least some of the aeromagnetic anomalies which recently have been identified in the Chinchaga Hills region by Marum Resources, may indicate that there are ultramafic intrusions yet to be discovered within or near the Clear Hills.

Although kimberlitic or lamproitic intrusions may occur in or near the Clear Hills region, and may have contributed mineral grains as nuclei for ooid formation, Olson *et al.* (1994) suggested that “*it is doubtful that the Clear Hills oolitic iron deposits are related to kimberlite/lamproite igneous activity because these intrusive phenomena are emplaced quickly, have minimal thermal anomalies associated with them and tend to be iron-poor rather than iron-rich*”. Alternatively, Collom (1998) suggested there may have been basaltic intrusions or extrusions in the Clear Hills region, possibly associated with a small (approximately 10 km diameter), buried impact crater which is reported to exist in the Naylor Hills area from oil and gas exploration data. Recent evidence for volcanic activity in the Clear Hills region includes a altered and reworked biotite-rich volcanic ash at the base of the Bad Heart Formation at the Spirit River area, and extensive basaltic to andesitic float in drainages at and near Peace River (D.R. Eccles and M.B. Dufresne, *personal communication*, 1999). An association between volcanism and oolitic ironstone has been postulated in some other places. For example, “*iron-rich oolites from a Middle Ordovician ... sequence in south-central Sweden are associated with volcanic ash beds, [which is] clear evidence that volcanic activity was coeval with a period of extensive iron ooid formation*” (Sturesson, 1992). Therefore, if such volcanism is present and heretofore unrecognized at the Clear Hills region, then this could be the source for either or both the iron and silica in the Clear Hills oolitic ironstone, or may have caused thermal anomalies that resulted in basinal hydrothermal leaching and then debouching high concentrations of these elements into the sea during Clear Hills Formation time. However, further research will be needed to clarify the genetic origin of the iron, silica and some other elements with elevated concentrations that comprise the bulk of the Clear Hills iron deposits.

7.2 **Discussion of Results From the Current Study With Respect to Potential Economic Development of the Clear Hills Iron Deposits**

The geochemical data in this study, indicate Au, As, Co, Cr, Mn, Mo, Ni, Pb, some REE (Eu, Lu, Nd, Sm, Tb, Y and Yb), Sb, Th, U, V, W and Zn, all have elevated to, in places, highly anomalous concentrations in the Clear Hills oolitic ironstone. Geochemical highlights for the oolitic ironstone are summarized in Table X. In contrast, Ba, Cu and Pd tend to have higher concentrations in either the underlying Kaskapau Formation claystone or the lower clay-rich ironstone. Some elements, including Ag, Bi, Cd, Hg, Ir, Pt and Sn, had either all or a majority of their results below detection, hence their lithological associations are uncertain. With respect to the rock forming elements:

- (a) some have higher concentrations in the oolitic ironstone, including: Ca (from 3.0% up to 17.4%), Fe (>15.0% up to 39.9%), Mg (>0.8% up to 1.43%), P (>0.5% up to 4.60%), Rb (>90 ppm up to 150 ppm), Sr (>150 ppm up to 992 ppm), whereas,
- (c) others have higher concentrations in the Kaskapau Formation claystone or clay-rich Bad Heart Formation, including: Al (up to 7.8%), K (up to 2.27%), Na (up to 0.71%) and Ti (up to 0.4 ppm).

Finally, the data in Appendix III indicate there are regional variations in the average concentrations for some elements. For example, the Rambling River samples tend to have higher mean, median and modes for the following elements: As, Co, Cr, Mo, Mn, Ni, Pb, Sb, V, W, Fe and possibly P, and lower amounts of Al, Ca and K. Vanadium is of particular interest as a potential co-product because at Rambling River the 'average' content is about 1,250 ppm V (0.125% V), or equivalent to about 0.22% V₂O₅. Thus, vanadium could be a significant co-product if the Rambling River iron deposit is, in future, mined. Also of interest are the elevated contents of As, Mo, Sb and W, which commonly are 'pathfinder elements' in gold exploration. The fact that these elements are elevated, coupled with at least a few elevated gold results, indicate that the potential for discovery of important auriferous zones associated with the Clear Hills iron deposits, can not be ruled out. In addition, because fumarolic hydrothermal activity appears to have been important at least locally during Bad Heart Formation time, potential exists for base- and precious-metal massive sulphide deposits. Finally, the presence of 'diamond indicator mineral grains' in places in the Bad Heart Formation and some other Late Cretaceous strata in northwestern Alberta, indicates potential exists for the discovery of diamondiferous ultramafic diatremes.

The geochemical highlights in Table X, from a strictly economic perspective, indicate that no elements, other than iron, and possibly vanadium, can be considered as potentially mineable in their own right at any of the areas sampled. However, the fact that elevated concentrations of some elements do exist locally, indicate that a further more extensive sampling program would need to be undertaken to identify prospective areas that have the potential for economically important co-products, which, in future,

may be economically important with respect to exploitation of the Clear Hills iron deposits. It is unfortunate that samples are not available from the extensive program of drilling that was conducted during the late 1950's and early 1960 (see Section 2.4). Because these old core or cuttings are not available, further evaluation of the geochemistry of the Clear Hills iron deposits will necessitate further drilling of some minimum number of holes at selected sites underlain by the known deposits at Rambling River, North Whitemud River, South Whitemud River and Worsley. Due to the elevated content of iron, plus As, Co, Cr, Mo, Mn, Ni, Pb, Sb, V and W at the Rambling River area, perhaps any initial follow-up drilling should be focused at and proximal to this area to search for important concentrations of selected elements.

8.0 CONCLUSIONS AND RECOMMENDATIONS

8.1 Conclusions With Respect to Potential Co-product Trace Elements in the Clear Hills Iron Deposits

Elements with elevated concentrations in the iron-rich portion of the Bad Heart Formation oolitic ironstone comprise gold (typically 10 ppb to 36 ppb Au), antimony (typically 8 ppm up to 75 ppm Sb), arsenic (typically 150 ppm up to 1,000 ppm As), cobalt (typically 30 ppm up to 210 ppm Co), chromium (typically 140 ppm up to 180 ppm Cr), lead (typically 45 ppm up to 59 ppm Pb), manganese (typically 500 ppm up to 1,661 ppm Mn), molybdenum (typically 10 ppm up to 92 ppm Mo), nickel (typically 50 ppm up to 250 ppm Ni), vanadium (typically 800 ppm up to 1,633 ppm V), zinc (typically 300 ppm up to 808 ppm Zn), plus some REE (Eu up to 4.4 ppm, Lu up to 1.03 ppm, Nd up to 53.0 ppm, Sm up to 14.0 ppm, Tb up to 3.6 ppm, Y up to 152.0 ppm, and Yb up to 7.9 ppm). Although Boulay (1995, 1996) reported gold concentrations ranging from 3.0 up to 25.03 g Au/t in a few samples of oolitic ironstone from the Worsley Pit area, no concentrations of gold this high were encountered during the current study. The reason for this apparent discrepancy in results is uncertain.

Although none of the above elements, except possibly vanadium, exist in concentrations that, in themselves, indicate they would be economically mineable at the restricted areas where the currently available samples are from. Nonetheless the elevated concentrations for some elements indicates there may be some places within the Clear Hills iron deposits where they exist in sufficiently high concentration whereby one or more of them could be an important co-product during any future mining of iron. However, further work will be needed to evaluate this suggestion. Of particular interest is the Rambling River area, where samples in this study tend to have higher mean, median and modes for As, Co, Cr, Mo, Mn, Ni, Pb, Sb, V, W, Fe and possibly P, and lower amounts of Al, Ca and K. Vanadium is of particular interest as a potential co-product because it is equivalent to about 0.22% V_2O_5 . Thus, vanadium could be a significant co-product if the Rambling River iron deposit is, in future, mined.

As well, the elevated contents of As, Mo, Sb and W at the Rambling River area, indicate that there is potential for discovery of important auriferous zones associated with the Clear Hills iron deposits. In addition, because fumarolic hydrothermal activity appears to

TABLE X

**GEOCHEMICAL RESULTS HIGHLIGHTS
FOR THE OOLITIC IRONSTONE FROM THIS STUDY**

Element	Remarks	Mode(s)	Maximum Concentration
Au	Many results below detection; a few samples of oolitic ironstone contain 10 to 30+ ppb Au	3 ppb	36 ppb (FA) in ironstone; 160 ppb (INAA) in claystone
As	Higher results (>150 ppm) are in oolitic ironstone	75, 225 & 475 ppm	11,000 ppm (INAA)
Co	Higher results (>30 ppm) are in oolitic ironstone	15 & 45 ppm	210 ppm (INAA)
Cr	Higher results (>140 ppm) are in oolitic ironstone	120 ppm	180 ppm (INAA)
Mn	Higher results (>500 ppm) are in oolitic ironstone	100 & 900	1,782 ppm (ICP)
Mo	Higher results (>10 ppm) are in oolitic ironstone	10 ppm	92 ppm (ICP) in ironstone; 264 ppm (ICP) in claystone
Ni	Higher results (>100 ppm) are in oolitic ironstone	<25 & 85 ppm	250 ppm (INAA)
Pb	Higher results (>45 ppm) are in oolitic ironstone	25 & 45 ppm	59 ppm (ICP)
REE	Eu, Lu, Nd, Sm, Tb, Y and Yb are all higher in oolitic ironstone	See Table IX	See Table IX
Sb	Higher results (>8 ppm) are in oolitic ironstone	3 & 11 ppm	21 ppm (INAA) in ironstone; 75 ppm (INAA) in claystone
Th	Higher results (>13 ppm) are in oolitic ironstone	11 ppm	15 ppm (INAA)
U	Higher results (>8 ppm) are in oolitic ironstone		20 ppm (INAA)
V	Higher results (>800 ppm) are in oolitic ironstone	300 & 1,300 ppm	1,633 ppm (ICP)
W	Higher results (>6 ppm) are in oolitic ironstone; most results below detection	6? ppm	11 ppm (INAA)
Zn	Higher results (>300 ppm) are in oolitic ironstone	150 & 475 ppm	808 ppm (INAA)

have been important at least locally during Bad Heart Formation time, potential exists for base- and precious-metal massive sulphide deposits. Finally, the presence of 'diamond indicator mineral grains' in places in the Bad Heart Formation and some other Late Cretaceous strata in northwestern Alberta, indicates potential exists for the discovery of diamondiferous ultramafic diatremes.

The Clear Hills iron deposits are an important resource of iron in Alberta and western Canada. Although the origin of the iron- and silica-rich oolites definitely occurred as a result of wave agitation in a shallow marine environment, the specific source(s) of the iron, silica and some other elements with elevated contents, is less certain. Although the elevated concentrations of iron, silica and the other elements in the Coniacian seawater may be due to continental weathering as suggested by Donaldson (1997), it also remains possible that these elements resulted from more local hydrothermal fumarolic activity as suggested by Olson *et al.* (1994) and, more recently, by Collom (1998). Support for the latter fumarolic hypothesis includes the existence of anomalous local concentrations of paleobiota that occur in modern environments only in the vicinity of seafloor hydrothermal seeps (Collom, 1997a,b,c, 1998, 1999). It is possible, perhaps even probable, that the location of any such hydrothermal seeps were controlled by one or more of the several faults which are postulated to have been active during deposition of the Bad Heart Formation (Donaldson, 1997; Donaldson *et al.*, 1998). Finally, recent work by the Alberta Geological Survey and industry in the Clear Hills – Chinchaga Hills – Naylor Hills region of northwestern Alberta, indicates there was andesitic to basaltic volcanism in the region, including a possible tuff unit at or near the base of the oolitic ironstone, plus possible ultramafic diatreme emplacement, coeval or nearly coeval with Bad Heart Formation deposition.

8.2 **Recommendations for Future Studies**

There is a definite need for more extensive sampling and analytical work of the Clear Hills iron deposits, and the Bad Heart Formation. This work should better evaluate the regional variations in lithochemistry of the Bad Heart Formation oolitic ironstone, and particularly whether some elements, other than iron, have potential to be important co-products in places. Because elevated contents of Fe, As, Co, Cr, Mo, Mn, Ni, Pb, Sb, V and W exist at the Rambling River area, future studies should perhaps be initially focused at and near this area. Further work on the Clear Hills iron deposits will require drilling to obtain core or, less desirably, cuttings on some selected systematic regional basis due to the fact that most of the Clear Hills iron deposit is covered by Late Cretaceous or younger sedimentary units, or by Quaternary to Recent till and other surficial sediments.

Further work also is required to understand the regional stratigraphy and paleogeographic setting, including faulting in the Precambrian Basement and reactivated contemporaneous intra-basinal faulting during deposition of the Phanerozoic strata. As well, further detailed regional to, in places, local-scale stratigraphic studies are needed for the Late Cretaceous strata in northwestern and northern Alberta, with possible emphasis on the Bad Heart Formation in the Clear Hills region. Such further

geoscientific and exploratory studies of the Bad Heart Formation would provide information about the potential for elevated concentrations of possible co-product elements, and for the existence of precious-metal or base-metal deposits to exist within the Bad Heart Formation. As well, such studies would assist in identifying sites favourable for the emplacement of ultramafic diatremes which currently are an important focus of diamond exploration in northern Alberta.

Finally, to ensure any future work on the Bad Heart Formation or other Late Cretaceous strata is done to professional geoscientific standards, such work should be done by, or under the supervisory auspices of, the Alberta Geological Survey.

R.A. Olson, Ph.D., P. Geol.
President, APEX Geoscience Ltd.

Edmonton, Alberta
February, 1999

9.0 REFERENCES CITED

Anonymous (1957) **Iron Prospecting Permit No. 7, Geological Report**; unpublished assessment report, now labeled Economic Minerals File Report FE-AF-007.

Anonymous (1957) **Iron Prospecting Permit No. 8, Geological Report**; unpublished assessment report, now labeled Economic Minerals File Report FE-AF-008(02).

Anonymous (1957) **Iron prospecting permit No. 9, Geological Report**; unpublished assessment report, now labeled Economic Minerals File Report FE-AF-009(02).

Anonymous (1958) **Lower Mesozoic Phosphorus Siderites in the Highwood area, Iron Prospecting Permit No. 15**; unpublished assessment report, now labeled Economic Minerals File Report FE-AF-015(03).

Anonymous (1966) **Air Photograph Interpretation of a part of Clear Hills area, Alberta**; unpublished assessment report, now labeled Economic Minerals File Report FE-AF-029(01).

Anonymous (1966) **Exploration Report, Iron Prospecting Permit No. 29., Clear Hills, Alberta**; unpublished assessment report by Carroll Oilfield Enterprises Ltd., now labeled Economic Minerals File Report FE-AF-029(03).

Anonymous (1966) **Magnetometer Evaluation of Iron Prospecting Permit No. 30, Alberta**; unpublished report prepared by Overland Exploration Services Ltd. for City Savings and Trust Company, now labeled Economic Minerals File Report FE-AF-030.

Anonymous (1966) **Magnetometer Evaluation of Iron Prospecting Permit No. 31, Alberta**; unpublished report prepared by Overland Exploration Services Ltd. for City Savings and Trust Company, now labeled Economic Minerals File Report FE-AF-031.

Anonymous (1966) **Magnetometer Evaluation of Iron Prospecting Permit No. 32, Alberta**; unpublished report prepared by Overland Exploration Services Ltd. for City Savings and Trust Company, now labeled Economic Minerals File Report FE-AF-032.

Anonymous (1966) **Magnetometer Evaluation of Iron Prospecting Permit No. 33, Alberta**; unpublished report prepared by Overland Exploration Services Ltd. for City Savings and Trust Company, now labeled Economic Minerals File Report FE-AF-033.

- Anonymous (1966) **Magnetometer Evaluation of Iron Prospecting Permit No. 34, Alberta**; unpublished report prepared by Overland Exploration Services Ltd for City Savings and Trust Company, now labeled Economic Minerals File Report FE-AF-034.
- Anonymous (1966) **Magnetometer Evaluation of Iron Prospecting Permit No. 35, Alberta**; unpublished report prepared by Overland Exploration Services Ltd for City Savings and Trust Company, now labeled Economic Minerals File Report FE-AF-035.
- Anonymous (1966) **Report on Helicopter Field Exploration**; unpublished assessment report, now labeled Economic Minerals File Report FE-AF-028(01).
- Barclay, J.E.; Krause, F.F.; Campbell, R.I. and Utting, J. (1990) **Dynamic Casting and Growth Faulting: Dawson Creek Graben Complex, Carboniferous - Permian Peace River Embayment, Western Canada**; Bulletin of Canadian Petroleum Geology, Special Volume 38A, pp. 115-145.
- Bertram, E.F. and Mellon, G.B. (1975) **Peace River Iron Deposits**; Alberta Research Council, Information Series No. 75, 53 p.
- Bhattacharyya, D.B. (1989) **Concentrated and Lean Oolites: Examples from the Nubia Formation at Aswan, Egypt, and Significance of the Oolitic Types in Ironstone Genesis**; *in* Phanerozoic Ironstones (ed. by T.P. Young and W.E.G. Taylor), Geological Society Special Publication No. 46, London, pp. 93-104.
- Battacharya, J. (1991) **Sequence Stratigraphic Applications in the Alberta Foreland Basin**; Alberta Research Council, Alberta Geological Survey, Unpublished Short Course, 1991.
- Battacharya, J. and Walker, R.G. (1991) **River- and Wave-dominated Depositional Systems of the Upper Cretaceous Dunvegan Formation, Northwestern Alberta**; *In*: Bulletin of Canadian Petroleum Geology, Vol. 39, No. 2 (June, 1991). pp. 165-191.
- Bi, D., and Morton, R.D. (1995) **Magnetic Spherules from Recent Fluvial Sediments in Alberta, Canada: characteristics and possible origins**; Canadian Journal of Earth Sciences, Vol. 32, pp. 351-358.
- Bloch, J., Schroder-Adams, C., Leckie, D.A., McIntyre, D.J., Craig, J. and Staniland, M. (1993) **Revised Stratigraphy of the Lower Colorado Group (Albian to Turonian), Western Canada**; *In*: Bulletin of Petroleum Geology, Vol. 41, No. 3 (Sept., 1993) pp. 325-348.

- Boulay, R.A. (1995) **Report on the Ironcap Gold Property, Peace River Area, Alberta, Metallic and Industrial Minerals Permits No. 9390100001 to 9390100008** (covering the period January 1, 1992 to December 31, 1994); unpublished assessment report prepared by Marum Resources Inc., 8 p., plus appendices.
- Boulay, R.A. (1996) **Assessment Work, Metallic and Industrial Minerals Permits No. 939010001 to 9390100008, covering the period January 1, 1995 to December 31, 1996**; unpublished assessment report prepared by Marum Resources Inc., 26 p., plus appendices.
- Braunberger, W.F. (1994) **Molluscan Biostratigraphy of the Cardium Formation (Upper Cretaceous, Turonian-Coniacian) and Contiguous Strata, Alberta Foothills and Adjacent Subsurface**; unpublished Msc. thesis, University of Calgary, 309 p., 36 plates.
- Bruce, R.A. (1958) **Flotation and High-Intensity Magnetic Separation Tests on a Sample of Iron-Bearing Carbonate Rock from the Zep Property in Southwestern Alberta, Submitted by Mr. G.C. McCartney, Consulting Geologist, Toronto, Ontario**; Canada Department of Mines and Technical Surveys, Ottawa, Mines Branch Investigation Report IR 58-50, 10 p.
- Brindley, G.W. (1982) **Chemical Compositions of Berthierines B - a review**; Clays and Clay Minerals, 30, pp. 153-155.
- Colborne, G.L. (1958) **Sedimentary Iron in the Cretaceous of the Clear Hills Area, Alberta**; unpublished M.Sc. thesis, Univ. of Alberta, 101 p.
- Cant, D.J. (1988) **Regional Structure and Development of the Peace River Arch, Alberta: A Paleozoic Failed-rift System?**; Bulletin of the Canadian Petroleum Geology, Vol. 36, pp. 284-295.
- Carlson, S.M., Hiller, W.D., Hood, C.T., Pryde, R.P., and Skelton, D.N. (1998) **The Buffalo Hills Kimberlite Province, North-Central Alberta, Canada**; in Seventh International Kimberlite Conference, Cape Town, April 1998, Extended Abstracts, pp. 138-140.
- Collom, C.J. (1997) **Effect of the Peace River Arch (*not* Embayment!) on deposition of the Upper Cretaceous Bad Heart Formation, and correlation with coeval strata of Alberta**; Abstract from Lithoprobe Meeting, 1997, 1 p.
- Collom, C.J. (1997a) **Invertebrate Paleontology and Paleontology of the Bad Heart Formation (Upper Cretaceous), West-central Alberta: Evidence of Ancient Hydrothermal Seep Communities in an Epiric Seaway**; 6th Canadian Paleontological Conference, September 27 – 29, Saskatoon, Saskatchewan.

- Collom, C.J. (1997b) **Carbon, Oxygen, and Sulfur Isotopic Analysis of an Upper Cretaceous 85.5 Myrs.) Hydrothermal Seep, Peace River Arch, Alberta, Canada;** 2nd A.I.G. Meeting, October 1 – 3, Lake Louise, Alberta.
- Collom, C.J. (1997c) **Stratigraphy, petrology, and geochemistry of the Bad Heart Sandstone (Smoky Group: Upper Cretaceous), Peace River Arch Region, Alberta: Evidence for Possible Syndepositional Hydrothermal Seeps;** G.S.A. Annual Meeting, Oct. 20 –23, Salt Lake City, Utah.
- Collom, C.J. (1998) **The Bad Heart Formation (Upper Cretaceous) of west-central Alberta: Origin, Paleoenvironments, and Relation to Kimberlite Pipe Swarms of the Buffalo Head and Chinchaga;** Abstract from oral paper presented to the Edmonton Geological Society, October 16, 1998, 2 p.
- Collom, C.J. (1999, in Final Preparation) **Systematic Paleontology, Biostratigraphy and Paleoenvironmental Analysis of the Upper Cretaceous Wapiabi Formation and Equivalents; Alberta and British Columbia, Western Canada;** unpublished Ph.D Dissertation, Department of Geology and Geophysics, University of Calgary, Alberta, Canada.
- Collom, C.J. and Krouse, H.R. (1997) **Carbon and Sulfur Isotopic and Geochemical Evidence for Fault-Related Seep Activity During the Upper Cretaceous, Peace River Arch Region, Alberta, Canada;** 2nd Applied Isotope Geochemistry Symposium, Sept. 30 to Oct. 4, Lake Louise, Alberta, Program with abstracts and figure, 2 p.
- Cook, M. (1955) **Exploration Evaluation Report, Iron Prospecting Permit No. 3.** unpublished assessment report, now labelled Economic Minerals File Report FE-AF-003(02).
- Dawson, G.M. (1881) **Report on an Exploration from Port Simpson on the Pacific Coast, to Edmonton on the Saskatchewan, Embracing a Portion of the Northern Part of British Columbia and the Peace River country, 1879;** Geological and Natural History Survey of Canada, Report of Progress for 1879-80. pp. 1B-177B.
- Donaldson, W.S. (1991) **Sedimentology and Subsurface Stratigraphy of the Bad Heart Formation of Northwestern Alberta;** in "Opportunities for the nineties; Canadian Society of Petroleum Geology 1991 Convention, Abstracts published in the Canadian Society of Petroleum Geology, v. 39, No. 2, p. 210-211.
- Donaldson, W.S. (1997) **The Sedimentology, Stratigraphy and Diagenesis of the Upper Cretaceous Bad Heart Formation, NW Alberta;** Ph.D. thesis, in 2 volumes, completed at the University of Western Ontario, 492 p.

- Donaldson, W.S., Plint, A.G. and Longstaff, F.J. (1998) **Basement Tectonic Control on Distribution of the Shallow Marine Bad Heart Formation, Peace River Arch Area, Northwest Alberta**; Canadian Society of Petroleum Geology Bulletin, V. 46, No. 4, pp. 576-598.
- Dufresne, M.B., Eccles, D.R., McKinstry, B., Schmitt, D.R., Fenton, M.M., Pawlowicz, J.G. and Edwards, W.A.D. (1996) **The Diamond Potential of Alberta**; Alberta Energy and Utilities Board, Alberta Geological Survey, Bulletin No. 63. p. 158.
- Dufresne, M.B., Leckie, D.A. and Eccles, D.R. (1999, in Final Preparation) **Study of the Geochemical and Stratigraphic Setting of the Shaftesbury and Associated mid-Cretaceous Formations in Northern Alberta and Its Potential to Host Ore Deposits**; Geological Survey of Canada, Open File Report.
- Eccles, D.R., Dufresne, M.B. and Lywood, P. (1998) **Diamond and Metallic Mineral Potential of the Kakwa/Wapiti Area, West-central Alberta**; Alberta Energy and Utilities Board, Alberta Geological Survey, Open File Report 1998-02. p. 165.
- Edgar, N.S. (1960) **Report on Clear Hills Iron Deposit of Alberta**; unpublished assessment report, now labelled Economic Minerals File Report FE-AF-017(01), 15 p.
- Edgar, N.S. (1961) **The Swift Creek Iron Deposit**; unpublished assessment report, now labelled Economic Minerals File Report FE-AF-016, 8 p.
- Edgar, N.S. (1962) **Report on Clear Hills Iron Deposit of Alberta**; unpublished assessment report, now labelled Economic Minerals File Report FE-AF-017(01), 12 p.
- Edgar, N.S. (1963a) **Iron Prospecting Permit No. 21 Report, First Six Months Exploration**; unpublished assessment report, now labelled Exploration Minerals, File Report FE-AF-021(001).
- Edgar, N.S. (1963b) **Report On Iron Prospecting Permit No. 22**; unpublished assessment report, now labelled Economic Minerals File Report FE-AH-022(01).
- Edgar, N.S. (1964a) **Iron Prospecting Permit No. 20 Final Report**; unpublished assessment report, now labelled Economic Minerals File Report FE-AF-020(01).
- Edgar, N.S. (1964b) **Iron Ore Prospecting Permit No. 21, Final Report**; unpublished assessment report, now labelled Economic Minerals File Report FE-AF-021(02).
- Edgar, N.S. (1964c) **Iron Prospecting Permit No. 24., Final Report**; unpublished assessment report, now labelled Economic Minerals File Report FE-AF-024(01).

- Edgar, N.S. (1964d) **Iron Prospecting Permit No. 25., Final Report**; unpublished assessment report, now labelled Economic Minerals File Report FE-AF-025(01).
- Edgar, N.S. (1964e) **Iron Prospecting Permit No. 26., Final Report**; unpublished assessment report, now labelled Economic Minerals File Report FE-AF-026(01).
- Edgar, N.S. (1965) **Iron Ore Prospecting Permit No. 24., Final Report**; unpublished assessment report, now labelled Economic Minerals File Report FE-AF-024(02).
- Gleddie, J. (1949) **Upper Cretaceous in Western Peace River Plains, Alberta**; American Association of Petroleum Geologists, v. 533, pp. 511-532.
- Green, R. and Mellon, G.B. (1962) **Geology of the Chinchaga River and Clear Hills (north half) map-areas, Alberta**; Alberta Research Council, Preliminary Report, 62-8, 18 p.
- Green, R. and Mellon, G.B. (1970) **Bedrock Geology of Northern Alberta**; Alberta Research Council, Alberta Geological Survey.
- Godfrey, J.D. (1955) **Report on the Bog Iron Deposit near Bellis, Alberta**; unpublished assessment report prepared for Varmac Mining and Exploration Co. Ltd., now labelled Economic Minerals File Report FE-AF-006, 5 p.
- Gross, G.A. (1965), **Geology of Iron Deposits in Canada, Volume I, General Geology and Evaluation of Iron Deposits**; Geological Survey of Canada, Economic Geology Report, Vol. 1, No. 22, 181 p.
- Hamilton, W.N. (1974) **Summary Report: Clear Hills Iron Sampling Program**; Alberta Research Council, Alberta Geological Survey, Open File Report 1974-27, 19 pp.
- Hamilton, W.N. (1980) **Clear Hills Iron Deposit Geology, Mineralogy and Ore Reserves**; Alberta Research Council, Alberta Geological Survey, Open File Report 1982-13, 43 p.
- Hamilton, W.N. and Olson, R.A. (1994) **Mineral Resources of the Western Canada Sedimentary Basin**; ; in G. Mossop and I. Shetsen, Geological Atlas of the Western Canada Sedimentary Basin, Ch. 20, pp. 483-501.
- Hart, B.S. and Plint, A.G. (1990) **Upper Cretaceous Warping and Fault-movement on the Southern Flank of the Peace River Arch, Alberta**; Bulletin of Canadian Petroleum Geology, Special Volume 38A, pp. 190-195.
- Haskin. M.A. and Haskin, L.A. (1966) **Rare Earths in European Shales: A Redetermination**; Science, v. 154, pp. 507-509.

- Haymon, R.M. and Koski, R.A. (1985) **Evidence of an Ancient Hydrothermal Vent Community: Fossil Worm Tubes in Cretaceous Sulfide deposits of the Samail Ophiolite, Oman**; Biological Society of Washington Bulletin, No. 6, pp. 57-65.
- Heffernan, G.R. (1956) **Iron Prospecting Permit No. 13**; unpublished assessment report, now labelled Economic Minerals File Report FE-AF-013.
- Heffernan, G.R. (1957) **Preliminary Report On Studies Carried Out On Iron Prospecting Permit No. 14**; unpublished assessment report, now labelled Economic Minerals File Report FE-AF-014(01).
- Heikoop, J.M., Tsujita, C.J., Risk, M.J., Tomascik, T. and Mah, A.J. (1996) **Modern Iron Ooids from a Shallow-marine Volcanic Setting, Mahengetang, Indonesia**; Geology, 24 (8), pp. 759-762.
- Irish, E.J.W. (1965) **Geology of the Rocky Mountain Foothills, Alberta**; Geological Survey of Canada, Memoir 334, 241 p.
- Kauffman, E.G., Arthur, M.A., Howe, B. and Scholle, P.A. (1996) **Widespread Venting of Methane-rich Fluids in Late Cretaceous (Campanian) Submarine Springs (Teepee Buttes), Western Interior Seaway, U.S.A.**; Geology, 24 (9), pp. 799-802.
- Kelly, M.J. (1995) **Peace River, Alberta, Clear Hills Iron Deposit in the Bad Heart Formation**; Metallic minerals exploration permits #93930800-32+33, #93939080-110+111; #9393080-678 to 680; unpublished report prepared for TUL Petroleums Ltd., 300 p.
- Kidd, D.J. (1959) **Iron Occurrences in the Peace River Region, Alberta**; Research Council of Alberta, Preliminary Report 59-3, 38 p.
- Kimberly, M.M. (1989) **Exhalative Origins of Iron Formations**; Ore Geology Reviews, 5, pp. 13-145.
- Kimberly, M.M. (1994) **Debate About Ironstone: Has Solute Supply Been Surficial Weathering, Hydrothermal Convection, or Exhalation of Deep Fluids?**; Terre Nova, 6, pp. 116-132.
- Krause, F.F., Deutsch, K.B., Joiner, S.D., Barclay, J.E., Hall, R.L. and Hills, L.V. (1994) **Cretaceous Cardium Formation of the Western Canada Sedimentary Basin**; in Mossop, G. and Shetsen, I., Geological Atlas of the Western Canada Sedimentary Basin, Canadian Society of Petroleum Geologists and the Alberta Geological Survey, Alberta Research Council, pp. 375-385.

- Krupp, F. (1975) **Final Report on Investigation and Tests Carried Out with Peace River Iron Ore**; unpublished report by Krupp Industrie – und Stahlbau, now labelled Alberta Research Councils Economic Minerals File FE-IR-12, 34 p.
- Leckie, D.A., Bhattacharya, J.P., Bloch, J., Gilboy, C.F. and Norris, B. (1994) **Cretaceous Colorado/Alberta Group of the Western Canada Sedimentary Basin**; in G. Mossop and I. Shetsen, Geological Atlas of the Western Canada Sedimentary Basin, Ch. 20, pp. 335-352.
- Leckie, D.A. and Craw, D. (1994) **Westerly-Derived Early Cretaceous Gold Paleoplacers in the Western Canada Foreland Basin, Southwestern Alberta: tectonic and economic implications**; Geological Survey of Canada, Contribution No. 57394, 107 p.
- Lenz, A.C. (1956) **Oolitic iron ore, Clear Hills, Alberta**; unpublished term paper, University of Alberta, Edmonton, 37 p.
- Levinson, A.A. (1974) **Introduction to Exploration Geochemistry**; Applied Publishing, Calgary, Alberta.
- Lockwood, C.M. (1962) **Report on Exploration Work Performed by Loram on Iron Prospecting Permit No. 18 (Donner Iron Deposit)**; unpublished report prepared by Loram Ltd.
- McColl, H.S. (1954) **Geological Report, Clear Hills District, Peace River, Alberta, Canada**; unpublished assessment report, now labelled Economic Minerals File Report FE-AF-002(01), 14 p.
- McCord, C.D. (1964) **Iron Prospecting Permit No. 23., Gordondale Area**; unpublished assessment report prepared by Teck Corporation Ltd., now labelled Economic Minerals File Report FE-AF-023(01), pp. 9-10.
- McDonald, D. and McDonald, E. (1957) **Summary of Exploration Carried Out on Iron Prospecting Permit No. 11**; unpublished assessment report, now labelled Economic Minerals File Report FE-AF-011(01).
- McDougall, D.B. (1954) **Preliminary Report on Peace River Iron Ore**; unpublished assessment report, now labelled Economic Minerals File Report FE-AF-010(01), 18 p.
- McLearn, F.H. (1919) **Cretaceous Lower Smoky River, Alberta**; Geological Survey of Canada, Summary Report, 1918, Part C, 52 p.
- McLearn, F.H. (1926) **New Species from the Coloradoan of Lower Smoky and Lower Peace Rivers, Alberta**; Canada Dept. of Mines Bulletin 42, Geological Series No. 45 (Contributions to Canadian Palæontology), Ottawa, pp. 117-126, 4 plates.

- McLearn, F.H. (1943) **Trends in Some Canadian Cretaceous Species of *Inoceramus***; *The Canadian Field-Naturalist*, 57, pp. 36-46.
- McLearn, F.H. and Kindle, E.D.. (1950) **Geology of Northeast British Columbia**; Geological Survey of Canada, Memoir 259.
- McMechan, M.E. (1990) **Upper Proterozoic to Middle Cambrian History of the Peace River Arch: Evidence From the Rocky Mountains**; *Bulletin of Canadian Petroleum Geology*, vol. 38A, pp. 36-44.
- McMechan, M.E. and Dawson, F.M. (1995) **Geology and Structure Cross-section, Wapiti, Alberta**; Geological Survey of Canada, Map 1875A, Scale 1:250 000.
- Mellon, G.B. (1962) **Petrology of Upper Cretaceous Oolitic Iron-Rich Rocks from Northern Alberta**; Alberta Research Council, Contribution No. 168, *Economic Geology*, Vol. 57, pp. 921-940.
- Mikhail, S.A., Turcotte, A.M., Putz, A.L., Kuyucak, S., Shehata, M.T., Prud'homme, P.J.A. and Demers, A. (1996) **Preliminary Evaluation of Clear Hills Iron Ore**; unpublished report by CANMET prepared for Marum Resources Inc., Appendix B in Boulay, R.A. (1996) *Assessment Work, Metallic Mineral Permits No. 9390100001 to 9390100008, Covering the Period January 1, 1995 to December 31, 1996*, 13 p.
- MT Environmental Systems Inc. (1996) **Confidential Iron Ore Market Study**; prepared for Marum Resources Inc., 32 p.
- Norman, H.C. (1957) **Report on the Zep Iron Deposit, Highwood River, Alberta**; unpublished assessment report, now labelled Economic Minerals File Report FE-AF-015(0).
- O'Connell, S.C. (1990) **The development of the Lower Carboniferous Peace River Embayment as Determined from Banff and Pekisko Formation Depositional Patterns**; *Bulletin of Canadian Petroleum Geology*, vol. 38A, pp. 93-114.
- O'Connell, S.C., Dix, G.R. and Barclay, J.E. (1990) **The Origin, History, and Regional Structural Development of the Peace River Arch, Western Canada**; *Bulletin of Canadian Petroleum Geology*, vol. 38A, pp. 4-24.
- O'Connell, S.C. (1994) **Geological History of the Peace River Arch**; *In*: Mossop, G.D. and Shetson, I. (compilers), *Geological Atlas of the Western Canada Sedimentary Basin*. Alberta Research Council, Alberta Geological Survey and Canadian Society of Petroleum Geologists.

- Olson, R.A., Dufresne, M.B., Freeman, M.E., Eccles, D.R. and Richardson, R.J.H. (1994) **Regional Metallogenic Evaluation of Alberta**; report prepared by R.A. Olson Consulting Ltd. for the Alberta Geological Survey (AGS), published as AGS Open File Report Report 1994-8, 150 p.
- Peirce, J.W.; Cordsen, A.; Ebner, E.J.; Goussev, S.A.; Hassan, H.; Heise, R.; Marchand, N.; Robinson, K. and Walker, D. (1997) **Aeromagnetic Interpretation: Dunvegan Block / Fort St. John Graben, HRAM Study**; Geophysical Exploration and Development Company (GEDCO) Proprietary Report, 45 p.
- Petruk, W. (1976) **Amorphous “minerals” from the Peace River oolitic iron deposit, Alberta**; in Program with Abstracts, Geological Association of Canada – Mineralogical Association of Canada – Canadian Geophysical Union, Joint Annual Meeting, 1976, p. 64.
- Petruk, W. (1977) **Mineralogy Characteristics of an Oolitic Iron-Ore Deposit in the Peace River District, Alberta**; Canadian Mineralogist, Vol. 15, pp. 3-13.
- Petruk, W., Harrison, D.C. and Pinard, R.G. (1974) **A Mineralogical Investigation of Samples from the Clear Hills Oolitic Iron Deposit, Peace River, Alberta**; Canada Mines Branch Investigation Report IR 74-33, 21 p.
- Petruk, W., Klymowsky, I.B. and Hayslip, G.O. (1977a) **Mineralogical Characteristics and Beneficiation of an Oolitic Iron-Ore from the Peace River District, Alberta**; CIM Bulletin, October 1977, pp. 122-131.
- Petruk, W., Farrell, D.M., Laufer, E.E., Tremblay, R.J. and Manning, P.G. (1977b) **Nontronite and Ferruginous Opal from the Peace River Iron Deposit in Alberta, Canada**; Canadian Mineralogist, Vol. 15, pp. 14-21.
- Phares, W.A. (1954) **Reconnaissance Survey Report, Iron Prospecting Permit No. 3**; unpublished assessment report, now labelled Economic Minerals File Report FE-AF-003(01).
- Plint, A.G. (1990) **An Allostratigraphic Correlation of the Muskiki and Marshybank Formations (Coniacian-Santonian) in the Foothills and Subsurface of the Alberta Basin**; Bulletin of Canadian Petroleum Geology, 38 (3), pp. 288-306.
- Plint, A.G. (1991) **High-frequency Relative Sea-level Oscillations in Upper Cretaceous Shelf Clastics of the Alberta Foreland Basin: Possible Evidence for a Glacio-eustatic Control?**; Special Publications of the international Association of Sedimentologists, 12, pp. 409-428.

- Plint, A.G.; Hart, B.S. and Donaldson, W.S. (1993) **Lithospheric Flexure as a Control on Stratal Geometry and Facies Distribution in Upper Cretaceous Rocks of the Alberta Foreland Basin**; Basin Research, 5, pp. 69-77.
- Plint, A.G., Norris, B. and Donaldson, W.S. (1990) **Revised Definitions for the Upper Cretaceous Bad Heart Formation and Associated Units in the Foothills and Plains of Alberta and British Columbia**; Canadian Society of Petroleum Geology Bulletin, v. 38, pp. 78-88.
- Plint, A.G. and Norris, B. (1991) **Anatomy of a Ramp Margin Sequence: Facies Successions, Paleogeography, and Sediment Dispersal Patterns in the Muskiki and Marshybank Formations, Alberta Foreland Basin**; Bulletin of Canadian Petroleum Geology, 39 (1), pp. 18-42.
- Plint, A.G., Walker, R.G. and Bergman, K.M. (1986) **Cardium Formation 6. Stratigraphic Framework of the Cardium in Subsurface**; Bulletin of Canadian Petroleum Geology, 34(2), pp. 213-225.
- Plint, A.G. and Walker, R.G. (1987a) **Cardium Formation 8. Facies and Environments of the Cardium Shoreline and Coastal Plain in the Kakwa Field and Adjacent Areas, Northwestern Alberta**; Bulletin of Canadian Petroleum Geology, 35 (1), pp. 48-64.
- Plint, A.G. and Walker, R.G. (1987b) **Morphology and Origin of an Erosion Surface Cut Into the Bad Heart Formation During Major Sea Level Change, Santonian of West-central Alberta, Canada**; Journal of Sedimentary Petrology, 57, pp. 639-650.
- Postgate, J.R. (1979) **The Sulphate-reducing Bacteria**; Cambridge University Press, Cambridge, 151 p.
- Price, M.C., Hamilton, W.N. and Olson, R.A. (1999, in preparation) **Summary of Available Data on Industrial and Metallic Mineral Deposits in the Western Canada Sedimentary Basin**; Alberta Geological Survey of the Alberta Research Council, to be published as an Open File Report.
- Renn, R. (1956-57) **Exploration Report, Iron Prospecting Permit No. 12**; unpublished assessment report, now labelled Economic Minerals File Report FE-AF-012(01).
- Rohrlich, V. (1974) **Microstructure and Microchemistry of Iron Oolites**; Mineralium Deposita, Springer – Verlag, v. 9, pp. 133-142.
- Ross, G.M. (1990) **Deep Crust and Basement Structure of the Peace River Arch Region: Constraints on Mechanisms of Formation**; Bulletin of Canadian Petroleum Geology, vol. 38A, pp. 25-35.

- Rostron, B.J., Toth, J. and Machel, H.G. (1995) **Basin-scale Fluid Flow, Hydrochemistry, and Petroleum Entrapment in Devonian Reef Complexes, West-central Alberta, Canada**; *in* American Association of Petroleum Geologists and Society of Economic Paleontologists and Mineralogists, Annual Meeting Abstracts, v. 4, p. 83.
- Rutherford, R.L. (1930) **Geology and Water Resources in Parts of the Peace River and Grande Prairie Districts, Alberta**; Research Council of Alberta, Report 21. 68 p.
- Samis, C.S. and Gregory, J. (1962) **The Reduction of Clear Hills Iron Ore by the R-N Process**; Research Council of Alberta, Information Series No. 40, 35 p.
- Stelck, C.R. (1955) **Cardium Formation of the Foothills of Northeastern British Columbia**; Canadian Institute of Mining and Metallurgy, v. 48, p. 266-273.
- Stott, D.F. (1963) **The Cretaceous Alberta Group and Equivalent Rocks, Rocky Mountain Foothills, Alberta**; Geological Survey of Canada, Memoir 317, 306 p.
- Stott, D.F. (1967) **The Cretaceous Smoky Group, Rocky Mountain Foothills, Alberta and British Columbia**; GSC Bulletin 132, 133 p.
- Sturesson, Ulf. (1992) **Volcanic Ash: The Source Material for Ordovician Chamosite Ooids in Sweden**; Society for Sedimentary Geology, Journal of Sedimentary Petrology, Vol. 62, No. 6, pp. 1084-1094.
- Turekian, K.K. and Wedepohl, K.H. (1961) **Distributions of Elements in Some Major Units of the Earth's Crust**; Geological Society of America Bulletin, v. 72, pp. 175-192.
- Underhill, J.C. (1964) **Iron Prospecting Permit No. 28, Russet Creek Area**; unpublished assessment report prepared by Imperial Oil Ltd., now labelled Economic Minerals File Report FE-AF-028(01).
- Wall, J.H. (1960) **Upper Cretaceous Foraminifera from the Smoky River Area, Alberta**; Research Council of Alberta Bulletin 6, 43 p.
- Wall, J.H. (1967) **Cretaceous Foraminifera of the Rocky Mountain Foothills, Alberta**; Research Council of Alberta, Bulletin 20, 185 p.
- Wall, J.H. and Germundson, R.K. (1963) **Microfaunas, Megafaunas, and Rock-stratigraphic Units in the Alberta Group (Cretaceous) of the Rocky Mountain Foothills**; Research Council of Alberta Contribution No. 227 *in* Bulletin of Canadian Petroleum Geology, 11 (4), pp. 327-349.

- Wallace-Dudley, K. and Leckie, D.A. (1993) **The Lower Kaskapau Formation (Cenomanian): A Retrogradational Shelf System, Alberta, Canada;** American Association of Petroleum Geologists, Bulletin, v. 77. pp. 414-435.
- Wickenden, R.T.D. (1949) **Some Cretaceous Sections Along Athabasca River from the Mouth of Calling River to Below Grand Rapids, Alberta;** Geological Survey of Canada Paper 49-15, 31 p.
- Young, T.P. (1989) **Phanerozoic Ironstones: An Introduction and Review;** *In:* Phanerozoic Ironstones (ed. by T.P. Young and W.E.G. Taylor), Geological Society Special Publication No. 46, London.

10.0 CERTIFICATION FOR SENIOR AUTHOR OF REPORT

I, R. A. OLSON OF 756 WANYANDI ROAD, EDMONTON, ALBERTA, CERTIFY AND DECLARE THAT I AM A GRADUATE OF THE UNIVERSITY OF BRITISH COLUMBIA WITH A B.SC. DEGREE IN GEOLOGY (1968), A GRADUATE OF THE UNIVERSITY OF WESTERN ONTARIO WITH A M.SC. DEGREE IN GEOLOGY (1971) AND A GRADUATE OF THE UNIVERSITY OF BRITISH COLUMBIA WITH A PH.D. DEGREE IN GEOLOGY (1977). I AM REGISTERED AS A PROFESSIONAL ENGINEER WITH THE ASSOCIATION OF PROFESSIONAL ENGINEERS OF BRITISH COLUMBIA, AND AS A PROFESSIONAL GEOLOGIST WITH THE ASSOCIATION OF PROFESSIONAL ENGINEERS, GEOLOGISTS AND GEOPHYSICISTS OF ALBERTA, AND WITH THE NORTHWEST TERRITORIES ASSOCIATION OF PROFESSIONAL ENGINEERS, GEOLOGISTS AND GEOPHYSICISTS.

MY EXPERIENCE INCLUDES SERVICE AS AN EXPLORATION GEOLOGIST WITH TEXASGULF INC., VANCOUVER, BRITISH COLUMBIA. BETWEEN 1969 AND 1991 I CONDUCTED AND DIRECTED PROPERTY EXAMINATIONS, PROPERTY EVALUATIONS AND EXPLORATION PROGRAMS ON BEHALF OF COMPANIES AS A GEOLOGIST IN THE EMPLOY OF TRIGG, WOOLLETT & ASSOCIATES LTD., AND AS A PARTNER IN THE FIRM OF TRIGG, WOOLLETT CONSULTING LTD. AND TRIGG, WOOLLETT, OLSON CONSULTING LTD., EDMONTON, ALBERTA. SINCE 1992 I HAVE BEEN A PRINCIPAL IN THE FIRM OF R.A. OLSON CONSULTING LTD., AND SINCE 1994 IN THE FIRM OF APEX GEOSCIENCE LTD, PROVIDING SENIOR GEOSCIENTIFIC CONSULTING TO BOTH PRIVATE INDUSTRY AND TO GOVERNMENT AGENCIES.

THIS REPORT CONCERNING POTENTIAL CO-PRODUCT TRACE ELEMENTS WITHIN THE CLEAR HILLS IRON DEPOSITS, NORTHWESTERN ALBERTA, WAS PREPARED BY ME OR UNDER MY SUPERVISION, AND IS BASED UPON STUDY OF PUBLISHED AND UNPUBLISHED DATA.

R. A. OLSON, PH.D., P.GEOL.

FEBRUARY, 1999
EDMONTON, ALBERTA

APPENDIX I

SYNOPSIS OF MINERALS AND DESCRIPTION OF CHEMISTRY WITHIN THE CLEAR HILLS IRON DEPOSITS

Mineral	Mineral Family	Chemical Composition	Remarks
Berthierine	Serpentine	$(\text{Fe}^{+2}, \text{Fe}^{+3}, \text{Mg}, \text{Al})_{3-x}(\text{Si}, \text{Al})_2\text{O}_5(\text{OH})_4$, with x about 0.1 to 0.2	Much so called chamosite appears to be identical with berthierine. Rohrlach (1974), for example, stated berthierine is a 7A chamosite, whereas Brindley (1982) stated berthierine is a Fe-Al 1:1 layer silicate belonging to the serpentine group.
Calcite	Carbonate	CaCO_3	
Chamosite	Septechlorites	$(\text{Fe}_4^{+2}, \text{Al}_2^{+3})(\text{Si}_2, \text{Fe}_2^{+3})\text{O}_{10}(\text{OH})_8$	Typically contains about 31% total Fe (mainly as Fe_2O_3), 11% MgO and 26% SiO_2
Glauconite	Mica	$\text{K}(\text{Fe}, \text{Mg}, \text{Al})_2(\text{Si}_4, \text{O}_{10})(\text{OH})_2$	Fe^{+3} predominates over Al
Goethite	Iron oxide	HFeO_2	
Hematite	Iron oxide of the 'Hematite Group'	Fe_2O_3	
Illite	Clay mica	$\text{KAl}_2(\text{Al}, \text{Si}_3, \text{O}_{10})(\text{OH})_2$	
Nontronite	Smectite clay	$\text{Na}_{0.33}\text{Fe}_2^{+3}(\text{Al}_{0.33}, \text{Si}_{3.67})\text{O}_{10}(\text{OH})_2 \cdot n\text{H}_2\text{O}$	Iron rich smectite clay (montmorillonite)
Ferruginous opal	Hydrous iron-rich cryptocrystalline silica	$\text{SiO}_x \cdot n\text{H}_2\text{O} + \text{Fe}_2\text{O}_3$	
Siderite	Iron carbonate	FeCO_3	

APPENDIX II

GEOCHEMICAL RESULTS FROM CURRENT STUDIES

- II.1 Certificates of Analysis from Activation Laboratories Ltd.
- II.2 Master Summary Table of Results
- II.3 Digital Copy of Results on CD-ROM Disk

APPENDIX II.1

GEOCHEMICAL RESULTS FROM CURRENT STUDIES

Certificates of Analysis from Activation Laboratories Ltd.

Sample Description	AU PPB	AG PPM	AS PPM	BA PPM	BR PPM	CA %	CO PPM	CR PPM	CS PPM	FE %	HF PPM	HG PPM	IR PPB	MO PPM	NA %	NI PPM	RB PPM	SB PPM	SC PPM	SE PPM	SN %	SR %	TA PPM	TH PPM
AS001	10	<5	200	410	<0.5	2	49	160	<1	29.8	2	<1	<5	11	0.12	93	<15	7.5	12	<3	<0.02	<0.05	<0.5	12
AS002	5	<5	180	670	2.4	<1	46	140	<1	30.3	2	<1	<5	11	0.12	83	<15	7	11	<3	<0.02	<0.05	1.2	11
AS003	8	<5	300	580	<0.5	2	42	160	<1	30.8	2	<1	<5	17	0.11	100	49	8.3	13	<3	<0.02	<0.05	1.2	12
AS004	<2	<5	270	660	<0.5	<1	42	130	<1	28.8	2	<1	<5	7	0.11	93	59	7	11	5	<0.02	<0.05	<0.5	11
AS005	<2	<5	240	2300	<0.5	3	210	160	2	28.1	2	<1	<5	89	0.12	250	<15	21	12	<3	<0.02	<0.05	<0.5	12
AS006	5	<5	320	570	<0.5	3	53	160	<1	32	2	<1	<5	<1	0.11	96	<15	7.7	13	<3	<0.02	<0.05	<0.5	13
AS007	8	<5	320	370	<0.5	4	62	130	3	28.7	2	<1	<5	12	0.12	120	<15	7.7	11	<3	<0.02	<0.05	<0.5	11
AS008	<2	<5	370	570	<0.5	1	50	140	<1	30.9	2	<1	<5	14	0.1	110	<15	9.4	11	<3	<0.02	<0.05	<0.5	12
AS009	<2	<5	460	360	<0.5	<2	50	170	4	36.1	2	<1	<5	20	0.12	100	<15	11	13	<3	<0.02	<0.05	1.2	13
AS010	<2	<5	490	480	<0.5	<2	51	170	2	35.8	2	<1	<5	18	0.14	99	<15	11	13	<3	<0.02	0.07	<0.5	14
AS011	<2	<5	480	690	<0.5	<2	50	180	<1	35.4	2	<1	<5	18	0.12	88	<15	11	13	7	<0.02	<0.05	<0.5	13
AS012	<2	<5	480	430	2	<1	46	160	<1	34.8	2	<1	<5	19	0.11	100	<15	11	12	<3	<0.02	<0.05	<0.5	11
AS013	5	<5	480	530	1	<1	49	160	2	34.8	2	<1	<5	15	0.13	83	<15	11	13	<3	<0.02	<0.05	<0.5	13
AS014	4	<5	470	510	<0.5	<1	46	160	1	32.8	2	<1	<5	17	0.14	91	<15	11	12	<3	<0.02	0.06	<0.5	12
AS015	<2	<5	490	510	0.9	<1	46	140	<1	31.9	2	<1	<5	13	0.14	90	58	11	12	<3	<0.02	<0.05	<0.5	11
AS016	4	<5	450	540	<0.5	<1	53	170	2	34.6	2	<1	<5	7	0.14	100	39	11	13	<3	<0.02	<0.05	<0.5	14
AS017	<2	<5	490	460	1.5	<1	51	160	<1	34.3	3	<1	<5	14	0.17	100	<15	11	12	<3	<0.02	<0.05	<0.5	12
AS018	<2	<5	420	840	3.7	<1	49	150	2	31.2	2	<1	<5	10	0.11	120	37	11	12	<3	<0.02	<0.05	<0.5	12
AS019	3	<5	450	430	<0.5	<1	44	140	2	32	1	<1	<5	17	0.11	170	<15	10	11	<3	<0.02	<0.05	<0.5	11
AS020	11	<5	490	620	<0.5	<1	50	160	<1	34.5	2	<1	<5	5	0.12	120	<15	11	12	<3	<0.02	<0.05	<0.5	13
AS021	4	<5	500	370	4	<1	53	170	<1	34.9	2	<1	<5	6	0.12	210	<15	11	13	<3	<0.02	<0.05	<0.5	13
AS022	<2	<5	450	420	1.5	<1	49	150	<1	33	2	<1	<5	18	0.12	110	<15	11	12	<3	<0.02	<0.05	<0.5	12
AS023	5	<5	470	500	1	<1	51	150	2	33.6	2	<1	<5	9	0.11	<26	<15	11	12	<3	<0.02	<0.05	0.7	11
AS024	<2	<5	430	590	1.5	1	47	140	2	31.1	2	<1	<5	19	0.12	110	<15	11	12	<3	<0.01	<0.05	<0.5	11
AS025	<2	<5	440	540	1.8	2	48	140	<1	31.2	2	<1	<5	16	0.11	100	49	11	12	<3	<0.01	<0.05	<0.5	12
AS026	3	<5	440	460	2.9	<1	46	140	2	30.6	2	<1	<5	10	0.08	110	26	11	11	<3	<0.01	<0.05	<0.5	11
AS027	10	<5	480	440	2.5	<1	45	140	<1	33.9	2	<1	<5	15	0.07	94	42	11	11	<3	<0.01	<0.05	1.3	10
AS028	<2	<5	440	500	<0.5	<1	44	130	<1	33.2	2	<1	<5	12	0.08	110	<15	11	12	<3	<0.01	<0.05	<0.5	11
AW001	<2	<5	87	790	<0.5	<1	6	86	5	2.85	6	<1	<5	8	0.19	<20	61	3.4	9.4	<3	<0.01	<0.05	0.9	7.7
AW002	<2	<5	81	820	<0.5	<1	2	70	4	7.29	5	<1	<5	10	0.35	<20	92	2.7	6.7	<3	<0.01	<0.05	<0.5	6.3
AW003	<2	<5	100	630	<0.5	1	34	110	2	18.5	3	<1	<5	4	0.16	62	55	4	13	<3	<0.01	<0.05	<0.5	11
AW004	<2	<5	48	530	2.2	<1	36	100	2	31.6	2	<1	<5	7	0.07	65	40	4.1	12	<3	<0.01	<0.05	0.7	10
AW005	2	<5	65	910	3.8	<1	46	140	3	28.7	3	<1	<5	22	0.08	87	70	6.1	17	<3	<0.01	<0.05	<0.5	13
AW006	3	<5	220	720	3.4	3	54	170	3	33.5	3	<1	<5	<1	0.07	100	48	9.8	17	<3	<0.01	<0.05	<0.5	15
AW007	<2	<5	230	710	3.7	2	40	170	2	39	2	<1	<5	13	0.06	78	56	7.4	15	<3	<0.01	<0.05	0.9	13
AW008	3	<5	310	520	1	<1	47	150	<1	39.9	1	<1	<5	15	0.04	100	39	8.9	13	<3	<0.01	<0.05	<0.5	12
AW009	4	<5	73	860	2.2	11	35	42	2	13.7	3	<1	<5	<1	0.24	60	25	2.8	5.3	<3	<0.01	0.08	<0.5	4.9
AW010	2	<5	89	940	2.1	10	32	49	2	17.3	3	<1	<5	12	0.22	53	49	3.1	6.2	<3	<0.01	0.06	<0.5	4.6
AW011	5	<5	68	790	<0.5	2	34	79	1	19.3	3	<1	5	<1	0.07	85	53	2.5	8.2	<3	<0.01	<0.05	<0.5	8.9
AW012	4	<5	140	820	1	5	33	100	2	19.5	3	<1	<5	13	0.12	71	59	5.8	11	<3	<0.01	<0.05	1.1	9.4
AW013	8	<5	210	640	3.7	<1	33	160	2	31.7	2	<1	<5	7	0.06	85	65	7.2	13	<3	<0.01	<0.05	<0.5	12
CS001	<2	<5	67	620	<0.5	8	18	38	2	12.6	3	<1	<5	18	0.12	40	30	2.4	11	<3	<0.01	<0.05	<0.5	5.3
CS002	3	<5	66	650	<0.5	20	35	40	1	9.22	1	<1	<5	19	0.11	70	39	2.6	5.2	<3	<0.01	0.05	<0.5	4.7
CS003	3	<5	730	850	<0.5	5	32	62	1	27.5	2	<1	<5	12	0.12	66	<15	17	8.7	<3	<0.01	<0.05	<0.5	5
CS004	<2	<5	11000	220	<0.5	<1	3	10	<1	33.1	<1	8	<5	160	0.04	<36	<15	75	0.4	27	<0.03	<0.05	<0.5	<0.2
MW001	3	<5	430	470	2.5	2	42	160	<1	37.3	2	<1	<5	16	0.07	94	<15	11	13	<3	<0.01	<0.05	<0.5	14
MD001	<2	<5	48	850	<0.5	<1	12	89	6	3.06	6	<1	<5	5	0.4	65	98	1.1	12	<3	<0.01	<0.05	0.9	9.6
MD002	<2	<5	71	740	<0.5	3	8	80	6	5.18	4	<1	<5	7	0.31	63	110	2	11	<3	<0.01	<0.05	1.2	8.5
MD003	<2	<5	30	900	<0.5	1	14	98	7	3.36	6	<1	<5	4	0.37	<20	130	1.3	14	<3	<0.01	<0.05	1.3	11
MD004	3	<5	62	940	<0.5	<1	15	110	8	3.71	5	<1	<5	6	0.35	<20	140	1.7	14	<3	<0.01	<0.05	1.7	11
MD005	<2	<5	60	950	<0.5	1	14	99	8	3.97	5	<1	<5	5	0.31	<20	120	1.7	13	<3	<0.01	<0.05	1.5	10
MD006	<2	<5	160	810	<0.5	2	7	75	5	4.87	5	<1	<5	7	0.37	<20	81	2.3	9.7	<3	<0.01	<0.05	<0.5	8.9
MD007	3	<5	99	780	<0.5	<1	6	82	4	5.03	6	<1	<5	4	0.28	<20	94	2.4	10	4	<0.01	<0.05	<0.5	9.6
MD008	<2	<5	150	750	<0.5	3	40	89	3	15.5	4	<1	<5	8	0.15	<20	85	4.4	9.9	<3	<0.01	<0.05	<0.5	9.6
MD009	<2	<5	100	770	<0.5	4	33	94	2	24.9	3	<1	<5	15	0.12	<22	52	4.8	11	6	<0.01	<0.05	<0.5	9.5
MD010	<2	<5	130	640	<0.5	5	37	110	2	25.1	3	<1	<5	13	0.13	97	44	5.3	11	<3	<0.01	<0.05	<0.5	9.8
MD011	<2	<5	570	810	<0.5	5	41	130	3	22.3	3	<1	<5	11	0.26	<23	74	15	14	<3	<0.01	<0.05	<0.5	11
MD012	4	<5	25	840	<0.5	<1	16	93	4	4.55	5	<1	<5	7	0.71	<20	63	1.8	14	<3	<0.01	<0.05	<0.5	7.2
MD013	<2	<5	57	950	2	<1	13	100	7	3.63	6	<1	<5	7	0.33	<20	120							

Sample Description	AU PPB	AG PPM	AS PPM	BA PPM	BR PPM	CA %	CO PPM	CR PPM	CS PPM	FE %	HF PPM	HG PPM	IR PPB	MO PPM	NA %	NI PPM	RB PPM	SB PPM	SC PPM	SE PPM	SN %	SR %	TA PPM	TH PPM
MD029	<2	<5	80	1200	1.4	<1	14	110	8	5.12	5	<1	<5	7	0.34	<24	140	2.1	15	<3	<0.01	<0.05	<0.5	11
MD030	6	<5	80	1200	1.3	2	16	120	8	5.14	6	<1	<5	10	0.33	130	60	2.2	15	<3	<0.01	<0.05	0.7	11
MD031	12	<5	140	1500	<0.5	<1	18	140	8	10	6	<1	<5	22	0.42	190	85	2.4	15	<3	<0.02	<0.05	<0.5	12
MD032	4	<5	300	970	2	4	21	94	5	9.18	4	<1	<5	10	0.24	<20	98	4.2	11	<3	<0.01	<0.05	<0.5	9.2
MD033	<2	<5	210	1000	<0.5	<1	18	94	5	7.68	5	<1	<5	4	0.25	<20	87	2.8	12	<3	<0.01	<0.05	1.3	10
MD034	3	5	560	680	<0.5	6	16	67	3	5.21	4	<1	<5	<1	0.19	<20	63	5.5	8.6	<3	<0.01	<0.05	<0.5	7.6
MD035	5	<5	84	820	<0.5	1	14	87	4	4.15	5	<1	<5	<1	0.24	<20	96	1.9	9.6	<3	<0.01	<0.05	<0.5	9.2
MD036	<2	<5	100	780	<0.5	7	15	66	3	5.35	5	<1	<5	8	0.22	<20	84	2.3	11	<3	<0.01	<0.05	<0.5	8.1
MD037	2	<5	140	780	<0.5	5	30	100	3	15.2	4	<1	<5	13	0.2	<22	68	4.5	12	<3	<0.01	<0.05	1.2	10
MD038	3	<5	160	710	<0.5	15	16	57	2	5.46	3	<1	<5	<1	0.2	<20	43	2.5	8.4	<3	<0.01	0.13	<0.5	5.6
MD039	<2	<5	170	760	<0.5	5	20	81	3	8.91	4	<1	<5	3	0.19	93	76	3.4	9.7	<3	<0.01	<0.05	<0.5	8.7
MD040	<2	<5	150	870	<0.5	3	20	86	4	8.14	5	<1	<5	4	0.21	<20	80	3.2	10	<3	<0.01	<0.05	<0.5	9.2
MD041	6	<5	110	720	<0.5	2	18	92	4	10	5	<1	<5	9	0.19	<21	79	3.1	11	<3	<0.01	<0.05	<0.5	10
MD042	2	<5	130	750	<0.5	3	30	100	3	16	4	<1	<5	19	0.16	<22	69	4.8	11	<3	<0.01	<0.05	0.8	10
MD043	<2	<5	130	570	<0.5	5	25	85	3	14.1	4	<1	<5	18	0.16	65	62	5.4	11	<3	<0.01	<0.05	<0.5	9.4
MD044	3	<5	110	680	<0.5	3	36	110	2	21	3	<1	<5	18	0.14	63	<15	5.2	11	<3	<0.01	<0.05	<0.5	10
MD045	10	<5	88	580	<0.5	3	24	93	3	22.1	4	<1	<5	6	0.12	46	79	3.2	10	<3	<0.01	<0.05	1.3	10
MD046	<2	<5	61	440	<0.5	3	18	59	1	23.8	2	<1	<5	14	0.09	41	26	2.5	7.3	<3	<0.01	<0.05	<0.5	5.7
MD047	5	<5	90	710	<0.5	4	40	130	2	19.4	3	<1	<5	26	0.11	91	27	6.2	12	<3	<0.01	<0.05	<0.5	13
MD048	<2	<5	74	360	<0.5	2	25	70	2	30	2	<1	<5	10	0.07	56	26	2.6	8.3	<3	<0.01	<0.05	<0.5	6.5
MD049	5	<5	110	550	<0.5	2	39	100	2	26.1	2	<1	<5	12	0.08	80	35	5.3	11	<3	<0.01	<0.05	<0.5	9.1
MD050	5	<5	180	610	<0.5	3	40	130	3	22.1	3	<1	<5	17	0.13	81	34	8	12	<3	<0.01	<0.05	0.7	11
MD051	<2	<5	210	590	<0.5	4	45	140	4	24	3	<1	<5	12	0.11	83	38	9.2	13	<3	<0.01	<0.05	<0.5	12
MD052	<2	<5	160	570	<0.5	4	42	120	2	25.9	2	<1	<5	<1	0.12	83	<15	6.2	13	<3	<0.01	<0.05	0.5	11
MD053	3	<5	64	550	<0.5	3	45	140	3	27.4	3	<1	<5	23	0.08	85	<15	6.9	13	<3	<0.01	0.08	<0.5	12
MD054	<2	<5	870	520	<0.5	4	48	150	3	26.5	3	<1	<5	10	0.18	100	33	22	14	<3	<0.02	0.05	<0.5	14
MD055	3	<5	290	580	1.8	6	55	160	<1	29.5	2	<1	<5	4	0.09	83	49	11	14	<3	<0.02	<0.05	<0.5	13
MD056	3	<5	180	580	1.8	2	43	140	3	27.3	3	<1	<5	10	0.18	83	51	6.1	13	<3	<0.02	<0.05	<0.5	13
MD057	3	<5	150	540	1.6	3	56	130	3	27.9	2	<1	<5	<1	0.09	70	37	5.5	13	<3	<0.02	0.06	0.8	11
MD058	<2	<5	180	690	<0.5	2	35	140	4	22.9	4	<1	<5	11	0.29	43	69	5.9	14	<3	<0.02	<0.05	<0.5	13
MD059	5	<5	240	610	<0.5	2	39	160	2	33.3	3	<1	<5	10	0.17	73	52	7.2	14	<3	<0.02	0.09	<0.5	13
MD060	<2	<5	230	490	<0.5	1	37	150	2	31	2	<1	<5	12	0.13	72	57	7.1	13	<3	<0.02	<0.05	<0.5	12
MD061	<2	<5	260	520	<0.5	2	42	150	2	34.6	2	<1	<5	18	0.07	94	<15	7.4	13	<3	<0.02	<0.05	<0.5	13
MD062	<2	<5	81	950	<0.5	<1	15	120	8	4.76	6	<1	<5	10	0.4	78	140	2.3	15	<3	<0.02	<0.05	1.6	12
MD063	6	<5	76	1000	<0.5	<1	15	120	8	5.32	6	<1	<5	<1	0.36	80	130	2.4	15	<3	<0.02	<0.05	0.8	12
MD064	2	<5	87	930	2.3	2	15	120	8	5.5	5	<1	<5	3	0.35	<20	150	2.8	15	<3	<0.02	<0.05	0.9	11
MD065	2	<5	200	710	<0.5	12	16	66	3	10.5	3	<1	<5	4	0.18	50	54	2.3	9.7	<3	<0.01	<0.05	1.1	6.8
MD066	<2	<5	74	580	<0.5	3	49	120	3	26.5	2	<1	<5	13	0.1	52	52	4.4	12	<3	<0.02	0.06	<0.5	11
MD067	<2	<5	1000	610	<0.5	2	46	110	<1	28.5	2	<1	<5	16	0.08	53	73	19	11	3	<0.02	<0.05	<0.5	10
MD068	7	<5	340	490	<0.5	3	44	140	<1	31.1	1	<1	<5	10	0.08	63	38	8.2	13	<3	<0.02	<0.05	<0.5	12
MD069	3	<5	300	470	3.1	1	48	160	<1	35.5	2	<1	<5	8	0.09	64	<15	8.5	14	<3	<0.02	<0.05	<0.5	14
MD070	3	<5	320	460	3.7	2	50	180	<1	37.7	2	<1	<5	9	0.08	<27	53	9.4	15	<3	<0.02	<0.05	0.8	14
MD071	<2	<5	86	720	1.1	7	23	55	2	13.6	2	<1	<5	7	0.18	<20	19	3	6.5	<3	<0.01	<0.05	<0.5	5.7
MD072	<2	<5	25	770	1	<1	14	93	5	4.07	5	<1	<5	5	0.55	<20	84	1.4	13	<3	<0.01	<0.05	1.1	7.8
MD073	<2	<5	150	590	<0.5	2	44	130	2	23.5	3	<1	<5	14	0.09	51	44	5.8	12	<3	<0.02	<0.05	<0.5	12
MD074	<2	<5	210	560	<0.5	1	49	150	2	31.4	2	<1	<5	9	0.09	63	<15	6.4	13	<3	<0.02	<0.05	<0.5	13
MD075	<2	<5	200	590	2.2	2	49	160	3	29.2	3	<1	<5	11	0.09	70	<15	6	14	<3	<0.02	<0.05	<0.5	14
MD076	<2	<5	150	640	1.1	2	48	130	2	27.5	2	<1	<5	4	0.08	80	35	5.1	13	<3	<0.02	<0.05	<0.5	12
MD077	4	<5	110	770	1.3	<1	18	110	5	11.1	6	<1	<5	9	0.3	70	78	3	14	<3	<0.02	<0.05	<0.5	11
MD078	4	<5	64	850	2.3	<1	8	110	6	4.16	5	<1	<5	7	0.39	<20	100	1.8	14	<3	<0.01	<0.05	1	9.6
MD079	7	<5	45	890	2	<1	12	110	7	3.42	6	<1	<5	3	0.4	<20	130	1.2	13	<3	<0.01	<0.05	1.3	11
MD080	4	<5	69	880	2	1	13	100	8	3.64	6	<1	<5	3	0.41	<20	140	1.2	14	<3	<0.01	<0.05	<0.5	11
MD081	<2	<5	41	880	<0.5	1	12	100	7	2.98	7	<1	<5	5	0.39	<20	110	1.1	13	<3	<0.01	<0.05	0.7	10
MD082	<2	<5	51	880	1.1	<1	15	110	7	2.8	6	<1	<5	2	0.35	<20	130	1	12	<3	<0.01	<0.05	1.2	11
MD083	3	<5	64	860	<0.5	<1	14	110	7	3.72	6	<1	<5	4	0.36	<20	130	1.4	14	<3	<0.01	<0.05	0.9	11
MD084	<2	<5	56	980	1.4	<1	14	110	7	3.54	6	<1	<5	3	0.35	94	130	1.3	14	<3	<0.01	<0.05	1.6	10
MD085	3	<5	56	860	2.1	<1	15	120	7	3.76	6	<1	<5	6	0.37	<20	150	1.4	14	<3	<0.01	<0.05	1.2	11
MD086	<2	<5	100	880	1	3	18	110	6	8.25	5	<1	<5	6	0.28	<20	130	2.4	13	<3	<0.01	<0.05	0.8	11
MD087	<2	<5	83	930	<0.5	8	15	100	6	6.09	5	<1	<5	11	0.3	<23	130	1.9	14	<3	<0.02	<0.05	<0.5	11
MD088	2	<5	240																					

Sample Description	U PPM	W PPM	ZN PPM	LA PPM	CE PPM	ND PPM	SM PPM	EU PPM	TB PPM	YB PPM	LU PPM	Mass g
AS001	4.9	8	425	34	49	31	9.7	3	2.3	4.7	0.7	32.14
AS002	5.1	<1	435	36	58	41	9.8	3.1	2.4	4.8	0.71	32.71
AS003	5.2	6	491	34	56	39	10	3.4	2.1	5	0.73	30.65
AS004	4.8	6	439	33	53	35	9.2	2.9	2.2	4.1	0.63	30.81
AS005	5.3	<1	808	36	57	30	10	3.4	2.3	4.8	0.79	29.69
AS006	5.4	<1	483	37	56	36	10	3.5	2.2	5.1	0.82	29.04
AS007	6.7	<1	488	33	55	32	8.7	2.7	2.1	4.7	0.6	27.78
AS008	6.4	<1	516	34	57	29	9.9	3.2	2	5.1	0.69	27.83
AS009	6.2	<1	573	38	62	44	11	3.5	2.1	5.4	0.85	26.9
AS010	7.1	<1	551	41	57	45	12	3.8	3.1	5.5	0.84	26.71
AS011	7.6	<1	535	39	63	37	11	3.6	2.6	5.5	0.78	28.38
AS012	6.7	<1	478	36	52	33	10	3.3	2.1	5.2	0.69	27.17
AS013	6.6	5	521	36	55	29	10	3.3	2.8	5.2	0.67	26.33
AS014	6.2	5	507	37	58	40	11	3.4	2.5	5.6	0.7	29.72
AS015	5	<1	434	36	55	39	11	3.4	2.8	4.9	0.75	30.26
AS016	8.5	<1	533	38	58	46	11	3.7	2.5	5.1	0.79	26.49
AS017	6.8	5	513	39	60	36	11	3.8	2.5	5.3	0.79	31.33
AS018	8.1	<1	545	34	53	39	9.8	3.2	2.4	4.4	0.61	26.9
AS019	7.4	<1	456	34	52	36	9.9	3.2	2.3	4.5	0.69	30.37
AS020	5.9	6	530	35	53	36	11	3.3	2.4	5.2	0.71	30.11
AS021	7.2	5	475	38	60	40	11	3.5	2.9	5.4	0.73	30.87
AS022	7	<1	455	38	55	41	11	3.5	2.3	5.1	0.71	34.24
AS023	8.6	6	505	40	60	39	11	3.5	2.7	5.4	0.71	34.04
AS024	7	5	475	40	56	37	11	3.5	2.6	4.8	0.68	37.09
AS025	5.9	5	451	39	58	39	11	3.5	1.9	5.1	0.67	35.29
AS026	6.2	6	457	38	54	39	10	3.3	2.6	4.8	0.73	37.74
AS027	5.6	5	461	38	54	35	10	3.3	2.4	4.8	0.68	40.76
AS028	5.8	5	453	40	53	39	11	3.3	2.4	4.8	0.67	41.62
AW001	1.8	<1	78	27	41	23	3.3	0.9	0.6	1.9	0.33	27.47
AW002	1.2	<1	<50	26	41	14	2.6	0.7	<0.5	1.4	0.25	26.37
AW003	3.6	<1	340	29	48	32	7.7	2.6	1.9	5.1	0.71	32.3
AW004	3.9	<1	374	29	44	24	7.3	2.3	1.3	4.2	0.58	36.01
AW005	7.3	<1	434	40	62	36	10	3	2.4	5.9	0.84	29.36
AW006	6.7	<1	571	49	74	52	13	4.3	3	6.9	1.03	29.55
AW007	8	7	714	41	61	41	12	4	2.6	6.9	1	30.69
AW008	4.1	6	533	29	45	32	9.4	3.1	2.3	5.5	0.81	35.96
AW009	19	<1	296	58	62	46	11	3.3	2.3	4.3	0.59	36.98
AW010	19	<1	316	64	68	53	12	3.7	2.4	4.7	0.77	36.85
AW011	6	<1	265	29	48	28	6.3	2	1.4	3.1	0.44	31.93
AW012	12	3	504	59	81	53	13	4.2	2.8	5.8	0.88	33.74
AW013	5.3	<1	385	33	54	32	9.5	3	1.9	5.3	0.74	32.34
CS001	3.5	<1	97	38	63	36	7	2.1	1.5	2.3	0.33	38.59
CS002	3.7	<1	122	17	27	12	3	1	0.8	1.7	0.26	33.82
CS003	3.2	<1	143	36	54	27	7.6	2.4	1.5	3.2	0.44	46.38
CS004	<0.5	<2	<50	2	<3	<5	0.2	<0.2	<0.5	<0.2	<0.05	55.67
MW001	4.2	6	504	26	39	28	8.3	2.7	2.3	5.1	0.71	34.71
MD001	2.9	<1	145	37	57	25	4.5	1.3	0.6	3.2	0.46	32.2
MD002	3.8	<1	75	33	51	26	3.8	1	0.6	2.4	0.39	26.38
MD003	4.2	<1	148	41	64	30	5.2	1.5	0.9	3.4	0.53	29.83
MD004	3.3	<1	194	41	62	29	5.1	1.3	0.8	3.4	0.57	25.41
MD005	3.6	<1	166	39	61	29	5	1.4	0.8	3.3	0.52	25.26
MD006	2.9	<1	85	29	44	25	3.3	0.9	<0.5	2.1	0.35	24.08
MD007	2.9	<1	87	31	49	23	3.7	1	<0.5	1.9	0.34	26.29
MD008	2.9	<1	270	27	44	24	5.4	1.7	1.2	3.1	0.46	32.66
MD009	3.8	<1	289	27	46	26	6.4	2.1	1.6	3.6	0.54	29.2
MD010	4.3	<1	272	27	42	22	6.4	2	1.5	3.6	0.56	32.96
MD011	11	<1	334	36	54	26	8	2.5	2	4.6	0.66	30.72
MD012	2.3	<1	137	30	48	26	4.5	1.4	0.9	3	0.49	27.1
MD013	3.5	<1	142	41	63	30	5.1	1.3	0.7	3.3	0.54	30.39
MD014	4.5	<1	135	43	66	29	5.4	1.5	0.9	3.7	0.56	24.01
MD015	4.1	<1	170	44	69	35	5.5	1.4	<0.5	3.5	0.53	25.45
MD016	3.8	<1	125	41	67	22	5.1	1.3	0.9	3.4	0.57	23.16
MD017	3	<1	230	31	51	26	5.4	1.7	1.1	3.2	0.48	28.7
MD018	4.5	<1	318	31	48	29	7.5	2.4	<0.5	4.4	0.62	31.17
MD019	5	<1	335	29	47	29	7.1	2.3	1.6	4.4	0.62	31.89
MD020	3.8	<1	343	29	47	27	6.9	2.2	1.7	4.3	0.64	32.4
MD021	6.2	<1	482	36	57	33	9.3	3.1	2.2	5.5	0.75	30.49
MD022	4.8	<1	154	41	66	34	5.1	1.5	<0.5	3.1	0.54	25.91
MD023	4	4	123	41	62	31	5.2	1.5	0.8	3.5	0.55	25.09
MD024	2.6	<1	118	31	52	23	5.2	1.6	1.3	2.3	0.4	28.85
MD025	3.2	<1	211	30	50	27	5.6	1.9	1.1	2.9	0.46	29.24
MD026	<0.5	<1	237	34	59	34	6.7	2	1.3	3.6	0.58	28.87
MD027	3.9	4	355	35	55	30	8.3	2.7	1.9	5	0.7	31.04
MD028	2.7	<1	162	42	64	27	5.3	1.5	0.7	3.3	0.53	24.69

Sample Description	U PPM	W PPM	ZN PPM	LA PPM	CE PPM	ND PPM	SM PPM	EU PPM	TB PPM	YB PPM	LU PPM	Mass g
MD029	3.7	<1	152	43	67	34	5.5	1.7	<0.5	3.8	0.54	24.62
MD030	3.6	<1	142	43	72	36	5.6	1.7	<0.5	3.6	0.62	24.48
MD031	4.6	<1	122	45	73	46	6	2	<0.5	3.9	0.65	13.89
MD032	4.8	<1	156	33	54	24	5.3	1.6	1.1	3.1	0.48	27.44
MD033	3.1	<1	167	36	56	20	5.6	1.7	0.9	3	0.42	29.17
MD034	5.2	<1	149	28	47	28	4.8	1.4	0.9	2.5	0.41	29.8
MD035	4	<1	140	31	48	29	4.6	1.4	<0.5	2.8	0.44	25.07
MD036	9.5	<1	138	40	68	32	8.1	2.5	1.8	4.8	0.74	23.44
MD037	4.4	<1	242	35	57	35	7.2	2.3	1.5	3.9	0.65	29.45
MD038	13	<1	123	36	56	33	6.1	2.1	1.3	4.3	0.66	28.11
MD039	4	<1	205	30	49	28	5.6	1.7	1.2	3.4	0.51	26.58
MD040	3.4	<1	196	30	50	28	5.2	1.6	<0.5	2.8	0.49	31.89
MD041	2	<1	205	32	51	24	5.5	1.7	<0.5	3.1	0.5	26.95
MD042	3.4	<1	261	29	48	27	6.3	2	<0.5	3.7	0.53	30.77
MD043	3.1	<1	209	33	55	27	6.6	2.1	1.3	3.6	0.54	30.97
MD044	3.3	<1	316	29	48	24	6.6	2.3	1.6	3.7	0.55	29.83
MD045	2.9	<1	269	23	38	20	4.8	1.4	1.1	2.8	0.44	21
MD046	2.4	<1	118	15	22	15	3	1	<0.5	1.8	0.31	33.47
MD047	3.5	<1	406	34	55	36	8.7	2.8	2.3	4.8	0.69	29.09
MD048	2.1	<1	172	20	36	19	4.3	1.4	0.9	2.3	0.38	35.65
MD049	4.9	<1	343	26	39	27	6.5	2	1.5	3.9	0.57	29.12
MD050	5.4	<1	373	29	46	26	7.7	2.5	2	4.6	0.61	36.02
MD051	5.5	<1	428	33	49	33	8.7	2.8	2	5.1	0.68	33.38
MD052	3.8	<1	393	31	48	33	8	2.7	1.9	4.6	0.64	34
MD053	6.1	<1	428	34	56	29	9.1	3.1	2.1	5.1	0.77	30.48
MD054	7.6	<1	539	38	59	27	11	3.2	2.2	5.7	0.72	28.73
MD055	4.7	<1	606	33	52	28	9.8	3	2.1	5.5	0.59	32.04
MD056	6.4	<1	536	34	55	29	9.5	2.8	2.1	5.1	0.69	30.89
MD057	7.2	<1	576	38	59	33	11	3.1	2.1	5.5	0.59	31.21
MD058	4.7	7	475	36	58	29	9.2	2.6	2	5.3	0.65	27.22
MD059	6.8	9	640	36	59	30	10	3.2	2.5	5.7	0.73	27.92
MD060	6.6	6	536	31	48	30	9.7	2.8	2	5.6	0.68	28.36
MD061	7.3	6	593	31	47	27	9.9	3	2.3	5.5	0.72	33.48
MD062	3.6	<1	206	46	81	30	6.2	1.5	0.9	4.4	0.54	24.31
MD063	3.7	<1	221	45	78	28	6.2	1.6	1	4	0.55	22.96
MD064	4.7	<1	192	45	77	29	6.2	1.5	1	4.1	0.49	23.89
MD065	2.4	<1	176	34	59	28	6.6	1.8	1	3.5	0.16	28.76
MD066	3.9	<1	422	31	55	27	8.2	2.4	1.8	4.4	0.5	30.47
MD067	5.1	<1	433	27	44	21	7.3	2.2	1.5	4.2	0.5	31.37
MD068	6.5	<1	563	32	50	25	9.5	2.9	2.3	5.6	0.66	31.92
MD069	10	8	614	34	53	29	11	3.3	2.4	6.1	0.8	32.3
MD070	11	6	614	37	58	28	12	3.6	2.2	6.5	0.85	27.79
MD071	12	<1	250	53	63	36	10	3	2	4.5	0.4	37.84
MD072	2.6	<1	110	31	55	24	5	1.4	0.9	3.3	0.43	25.8
MD073	4.5	<1	464	31	53	22	8.5	2.5	1.9	5	0.58	30.77
MD074	5.4	5	574	35	55	31	10	3.1	2.3	5.8	0.73	32.12
MD075	6.4	4	559	39	63	31	11	3.3	2.2	5.9	0.78	30.74
MD076	7.5	<1	575	52	83	45	14	4.4	3.6	7.9	0.96	33.88
MD077	6.5	<1	278	33	57	26	5.7	1.5	0.9	3.4	0.46	24.6
MD078	4	<1	127	34	58	22	4.4	1.1	<0.5	3.3	0.43	26.71
MD079	3.7	<1	168	40	68	27	5.5	1.4	0.7	3.8	0.47	23.86
MD080	4.2	2	164	42	72	27	5.7	1.4	<0.5	3.7	0.49	25.13
MD081	3.7	<1	154	40	71	28	5.6	1.3	0.7	3.8	0.42	24.85
MD082	3.6	<1	88	38	67	26	5.3	1.4	0.8	3.5	0.4	24.78
MD083	4.2	3	148	42	74	26	5.7	1.4	0.8	3.5	0.45	24.32
MD084	4	<1	133	43	74	30	5.7	1.4	<0.5	3.6	0.46	25.72
MD085	4.6	2	136	44	74	32	5.9	1.4	<0.5	4	0.5	24.81
MD086	3.7	<1	222	39	66	27	5.9	1.5	1	3.5	0.36	26.01
MD087	6.4	<1	141	40	69	35	6.1	1.5	1.1	3.9	0.32	24.62
MD088	3.9	<1	227	33	57	27	6.3	1.6	1.1	3	0.37	28.73
MD089	7.4	<1	648	34	56	28	10	3	2.4	5.9	0.66	33.12
MD090	4.9	<1	566	34	57	31	10	2.9	2.5	5.5	0.64	30.18
MD091	8	<1	532	39	59	23	11	3.3	2.7	6.2	0.69	34.3
MD092	20	<1	421	66	83	39	14	4.1	2.8	6.8	0.59	29.7
MD093	7.5	11	507	41	66	37	11	3.2	2.7	6	0.64	33.59

Sample Description	MO PPM	CU PPM	PB PPM	ZN PPM	AG PPM	NI PPM	MN PPM	SR PPM	CD PPM	BI PPM	V PPM	CA %	P %	MG %	TI %	AL %	K %	Y PPM	BE PPM
AS001	5	17	38	443	<0.4	93	1145	161	<0.5	<5	1069	2.09	0.522	1.04	0.1	3.27	0.47	73	2
AS002	4	13	37	388	<0.4	81	1413	191	<0.5	<5	929	2.74	0.693	1.06	0.09	3.08	0.47	71	<2
AS003	7	10	44	446	0.5	81	908	153	<0.5	10	1205	1.34	0.446	0.86	0.09	3.33	0.45	79	<2
AS004	6	10	44	452	0.5	88	1146	216	<0.5	<5	994	2.52	0.793	0.86	0.1	3.22	0.45	76	<2
AS005	92	8	41	795	0.7	215	1370	247	<0.5	<5	1145	2.32	0.544	0.96	0.08	2.92	0.32	80	2
AS006	8	9	36	438	0.6	91	1384	165	<0.5	<5	1102	1.72	0.571	0.74	0.1	3.35	0.44	77	2
AS007	7	16	43	477	0.4	118	1198	243	<0.5	<5	956	3.25	1.133	0.7	0.11	3.55	0.53	68	<2
AS008	9	26	36	467	<0.4	101	1088	162	<0.5	<5	1118	1.43	0.578	0.56	0.09	2.89	0.35	80	<2
AS009	10	8	37	521	<0.4	86	1011	174	<0.5	5	1144	1.42	0.637	0.52	0.08	2.94	0.35	82	<2
AS010	11	8	41	467	<0.4	90	853	168	<0.5	<5	1190	1.28	0.6	0.52	0.08	2.9	0.33	85	<2
AS011	11	7	37	493	<0.4	83	981	170	<0.5	<5	1251	1.14	0.579	0.48	0.08	2.9	0.32	86	<2
AS012	12	5	42	509	0.6	90	1049	148	<0.5	6	1296	0.92	0.534	0.47	0.07	2.66	0.26	84	<2
AS013	11	8	39	494	0.7	81	918	149	<0.5	<5	1249	1.04	0.551	0.48	0.08	2.9	0.33	79	<2
AS014	12	6	44	495	<0.4	93	872	188	<0.5	<5	1247	1.34	0.65	0.49	0.08	2.94	0.35	92	<2
AS015	11	6	36	497	0.8	92	815	174	<0.5	<5	1292	1.28	0.661	0.48	0.07	2.8	0.31	91	2
AS016	12	6	40	513	<0.4	100	842	156	<0.5	<5	1301	1.2	0.632	0.49	0.08	2.83	0.29	85	<2
AS017	11	6	41	512	0.8	94	969	203	<0.5	6	1248	1.7	0.771	0.49	0.07	2.74	0.3	92	<2
AS018	11	8	41	538	0.8	106	770	156	<0.5	6	1344	1.06	0.573	0.52	0.09	3.18	0.36	82	<2
AS019	11	5	39	506	<0.4	98	1010	151	<0.5	8	1285	0.97	0.543	0.47	0.07	2.7	0.28	86	<2
AS020	12	6	41	506	<0.4	101	1001	158	<0.5	<5	1286	1.08	0.577	0.47	0.07	2.69	0.27	88	<2
AS021	12	6	41	513	0.7	93	825	164	<0.5	5	1345	1.22	0.639	0.49	0.08	2.83	0.28	89	2
AS022	11	7	41	528	0.7	97	945	180	<0.5	<5	1286	1.6	0.743	0.52	0.08	2.87	0.32	91	<2
AS023	12	5	47	524	<0.4	94	978	174	<0.5	<5	1326	1.54	0.743	0.49	0.07	2.75	0.29	100	<2
AS024	11	8	41	504	0.7	92	798	205	0.5	<5	1239	1.9	0.837	0.54	0.09	3.03	0.39	98	2
AS025	11	8	40	487	0.5	100	753	167	<0.5	<5	1289	1.46	0.685	0.57	0.1	3.3	0.43	94	<2
AS026	12	7	46	505	1	97	1011	162	0.7	<5	1341	1.7	0.772	0.51	0.08	2.85	0.35	103	2
AS027	11	5	41	554	0.7	91	1249	168	<0.5	<5	1300	1.85	0.768	0.46	0.06	2.54	0.3	100	2
AS028	11	7	44	509	0.6	87	1032	192	<0.5	<5	1252	2.32	0.895	0.45	0.08	2.86	0.36	106	<2
AW001	5	14	19	52	<0.4	13	84	123	<0.5	<5	356	0.29	0.043	0.41	0.25	4.76	1.2	12	<2
AW002	4	9	26	27	0.6	7	38	182	<0.5	<5	332	0.26	0.066	0.35	0.2	3.77	1.35	11	<2
AW003	<2	14	32	337	<0.4	66	1371	86	<0.5	<5	744	0.83	0.228	0.75	0.16	4.42	0.94	62	2
AW004	5	9	29	346	<0.4	55	1095	120	<0.5	<5	848	1.69	0.462	0.94	0.11	3.31	0.66	60	2
AW005	15	13	48	470	<0.4	83	1057	158	<0.5	6	1151	2.42	0.684	0.67	0.16	4.82	0.94	90	2
AW006	3	11	46	559	0.6	94	935	151	<0.5	<5	1321	2.1	0.867	0.75	0.13	4.13	0.72	107	2
AW007	6	10	46	648	0.6	74	1101	99	<0.5	11	1295	1.49	0.86	0.47	0.1	3.38	0.55	106	3
AW008	10	8	49	547	<0.4	89	1334	108	<0.5	14	1550	1.32	0.656	0.44	0.07	2.77	0.3	97	3
AW009	<2	9	14	337	<0.4	60	754	699	<0.5	<5	311	12.46	4.599	0.32	0.07	1.89	0.54	128	2
AW010	<2	10	18	353	<0.4	53	908	623	<0.5	<5	397	11.1	4.033	0.36	0.08	2.05	0.58	132	2
AW011	<2	10	22	270	<0.4	67	577	109	<0.5	<5	620	1.43	0.448	0.49	0.1	2.77	0.69	44	<2
AW012	3	14	33	564	<0.4	76	653	313	<0.5	<5	933	5.2	1.889	0.44	0.11	3.35	0.74	126	3
AW013	6	16	41	417	0.4	85	1182	80	<0.5	12	1238	0.86	0.553	0.52	0.13	3.82	0.73	88	3
CS001	9	9	7	73	<0.4	39	664	224	<0.5	<5	316	8.74	0.365	1.15	0.08	1.94	0.56	37	<2
CS002	14	8	9	100	0.4	52	792	379	<0.5	<5	216	17.44	0.446	0.65	0.07	1.6	0.43	25	<2
CS003	16	5	22	176	<0.4	57	1772	239	0.5	8	580	4.96	0.949	1.08	0.06	1.92	0.39	62	<2
CS004	264	20	<5	2	<0.4	9	5	10	<0.5	9	51	0.06	0.008	0.01	0.02	0.17	0.05	4	<2
MW001	13	9	44	560	<0.4	90	736	100	<0.5	17	1633	1.08	0.545	0.48	0.08	3	0.31	85	2
MD001	<2	26	20	116	0.4	39	99	132	<0.5	<5	234	0.41	0.075	0.73	0.35	7.17	2.06	26	<2
MD002	3	20	15	74	<0.4	22	588	181	<0.5	<5	254	3.22	0.215	0.49	0.3	6.11	1.8	20	<2
MD003	<2	32	19	131	0.7	41	141	130	<0.5	<5	223	0.4	0.083	0.8	0.4	7.76	2.27	29	<2
MD004	<2	26	17	142	0.5	46	120	145	<0.5	<5	249	0.47	0.072	0.8	0.36	7.56	2.17	29	<2
MD005	2	29	22	166	0.6	54	133	185	<0.5	<5	258	0.56	0.083	0.82	0.37	7.8	2.2	32	<2
MD006	3	19	19	59	0.7	19	121	189	<0.5	<5	254	2.14	0.104	0.39	0.24	5.02	1.56	16	<2
MD007	<2	18	21	84	0.5	19	90	178	<0.5	<5	319	0.3	0.093	0.44	0.21	4.84	1.43	16	<2
MD008	9	13	26	269	0.7	64	589	168	<0.5	<5	572	3.42	0.199	0.66	0.16	3.84	0.97	38	2
MD009	9	13	30	294	<0.4	61	911	192	<0.5	7	741	3.92	0.395	0.77	0.13	3.54	0.74	50	<2

Sample Description	MO PPM	CU PPM	PB PPM	ZN PPM	AG PPM	NI PPM	MN PPM	SR PPM	CD PPM	BI PPM	V PPM	CA %	P %	MG %	TI %	AL %	K %	Y PPM	BE PPM
MD010	9	13	33	298	<0.4	62	965	206	<0.5	<5	735	4.84	0.381	0.76	0.13	3.64	0.76	49	2
MD011	2	18	28	338	0.4	74	989	211	<0.5	<5	795	5.45	0.602	0.66	0.19	5.01	0.96	60	2
MD012	<2	34	16	104	0.6	41	393	132	<0.5	<5	173	1.1	0.062	0.72	0.36	7.59	1.36	28	<2
MD013	2	29	18	122	0.7	43	120	136	<0.5	<5	247	0.6	0.067	0.79	0.36	7.46	2.15	28	<2
MD014	3	28	21	125	0.5	44	104	129	<0.5	<5	242	0.5	0.07	0.79	0.35	7.51	2.12	29	<2
MD015	2	29	18	123	0.4	44	135	135	<0.5	<5	247	0.72	0.069	0.8	0.37	7.54	2.18	29	<2
MD016	<2	26	17	128	0.8	43	101	127	<0.5	<5	259	0.36	0.076	0.85	0.37	7.78	2.23	29	<2
MD017	7	18	22	192	<0.4	41	342	115	<0.5	<5	451	1.31	0.16	0.65	0.19	4.6	1.25	34	<2
MD018	10	12	29	320	<0.4	60	814	216	<0.5	<5	797	4.52	0.42	0.93	0.13	3.65	0.78	55	<2
MD019	12	12	33	340	<0.4	66	906	243	<0.5	<5	860	4.67	0.481	0.88	0.13	3.68	0.75	56	<2
MD020	13	13	35	351	0.4	67	891	195	<0.5	<5	880	3.38	0.363	0.9	0.15	4.06	0.81	56	<2
MD021	5	15	34	451	<0.4	88	943	197	<0.5	<5	1070	4.06	0.551	0.81	0.16	4.47	0.79	72	<2
MD022	<2	22	15	109	0.7	36	109	135	<0.5	<5	226	0.46	0.07	0.65	0.31	6.66	1.86	24	<2
MD023	2	30	16	122	<0.4	45	126	132	<0.5	<5	242	0.68	0.073	0.75	0.34	7.34	2.07	26	<2
MD024	6	17	21	133	0.4	33	151	145	<0.5	<5	310	1.79	0.475	0.5	0.21	4.79	1.45	31	<2
MD025	4	16	24	173	0.4	41	338	99	<0.5	<5	401	1.01	0.166	0.61	0.18	4.21	1.18	31	<2
MD026	7	16	32	222	<0.4	46	620	106	<0.5	<5	520	1.32	0.26	0.56	0.17	4.15	1.09	41	<2
MD027	14	17	41	396	<0.4	80	784	124	<0.5	<5	924	1.79	0.436	0.71	0.19	5.03	1.04	66	<2
MD028	<2	28	15	127	<0.4	42	103	125	<0.5	<5	258	0.34	0.069	0.83	0.38	7.72	2.23	26	<2
MD029	2	26	17	136	0.7	43	198	130	<0.5	<5	267	1.49	0.093	0.81	0.36	7.36	2.1	30	<2
MD030	2	26	17	130	<0.4	41	180	126	<0.5	<5	256	1.54	0.091	0.79	0.33	7.12	2.01	26	<2
MD031	10	38	12	113	0.4	51	272	105	<0.5	<5	253	0.52	0.077	0.71	0.31	6.65	1.89	28	<2
MD032	5	18	19	148	<0.4	36	421	174	<0.5	<5	329	3.85	0.444	0.6	0.21	4.74	1.38	34	<2
MD033	6	22	18	146	<0.4	40	162	118	<0.5	<5	305	0.94	0.223	0.59	0.25	5.5	1.61	28	<2
MD034	2	14	18	119	0.4	25	1002	144	<0.5	<5	252	7.02	0.121	0.53	0.16	3.6	1.13	26	<2
MD035	2	21	14	111	<0.4	32	238	118	<0.5	<5	285	1.66	0.203	0.49	0.2	4.43	1.3	25	<2
MD036	<2	13	17	125	0.6	27	1089	260	<0.5	<5	259	8.33	0.845	0.55	0.16	3.69	1.07	64	<2
MD037	8	16	25	240	<0.4	51	963	202	<0.5	<5	569	5.26	0.446	0.73	0.17	4.03	1	52	<2
MD038	2	12	18	109	<0.4	28	1782	992	<0.5	<5	200	15.49	1.699	0.54	0.13	2.82	0.82	66	<2
MD039	4	16	21	168	<0.4	37	828	165	<0.5	<5	377	4.66	0.258	0.62	0.17	4.02	1.1	37	<2
MD040	4	16	19	163	<0.4	38	456	140	<0.5	<5	377	2.77	0.206	0.62	0.18	4.32	1.21	34	<2
MD041	4	16	25	181	<0.4	34	768	124	<0.5	<5	436	3.11	0.185	0.55	0.18	4.35	1.18	32	<2
MD042	12	13	31	264	<0.4	53	843	173	<0.5	<5	634	4.06	0.333	0.71	0.15	3.87	0.96	48	<2
MD043	16	12	20	201	<0.4	47	1013	164	<0.5	<5	475	5.52	0.416	0.68	0.15	3.48	0.9	46	<2
MD044	12	11	38	304	<0.4	58	830	203	<0.5	<5	732	3.82	0.315	0.85	0.14	3.74	0.84	50	<2
MD045	4	10	21	220	<0.4	41	744	234	<0.5	<5	579	3.62	0.094	0.73	0.12	3.31	0.82	31	<2
MD046	10	8	23	152	<0.4	36	1204	233	0.6	<5	479	3.97	0.121	0.78	0.09	2.39	0.6	25	<2
MD047	25	12	50	415	<0.4	69	647	249	<0.5	<5	958	3.85	0.45	0.99	0.14	3.88	0.84	67	<2
MD048	5	6	24	193	<0.4	43	1159	138	<0.5	<5	566	2.6	0.309	1.16	0.1	2.71	0.61	36	<2
MD049	10	8	35	365	<0.4	67	911	201	<0.5	<5	885	3.77	0.427	1.09	0.11	3.32	0.65	58	<2
MD050	13	13	39	464	<0.4	80	968	197	<0.5	<5	1127	3.79	0.499	0.98	0.13	4.06	0.72	73	<2
MD051	13	12	45	464	<0.4	79	980	206	<0.5	<5	1114	4.07	0.516	0.94	0.13	4.03	0.73	74	<2
MD052	4	13	46	433	<0.4	78	857	212	<0.5	<5	1067	5.17	0.499	0.73	0.14	4.06	0.7	70	<2
MD053	15	10	38	485	0.4	84	1275	212	<0.5	<5	1182	3.97	0.638	1.14	0.12	3.78	0.67	80	<2
MD054	9	14	45	455	<0.4	79	931	226	<0.5	<5	1083	4.25	0.652	0.77	0.14	4.16	0.73	80	<2
MD055	3	9	49	483	<0.4	81	946	215	<0.5	<5	1182	6.08	0.501	0.76	0.11	3.49	0.56	74	<2
MD056	6	13	52	461	<0.4	74	713	190	<0.5	<5	1097	2.7	0.559	0.64	0.15	4.32	0.76	78	<2
MD057	4	10	49	508	<0.4	83	704	252	<0.5	<5	1095	4.09	0.832	0.7	0.12	3.75	0.66	83	<2
MD058	5	17	46	375	<0.4	72	653	164	<0.5	<5	982	2.35	0.477	0.62	0.17	4.66	0.91	72	2
MD059	7	10	51	469	<0.4	71	809	167	<0.5	<5	1179	2.45	0.602	0.54	0.13	3.81	0.61	82	<2
MD060	8	10	47	457	<0.4	76	853	170	<0.5	<5	1230	2.53	0.562	0.54	0.12	3.7	0.58	83	<2
MD061	9	5	54	521	<0.4	79	875	164	<0.5	<5	1412	2.4	0.627	0.51	0.09	3.11	0.41	88	<2
MD062	2	31	20	136	<0.4	47	162	128	<0.5	<5	280	0.56	0.096	0.82	0.36	7.49	2.14	30	<2
MD063	2	29	22	135	<0.4	44	137	123	<0.5	5	270	0.66	0.093	0.8	0.35	7.43	2.08	30	<2
MD064	3	33	23	134	<0.4	45	190	125	<0.5	<5	269	1.42	0.106	0.78	0.33	7.06	1.97	29	<2

Sample Description	MO PPM	CU PPM	PB PPM	ZN PPM	AG PPM	NI PPM	MN PPM	SR PPM	CD PPM	BI PPM	V PPM	CA %	P %	MG %	TI %	AL %	K %	Y PPM	BE PPM
MD065	<2	12	17	114	0.6	27	942	221	<0.5	<5	239	12.66	0.481	0.76	0.14	2.98	0.86	41	<2
MD066	8	9	43	332	<0.4	68	827	212	<0.5	<5	834	3.78	0.497	1.18	0.12	3.43	0.73	60	<2
MD067	11	8	39	350	<0.4	73	1039	168	<0.5	<5	896	3.25	0.492	1.18	0.11	3.18	0.63	59	<2
MD068	7	6	52	538	<0.4	79	795	206	<0.5	<5	1306	3.22	0.661	0.6	0.1	3.43	0.53	89	<2
MD069	10	7	59	521	<0.4	102	1661	138	<0.5	<5	1540	1.73	0.708	0.5	0.09	3.31	0.43	96	<2
MD070	10	7	57	511	<0.4	93	1346	141	<0.5	<5	1550	1.8	0.741	0.49	0.09	3.24	0.4	100	<2
MD071	2	9	26	261	<0.4	46	723	504	<0.5	<5	522	9.56	2.859	0.33	0.09	2.35	0.62	113	<2
MD072	2	35	15	102	<0.4	39	270	123	0.5	5	181	0.82	0.083	0.71	0.35	7.44	1.45	28	<2
MD073	10	10	46	405	<0.4	71	840	208	<0.5	<5	974	3.86	0.467	1.26	0.13	3.67	0.75	70	<2
MD074	6	8	55	518	<0.4	81	787	173	<0.5	<5	1275	2.8	0.67	0.81	0.11	3.55	0.57	86	<2
MD075	5	11	47	490	<0.4	110	1050	181	<0.5	<5	1213	2.99	0.651	0.5	0.13	3.77	0.69	88	<2
MD076	5	12	52	565	<0.4	147	1325	233	0.5	<5	1199	3.79	0.962	0.51	0.13	3.86	0.71	152	2
MD077	4	35	34	223	<0.4	57	187	97	<0.5	9	535	0.47	0.129	0.56	0.25	6.23	1.48	26	2
MD078	2	32	22	103	<0.4	28	117	124	<0.5	<5	234	0.61	0.07	0.71	0.36	7.43	1.77	20	<2
MD079	2	27	16	128	<0.4	44	116	144	<0.5	<5	245	0.4	0.076	0.73	0.35	7.3	2.09	28	<2
MD080	<2	26	22	124	0.7	40	107	144	<0.5	<5	243	0.44	0.077	0.72	0.35	7.25	2.08	29	<2
MD081	<2	23	18	106	<0.4	35	116	144	<0.5	<5	205	1.19	0.071	0.63	0.3	6.37	1.82	24	<2
MD082	<2	24	16	115	0.5	36	87	140	<0.5	<5	224	0.38	0.073	0.67	0.32	6.71	1.93	26	<2
MD083	<2	26	19	126	0.6	42	122	135	<0.5	<5	264	0.37	0.066	0.76	0.34	7.12	2.05	26	<2
MD084	<2	27	22	121	<0.4	41	107	141	<0.5	<5	247	0.71	0.069	0.76	0.34	7.1	2.06	28	<2
MD085	2	26	22	126	<0.4	42	121	126	<0.5	<5	255	0.49	0.083	0.83	0.35	7.27	2.12	26	<2
MD086	6	24	22	159	<0.4	44	300	166	<0.5	<5	343	3.29	0.148	0.83	0.3	6.45	1.84	34	<2
MD087	4	24	22	126	<0.4	39	519	233	<0.5	<5	255	8.96	0.136	0.85	0.29	6.26	1.79	31	<2
MD088	2	15	24	164	<0.4	38	265	105	<0.5	<5	396	1.48	0.139	0.68	0.18	4.3	1.24	28	<2
MD089	9	9	58	476	0.5	79	936	197	<0.5	<5	1157	4.92	0.594	1.43	0.12	3.57	0.63	78	<2
MD090	7	10	45	469	0.4	76	964	185	<0.5	<5	1140	5.18	0.606	1.43	0.12	3.82	0.62	79	<2
MD091	8	8	41	490	<0.4	84	877	213	<0.5	<5	1323	3.13	0.946	0.7	0.11	3.48	0.52	97	<2
MD092	4	8	32	331	<0.4	56	782	525	<0.5	<5	717	9.88	3.054	0.49	0.1	2.93	0.61	113	2
MD093	5	11	41	428	<0.4	89	842	206	<0.5	<5	1143	4.02	0.832	0.63	0.13	3.78	0.69	90	<2

Actlabs PGE Job #: 14551

Sample ID:

Report#: 14446**Client: Apex Geoscience Ltd.****Contact: R.A. Olson**

	Pd ppb	Pt ppb	Au ppb
as001	5.1	0.5	1
as002	2.4	0.3	-1
as003	1.6	0.3	1
as004	1.9	0.2	-1
as005	1.2	0.2	1
as006	1.1	0.2	-1
as007	3.9	0.2	-1
as008	3.4	0.3	-1
as009	0.6	0.3	-1
as010	0.4	0.2	-1
as011	0.5	0.1	1
as012	0.3	0.1	-1
as013	0.4	0.2	-1
as014	0.7	0.1	-1
as015	2.7	0.3	-1
as016	0.8	0.1	11
as017	0.4	0.1	-1
as018	0.2	0.1	-1
as019	0.3	0.1	3
as020	0.7	0.1	-1
as021	-0.1	-0.1	-1
as022	0.6	0.1	-1
as023	0.3	-0.1	5
as024	0.4	-0.1	-1
as025	0.4	0.1	1
as026	0.3	0.2	2
as027	0.4	-0.1	-1
as028	0.2	-0.1	1
aw001	0.8	0.2	2
aw002	0.6	0.1	-1
aw003	0.6	0.2	-1
aw004	0.5	0.1	1
aw005	0.7	0.2	1
aw006	0.5	0.2	-1
aw007	0.3	0.1	-1
aw008	0.3	-0.1	-1
aw009	0.5	0.2	-1
aw010	0.5	0.1	-1
aw011	0.3	0.2	1
aw012	0.4	0.1	-1
aw013	0.3	0.1	-1
cs-001	0.4	0.1	-1
cs-002	0.5	0.3	-1
cs-003	0.7	0.2	-1
cs-004	0.5	0.4	31
mw001	0.3	0.1	-1
md004	0.8	0.3	-1
md005	0.9	0.4	7
md006	0.6	0.2	-1
md007	0.5	0.2	-1
md008	0.4	0.1	-1

Actlabs PGE Job #: 14551

Sample ID:

Report#: 14446**Client: Apex Geoscience Ltd.****Contact: R.A. Olson**

Pd ppb Pt ppb Au ppb

md009	0.6	0.1	-1
md010	0.4	0.2	-1
md011	0.5	0.2	-1
md012	0.9	0.5	2
md022	0.8	0.3	1
md023	1.9	0.4	1
md024	0.6	0.2	2
md025	0.4	0.2	-1
md026	0.6	0.2	3
md027	0.5	0.3	-1
md028	0.7	0.6	-1
md029	0.8	0.3	-1
md030	0.8	0.3	1
md031	1	0.7	-1
md032	0.7	0.3	-1
md033	0.8	0.3	4
md034	0.4	0.2	12
md035	0.5	0.3	5
md036	0.4	0.2	4
md037	0.5	0.2	3
md038	0.4	0.1	5
md039	0.5	0.2	4
md040	0.5	0.3	5
md041	0.4	0.2	14
md042	0.4	0.2	3
md043	0.4	0.2	20
md044	0.4	0.2	4
md045	0.3	0.1	3
md046	0.7	63	8
md047	0.3	0.2	3
md048	0.4	0.1	13
md049	0.4	0.1	4
md050	0.3	0.2	13
md051	0.3	0.2	10
md052	0.3	0.2	8
md053	0.3	0.2	8
md054	0.4	0.2	36
md055	0.4	0.1	5
md056	0.4	0.2	2
md057	0.4	0.2	2
md058	0.5	0.3	4
md059	0.3	0.2	3
md060	0.3	0.2	2
md061	0.2	0.1	2
md073	0.3	0.1	4
md074	0.3	0.1	3
md075	0.3	0.2	4
md079	0.9	0.4	3
md080	1.1	0.5	3
md081	0.7	0.3	4
md082	0.7	0.3	3

Actlabs PGE Job #: 14551

Sample ID:

md083
md084
md085
md086
md087
md088
md089
md090
md091
md092
md093

Report#: 14446

Pd ppb Pt ppb

Client: Apex Geoscience Ltd.

Au ppb

Contact: R.A. Olson

0.7	0.3	4
0.7	0.3	6
0.7	0.3	4
0.7	0.3	5
0.9	0.3	-1
0.4	0.2	4
0.2	0.1	2
0.3	0.2	3
0.6	0.2	2
0.3	0.1	1
0.3	0.1	-1

Certified By:



D. D'Anna, Dipl. T.
ICPMS Technical Manager, Actlabs Ltd.

Date: 18 Dec 97

This report shall not be reproduced except in full without the written approval of the laboratory.
Unless otherwise instructed, samples will be disposed of 90 days from the date of this report.

ACTLABS

ACTIVATION LABORATORIES LTD

Invoice No.: 14559
Work Order: 14626
Invoice Date: 05-JAN-98
Date Submitted: 10-DEC-97
Your Reference: NONE
Account Number: 1454

APEX GEOSCIENCE LTD.
SUITE 200, 9797 - 45 AVE.
EDMONTON, ALBERTA
T6E 5V8

ATTN: CHRIS BUCHANAN

CERTIFICATE OF ANALYSIS

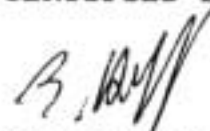
1 ROCK(S) (PREP.REV1) were submitted for analysis.

The following analytical packages were requested. Please see
our current fee schedule for elements and detection limits.

REPORT 14559 CODE 1H INAA(INAA.REV1)
REPORT 14559 B TOTAL DIGESTION ICP/CODE 1C-FIRE ASSAY ICP

This report may only be reproduced in its entirety without the express
consent of ACTIVATION LABS. If no instructions were received or will be
received within 90 days from the date of this report, excess material
will be discarded. Our liability is limited solely to the analytical
cost of these analyses. Test results are representative only of material
submitted for analysis.

CERTIFIED BY :



DR E. HOFFMAN / GENERAL MANAGER

Sample Description	AU PPB	AG PPM	AS PPM	BA PPM	BR PPM	CA %	CO PPM	CR PPM	CS PPM	FE %	HF PPM	HG PPM	IR PPB	MO PPM	NA %	NI PPM	RB PPM	SB PPM	SC PPM	SE PPM	SN %	SR %	TA PPM	TH PPM
CS-005	3	<5	59	590	<0.5	15	39	35	1	10.1	2	<1	<5	16	0.12	<20	29	2.1	5.1	<3	<0.01	<0.05	<0.5	3.3

Sample Description	U PPM	W PPM	ZN PPM	LA PPM	CE PPM	ND PPM	SM PPM	EU PPM	TB PPM	YB PPM	LU PPM	Mass g
CS<005	2.7	<1	106	28	36	15	4.7	1.6	1.2	1.5	0.24	38.51

Sample Description	MO PPM	CU PPM	PB PPM	ZN PPM	AG PPM	NI PPM	MN PPM	SR PPM	CD PPM	BI PPM	V PPM	CA %	P %	MG %	TI %	AL %	K %	Y PPM	BE PPM	AU PPB	PT PPB	PD PPB
CS-005	15	6	12	107	<0.4	52	888	387	<0.5	<5	230	16.54	0.744	0.8	0.07	1.62	0.46	34	<2	<2	<5	<4

ACTLABS

ACTIVATION LABORATORIES LTD

Invoice No.: 14846
Work Order: 14954
Invoice Date: 17-FEB-98
Date Submitted: 30-JAN-98
Your Reference: 97213
Account Number: 1454

APEX GEOSCIENCE LTD.
SUITE 200, 9797 - 45 AVE.
EDMONTON, ALBERTA
T6E 5V8

ATTN: CHRIS BUCHANAN

CERTIFICATE OF ANALYSIS

11 ROCKS(PREP.REV1) were submitted for analysis.

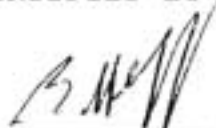
The following analytical packages were requested. Please see our current fee schedule for elements and detection limits.

REPORT 14846 CODE 1H INAA(INAA.REV1)
REPORT 14846 B TOTAL DIGESTION ICP

REPORT 14846 RPT.XLS CODE 1CRES-FIRE ASSAY ICP/MS

This report may only be reproduced in its entirety without the express consent of ACTIVATION LABS. If no instructions were received or will be received within 90 days from the date of this report, excess material will be discarded. Our liability is limited solely to the analytical cost of these analyses. Test results are representative only of material submitted for analysis.

CERTIFIED BY :



DR E.HOFFMAN/GENERAL MANAGER

Sample Description	AU PPB	AG PPM	AS PPM	BA PPM	BR PPM	CA %	CO PPM	CR PPM	CS PPM	FE %	HF PPM	HG PPM	IR PPB	MO PPM	NA %	NI PPM	RB PPM	SB PPM	SC PPM	SE PPM	SN %	SR %	TA PPM	TH PPM
BW001	<2	<5	72	1200	<0.5	2	2	82	5	2.98	6	<1	<5	8	0.33	<20	72	2.4	9	<3	<0.01	<0.05	<0.5	9.6
BW002	160	<5	100	750	1	<1	3	67	3	12.6	6	<1	<5	5	0.44	<20	66	3.4	5.5	<3	<0.01	<0.05	<0.5	5.5
BW003	<2	<5	55	640	<0.5	7	37	110	2	25.6	2	<1	<5	15	0.07	64	47	4.6	12	<3	<0.01	<0.05	<0.5	11
BW004	3	<5	54	700	1.6	<1	46	120	3	25.9	2	<1	<5	11	0.06	85	52	4.1	13	<3	<0.01	<0.05	<0.5	11
BW005	<2	<5	57	460	<0.5	2	20	70	2	32.3	2	<1	<5	7	0.08	<25	<15	2.4	8.7	<3	<0.01	<0.05	<0.5	6
BW006	<2	<5	60	440	<0.5	2	24	82	2	31.1	2	<1	<5	16	0.08	<24	<15	3.4	10	<3	<0.01	<0.05	<0.5	8.2
BW007	3	<5	260	590	1.9	2	37	150	<1	32.1	1	<1	<5	6	0.05	95	<15	7.3	14	<3	<0.01	<0.05	<0.5	12
BW008	<2	<5	240	570	2.9	<1	43	130	2	34.7	1	<1	<5	9	0.05	96	28	7.4	12	<3	<0.01	<0.05	<0.5	11
BW009	3	<5	220	650	2.5	<1	72	150	2	34.9	1	<1	<5	6	0.06	88	46	8.3	15	<3	<0.02	<0.05	<0.5	13
BW010	3	<5	72	840	0.9	8	35	62	1	17.6	3	<1	<5	10	0.15	110	35	2.7	7.4	<3	<0.01	<0.05	<0.5	6.8
BW011	<2	<5	230	590	4	<1	40	170	2	30.8	2	<1	<5	7	0.06	86	49	7.6	13	<3	<0.01	<0.05	<0.5	14

Sample Description	U PPM	W PPM	ZN PPM	LA PPM	CE PPM	ND PPM	SM PPM	EU PPM	TB PPM	YB PPM	LU PPM	Mass g
BW001	1.5	<1	<50	39	62	21	3.2	0.8	0.6	2	0.3	23.95
BW002	1	<1	52	25	40	12	1.9	0.5	<0.5	1.1	0.23	25.95
BW003	3.7	<1	323	27	41	27	6.4	2.1	1.4	3.6	0.56	29.07
BW004	5	2	334	35	54	34	8.6	2.9	2	4.7	0.69	29.78
BW005	2.1	<1	174	23	37	23	5	1.6	1.2	2.8	0.41	29.97
BW006	1.8	<1	211	24	40	20	5.8	1.9	1.3	3.3	0.49	30.94
BW007	5.5	5	466	38	59	40	11	3.7	2.7	6.4	0.92	34.34
BW008	5.6	5	422	39	56	37	11	3.4	2.2	5.8	0.87	32.12
BW009	6.3	5	589	41	67	36	13	4.2	3.2	7	1.01	29.72
BW010	13	<1	337	49	58	36	9.3	3	2.1	4.7	0.63	33.65
BW011	3.5	4	392	34	55	31	9.6	3.2	2.2	5.2	0.73	31.35

Sample Description	AU PPB	AG PPM	AS PPM	BA PPM	BR PPM	CA %	CO PPM	CR PPM	CS PPM	FE %	HF PPM	HG PPM	IR PPB	MO PPM	NA %	NI PPM	RB PPM	SB PPM	SC PPM	SE PPM
Sample Description	MO PPM	CU PPM	PB PPM	ZN PPM	AG PPM	NI PPM	MN PPM	SR PPM	CD PPM	BI PPM	V PPM	CA %	P %	MG %	TI %	AL %	K %	Y PPM	BE PPM	
BW001	3	9	23	21	0.6	7	114	228	<0.5	<5	264	0.25	0.061	0.37	0.25	4.34	1.44	11	<2	
BW002	3	5	26	30	<0.4	7	51	207	<0.5	<5	326	0.29	0.07	0.29	0.15	2.68	1.02	8	<2	
BW003	9	10	38	334	0.9	63	890	197	<0.5	<5	920	7.43	0.353	0.77	0.13	3.21	0.72	52	2	
BW004	<2	12	41	421	<0.4	84	987	127	<0.5	<5	1071	1.48	0.627	0.77	0.15	3.83	0.93	83	2	
BW005	2	9	18	178	0.9	39	1445	125	<0.5	<5	545	1.72	0.448	0.8	0.1	2.22	0.58	40	<2	
BW006	6	8	26	228	0.7	47	1282	121	<0.5	<5	652	1.55	0.376	0.88	0.1	2.42	0.62	46	2	
BW007	7	6	53	477	0.8	82	926	157	<0.5	<5	1613	1.86	0.827	0.43	0.08	2.68	0.39	115	3	
BW008	7	7	41	462	0.5	91	944	104	0.7	<5	1295	1.33	0.843	0.43	0.09	2.66	0.47	113	3	
BW009	5	8	49	648	0.9	87	813	141	<0.5	<5	1386	1.55	0.697	0.56	0.11	3.11	0.51	107	3	
BW010	2	7	25	336	0.8	70	657	434	<0.5	<5	486	7.49	2.393	0.44	0.09	2.16	0.6	108	<2	
BW011	7	10	47	441	<0.4	89	1066	78	<0.5	<5	1316	0.68	0.47	0.45	0.12	3.17	0.67	85	<2	

Actlabs PGE Job #: 14954

Report#: 14846

Client: Apex Geoscience

Contact: Chris Buchanan / Reg Olson

Sample ID:	Pd ppb	Pt ppb	Au ppb
bw001	-0.1	-0.1	-1
bw002	-0.1	-0.1	12
bw003	-0.1	-0.1	-1
bw004	-0.1	-0.1	-1
bw005	-0.1	-0.1	-1
bw006	-0.1	-0.1	-1
bw007	-0.1	-0.1	-1
bw008	-0.1	-0.1	-1
bw009	-0.1	-0.1	-1
bw010	-0.1	-0.1	-1
bw011	-0.1	-0.1	-1

Certified By:



D. D'Anna, Dipl. T.
ICPMS Technical Manager, Actlabs Ltd.

Date: 18 Feb 99

This report shall not be reproduced except in full without the written approval of the laboratory.
Unless otherwise instructed, samples will be disposed of 90 days from the date of this report.

APPENDIX II.2

GEOCHEMICAL RESULTS FROM CURRENT STUDIES

Master Summary Table of Results

APPENDIX II.2

MASTER SUMMARY TABLE OF RESULTS CLEAR HILLS IRON DEPOSIT STUDY

Basic Lithology	SAMPLE NO.		Original Sample No.	Precious metals and Platinum Group Elements								Base metals and Pathfinder Elements																				
	Assigned for Study	Duplicate	Assigned by Collector	Au (INAA) ppb	Au (FA) ppb	Ag (INAA) ppm	Ag (ICP) ppm	Pt (FA) ppb	Pd (FA) ppb	Ir (INAA) ppb	As (INAA) ppm	Ba (INAA) ppm	Bi (ICP) ppm	Cd (ICP) ppm	Co (INAA) ppm	Cu (ICP) ppm	Cr (INAA) ppm	Hg (INAA) ppm	Mo (INAA) ppm	Mo (ICP) ppm	Mn (ICP) ppm	Ni (INAA) ppm	Ni (ICP) ppm	Pb (ICP) ppm	Sb (INAA) ppm	Se (INAA) ppm	Sn (INAA) ppm	V (ICP) ppm	W (INAA) ppm	Zn (INAA) ppm	Zn (ICP) ppm	
			RAMBLING RIVER (SWIFT CREEK) SAMPLES WHICH WERE COLLECTED BY THE ALBERTA GEOLOGICAL SURVEY																													
	AS028	D	1	10	1.0	2.5	0.6	0.1	0.2	2.5	440	500	2.5	0.25	44	7	130	0.5	12.0	11	1032	110	87	44	11.0	1.5	0.005	1252	5.0	453	509	
	AS027		2	10	0.5	2.5	0.7	0.1	0.4	2.5	480	440	2.5	0.25	45	5	140	0.5	15.0	11	1249	94	91	41	11.0	1.5	0.005	1300	5.0	461	554	
	AS026		3	3	2.0	2.5	1.0	0.2	0.3	2.5	440	460	2.5	0.70	46	7	140	0.5	10.0	12	1011	110	97	46	11.0	1.5	0.005	1341	6.0	457	505	
	AS025		4	1	1.0	2.5	0.5	0.1	0.4	2.5	440	540	2.5	0.25	48	8	140	0.5	16.0	11	753	100	100	40	11.0	1.5	0.005	1289	5.0	451	487	
	AS024		5	1	0.5	2.5	0.7	0.1	0.4	2.5	430	590	2.5	0.50	47	8	140	0.5	19.0	11	798	110	92	41	11.0	1.5	0.005	1239	5.0	475	504	
	AS023		6	5	5.0	2.5	0.2	0.1	0.3	2.5	470	500	2.5	0.25	51	5	150	0.5	9.0	12	978	10	94	47	11.0	1.5	0.005	1326	6.0	505	524	
	AS022		7	1	0.5	2.5	0.7	0.1	0.6	2.5	450	420	2.5	0.25	49	7	150	0.5	18.0	11	945	110	97	41	11.0	1.5	0.005	1286	0.5	455	528	
	AS021		8	4	0.5	2.5	0.7	0.1	0.1	2.5	500	370	5.0	0.25	53	6	170	0.5	6.0	12	825	210	93	41	11.0	1.5	0.005	1345	5.0	475	513	
	AS020		9	11	0.5	2.5	0.2	0.1	0.7	2.5	490	620	2.5	0.25	50	6	160	0.5	5.0	12	1001	120	101	41	11.0	1.5	0.005	1286	6.0	530	506	
	AS019		9	3	3.0	2.5	0.2	0.1	0.3	2.5	450	430	8.0	0.25	44	5	140	0.5	17.0	11	1010	170	98	39	10.0	1.5	0.005	1285	0.5	456	506	
	AS018		10	1	0.5	2.5	0.8	0.1	0.2	2.5	420	840	6.0	0.25	49	8	150	0.5	10.0	11	770	120	106	41	11.0	1.5	0.005	1344	0.5	545	538	
	AS017		11	1	0.5	2.5	0.8	0.1	0.4	2.5	490	460	6.0	0.25	51	6	160	0.5	14.0	11	969	100	94	41	11.0	1.5	0.005	1248	5.0	513	512	
	AS016		12	4	11.0	2.5	0.2	0.1	0.8	2.5	450	540	2.5	0.25	53	6	170	0.5	7.0	12	842	100	100	40	11.0	1.5	0.005	1301	0.5	533	513	
	AS015		13	1	0.5	2.5	0.8	0.3	2.7	2.5	490	510	2.5	0.25	46	6	140	0.5	13.0	11	815	90	92	36	11.0	1.5	0.005	1292	0.5	434	497	
	AS014	14	4	0.5	2.5	0.2	0.1	0.7	2.5	470	510	2.5	0.25	46	6	160	0.5	17.0	12	872	91	93	44	11.0	1.5	0.005	1247	5.0	507	495		
	AS013	15	5	0.5	2.5	0.7	0.2	0.4	2.5	480	530	2.5	0.25	49	8	160	0.5	15.0	11	918	83	81	39	11.0	1.5	0.005	1249	5.0	521	494		
	AS012	16	1	0.5	2.5	0.6	0.1	0.3	2.5	480	430	6.0	0.25	46	5	160	0.5	19.0	12	1049	100	90	42	11.0	1.5	0.005	1296	0.5	478	509		
	AS011	17	1	1.0	2.5	0.2	0.1	0.5	2.5	480	690	2.5	0.25	50	7	180	0.5	18.0	11	981	88	83	37	11.0	7.0	0.005	1251	0.5	535	493		
	AS010	18	1	0.5	2.5	0.2	0.2	0.4	2.5	490	480	2.5	0.25	51	8	170	0.5	18.0	11	853	99	90	41	11.0	1.5	0.005	1190	0.5	551	467		
	AS009	18	1	0.5	2.5	0.2	0.3	0.6	2.5	460	360	5.0	0.25	50	8	170	0.5	20.0	10	1011	100	86	37	11.0	1.5	0.005	1144	0.5	573	521		
	AS008	19	1	0.5	2.5	0.2	0.3	3.4	2.5	370	570	2.5	0.25	50	26	140	0.5	14.0	9	1088	110	101	36	9.4	1.5	0.005	1118	0.5	516	467		
	AS007	20	8	0.5	2.5	0.4	0.2	3.9	2.5	320	370	2.5	0.25	62	16	130	0.5	12.0	7	1198	120	118	43	7.7	1.5	0.005	956	0.5	488	477		
	AS006	21	5	0.5	2.5	0.6	0.2	1.1	2.5	320	570	2.5	0.25	53	9	160	0.5	0.5	8	1384	96	91	36	7.7	1.5	0.005	1102	0.5	483	438		
	AS005	22	1	1.0	2.5	0.7	0.2	1.2	2.5	240	2300	2.5	0.25	210	8	160	0.5	89.0	92	1370	250	215	41	21.0	1.5	0.005	1145	0.5	808	795		
	AS004	23	1	0.5	2.5	0.5	0.2	1.9	2.5	270	660	2.5	0.25	42	10	130	0.5	7.0	6	1146	93	88	44	7.0	5.0	0.005	994	6.0	439	452		
	AS003	24	8	1.0	2.5	0.5	0.3	1.6	2.5	300	580	10.0	0.25	42	10	160	0.5	17.0	7	908	100	81	44	8.3	1.5	0.005	1205	6.0	491	446		
AS002	25	5	0.5	2.5	0.2	0.3	2.4	2.5	180	670	2.5	0.25	46	13	140	0.5	11.0	4	1413	83	81	37	7.0	1.5	0.005	929	0.5	435	388			
AS001	26	10	1.0	2.5	0.2	0.5	5.1	2.5	200	410	2.5	0.25	49	17	160	0.5	11.0	5	1145	93	93	38	7.5	1.5	0.005	1069	8.0	425	443			
			WORSLEY PIT SAMPLES WHICH WERE COLLECTED BY THE ALBERTA GEOLOGICAL SURVEY																													
	AW013	D	95SH-47-012	8	0.5	2.5	0.4	0.1	0.3	2.5	210	640	12.0	0.25	33	16	160	0.5	7.0	6	1182	85	85	41	7.2	1.5	0.005	1238	0.5	385	417	
	AW012		95SH-47-011	4	0.5	2.5	0.2	0.1	0.4	2.5	140	820	2.5	0.25	33	14	100	0.5	13.0	3	653	71	76	33	5.8	1.5	0.005	933	3.0	504	564	
	AW011		95SH-47-010	5	1.0	2.5	0.2	0.2	0.3	5.0	68	790	2.5	0.25	34	10	79	0.5	0.5	1	577	85	67	22	2.5	1.5	0.005	620	0.5	265	270	
	AW010		95SH-47-009	2	0.5	2.5	0.2	0.1	0.5	2.5	89	940	2.5	0.25	32	10	49	0.5	12.0	1	908	53	53	18	3.1	1.5	0.005	397	0.5	316	353	
	AW009		95SH-47-009	4	0.5	2.5	0.2	0.2	0.5	2.5	73	860	2.5	0.25	35	9	42	0.5	0.5	1	754	60	60	14	2.8	1.5	0.005	311	0.5	296	337	
	AW008		95SH-47-008	3	0.5	2.5	0.2	0.2	0.3	2.5	310	520	14.0	0.25	47	8	150	0.5	15.0	10	1334	100	89	49	8.9	1.5	0.005	1550	6.0	533	547	
	AW007		95SH-47-007	1	0.5	2.5	0.6	0.1	0.3	2.5	230	710	11.0	0.25	40	10	170	0.5	13.0	6	1101	78	74	46	7.4	1.5	0.005	1295	7.0	714	648	
	AW006		95SH-47-006	3	0.5	2.5	0.6	0.2	0.5	2.5	220	720	2.5	0.25	54	11	170	0.5	0.5	3	935	100	94	46	9.8	1.5	0.005	1321	0.5	571	559	
	AW005		95SH-47-005	2	1.0	2.5	0.2	0.2	0.7	2.5	65	910	6.0	0.25	46	13	140	0.5	22.0	15	1057	87	83	48	6.1	1.5	0.005	1151	0.5	434	470	
	AW004		95SH-47-004	1	1.0	2.5	0.2	0.1	0.5	2.5	48	530	2.5	0.25	36	9	100	0.5	7.0	5	1095	65	55	29	4.1	1.5	0.005	848	0.5	374	346	
	AW003		95SH-47-003	1	0.5	2.5	0.2	0.2	0.6	2.5	100	630	2.5	0.25	34	14	110	0.5	4.0	1	1371	62	66	32	4.0	1.5	0.005	744	0.5	340	337	
AW002	95SH-47-002	1	0.5	2.5	0.6	0.1	0.6	2.5	81	820	2.5	0.25	2	9	70	0.5	10.0	4	38	10	7	26	2.7	1.5	0.005	332	0.5	25	27			
AW001	95SH-47-001	1	2.0	2.5	0.2	0.2	0.8	2.5	87	790	2.5	0.25	6	14	86	0.5	8.0	5	84	10	13	19	3.4	1.5	0.005	356	0.5	78	52			
			WORSLEY PIT SAMPLE COLLECTED BY MARUM																													
	MW001		"Lower Bad Heart"	3	0.5	2.5	0.2	0.1	0.3	2.5	430	470	17.0	0.25	42	9	160	0.5	16.0	13	736	94	90	44	11.0	1.5	0.005	1633	6.0	504	560	
			WORSLEY PIT SAMPLES COLLECTED BY TOM BRYANT																													
	BW011		TS-14	1	0.5	2.5	0.2	0.1	0.1	2.5	230	590	2.5	0.25	40	10	170	0.5	7.0	7	1066	86	89	47	7.6	1.5	0.005	1316	4.0	392	441	
	BW010		TS-11	3	0.5	2.5	0.8	0.1	0.1	2.5	72	840	2.5	0.25	35	7	62	0.5	10.0	2	657	110	70	25	2.7	1.5	0.005	486	0.5	337	336	
	BW009		TS-10	3	0.5	2.5	0.9	0.1	0.1	2.5	220	650	2.5	0.25	72	8	150	0.5	6.0	5	813	88	87	49	8.3	1.5	0.005	1386	5.0	589	648	
	BW008		TS-9	1	0.5	2.5	0.5	0.1	0.1	2.5	240	570	2.5	0.70	43	7	130	0.5	9.0	7	944	96	91	41	7.4	1.5	0.005	1295	5.0	422	462	
	BW007		TS-7	3	0.5	2.5	0.8	0.1	0.1	2.5	260	590	2.5	0.25	37	6	150	0.5	6.0	7	926	95	82	53	7.3	1.5	0.005	1613	5.0	466	477	
	BW006		TS-6	1	0.5	2.5	0.7	0.1	0.1	2.5	60	440	2.5	0.25	24	8	82	0.5	16.0	6	1282	10	47	26	3.4	1.5	0.005	652	0.5	211	228	
	BW005		TS-5	1</																												

Basic Lithology	SAMPLE NO.		Original Sample No.		Precious metals and Platinum Group Elements							Base metals and Pathfinder Elements																				
	Assigned for Study	Duplicate	Assigned by Collector	Au (INAA) ppb	Au (FA) ppb	Ag (INAA) ppm	Ag (ICP) ppm	Pt (FA) ppb	Pd (FA) ppb	Ir (INAA) ppb	As (INAA) ppm	Ba (INAA) ppm	Bi (ICP) ppm	Cd (ICP) ppm	Co (INAA) ppm	Cu (ICP) ppm	Cr (INAA) ppm	Hg (INAA) ppm	Mo (INAA) ppm	Mo (ICP) ppm	Mn (ICP) ppm	Ni (INAA) ppm	Ni (ICP) ppm	Pb (ICP) ppm	Sb (INAA) ppm	Se (INAA) ppm	Sn (INAA) ppm	V (ICP) ppm	W (INAA) ppm	Zn (INAA) ppm	Zn (ICP) ppm	
DRILL HOLE CUTTINGS FROM HOLES DRILLED BY MARUM NEAR WORSLEY PIT																																
			Hole	Interval																												
	MD093	D	NS 9	11'-15'	1	0.5	2.5	0.2	0.1	0.3	2.5	230	650	2.5	0.25	43	11	160	0.5	9.0	5	842	100	89	41	7.2	1.5	0.005	1143	11.0	507	428
	MD092		NS 9	15'-16'	1	1.0	2.5	0.2	0.1	0.3	2.5	200	1200	2.5	0.25	42	8	130	0.5	16.0	4	782	95	56	32	5.7	1.5	0.005	717	0.5	421	331
	MD091		NS 9	16'-20'	1	2.0	2.5	0.2	0.2	0.6	2.5	280	570	2.5	0.25	46	8	160	0.5	13.0	8	877	60	84	41	9.1	1.5	0.005	1323	0.5	532	490
	MD090		NS 9	20'-25'	3	3.0	2.5	0.4	0.2	0.3	2.5	310	670	2.5	0.25	49	10	130	0.5	13.0	7	964	110	76	45	9.5	1.5	0.005	1140	0.5	566	469
	MD089		NS 9	20'-25'	5	2.0	2.5	0.5	0.1	0.2	2.5	270	680	2.5	0.25	53	9	160	0.5	8.0	9	936	110	79	58	9.9	1.5	0.005	1157	0.5	648	476
	MD088		NS 9	25'-29'6"	2	4.0	2.5	0.2	0.2	0.4	2.5	240	890	2.5	0.25	23	15	99	0.5	0.5	2	265	10	38	24	3.6	1.5	0.005	396	0.5	227	164
	MD087		NS 9	29'6"-31'	1	0.5	2.5	0.2	0.3	0.9	2.5	83	930	2.5	0.25	15	24	100	0.5	11.0	4	519	10	39	22	1.9	1.5	0.005	255	0.5	141	126
	MD086		NS 9	31'-33'	1	5.0	2.5	0.2	0.3	0.7	2.5	100	880	2.5	0.25	18	24	110	0.5	6.0	6	300	10	44	22	2.4	1.5	0.005	343	0.5	222	159
	MD085		NS 9	33'-35'	3	4.0	2.5	0.2	0.3	0.7	2.5	56	860	2.5	0.25	15	26	120	0.5	6.0	2	121	10	42	22	1.4	1.5	0.005	255	2.0	136	126
	MD084		NS 9	35'-37'	1	6.0	2.5	0.2	0.3	0.7	2.5	56	980	2.5	0.25	14	27	110	0.5	3.0	1	107	94	41	22	1.3	1.5	0.005	247	0.5	133	121
	MD083		NS 9	37'-40'	3	4.0	2.5	0.6	0.3	0.7	2.5	64	860	2.5	0.25	14	26	110	0.5	4.0	1	122	10	42	19	1.4	1.5	0.005	264	3.0	148	126
	MD082		NS 9	40'-45'	1	3.0	2.5	0.5	0.3	0.7	2.5	51	880	2.5	0.25	15	24	110	0.5	2.0	1	87	10	36	16	1.0	1.5	0.005	224	0.5	88	115
	MD081		NS 9	45'-50'	1	4.0	2.5	0.2	0.3	0.7	2.5	41	880	2.5	0.25	12	23	100	0.5	5.0	1	116	10	35	18	1.1	1.5	0.005	205	0.5	154	106
	MD080		NS 9	50'-55'	4	3.0	2.5	0.7	0.5	1.1	2.5	69	880	2.5	0.25	13	26	100	0.5	3.0	1	107	10	40	22	1.2	1.5	0.005	243	2.0	164	124
	MD079		NS 9	50'-55'	7	3.0	2.5	0.2	0.4	0.9	2.5	45	890	2.5	0.25	12	27	110	0.5	3.0	2	116	10	44	16	1.2	1.5	0.005	245	0.5	168	128
	MD078		NS 7A	7'-8'	4	NA	2.5	0.2	NA	NA	2.5	64	850	2.5	0.25	8	32	110	0.5	7.0	2	117	10	28	22	1.8	1.5	0.005	234	0.5	127	103
	MD077		NS 7A	8'-8'4"	4	NA	2.5	0.2	NA	NA	2.5	110	770	9.0	0.25	18	35	110	0.5	9.0	4	187	70	57	34	3.0	1.5	0.005	535	0.5	278	223
	MD076		NS 7A	8'4"-11'3"	1	NA	2.5	0.2	NA	NA	2.5	150	640	2.5	0.50	48	12	130	0.5	4.0	5	1325	80	147	52	5.1	1.5	0.005	1199	0.5	575	565
	MD075		NS 7	9'-13'	1	4.0	2.5	0.2	0.2	0.3	2.5	200	590	2.5	0.25	49	11	160	0.5	11.0	5	1050	70	110	47	6.0	1.5	0.005	1213	4.0	559	490
	MD074		NS 7	15'-20'	1	3.0	2.5	0.2	0.1	0.3	2.5	210	560	2.5	0.25	49	8	150	0.5	9.0	6	787	63	81	55	6.4	1.5	0.005	1275	5.0	574	518
	MD073		NS 7	20'-25'	1	4.0	2.5	0.2	0.1	0.3	2.5	150	590	2.5	0.25	44	10	130	0.5	14.0	10	840	51	71	46	5.8	1.5	0.005	974	0.5	464	405
	MD072	D	NS 5A	8'-12'7"	1	NA	2.5	0.2	NA	NA	2.5	25	770	5.0	0.50	14	35	93	0.5	5.0	2	270	10	39	15	1.4	1.5	0.005	181	0.5	110	102
	MD071		NS 5A	11'3"-12'1"	1	NA	2.5	0.2	NA	NA	2.5	86	720	2.5	0.25	23	9	55	0.5	7.0	2	723	10	46	26	3.0	1.5	0.005	522	0.5	250	261
	MD070		NS 5A	12'7"-13'	3	NA	2.5	0.2	NA	NA	2.5	320	460	2.5	0.25	50	7	180	0.5	9.0	10	1346	10	93	57	9.4	1.5	0.005	1550	6.0	614	511
	MD069		NS 5A	12'7"-13'	3	NA	2.5	0.2	NA	NA	2.5	300	470	2.5	0.25	48	7	160	0.5	8.0	10	1661	64	102	59	8.5	1.5	0.005	1540	8.0	614	521
	MD068		NS 5A	13'-15'6"	7	NA	2.5	0.2	NA	NA	2.5	340	490	2.5	0.25	44	6	140	0.5	10.0	7	795	63	79	52	8.2	1.5	0.005	1306	0.5	563	538
	MD067		NS 5A	17'6"-18'6"; 1 of 2	1	NA	2.5	0.2	NA	NA	2.5	1000	610	2.5	0.25	46	8	110	0.5	16.0	11	1039	53	73	39	19.0	3.0	0.005	896	0.5	433	350
	MD066		NS 5A	17'6"-18'6"; 2 of 2	1	NA	2.5	0.2	NA	NA	2.5	74	580	2.5	0.25	49	9	120	0.5	13.0	8	827	52	68	43	4.4	1.5	0.005	834	0.5	422	332
	MD065		NS 5A	21																												

Basic Lithology	SAMPLE NO.		Original Sample No.		Precious metals and Platinum Group Elements								Base metals and Pathfinder Elements																							
	Assigned for Study	Duplicate	Assigned by Collector		Au (INAA) ppb	Au (FA) ppb	Ag (INAA) ppm	Ag (ICP) ppm	Pt (FA) ppb	Pd (FA) ppb	Ir (INAA) ppb	As (INAA) ppm	Ba (INAA) ppm	Bi (ICP) ppm	Cd (ICP) ppm	Co (INAA) ppm	Cu (ICP) ppm	Cr (INAA) ppm	Hg (INAA) ppm	Mo (INAA) ppm	Mo (ICP) ppm	Mn (ICP) ppm	Ni (INAA) ppm	Ni (ICP) ppm	Pb (ICP) ppm	Sb (INAA) ppm	Se (INAA) ppm	Sn (INAA) ppm	V (ICP) ppm	W (INAA) ppm	Zn (INAA) ppm	Zn (ICP) ppm				
	MD027		NS4	17'-20'	4	0.5	2.5	0.2	0.3	0.5	2.5	73	810	2.5	0.25	44	17	130	0.5	23.0	14	784	10	80	41	5.7	1.5	0.005	924	4.0	355	396				
	MD026		NS4	20'-21'	4	3.0	2.5	0.2	0.2	0.6	2.5	160	900	2.5	0.25	26	16	100	0.5	10.0	7	620	10	46	32	4.3	1.5	0.005	520	0.5	237	222				
	MD025		NS4	21'-22'	3	0.5	2.5	0.4	0.2	0.4	2.5	170	770	2.5	0.25	22	16	93	0.5	7.0	4	338	10	41	24	3.5	1.5	0.005	401	0.5	211	173				
	MD024		NS4	23'-25'	1	2.0	2.5	0.4	0.2	0.6	2.5	280	730	2.5	0.25	14	17	81	0.5	8.0	6	151	190	33	21	3.1	1.5	0.005	310	0.5	118	133				
	MD023		NS4	25'-27'	3	1.0	2.5	0.2	0.4	1.9	2.5	60	1200	2.5	0.25	14	30	120	0.5	6.0	2	126	10	45	16	1.3	1.5	0.005	242	4.0	123	122				
	MD022		NS4	35'-40'	1	1.0	2.5	0.7	0.3	0.8	2.5	58	860	2.5	0.25	14	22	100	0.5	0.5	1	109	10	36	15	1.2	4.0	0.005	226	0.5	154	109				
	MD021		NS3	15' 6"-17"	3	NA	2.5	0.2	NA	NA	2.5	120	770	2.5	0.25	52	15	150	0.5	13.0	5	943	230	88	34	6.9	1.5	0.005	1070	0.5	482	451				
	MD020	D	NS3	17'-18' 6"	1	NA	2.5	0.4	NA	NA	2.5	88	740	2.5	0.25	41	13	120	0.5	15.0	13	891	10	67	35	5.5	1.5	0.005	880	0.5	343	351				
	MD019	D	NS3	17'-18' 6"	6	NA	2.5	0.2	NA	NA	2.5	84	600	2.5	0.25	39	12	120	0.5	22.0	12	906	92	66	33	5.2	1.5	0.005	860	0.5	335	340				
	MD018		NS3	18' 6"-20'	1	NA	2.5	0.2	NA	NA	2.5	88	620	2.5	0.25	38	12	120	0.5	17.0	10	814	140	60	29	4.7	1.5	0.005	797	0.5	318	320				
	MD017		NS3	20'-24'	1	NA	5.0	0.2	NA	NA	2.5	140	790	2.5	0.25	21	18	100	0.5	10.0	7	342	10	41	22	3.9	1.5	0.005	451	0.5	230	192				
	MD016		NS3	29'-30'	1	NA	2.5	0.8	NA	NA	2.5	51	1100	2.5	0.25	13	26	110	0.5	5.0	1	101	110	43	17	1.8	1.5	0.005	259	0.5	125	128				
	MD015		NS3	30'-31'	1	NA	2.5	0.4	NA	NA	2.5	62	860	2.5	0.25	16	29	110	0.5	5.0	2	135	75	44	18	1.7	1.5	0.005	247	0.5	170	123				
	MD014		NS3	31'-32'	1	NA	2.5	0.5	NA	NA	2.5	70	1100	2.5	0.25	15	28	110	0.5	0.5	3	104	10	44	21	1.9	1.5	0.005	242	0.5	135	125				
	MD013		NS3	32'-35'	1	NA	2.5	0.7	NA	NA	2.5	57	950	2.5	0.25	13	29	100	0.5	7.0	2	120	10	43	18	1.5	1.5	0.005	247	0.5	142	122				
	MD012		NS2	8'-12'6"	4	2.0	2.5	0.6	0.5	0.9	2.5	25	840	2.5	0.25	16	34	93	0.5	7.0	1	393	10	41	16	1.8	1.5	0.005	173	0.5	137	104				
	MD011		NS2	12'6"-15'	1	0.5	2.5	0.4	0.2	0.5	2.5	570	810	2.5	0.25	41	18	130	0.5	11.0	2	989	10	74	28	15.0	1.5	0.005	795	0.5	334	338				
	MD010	D	NS2	15'-17'	1	0.5	2.5	0.2	0.2	0.4	2.5	130	640	2.5	0.25	37	13	110	0.5	13.0	9	965	97	62	33	5.3	1.5	0.005	735	0.5	272	298				
	MD009	D	NS2	15'-17'	1	0.5	2.5	0.2	0.1	0.6	2.5	100	770	7.0	0.25	33	13	94	0.5	15.0	9	911	10	61	30	4.8	6.0	0.005	741	0.5	289	294				
	MD008		NS2	17'-20'	1	0.5	2.5	0.7	0.1	0.4	2.5	150	750	2.5	0.25	40	13	89	0.5	8.0	9	589	10	64	26	4.4	1.5	0.005	572	0.5	270	269				
	MD007		NS2	20'-22'	3	0.5	2.5	0.5	0.2	0.5	2.5	99	780	2.5	0.25	6	18	82	0.5	4.0	1	90	10	19	21	2.4	4.0	0.005	319	0.5	87	84				
	MD006		NS2	22'-25'	1	0.5	2.5	0.7	0.2	0.6	2.5	160	810	2.5	0.25	7	19	75	0.5	7.0	3	121	10	19	19	2.3	1.5	0.005	254	0.5	85	59				
	MD005		NS2	25'-26'	1	7.0	2.5	0.6	0.4	0.9	2.5	60	950	2.5	0.25	14	29	99	0.5	5.0	2	133	10	54	22	1.7	1.5	0.005	258	0.5	166	166				
	MD004		NS2	26'-30'	3	0.5	2.5	0.5	0.3	0.8	2.5	62	940	2.5	0.25	15	26	110	0.5	6.0	1	120	10	46	17	1.7	1.5	0.005	249	0.5	194	142				
	MD003		EW STN A	15'-20'	1	NA	2.5	0.7	NA	NA	2.5	30	900	2.5	0.25	14	32	98	0.5	4.0	1	141	10	41	19	1.3	1.5	0.005	223	0.5	148	131				
	MD002		NS1	19'-20'	1	NA	2.5	0.2	NA	NA	2.5	71	740	2.5	0.25	8	20	80	0.5	7.0	3	588	63	22	15	2.0	1.5	0.005	254	0.5	75	74				
	MD001		NS1	42'-45'	1	NA	2.5	0.4	NA	NA	2.5	48	850	2.5	0.25	12	26	89	0.5	5.0	1	99	65	39	20	1.1	1.5	0.005	234	0.5	145	116				
			SMOKY RIVER SAMPLES WHICH WERE COLLECTED BY C. COLLOM																																	
	CS005	D	HB-3		3	NA	2.5	0.2	NA	NA	2.5	59	590	2.5	0.25	39	6	35	0.5	16.0	15	888	10	52	12	2.1	1.5	0.005	230	0.5	106	107				
	CS003	D	HB-3		3	0.5	2.5	0.2	0.2	0.7	2.5	730	850	8.0	0.50	32	5	62	0.5	12.0	16	1772	66	57	22	17.0	1.5	0.005	580	0.5	143	176				
	CS004		No ID		1	31.0	2.5	0.2	0.4	0.5	2.5	11000	220	9.0	0.25	3	20	10	8	160.0	264	5	10	9	2.5	75.0	27.0	0.005	51	1.0	25	2				
	CS002		HB-2		3	0.5	2.5	0.4	0.3	0.5	2.5	66	650	2.5	0.25	35	8	40	0.5	19.0	14	792	70	52	9	2.6	1.5	0.005	216	0.5	122	100				
	CS001		HB-1		1	0.5	2.5	0.2	0.1	0.4	2.5	67	620	2.5	0.25	18	9	38	0.5	18.0	9	664	40	39	7	2.4	1.5	0.005	316	0.5	97	73				

NOTE: "N.A." denotes "Not Analyzed" due to budgetary restraints.

LEGEND FOR BASIC LITHOLOGY

	Glacial Deposit or Transitional Glacial to Oolitic Ironstone
	Densely Oolitic Ironstone
	Oolitic Ironstone with Mudstone or Conglomerate
	Pyritic Blue Clay; either base of oolitic unit, or top of Kaskapau Formation
	Blue Clay of Kaskapau Formation

APPENDIX II.2 (Cont.)

MASTER ASSAY SPREADSHEET

CLEAR HILLS IRON DEPOSIT STUDY

Basic Lithology	SAMPLE NO.		Uranium, Thorium, Rare Earth and Selected Other Related Elements																	Rock Forming and Related Trace Elements																
	Assigned for Study	Duplicate	Be (ICP) ppm	Ce (INAA) ppm	Cs (INAA) ppm	Eu (INAA) ppm	Hf (INAA) ppm	La (INAA) ppm	Lu (INAA) ppm	Nd (INAA) ppm	Sc (INAA) ppm	Sm (INAA) ppm	Ta (INAA) ppm	Tb (INAA) ppm	Th (INAA) ppm	U (INAA) ppm	Y (ICP) ppm	Yb (INAA) ppm	Al (ICP) %	Br (INAA) ppm	Ca (INAA) %	Ca (ICP) %	Fe (INAA) %	K (ICP) %	Mg (ICP) %	Na (INAA) %	P (ICP) %	Rb (INAA) ppm	Sr (INAA) ppm	Sr (ICP) ppm	Ti (ICP) ppm					
			RAMBLING RIVER (SWIFT CREEK) SAMPLES WHICH WERE COLLECTED BY THE ALBERTA GEOLOGICAL SURVEY																																	
	AS028	D	1	53	0.5	3.3	2	40	0.67	39	12.0	11.0	0.25	2.4	11.0	5.8	106	4.8	2.86	0.25	0.5	2.32	33.20	0.36	0.45	0.08	0.895	7.5	0.025	192	0.08					
	AS027		2	54	0.5	3.3	2	38	0.68	35	11.0	10.0	1.30	2.4	10.0	5.6	100	4.8	2.54	2.50	0.5	1.85	33.90	0.30	0.46	0.07	0.768	42.0	0.025	168	0.06					
	AS026		2	54	2.0	3.3	2	38	0.73	39	11.0	10.0	0.25	2.6	11.0	6.2	103	4.8	2.85	2.90	0.5	1.70	30.60	0.35	0.51	0.08	0.772	26.0	0.025	162	0.08					
	AS025		1	58	0.5	3.5	2	39	0.67	39	12.0	11.0	0.25	1.9	12.0	5.9	94	5.1	3.30	1.80	2.0	1.46	31.20	0.43	0.57	0.11	0.685	49.0	0.025	167	0.1					
	AS024		2	56	2.0	3.5	2	40	0.68	37	12.0	11.0	0.25	2.6	11.0	7.0	98	4.8	3.03	1.50	1.0	1.90	31.10	0.39	0.54	0.12	0.837	7.5	0.025	205	0.09					
	AS023		1	60	2.0	3.5	2	40	0.71	39	12.0	11.0	0.70	2.7	11.0	8.6	100	5.4	2.75	1.00	0.5	1.54	33.60	0.29	0.49	0.11	0.743	7.5	0.025	174	0.07					
	AS022		1	55	0.5	3.5	2	38	0.71	41	12.0	11.0	0.25	2.3	12.0	7.0	91	5.1	2.87	1.50	0.5	1.60	33.00	0.32	0.52	0.12	0.743	7.5	0.025	180	0.08					
	AS021		2	60	0.5	3.5	2	38	0.73	40	13.0	11.0	0.25	2.9	13.0	7.2	89	5.4	2.83	4.00	0.5	1.22	34.90	0.28	0.49	0.12	0.639	7.5	0.025	164	0.08					
	AS020		1	53	0.5	3.3	2	35	0.71	36	12.0	11.0	0.25	2.4	13.0	5.9	88	5.2	2.69	0.25	0.5	1.08	34.50	0.27	0.47	0.12	0.577	7.5	0.025	158	0.07					
	AS019		1	52	2.0	3.2	1	34	0.69	36	11.0	9.9	0.25	2.3	11.0	7.4	86	4.5	2.70	0.25	0.5	0.97	32.00	0.28	0.47	0.11	0.543	7.5	0.025	151	0.07					
	AS018	1	53	2.0	3.2	2	34	0.61	39	12.0	9.8	0.25	2.4	12.0	8.1	82	4.4	3.18	3.70	0.5	1.06	31.20	0.36	0.52	0.11	0.573	37.0	0.025	156	0.09						
	AS017	1	60	0.5	3.8	3	39	0.79	36	12.0	11.0	0.25	2.5	12.0	6.8	92	5.3	2.74	1.50	0.5	1.70	34.30	0.30	0.49	0.17	0.771	7.5	0.025	203	0.07						
	AS016	1	58	2.0	3.7	2	38	0.79	46	13.0	11.0	0.25	2.5	14.0	8.5	85	5.1	2.83	0.25	0.5	1.20	34.60	0.29	0.49	0.14	0.632	39.0	0.025	156	0.08						
	AS015	2	55	0.5	3.4	2	36	0.75	39	12.0	11.0	0.25	2.8	11.0	5.0	91	4.9	2.80	0.90	0.5	1.28	31.90	0.31	0.48	0.14	0.661	58.0	0.025	174	0.07						
	AS014	1	58	1.0	3.4	2	37	0.70	40	12.0	11.0	0.25	2.5	12.0	6.2	92	5.6	2.94	0.25	0.5	1.34	32.80	0.35	0.49	0.14	0.650	7.5	0.060	188	0.08						
	AS013	1	55	2.0	3.3	2	36	0.67	29	13.0	10.0	0.25	2.8	13.0	6.6	79	5.2	2.90	1.00	0.5	1.04	34.80	0.33	0.48	0.13	0.551	7.5	0.025	149	0.08						
	AS012	1	52	0.5	3.3	2	36	0.69	33	12.0	10.0	0.25	2.1	11.0	6.7	84	5.2	2.66	2.00	0.5	0.92	34.80	0.26	0.47	0.11	0.534	7.5	0.025	148	0.07						
	AS011	1	63	0.5	3.6	2	39	0.78	37	13.0	11.0	0.25	2.6	13.0	7.6	86	5.5	2.90	0.25	0.5	1.14	35.40	0.32	0.48	0.12	0.579	7.5	0.025	170	0.08						
	AS010	D	1	57	2.0	3.8	2	41	0.84	45	13.0	12.0	0.25	3.1	14.0	7.1	85	5.5	2.90	0.25	0.5	1.28	35.80	0.33	0.52	0.14	0.600	7.5	0.070	168	0.08					
	AS009	D	1	62	4.0	3.5	2	38	0.85	44	13.0	11.0	1.20	2.1	13.0	6.2	82	5.4	2.94	0.25	0.5	1.42	36.10	0.35	0.52	0.12	0.637	7.5	0.025	174	0.08					
AS008	1		57	0.5	3.2	2	34	0.69	29	11.0	9.9	0.25	2.0	12.0	6.4	80	5.1	2.89	0.25	1.0	1.43	30.90	0.35	0.56	0.10	0.578	7.5	0.025	162	0.09						
AS007	1		55	3.0	2.7	2	33	0.60	32	11.0	8.7	0.25	2.1	11.0	6.7	68	4.7	3.55	0.25	4.0	3.25	28.70	0.53	0.70	0.12	1.133	7.5	0.025	243	0.11						
AS006	2		56	0.5	3.5	2	37	0.82	36	13.0	10.0	0.25	2.2	13.0	5.4	77	5.1	3.35	0.25	3.0	1.72	32.00	0.44	0.74	0.11	0.571	7.5	0.025	165	0.1						
	AS005	2	57	2.0	3.4	2	36	0.79	30	12.0	10.0	0.25	2.3	12.0	5.3	80	4.8	2.92	0.25	3.0	2.32	28.10	0.32	0.96	0.12	0.544	7.5	0.025	247	0.08						
	AS004	1	53	0.5	2.9	2	33	0.63	35	11.0	9.2	0.25	2.2	11.0	4.8	76	4.1	3.22	0.25	0.5	2.52	28.80	0.45	0.86	0.11	0.793	59.0	0.025	216	0.1						
	AS003	1	56	0.5	3.4	2	34	0.73	39	13.0	10.0	1.20	2.1	12.0	5.2	79	5.0	3.33	0.25	2.0	1.34	30.80	0.45	0.86	0.11	0.446	49.0	0.025	153	0.09						
	AS002	1	58	0.5	3.1	2	36	0.71	41	11.0	9.8	1.20	2.4	11.0	5.1	71	4.8	3.08	2.40	0.5	2.74	30.30	0.47	1.06	0.12	0.693	7.5	0.025	191	0.09						
	AS001	2	49	0.5	3.0	2	34	0.70	31	12.0	9.7	0.25	2.3	12.0	4.9	73	4.7	3.27	0.25	2.0	2.09	29.80	0.47	1.04	0.12	0.522	7.5	0.025	161	0.1						
			WORSLEY PIT SAMPLES WHICH WERE COLLECTED BY THE ALBERTA GEOLOGICAL SURVEY																																	
	AW013	D	3	54	2.0	3.0	2	33	0.74	32	13.0	9.5	0.25	1.9	12.0	5.3	88	5.3	3.82	3.70	0.5	0.86	31.70	0.73	0.52	0.06	0.553	65.0	0.025	80	0.13					
	AW012		3	81	2.0	4.2	3	59	0.88	53	11.0	13.0	1.10	2.8	9.4	12.0	126	5.8	3.35	1.00	5.0	5.20	19.50	0.74	0.44	0.12	1.889	59.0	0.025	313	0.11					
	AW011		1	48	1.0	2.0	3	29	0.44	28	8.2	6.3	0.25	1.4	8.9	6.0	44	3.1	2.77	0.25	2.0	1.43	19.30	0.69	0.49	0.07	0.448	53.0	0.025	109	0.1					
	AW010		2	68	2.0	3.7	3	64	0.77	53	6.2	12.0	0.25	2.4	4.6	19.0	132	4.7	2.05	2.10	10.0	11.10	17.30	0.58	0.36	0.22	4.033	49.0	0.060	623	0.08					
	AW009		2	62	2.0	3.3	3	58	0.59	46	5.3	11.0	0.25	2.3	4.9	19.0	128	4.3	1.89	2.20	11.0	12.46	13.70	0.54	0.32	0.24	4.599	25.0	0.080	699	0.07					
	AW008		3	45	0.5	3.1	1	29</																												

Basic Lithology	SAMPLE NO.		Uranium, Thorium, Rare Earth and Selected Other Related Elements																	Rock Forming and Related Trace Elements													
	Assigned for Study	Duplicate	Be (ICP) ppm	Ce (INAA) ppm	Cs (INAA) ppm	Eu (INAA) ppm	Hf (INAA) ppm	La (INAA) ppm	Lu (INAA) ppm	Nd (INAA) ppm	Sc (INAA) ppm	Sm (INAA) ppm	Ta (INAA) ppm	Tb (INAA) ppm	Th (INAA) ppm	U (INAA) ppm	Y (ICP) ppm	Yb (INAA) ppm	Al (ICP) %	Br (INAA) ppm	Ca (INAA) %	Ca (ICP) %	Fe (INAA) %	K (ICP) %	Mg (ICP) %	Na (INAA) %	P (ICP) %	Rb (INAA) ppm	Sr (INAA) ppm	Sr (ICP) ppm	Ti (ICP) ppm		
			DRILL HOLE CUTTINGS FROM HOLES DRILLED BY MARUM NEAR WORSLEY PIT																														
											</																						

Basic Lithology	SAMPLE NO.		Uranium, Thorium, Rare Earth and Selected Other Related Elements																		Rock Forming and Related Trace Elements															
	Assigned for Study	Duplicate	Be (ICP) ppm	Ce (INAA) ppm	Cs (INAA) ppm	Eu (INAA) ppm	Hf (INAA) ppm	La (INAA) ppm	Lu (INAA) ppm	Nd (INAA) ppm	Sc (INAA) ppm	Sm (INAA) ppm	Ta (INAA) ppm	Tb (INAA) ppm	Th (INAA) ppm	U (INAA) ppm	Y (ICP) ppm	Yb (INAA) ppm	Al (ICP) %	Br (INAA) ppm	Ca (INAA) %	Ca (ICP) %	Fe (INAA) %	K (ICP) %	Mg (ICP) %	Na (INAA) %	P (ICP) %	Rb (INAA) ppm	Sr (INAA) ppm	Sr (ICP) ppm	Ti (ICP) ppm					
	MD027		1	55	3.0	2.7	4	35	0.70	30	13.0	8.3	0.25	1.9	12.0	3.9	66	5.0	5.03	0.25	3.0	1.79	22.00	1.04	0.71	0.20	0.436	90.0	0.025	124	0.19					
	MD026		1	59	3.0	2.0	5	34	0.58	34	12.0	6.7	0.25	1.3	12.0	0.3	41	3.6	4.15	0.25	0.5	1.32	14.00	1.09	0.56	0.21	0.260	67.0	0.025	106	0.17					
	MD025		1	50	4.0	1.9	5	30	0.46	27	10.0	5.6	0.25	1.1	10.0	3.2	31	2.9	4.21	0.25	0.5	1.01	9.60	1.18	0.61	0.20	0.166	86.0	0.025	99	0.18					
	MD024		1	52	4.0	1.6	5	31	0.40	23	9.5	5.2	0.25	1.3	9.5	2.6	31	2.3	4.79	0.25	2.0	1.79	8.17	1.45	0.50	0.24	0.475	73.0	0.025	145	0.21					
	MD023		1	62	7.0	1.5	6	41	0.55	31	14.0	5.2	1.10	0.8	10.0	4.0	26	3.5	7.34	0.25	0.5	0.68	3.77	2.07	0.75	0.34	0.073	120.0	0.025	132	0.34					
	MD022		1	66	7.0	1.5	7	41	0.54	34	13.0	5.1	1.20	0.3	11.0	4.8	24	3.1	6.66	1.60	0.5	0.46	3.46	1.86	0.65	0.36	0.070	100.0	0.025	135	0.31					
	MD021		1	57	3.0	3.1	3	36	0.75	33	15.0	9.3	0.25	2.2	14.0	6.2	72	5.5	4.47	0.25	4.0	4.06	28.10	0.79	0.81	0.16	0.551	55.0	0.025	197	0.16					
	MD020	D	1	47	2.0	2.2	3	29	0.64	27	12.0	6.9	0.25	1.7	11.0	3.8	56	4.3	4.06	0.25	3.0	3.38	26.10	0.81	0.90	0.14	0.363	54.0	0.025	195	0.15					
	MD019	D	1	47	3.0	2.3	3	29	0.62	29	12.0	7.1	0.25	1.6	11.0	5.0	56	4.4	3.68	0.25	5.0	4.67	27.70	0.75	0.88	0.11	0.481	65.0	0.025	243	0.13					
	MD018		1	48	2.0	2.4	3	31	0.62	29	12.0	7.5	0.25	0.3	12.0	4.5	55	4.4	3.65	0.25	4.0	4.52	25.30	0.78	0.93	0.11	0.420	67.0	0.025	216	0.13					
	MD017		1	51	4.0	1.7	5	31	0.48	26	11.0	5.4	1.30	1.1	11.0	3.0	34	3.2	4.60	0.25	0.5	1.31	9.30	1.25	0.65	0.19	0.160	71.0	0.025	115	0.19					
	MD016		1	67	7.0	1.3	6	41	0.57	22	14.0	5.1	1.00	0.9	11.0	3.8	29	3.4	7.78	0.25	0.5	0.36	3.41	2.23	0.85	0.37	0.076	140.0	0.025	127	0.37					
	MD015		1	69	9.0	1.4	6	44	0.53	35	15.0	5.5	0.25	0.3	11.0	4.1	29	3.5	7.54	2.70	0.5	0.72	4.45	2.18	0.80	0.38	0.069	140.0	0.025	135	0.37					
	MD014		1	66	7.0	1.5	6	43	0.56	29	15.0	5.4	0.90	0.9	12.0	4.5	29	3.7	7.51	1.90	0.5	0.50	5.63	2.12	0.79	0.37	0.070	130.0	0.025	129	0.35					
	MD013		1	63	7.0	1.3	6	41	0.54	30	14.0	5.1	0.25	0.7	10.0	3.5	28	3.3	7.46	2.00	0.5	0.60	3.63	2.15	0.79	0.33	0.067	120.0	0.025	136	0.36					
	MD012		1	48	4.0	1.4	5	30	0.49	26	14.0	4.5	0.25	0.9	7.2	2.3	28	3.0	7.59	0.25	0.5	1.10	4.55	1.36	0.72	0.71	0.062	63.0	0.025	132	0.36					
	MD011		2	54	3.0	2.5	3	36	0.66	26	14.0	8.0	0.25	2.0	11.0	11.0	60	4.6	5.01	0.25	5.0	5.45	22.30	0.96	0.66	0.26	0.602	74.0	0.025	211	0.19					
	MD010	D	2	42	2.0	2.0	3	27	0.56	22	11.0	6.4	0.25	1.5	9.8	4.3	49	3.6	3.64	0.25	5.0	4.84	25.10	0.76	0.76	0.13	0.381	44.0	0.025	206	0.13					
	MD009	D	1	46	2.0	2.1	3	27	0.54	26	11.0	6.4	0.25	1.6	9.5	3.8	50	3.6	3.54	0.25	4.0	3.92	24.90	0.74	0.77	0.12	0.395	52.0	0.025	192	0.13					
	MD008		2	44	3.0	1.7	4	27	0.46	24	9.9	5.4	0.25	1.2	9.6	2.9	38	3.1	3.84	0.25	3.0	3.42	15.50	0.97	0.66	0.15	0.199	85.0	0.025	168	0.16					
	MD007		1	49	4.0	1.0	6	31	0.34	23	10.0	3.7	0.25	0.3	9.6	2.9	16	1.9	4.84	0.25	0.5	0.30	5.03	1.43	0.44	0.28	0.093	94.0	0.025	178	0.21					
	MD006		1	44	5.0	0.9	5	29	0.35	25	9.7	3.3	0.25	0.3	8.9	2.9	16	2.1	5.02	0.25	2.0	2.14	4.87	1.56	0.39	0.37	0.104	81.0	0.025	189	0.24					
	MD005		1	61	8.0	1.4	5	39	0.52	29	13.0	5.0	1.50	0.8	10.0	3.6	32	3.3	7.80	0.25	1.0	0.56	3.97	2.20	0.82	0.31	0.083	120.0	0.025	185	0.37					
	MD004		1	62	8.0	1.3	5	41	0.57	29	14.0	5.1	1.70	0.8	11.0	3.3	29	3.4	7.56	0.25	0.5	0.47	3.71	2.17	0.80	0.35	0.072	140.0	0.025	145	0.36					
	MD003		1	64	7.0	1.5	6	41	0.53	30	14.0	5.2	1.30	0.9	11.0	4.2	29	3.4	7.76	0.25	1.0	0.40	3.36	2.27	0.80	0.37	0.083	130.0	0.025	130	0.4					
	MD002		1	51	6.0	1.0	4	33	0.39	26	11.0	3.8	1.20	0.6	8.5	3.8	20	2.4	6.11	0.25	3.0	3.22	5.18	1.80	0.49	0.31	0.215	110.0	0.025	181	0.3					
	MD001		1	57	6.0	1.3	6	37	0.46	25	12.0	4.5	0.90	0.6	9.6	2.9	26	3.2	7.17	0.25	0.5	0.41	3.06	2.06	0.73	0.40	0.075	98.0	0.025	132	0.35					
			SMOKY RIVER SAMPLES WHICH WERE COLLECTED BY C. COLLOM																																	
	CS005	D	1	36	1.0	1.6	2	28	0.24	15	5.1	4.7	0.25	1.2	3.3	2.7	34	1.5	1.62	0.25	15.0	16.54	10.10	0.46	0.80	0.12	0.774	29.0	0.025	387	0.07					
	CS003	D	1	54	1.0	2.4	2	36	0.44	27	8.7	7.6	0.25	1.5	5.0	3.2	62	3.2	1.92	0.25	5.0	4.96	27.50	0.39	1.08	0.12	0.949	7.5	0.025	239	0.06					
	CS004		1	1.5	0.5	0.1	0.05	2	0.03	2.5	0.4	0.2	0.25	0.3	0.1	0.3	4	0.1	0.17	0.25	0.5	0.06	33.10	0.05	0.01	0.04	0.008	7.5	0.025	10	0.02					
	CS002		1	27	1.0	1.0	1	17	0.26	12	5.2	3.0	0.25	0.8	4.7	3.7	25	1.7	1.60	0.25	20.0	17.44	9.22	0.43	0.65	0.11	0.446	39.0	0.050	379	0.07					
	CS001		1	63	2.0	2.1	3	38	0.33	36	11.0	7.0	0.25	1.5	5.3	3.5	37	2.3	1.94	0.25	8.0	8.74	12.60	0.56	1.15	0.12	0.365	30.0	0.025	224	0.08					

NOTE: "N.A." denotes "Not Analyzed" due to

LEGEND FOR BASIC LITHOLOGY

- Glacial Deposit or Transitional Glacial to Oolitic Ironstone
- Densely Oolitic Ironstone
- Oolitic Ironstone with Mudstone or Conglomerate
- Pyritic Blue Clay; either base of oolitic unit, or top of Kaskapau Formation
- Blue Clay of Kaskapau Formation

APPENDIX II.3

GEOCHEMICAL RESULTS FROM CURRENT STUDIES

Digital Copy of Results on CD-ROM Disk

Note: A copy of this CD-ROM has been included with each of the copies of this report that was delivered to Alberta Energy, the Alberta Geological Survey, and to Marum Resources Inc. As well, a copy of the original CD-ROM in Appendix II.3 is on file at APEX Geoscience Ltd. In summary, the CD-ROM in the Directory, "ClearHills_FnRpt", includes the following sub-Directories and contained Files:

FILE TYPE Directory	File Name	Description
WORD 97 Word_Files	PeaceRiver_FnRpt_Feb99.doc	Text of report
	PeaceRiver_FnRpt_Apdx_Feb99.doc	Appendix title pages in report
EXCEL 97 XLS_Files	2 files; see table below	Table below summarizes the contents of these 2 files
AUTOCAD Map 3.0 (equals AutoCAD 14.0) Graphic_Files	Figure1.dwg, Figure2.dwg, and Figure4.dwg to Figure7.dwg	AutoCAD files for Figures 1, 2, and 4 to 7
CORELDRAW 8.0 & COREL PHOTOPAINT 8.0 Graphic Files	Figure3.cdr, Figure8.cdr, Figure9.cdr, Plate1.cdr, and Table1.cpt	CorelDraw files for Figures 3, 8 and 9, and Plate 1. CorelPhotopaint file for Table 1
VARIOUS ActLab_Assay_Reports	6 files with prefix 14446*.csv, .lot or .wk1; 4 files with prefix 14559*.csv or .lot; 1 file named act14846.xls	11 comma-delimited, Lotus1-2-3 or Excel files which provide the raw assay data received from ActLabs for the 151 samples submitted to them for analysis. Includes 139 samples on report 14446, 1 sample on report 14559, and 11 samples on report 14846.

Excel Files In XLS_Files subdirectory	Excel Sheet		Description
	No.	Name	
PRFeMaster.xls	1	APNDX II.3 – Master Assay List	Tabulation of assays for all 151 samples, grouped into: (a) Precious Metals and Platinum Group Elements, (b) Base Metals and Pathfinder Elements, (c) Uranium, Thorium, Rare Earths and Selected Other Related Elements, and (d) Rock Forming and Related Trace Elements
	2	APNDX III – Assay Stats	Summary statistical data, by area and in total
	3 to 45	AU (INAA) to TI (ICP)	Histograms for selected elements which exist in Appendix VI.1 to VI.4
PRFE_Final_Tables&Apndxs.xls	1	TABLE VI	Table VI, Summary of Samples Used, Clear Hills Iron Deposit Study
	2	TABLE VII	Table VII, Summary of Analytical Methods Used, Clear Hills Iron Deposit Study
	3	TABLE VIII	Table VIII, Summary of Elements and Detection Methods, Clear Hills Iron Deposit Study
	4	APPENDIX IV	Appendix IV, Comparative Results of Duplicate Sample Pairs
	5	APPENDIX V	Appendix V, Comparative Results Between the INAA and Fire Assay or ICP Methods

APPENDIX III

SYNOPTIC STATISTICAL ANALYSIS OF RESULTS
BY MAJOR SAMPLING AREA

CLEAR HILLS IRON DEPOSIT STUDY

APPENDIX III

SYNOPTIC STATISTICAL ANALYSIS BY MAJOR SAMPLING AREA
CLEAR HILLS IRON DEPOSIT STUDY

SUMMARY SPREADSHEET FOR AGS RAMBLING RIVER (SWIFT CREEK) SAMPLES

	Precious metals and Platinum Group Elements							Base metals and Pathfinder Elements																				
	Au (INAA) ppb	Au (FA) ppb	Ag (INAA) ppm	Ag (ICP) ppm	Pt (FA) ppb	Pd (FA) ppb	Ir (INAA) ppb	As (INAA) ppm	Ba (INAA) ppm	Bi (ICP) ppm	Cd (ICP) ppm	Co (INAA) ppm	Cu (ICP) ppm	Cr (INAA) ppm	Hg (INAA) ppm	Mo (INAA) ppm	Mo (ICP) ppm	Mn (ICP) ppm	Ni (INAA) ppm	Ni (ICP) ppm	Pb (ICP) ppm	Sb (INAA) ppm	Se (INAA) ppm	Sn (INAA) ppm	V (ICP) ppm	W (INAA) ppm	Zn (INAA) ppm	Zn (ICP) ppm
DETECTION LIMIT	2.0	1.0	5.0	0.5	0.1	0.1	5.0	0.5	50.0	5.0	0.5	1.0	1.0	5.0	1.0	1.0	2.0	1.0	20.0	1.0	5.0	0.1	3.0	0.01	2.0	1.0	50.0	1.0
MEAN	3.54	1.29	2.50	0.48	0.17	1.12	2.50	410.71	583.93	3.52	0.28	54.36	8.61	152.14	0.50	15.70	13.00	1011.93	109.29	97.61	40.64	10.52	1.82	0.01	1215.32	3.04	499.75	502.89
MEDIAN	2.00	0.50	2.50	0.50	0.10	0.55	2.50	450.00	510.00	2.50	0.25	49.00	7.50	155.00	0.50	14.00	11.00	991.00	100.00	93.00	41.00	11.00	1.50	0.01	1250.00	2.75	485.50	504.50
MODE	1.00	0.50	2.50	0.20	0.10	0.40	2.50	480.00	500.00	2.50	0.25	46.00	8.00	160.00	0.50	18.00	11.00	1011.00	100.00	93.00	41.00	11.00	1.50	0.01	1286.00	0.50	475.00	509.00
STANDARD DEVIATION	3.21	2.14	0.00	0.26	0.11	1.27	0.00	95.53	353.65	1.99	0.10	30.77	4.54	13.97	0.00	15.18	15.65	183.44	42.14	24.37	2.98	2.51	1.21	0.00	116.70	2.65	72.29	67.10
KURTOSIS	0.10	16.88	N.C.	-1.38	1.62	2.89	N.C.	0.35	22.33	3.49	16.02	26.93	7.61	-1.01	N.C.	21.88	26.70	-0.04	5.55	21.60	-0.46	11.26	14.30	-2.16	0.54	-1.78	12.19	13.79
SKEWNESS	1.10	3.95	N.C.	0.13	1.20	1.85	N.C.	-1.26	4.52	1.99	3.99	5.15	2.57	0.03	N.C.	4.40	5.11	0.76	1.59	4.42	0.16	2.46	3.82	-1.06	-1.17	0.18	2.98	3.00
LARGEST #	11.00	11.00	2.50	1.00	0.50	5.10	2.50	500.00	2300.00	10.00	0.70	210.00	26.00	180.00	0.50	89.00	92.00	1413.00	250.00	215.00	47.00	21.00	7.00	0.01	1345.00	8.00	808.00	795.00
SMALLEST #	1.00	0.50	2.50	0.20	0.05	0.05	2.50	180.00	360.00	2.50	0.25	42.00	5.00	130.00	0.50	0.50	4.00	753.00	10.00	81.00	36.00	7.00	1.50	0.01	929.00	0.50	425.00	388.00

SUMMARY SPREADSHEET FOR AGS WORSLEY PIT SAMPLES

	Precious metals and Platinum Group Elements							Base metals and pathfinders																				
	Au (INAA) ppb	Au (FA) ppb	Ag (INAA) ppm	Ag (ICP) ppm	Pt (FA) ppb	Pd (FA) ppb	Ir (INAA) ppb	As (INAA) ppm	Ba (INAA) ppm	Bi (ICP) ppm	Cd (ICP) ppm	Co (INAA) ppm	Cu (ICP) ppm	Cr (INAA) ppm	Hg (INAA) ppm	Mo (INAA) ppm	Mo (ICP) ppm	Mn (ICP) ppm	Ni (INAA) ppm	Ni (ICP) ppm	Pb (ICP) ppm	Sb (INAA) ppm	Se (INAA) ppm	Sn (INAA) ppm	V (ICP) ppm	W (INAA) ppm	Zn (INAA) ppm	Zn (ICP) ppm
DETECTION LIMIT	2.0	1.0	5.0	0.5	0.1	0.1	5.0	0.5	50.0	5.0	0.5	1.0	1.0	5.0	1.0	1.0	2.0	1.0	20.0	1.0	5.0	0.1	3.0	0.01	2.0	1.0	50.0	1.0
MEAN	2.77	0.73	2.50	0.31	0.15	0.48	2.69	132.38	744.62	5.04	0.25	33.23	11.31	109.69	0.50	8.65	4.69	853.00	66.62	63.23	32.54	5.22	1.50	0.01	853.54	1.62	371.92	379.00
MEDIAN	2.00	0.50	2.50	0.20	0.20	0.50	2.50	89.00	790.00	2.50	0.25	34.00	10.00	100.00	0.50	8.00	4.00	935.00	71.00	67.00	32.00	4.10	1.50	0.01	848.00	0.50	374.00	353.00
MODE	1.00	0.50	2.50	0.20	0.20	0.30	2.50	N.C.	820.00	2.50	0.25	33.00	14.00	100.00	0.50	0.50	1.00	N.C.	85.00	N.C.	46.00	N.C.	1.50	0.01	N.C.	0.50	N.C.	337.00
STANDARD DEVIATION	2.09	0.44	0.00	0.18	0.05	0.16	0.69	82.56	134.39	4.31	0.00	14.61	2.56	44.61	0.00	6.43	4.07	424.35	29.06	26.84	12.41	2.49	0.00	0.00	431.08	2.28	189.77	188.18
KURTOSIS	2.08	5.90	N.C.	-0.55	-2.36	-0.55	13.00	-0.08	-0.79	0.23	N.C.	1.38	-1.16	-1.33	N.C.	-0.06	2.53	0.09	0.61	0.89	-1.53	-0.96	N.C.	-2.40	-1.46	2.31	0.15	-0.05
SKEWNESS	1.40	2.33	N.C.	1.18	-0.18	0.43	3.61	1.04	-0.38	1.38	N.C.	-1.16	0.51	0.02	N.C.	0.41	1.52	-0.90	-1.08	-1.21	0.01	0.62	N.C.	1.14	0.09	1.90	-0.21	-0.63
LARGEST #	8.00	2.00	2.50	0.60	0.20	0.80	5.00	310.00	940.00	14.00	0.25	54.00	16.00	170.00	0.50	22.00	15.00	1371.00	100.00	94.00	49.00	9.80	1.50	0.01	1550.00	7.00	714.00	648.00
SMALLEST #	1.00	0.50	2.50	0.20	0.10	0.30	2.50	48.00	520.00	2.50	0.25	2.00	8.00	42.00	0.50	0.50	1.00	38.00	10.00	7.00	14.00	2.50	1.50	0.01	311.00	0.50	25.00	27.00

SUMMARY SPREADSHEET FOR BRYANT AND MARUM WORSLEY PIT SAMPLES

	Precious metals and Platinum Group Elements							Base metals and pathfinders																				
	Au (INAA) ppb	Au (FA) ppb	Ag (INAA) ppm	Ag (ICP) ppm	Pt (FA) ppb	Pd (FA) ppb	Ir (INAA) ppb	As (INAA) ppm	Ba (INAA) ppm	Bi (ICP) ppm	Cd (ICP) ppm	Co (INAA) ppm	Cu (ICP) ppm	Cr (INAA) ppm	Hg (INAA) ppm	Mo (INAA) ppm	Mo (ICP) ppm	Mn (ICP) ppm	Ni (INAA) ppm	Ni (ICP) ppm	Pb (ICP) ppm	Sb (INAA) ppm	Se (INAA) ppm	Sn (INAA) ppm	V (ICP) ppm	W (INAA) ppm	Zn (INAA) ppm	Zn (ICP) ppm
DETECTION LIMIT	2.0	1.0	5.0	0.5	0.1	0.1	5.0	0.5	50.0	5.0	0.5	1.0	1.0	5.0	1.0	1.0	2.0	1.0	20.0	1.0	5.0	0.1	3.0	0.01	2.0	1.0	50.0	1.0
MEAN	16.18	1.55	2.50	0.61	0.05	0.05	2.50	129.09	675.45	2.50	0.29	32.64	8.27	108.45	0.50	9.09	4.73	834.09	60.36	60.55	35.18	4.87	1.50	0.01	897.64	2.18	302.27	325.09
MEDIAN	1.00	0.50	2.50	0.70	0.05	0.05	2.50	72.00	640.00	2.50	0.25	37.00	8.00	110.00	0.50	8.00	5.00	926.00	85.00	70.00	38.00	4.10	1.50	0.01	920.00	0.50	334.00	336.00
MODE	1.00	0.50	2.50	0.20	0.05	0.05	2.50	72.00	590.00	2.50	0.25	37.00	10.00	150.00	0.50	7.00	7.00	N.C.	10.00	7.00	41.00	3.40	1.50	0.01	N.C.	0.50	N.C.	N.C.
STANDARD DEVIATION	47.71	3.47	0.00	0.29	0.00	0.00	0.00	87.38	209.25	0.00	0.14	19.96	2.00	38.20	0.00	3.65	2.65	428.74	41.38	31.50	12.00	2.31	0.00	0.00	468.63	2.10	172.73	194.82
KURTOSIS	10.99	11.00	N.C.	-1.41	-2.50	-2.50	N.C.	-1.81	3.67	N.C.	11.00	0.60	-0.10	-1.47	N.C.	0.00	-1.42	0.33	-1.90	-0.59	-1.57	-1.75	N.C.	-2.50	-1.54	-1.83	-0.47	-0.51
SKEWNESS	3.31	3.32	N.C.	-0.58	1.17	1.17	N.C.	0.63	1.65	N.C.	3.32	0.12	0.18	0.27	N.C.	1.00	0.08	-0.81	-0.43	-0.88	0.06	0.43	N.C.	1.17	0.06	0.59	-0.22	-0.26
LARGEST #	160.00	12.00	2.50	0.90	0.05	0.05	2.50	260.00	1200.00	2.50	0.70	72.00	12.00	170.00	0.50	16.00	9.00	1445.00	110.00	91.00	53.00	8.30	1.50	0.01	1613.00	5.00	589.00	648.00
SMALLEST #	1.00	0.50	2.50	0.20	0.05	0.05	2.50	54.00	440.00	2.50	0.25	2.00	5.00	62.00	0.50	5.00	1.00	51.00	10.00	7.00	18.00	2.40	1.50	0.01	264.00	0.50	25.00	21.00

SUMMARY SPREADSHEET FOR MARUM DRILLING NEAR WORSLEY PIT SAMPLES

	Precious metals and Platinum Group Elements							Base metals and pathfinders																				
	Au (INAA) ppb	Au (FA) ppb	Ag (INAA) ppm	Ag (ICP) ppm	Pt (FA) ppb	Pd (FA) ppb	Ir (INAA) ppb	As (INAA) ppm	Ba (INAA) ppm	Bi (ICP) ppm	Cd (ICP) ppm	Co (INAA) ppm	Cu (ICP) ppm	Cr (INAA) ppm	Hg (INAA) ppm	Mo (INAA) ppm	Mo (ICP) ppm	Mn (ICP) ppm	Ni (INAA) ppm	Ni (ICP) ppm	Pb (ICP) ppm	Sb (INAA) ppm	Se (INAA) ppm	Sn (INAA) ppm	V (ICP) ppm	W (INAA) ppm	Zn (INAA) ppm	Zn (ICP) ppm
DETECTION LIMIT	2.0	1.0	5.0	0.5	0.1	0.1	5.0	0.5	50.0	5.0	0.5	1.0	1.0	5.0	1.0	1.0	2.0	1.0	20.0	1.0	5.0	0.1	3.0	0.01	2.0	1.0	50.0	1.0
MEAN	2.46	4.31	2.55	0.30	1.17	0.54	2.50	158.86	767.85	2.67	0.26	27.67	17.65	112.44	0.50	8.91	5.57	609.24	50.00	55.23	29.56	4.57	1.62	0.01	617.61	1.30	288.48	258.22
MEDIAN	1.00	3.00	2.50	0.20	0.20	0.50	2.50	110.00	770.00	2.50	0.25	22.00	16.00	110.00	0.50	8.00	4.00	713.00	46.00	46.00	24.00	3.50	1.50	0.01	475.00	0.50	222.00	192.00
MODE	1.00	0.50	2.50	0.20	0.20	0.40	2.50	150.00	770.00	2.50	0.25	14.00	13.00	110.00	0.50	10.00	2.00	121.00	10.00	41.00	22.00	2.40	1.50	0.01	247.00	0.50	148.00	126.00
STANDARD DEVIATION	2.10	5.46	0.36	0.17	7.67	0.27	0.00	153.30	198.08	0.89	0.05	14.53	8.40	26.89	0.00	5.85	4.44	412.27	46.65	22.42	13.12	3.61	0.61	0.00	401.03	2.09	168.67	151.86
KURTOSIS	4.90	17.44	43.91	0.60	66.97	8.23	N.C.	14.10	1.20	34.77	31.47	-1.42	-0.83	-0.31	N.C.	0.21	2.77	-0.63	2.11	1.78	-0.85	7.52	34.66	-2.04	-1.01	7.62	-0.86	-1.26
SKEWNESS	1.94	3.62	6.71	1.42	8.18	2.15	N.C.	3.33	0.74	5.73	5.64	0.36	0.57	0.16	N.C.	0.72	1.35	0.30	1.27	1.03	0.70	2.28	5.69	-1.02	0.63	2.81	0.73	0.55
LARGEST #	12.00	36.00	5.00	0.80	63.00	1.90	2.50	1000.00	1500.00	9.00	0.60	56.00	38.00	180.00	0.50	26.00	25.00	1782.00	230.00	147.00	59.00	22.00	6.00	0.01	1550.00	11.00	648.00	565.00
SMALLEST #	1.00	0.50	2.50	0.20	0.10	0.20	2.50	25.00	360.00	2.50	0.25	6.00	5.00	55.00	0.50	0.50	1.00	87.00	10.00	19.00	12.00	1.00	1.50	0.01	173.00	0.50	75.00	59.00

	SUMMARY SPREADSHEET FOR COLLOM SMOKEY RIVER SAMPLES																											
	Precious metals and Platinum Group Elements							Base metals and pathfinders																				
	Au (INAA) ppb	Au (FA) ppb	Ag (INAA) ppm	Ag (ICP) ppm	Pt (FA) ppb	Pd (FA) ppb	Ir (INAA) ppb	As (INAA) ppm	Ba (INAA) ppm	Bi (ICP) ppm	Cd (ICP) ppm	Co (INAA) ppm	Cu (ICP) ppm	Cr (INAA) ppm	Hg (INAA) ppm	Mo (INAA) ppm	Mo (ICP) ppm	Mn (ICP) ppm	Ni (INAA) ppm	Ni (ICP) ppm	Pb (ICP) ppm	Sb (INAA) ppm	Se (INAA) ppm	Sn (INAA) ppm	V (ICP) ppm	W (INAA) ppm	Zn (INAA) ppm	Zn (ICP) ppm
DETECTION LIMIT	2.0	1.0	5.0	0.5	0.1	0.1	5.0	0.5	50.0	5.0	0.5	1.0	1.0	5.0	1.0	1.0	2.0	1.0	20.0	1.0	5.0	0.1	3.0	0.01	2.0	1.0	50.0	1.0
MEAN	2.20	8.13	2.50	0.24	0.25	0.53	2.50	2384.40	586.00	4.90	0.30	25.40	9.60	37.00	2.00	45.00	63.60	824.20	39.20	41.80	10.50	19.82	6.60	0.01	278.60	0.60	98.60	91.60
MEDIAN	3.00	0.50	2.50	0.20	0.25	0.50	2.50	67.00	620.00	2.50	0.25	32.00	8.00	38.00	0.50	18.00	15.00	792.00	40.00	52.00	9.00	2.60	1.50	0.01	230.00	0.50	106.00	100.00
MODE	3.00	0.50	2.50	0.20	N.C.	0.50	2.50	N.C.	N.C.	2.50	0.25	N.C.	N.C.	N.C.	N.C.	N.C.	N.C.	N.C.	10.00	52.00	N.C.	N.C.	1.50	0.01	N.C.	0.50	N.C.	N.C.
STANDARD DEVIATION	1.10	15.25	0.00	0.09	0.13	0.13	0.00	4824.89	228.54	3.31	0.11	14.81	6.02	18.49	3.35	64.34	112.06	632.49	29.04	19.51	7.30	31.49	11.40	0.00	193.86	0.22	44.70	62.86
KURTOSIS	-3.33	4.00	N.C.	5.00	-1.20	2.23	N.C.	4.93	2.46	-3.03	5.00	-0.22	3.69	1.86	5.00	4.97	4.99	1.83	-2.95	2.63	1.59	4.14	5.00	N.C.	1.70	5.00	2.50	1.24
SKEWNESS	-0.61	2.00	N.C.	2.24	0.00	1.13	N.C.	2.22	-1.06	0.66	2.24	-1.02	1.86	-0.27	2.24	2.23	2.23	0.49	-0.02	-1.66	1.04	2.03	2.24	N.C.	0.87	2.24	-1.39	-0.20
LARGEST #	3.00	31.00	2.50	0.40	0.40	0.70	2.50	11000.00	850.00	9.00	0.50	39.00	20.00	62.00	8.00	160.00	264.00	1772.00	70.00	57.00	22.00	75.00	27.00	0.01	580.00	1.00	143.00	176.00
SMALLEST #	1.00	0.50	2.50	0.20	0.10	0.40	2.50	59.00	220.00	2.50	0.25	3.00	5.00	10.00	0.50	12.00	9.00	5.00	10.00	9.00	2.50	2.10	1.50	0.01	51.00	0.50	25.00	2.00

	SUMMARY SPREADSHEET FOR ALL PEACE RIVER IRON STUDY SAMPLES																											
	Precious metals and Platinum Group Elements							Base metals and pathfinders																				
	Au (INAA) ppb	Au (FA) ppb	Ag (INAA) ppm	Ag (ICP) ppm	Pt (FA) ppb	Pd (FA) ppb	Ir (INAA) ppb	As (INAA) ppm	Ba (INAA) ppm	Bi (ICP) ppm	Cd (ICP) ppm	Co (INAA) ppm	Cu (ICP) ppm	Cr (INAA) ppm	Hg (INAA) ppm	Mo (INAA) ppm	Mo (ICP) ppm	Mn (ICP) ppm	Ni (INAA) ppm	Ni (ICP) ppm	Pb (ICP) ppm	Sb (INAA) ppm	Se (INAA) ppm	Sn (INAA) ppm	V (ICP) ppm	W (INAA) ppm	Zn (INAA) ppm	Zn (ICP) ppm
DETECTION LIMIT	2.0	1.0	5.0	0.5	0.1	0.1	5.0	0.5	50.0	5.0	0.5	1.0	1.0	5.0	1.0	1.0	2.0	1.0	20.0	1.0	5.0	0.1	3.0	0.01	2.0	1.0	50.0	1.0
MEAN	3.68	3.10	2.53	0.36	0.70	0.62	2.52	276.60	717.02	3.19	0.26	33.48	14.42	117.09	0.55	11.40	8.78	729.23	63.11	63.95	31.75	6.30	1.80	0.01	764.66	1.72	330.99	315.34
MEDIAN	1.00	1.00	2.50	0.20	0.20	0.40	2.50	150.00	690.00	2.50	0.25	36.00	12.00	120.00	0.50	10.00	6.00	828.00	66.00	64.00	32.00	5.20	1.50	0.01	744.00	0.50	334.00	336.00
MODE	1.00	0.50	2.50	0.20	0.20	0.40	2.50	100.00	590.00	2.50	0.25	14.00	8.00	160.00	0.50	10.00	1.00	1,011.00	10.00	41.00	41.00	11.00	1.50	0.01	247.00	0.50	475.00	521.00
STANDARD DEVIATION	13.01	5.18	0.29	0.22	5.64	0.70	0.20	895.27	241.69	2.20	0.07	21.32	8.13	34.98	0.61	14.94	22.48	417.03	48.89	28.80	12.85	6.94	2.18	0.00	444.75	2.29	178.76	177.31
KURTOSIS	141.60	19.59	72.95	-0.26	123.89	18.84	151.00	139.77	11.70	16.29	24.16	30.15	0.02	-0.32	151.00	69.97	113.47	-0.67	1.43	3.94	-1.12	64.30	120.77	-2.03	-1.51	1.99	-1.12	-1.26
SKEWNESS	11.72	3.98	8.60	1.06	11.13	3.94	12.29	11.61	2.21	3.86	4.91	3.69	1.02	-0.39	12.29	7.57	10.22	-0.13	0.87	0.94	0.08	6.75	10.58	-1.01	0.10	1.72	0.18	0.06
LARGEST #	160.00	36.00	5.00	1.00	63.00	5.10	5.00	11,000.00	2,300.00	17.00	0.70	210.00	38.00	180.00	8.00	160.00	264.00	1,782.00	250.00	215.00	59.00	75.00	27.00	0.01	1,633.00	11.00	808.00	795.00
SMALLEST #	1.00	0.50	2.50	0.20	0.05	0.05	2.50	25.00	220.00	2.50	0.25	2.00	5.00	10.00	0.50	0.50	1.00	5.00	10.00	7.00	2.50	1.00	1.50	0.01	51.00	0.50	25.00	2.00

NOTE: N.C. denotes "Not Calculatable" for some reason, which may include too many results below detection, too few results for a meaningful statistic, etc.

APPENDIX III (Cont.)

SYNOPTIC STATISTICAL ANALYSIS

CLEAR HILLS IRON DEPOSIT STUDY

	Uranium, Thorium, Rare Earth and Selected Other Related Elements																Rock Forming and Related Trace Elements												
	Be (ICP) ppm	Ce (INAA) ppm	Cs (INAA) ppm	Eu (INAA) ppm	Hf (INAA) ppm	La (INAA) ppm	Lu (INAA) ppm	Nd (INAA) ppm	Sc (INAA) ppm	Sm (INAA) ppm	Ta (INAA) ppm	Tb (INAA) ppm	Th (INAA) ppm	U (INAA) ppm	Y (ICP) ppm	Yb (INAA) ppm	Al (ICP) %	Br (INAA) ppm	Ca (INAA) %	Ca (ICP) %	Fe (INAA) %	K (ICP) %	Mg (ICP) %	Na (INAA) %	P (ICP) %	Rb (INAA) ppm	Sr (INAA) ppm	Sr (ICP) ppm	Ti (ICP) ppm
DETECTION LIMIT	2.0	3.0	1.0	0.2	1.0	0.5	0.1	5.0	0.1	0.1	0.5	0.5	0.2	0.5	2.0	0.2	0.01	0.5	3.0	0.01	0.01	0.01	0.01	0.01	0.001	5.0	0.05	1.0	0.01
MEAN	1.29	56.04	1.21	3.36	2.00	36.82	0.72	37.21	12.04	10.43	0.41	2.41	11.93	6.40	86.32	5.01	2.96	1.09	1.00	1.62	32.47	0.36	0.60	0.12	0.67	18.18	0.03	176.61	0.08
MEDIAN	1.00	56.00	0.50	3.40	2.00	37.00	0.71	38.00	12.00	10.50	0.25	2.40	12.00	6.30	85.50	5.10	2.90	0.25	0.50	1.45	32.40	0.34	0.52	0.12	0.64	7.50	0.03	168.00	0.08
MODE	1.00	53.00	0.50	3.50	2.00	38.00	0.71	39.00	12.00	11.00	0.25	2.40	11.00	6.20	100.00	4.80	2.90	0.25	0.50	2.32	31.20	0.35	0.49	0.12	0.74	7.50	0.03	174.00	0.08
STANDARD DEVIATION	0.46	3.23	0.96	0.25	0.27	2.33	0.06	4.46	0.74	0.73	0.35	0.28	1.02	1.06	9.68	0.36	0.24	1.13	0.96	0.58	2.27	0.07	0.19	0.02	0.14	18.10	0.01	26.01	0.01
KURTOSIS	-1.08	-0.04	0.94	1.02	13.50	-1.08	-0.19	-0.23	-1.11	-0.15	2.26	0.01	-0.50	-0.52	-0.46	0.16	-0.03	0.68	2.96	1.07	-0.97	-0.22	1.10	1.76	3.08	0.08	12.24	1.73	-0.19
SKEWNESS	1.00	0.19	1.18	-0.59	0.00	-0.07	0.35	-0.14	-0.06	-0.25	1.98	0.45	0.38	0.38	0.20	-0.50	0.71	1.26	1.95	1.18	-0.20	0.83	1.56	-0.03	1.39	1.31	3.62	1.45	0.41
LARGEST #	2.00	63.00	4.00	3.80	3.00	41.00	0.85	46.00	13.00	12.00	1.30	3.10	14.00	8.60	106.00	5.60	3.55	4.00	4.00	3.25	36.10	0.53	1.06	0.17	1.13	59.00	0.07	247.00	0.11
SMALLEST #	1.00	49.00	0.50	2.70	1.00	33.00	0.60	29.00	11.00	8.70	0.25	1.90	10.00	4.80	68.00	4.10	2.54	0.25	0.50	0.92	28.10	0.26	0.45	0.07	0.45	7.50	0.03	148.00	0.06

SUMMARY SPREADSHEET FOR AGS WORSLEY PIT SAMPLES																													
	Uranium, Thorium, Rare Earth and Selected Other Elements																Rock Forming and Related Trace Elements												
	Be (ICP) ppm	Ce (INAA) ppm	Cs (INAA) ppm	Eu (INAA) ppm	Hf (INAA) ppm	La (INAA) ppm	Lu (INAA) ppm	Nd (INAA) ppm	Sc (INAA) ppm	Sm (INAA) ppm	Ta (INAA) ppm	Tb (INAA) ppm	Th (INAA) ppm	U (INAA) ppm	Y (ICP) ppm	Yb (INAA) ppm	Al (ICP) %	Br (INAA) ppm	Ca (INAA) %	Ca (ICP) %	Fe (INAA) %	K (ICP) %	Mg (ICP) %	Na (INAA) %	P (ICP) %	Rb (INAA) ppm	Sr (INAA) ppm	Sr (ICP) ppm	Ti (ICP) ppm
DETECTION LIMIT	2.0	3.0	1.0	0.2	1.0	0.5	0.1	5.0	0.1	0.1	0.5	0.5	0.2	0.5	2.0	0.2	0.01	0.5	3.0	0.01	0.01	0.01	0.01	0.01	0.001	5.0	0.05	1.0	0.01
MEAN	2.08	56.08	2.35	2.85	3.00	39.46	0.69	35.85	11.29	9.01	0.45	1.93	9.83	7.53	81.77	4.69	3.48	1.85	2.85	3.19	23.30	0.76	0.53	0.13	1.18	54.77	0.03	219.31	0.13
MEDIAN	2.00	54.00	2.00	3.00	3.00	33.00	0.74	32.00	12.00	9.50	0.25	2.30	10.00	6.00	90.00	5.10	3.38	2.10	1.00	1.49	19.50	0.72	0.47	0.08	0.66	55.00	0.03	123.00	0.11
MODE	2.00	48.00	2.00	3.00	3.00	29.00	N.C.	32.00	13.00	13.00	0.25	1.90	12.00	19.00	N.C.	6.90	2.77	0.25	0.50	N.C.	N.C.	0.94	0.44	0.07	N.C.	N.C.	0.03	N.C.	0.13
STANDARD DEVIATION	0.76	13.03	1.18	1.15	1.29	13.65	0.24	12.48	3.92	3.42	0.32	0.83	3.26	5.81	41.18	1.71	0.94	1.44	3.65	4.02	11.73	0.28	0.19	0.09	1.47	16.37	0.02	205.55	0.05
KURTOSIS	-1.05	-0.77	1.24	-0.21	1.83	-0.99	-0.58	-0.90	-1.09	-0.42	-0.38	-0.03	-0.89	0.71	-0.73	-0.13	-0.74	-1.68	1.69	2.17	-0.94	0.55	0.13	0.82	2.19	1.61	5.11	2.33	1.01
SKEWNESS	-0.14	0.55	0.89	-0.69	1.10	0.78	-0.47	0.03	-0.07	-0.70	1.17	-0.87	-0.27	1.26	-0.59	-0.71	-0.24	0.20	1.68	1.82	-0.19	0.71	1.00	1.19	1.80	0.50	2.43	1.87	1.11
LARGEST #	3.00	81.00	5.00	4.30	6.00	64.00	1.03	53.00	17.00	13.00	1.10	3.00	15.00	19.00	132.00	6.90	4.82	3.80	11.00	12.46	39.90	1.35	0.94	0.35	4.60	92.00	0.08	699.00	0.25
SMALLEST #	1.00	41.00	0.50	0.70	1.00	26.00	0.25	14.00	5.30	2.60	0.25	0.25	4.60	1.20	11.00	1.40	1.89	0.25	0.50	0.26	2.85	0.30	0.32	0.04	0.04	25.00	0.03	80.00	0.07

SUMMARY SPREADSHEET FOR BRYANT AND MARUM WORSLEY PIT SAMPLES																													
	Uranium, Thorium, Rare Earth and Selected Other Elements																Rock Forming and Related Trace Elements												
	Be (ICP) ppm	Ce (INAA) ppm	Cs (INAA) ppm	Eu (INAA) ppm	Hf (INAA) ppm	La (INAA) ppm	Lu (INAA) ppm	Nd (INAA) ppm	Sc (INAA) ppm	Sm (INAA) ppm	Ta (INAA) ppm	Tb (INAA) ppm	Th (INAA) ppm	U (INAA) ppm	Y (ICP) ppm	Yb (INAA) ppm	Al (ICP) %	Br (INAA) ppm	Ca (INAA) %	Ca (ICP) %	Fe (INAA) %	K (ICP) %	Mg (ICP) %	Na (INAA) %	P (ICP) %	Rb (INAA) ppm	Sr (INAA) ppm	Sr (ICP) ppm	Ti (ICP) ppm
DETECTION LIMIT	2.0	3.0	1.0	0.2	1.0	0.5	0.1	5.0	0.1	0.1	0.5	0.5	0.2	0.5	2.0	0.2	0.01	0.5	3.0	0.01	0.01	0.01	0.01	0.01	0.001	5.0	0.05	1.0	0.01
MEAN	1.82	51.73	2.23	2.48	2.55	34.00	0.62	28.82	10.87	7.71	0.25	1.74	9.83	4.45	69.82	1.73	2.95	1.44	2.32	2.33	25.51	0.72	0.56	0.13	0.65	37.95	0.03	174.45	0.12
MEDIAN	2.00	55.00	2.00	2.90	2.00	35.00	0.63	31.00	12.00	8.60	0.25	2.00	11.00	3.70	83.00	2.00	2.68	1.00	2.00	1.55	30.80	0.62	0.45	0.07	0.47	46.00	0.03	141.00	0.11
MODE	1.00	40.00	2.00	N.C.	2.00	39.00	N.C.	36.00	13.00	11.00	0.25	2.20	11.00	N.C.	N.C.	2.20	2.68	0.25	0.50	1.55	N.C.	N.C.	0.43	0.06	N.C.	7.50	0.03	N.C.	0.09
STANDARD DEVIATION	0.87	10.35	1.17	1.19	1.81	8.32	0.25	8.86	2.97	3.51	0.00	0.88	2.86	3.37	40.26	0.91	0.67	1.27	2.67	2.60	10.29	0.30	0.20	0.13	0.63	23.03	0.00	97.49	0.05
KURTOSIS	-1.62	-1.48	2.79	-0.90	1.01	-0.79	-0.99	-0.69	-0.77	-0.96	N.C.	-0.47	-1.17	3.82	-1.41	-0.28	0.41	-0.17	1.55	1.61	0.91	2.27	-1.55	2.61	6.51	-1.16	-2.50	5.33	4.81
SKEWNESS	0.41	-0.25	1.16	-0.38	1.46	0.13	-0.03	-0.58	-0.43	-0.24	N.C.	-0.15	-0.26	1.70	-0.37	-0.26	0.91	0.85	1.65	1.71	-1.30	1.48	0.40	1.90	2.31	-0.19	1.17	2.11	2.02
LARGEST #	3.00	67.00	5.00	4.20	6.00	49.00	1.01	40.00	15.00	13.00	0.25	3.20	14.00	13.00	115.00	3.20	4.34	4.00	8.00	7.49	34.90	1.44	0.88	0.44	2.39	72.00	0.03	434.00	0.25
SMALLEST #	1.00	37.00	0.50	0.50	1.00	23.00	0.23	12.00	5.50	1.90	0.25	0.25	5.50	1.00	8.00	0.10	2.16	0.25	0.50	0.25	2.98	0.39	0.29	0.05	0.06	7.50	0.03	78.00	0.08

SUMMARY SPREADSHEET FOR MARUM DRILLING NEAR WORSLEY PIT SAMPLES																													
	Uranium, Thorium, Rare Earth and Selected Other Elements															Rock Forming and Related Trace Elements													
	Be (ICP) ppm	Ce (INAA) ppm	Cs (INAA) ppm	Eu (INAA) ppm	Hf (INAA) ppm	La (INAA) ppm	Lu (INAA) ppm	Nd (INAA) ppm	Sc (INAA) ppm	Sm (INAA) ppm	Ta (INAA) ppm	Tb (INAA) ppm	Th (INAA) ppm	U (INAA) ppm	Y (ICP) ppm	Yb (INAA) ppm	Al (ICP) %	Br (INAA) ppm	Ca (INAA) %	Ca (ICP) %	Fe (INAA) %	K (ICP) %	Mg (ICP) %	Na (INAA) %	P (ICP) %	Rb (INAA) ppm	Sr (INAA) ppm	Sr (ICP) ppm	Ti (ICP) ppm
DETECTION LIMIT	2.0	3.0	1.0	0.2	1.0	0.5	0.1	5.0	0.1	0.1	0.5	0.5	0.2	0.5	2.0	0.2	0.01	0.5	3.0	0.01	0.01	0.01	0.01	0.01	0.001	5.0	0.05	1.0	0.01
MEAN	1.08	57.26	4.11	2.08	4.08	35.55	0.55	28.47	12.38	7.00	0.54	1.30	10.74	4.95	50.11	4.09	4.95	0.74	2.66	3.06	15.48	1.23	0.74	0.23	0.40	74.62	0.03	183.71	0.21
MEDIAN	1.00	56.00	3.00	1.80	4.00	34.00	0.54	28.00	13.00	6.20	0.25	1.10	11.00	4.10	37.00	3.80	4.21	0.25	2.00	2.77	11.10	1.04	0.73	0.20	0.31	71.00	0.03	167.00	0.17
MODE	1.00	55.00	2.00	1.40	3.00	31.00	0.54	27.00	14.00	11.00	0.25	0.25	11.00	3.70	26.00	3.50	4.06	0.25	0.50	0.40	33.30	0.61	0.76	0.09	0.08	7.50	0.03	206.00	0.13
STANDARD DEVIATION	0.27	10.86	2.34	0.77	1.54	7.14	0.13	4.97	1.90	2.35	0.43	0.78	1.89	2.73	27.31	1.18	1.68	0.84	2.60	2.71	10.89	0.60	0.20	0.13	0.48	41.51	0.02	106.77	0.10
KURTOSIS	8.90	0.55	-1.06	-0.23	-1.28	3.20	0.51	2.10	0.18	0.26	-0.14	-0.62	0.55	10.11	0.82	0.17	-1.30	1.96	7.31	5.49	-1.49	-1.36	2.13	0.86	17.25	-0.91	20.74	37.22	-1.34
SKEWNESS	3.27	0.08	0.44	0.72	-0.02	0.77	0.15	0.69	-0.73	0.90	1.12	0.37	-0.58	2.58	1.04	0.62	0.51	1.65	2.33	1.93	0.31	0.44	1.14	0.82	3.65	0.12	4.41	5.43	0.55
LARGEST #	2.00	83.00	9.00	4.40	7.00	66.00	0.96	46.00	15.00	14.00	1.70	3.60	14.00	20.00	152.00	7.90	7.80	3.70	15.00	15.49	37.70	2.27	1.43	0.71	3.05	150.00	0.13	992.00	0.40
SMALLEST #	1.00	22.00	0.50	0.90	1.00	15.00	0.16	15.00	6.50	3.00	0.25	0.25	5.60	0.25	16.00	1.80	2.35	0.25	0.50	0.30	2.80	0.40	0.33	0.07	0.06	7.50	0.03	97.00	0.09

	Uranium, Thorium, Rare Earth and Selected Other Elements																Rock Forming and Related Trace Elements												
	Be (ICP ppm	Ce (INAA) ppm	Cs (INAA) ppm	Eu (INAA) ppm	Hf (INAA) ppm	La (INAA) ppm	Lu (INAA) ppm	Nd (INAA) ppm	Sc (INAA) ppm	Sm (INAA) ppm	Ta (INAA) ppm	Tb (INAA) ppm	Th (INAA) ppm	U (INAA) ppm	Y (ICP) ppm	Yb (INAA) ppm	Al (ICP) %	Br (INAA) ppm	Ca (INAA) %	Ca (ICP) %	Fe (INAA) %	K (ICP) %	Mg (ICP) %	Na (INAA) %	P (ICP) %	Rb (INAA) ppm	Sr (INAA) ppm	Sr (ICP) ppm	Ti (ICP) ppm
DETECTION LIMIT	2.0	3.0	1.0	0.2	1.0	0.5	0.1	5.0	0.1	0.1	0.5	0.5	0.2	0.5	2.0	0.2	0.01	0.5	3.0	0.01	0.01	0.01	0.01	0.01	0.001	5.0	0.05	1.0	0.01
MEAN	1.00	36.30	1.10	1.44	1.61	24.20	0.26	18.50	6.08	4.50	0.25	1.05	3.68	2.67	32.40	1.76	1.45	0.25	9.70	9.55	18.50	0.38	0.74	0.10	0.51	22.60	0.03	247.80	0.06
MEDIAN	1.00	36.00	1.00	1.60	2.00	28.00	0.26	15.00	5.20	4.70	0.25	1.20	4.70	3.20	34.00	1.70	1.62	0.25	8.00	8.74	12.60	0.43	0.80	0.12	0.45	29.00	0.03	239.00	0.07
MODE	1.00	N.C.	1.00	N.C.	2.00	N.C.	N.C.	N.C.	N.C.	N.C.	0.25	1.50	N.C.	N.C.	N.C.	N.C.	N.C.	0.25	N.C.	N.C.	N.C.	N.C.	N.C.	0.12	N.C.	7.50	0.03	N.C.	0.07
STANDARD DEVIATION	0.00	24.10	0.55	0.92	1.12	14.91	0.15	13.12	4.03	3.03	0.00	0.53	2.14	1.40	20.98	1.14	0.73	0.00	7.81	7.46	11.02	0.19	0.46	0.03	0.37	14.32	0.01	153.12	0.02
KURTOSIS	N.C.	-0.29	2.92	-0.43	-0.26	-0.37	1.49	-0.99	-0.09	-0.87	N.C.	-0.23	2.39	3.56	1.17	0.89	4.07	N.C.	-1.37	-2.04	-2.44	3.27	1.43	4.68	-0.73	-2.63	5.00	0.80	3.32
SKEWNESS	N.C.	-0.55	1.29	-0.71	-0.36	-0.88	-0.77	0.29	-0.30	-0.56	N.C.	-0.95	-1.62	-1.86	0.12	-0.41	-1.97	N.C.	0.31	-0.12	0.70	-1.63	-1.22	-2.15	-0.20	-0.26	2.24	-0.99	-1.74
LARGEST #	1.00	63.00	2.00	2.40	3.00	38.00	0.44	36.00	11.00	7.60	0.25	1.50	5.30	3.70	62.00	3.20	1.94	0.25	20.00	17.44	33.10	0.56	1.15	0.12	0.95	39.00	0.05	387.00	0.08
SMALLEST #	1.00	1.50	0.50	0.10	0.05	2.00	0.03	2.50	0.40	0.20	0.25	0.25	0.10	0.25	4.00	0.10	0.17	0.25	0.50	0.06	9.22	0.05	0.01	0.04	0.01	7.50	0.03	10.00	0.02

	Uranium, Thorium, Rare Earth and Selected Other Elements																Rock Forming and Related Trace Elements												
	Be (ICP ppm	Ce (INAA) ppm	Cs (INAA) ppm	Eu (INAA) ppm	Hf (INAA) ppm	La (INAA) ppm	Lu (INAA) ppm	Nd (INAA) ppm	Sc (INAA) ppm	Sm (INAA) ppm	Ta (INAA) ppm	Tb (INAA) ppm	Th (INAA) ppm	U (INAA) ppm	Y (ICP) ppm	Yb (INAA) ppm	Al (ICP) %	Br (INAA) ppm	Ca (INAA) %	Ca (ICP) %	Fe (INAA) %	K (ICP) %	Mg (ICP) %	Na (INAA) %	P (ICP) %	Rb (INAA) ppm	Sr (INAA) ppm	Sr (ICP) ppm	Ti (ICP) ppm
DETECTION LIMIT	2.0	3.0	1.0	0.2	1.0	0.5	0.1	5.0	0.1	0.1	0.5	0.5	0.2	0.5	2.0	0.2	0.01	0.5	3.0	0.01	0.01	0.01	0.01	0.01	0.001	5.0	0.05	1.0	0.01
MEAN	1.26	55.71	3.16	2.39	3.39	35.57	0.59	30.42	11.91	7.79	0.47	1.59	10.60	5.32	60.63	4.07	4.18	0.95	2.57	2.95	20.28	0.96	0.68	0.19	0.54	57.61	0.03	186.35	0.17
MEDIAN	1.00	56.00	2.00	2.40	3.00	35.00	0.59	29.00	12.00	7.60	0.25	1.70	11.00	4.70	60.00	4.10	3.69	0.25	2.00	1.79	24.00	0.73	0.67	0.14	0.48	52.00	0.03	166.00	0.13
MODE	1.00	55.00	2.00	1.40	2.00	34.00	0.69	27.00	13.00	11.00	0.25	0.25	11.00	3.70	26.00	5.10	2.90	0.25	0.50	2.32	31.10	0.35	0.49	0.12	0.07	7.50	0.03	168.00	0.08
STANDARD DEVIATION	0.53	11.29	2.30	0.94	1.64	8.03	0.17	7.71	2.44	2.77	0.39	0.84	2.45	3.05	31.58	1.41	1.71	1.05	3.11	3.11	11.91	0.61	0.22	0.12	0.63	41.65	0.01	109.79	0.10
KURTOSIS	3.08	3.40	-0.30	-1.01	-1.04	3.92	0.36	1.47	3.35	-0.77	0.75	-1.08	2.19	7.72	-0.83	0.08	-0.24	0.88	9.54	7.00	-1.54	-0.53	1.24	1.43	19.25	-0.60	21.13	23.65	-0.34
SKEWNESS	1.99	-0.63	0.86	0.00	0.47	0.32	-0.18	0.11	-1.35	0.00	1.46	-0.12	-1.25	2.26	0.28	-0.32	0.84	1.38	2.75	2.43	-0.21	0.87	0.69	1.21	3.90	0.55	4.36	4.21	1.01
LARGEST #	3.00	83.00	9.00	4.40	7.00	66.00	1.03	53.00	17.00	14.00	1.70	3.60	15.00	20.00	152.00	7.90	7.80	4.00	20.00	17.44	39.90	2.27	1.43	0.71	4.60	150.00	0.13	992.00	0.40
SMALLEST #	1.00	1.50	0.50	0.10	0.05	2.00	0.03	2.50	0.40	0.20	0.25	0.25	0.10	0.25	4.00	0.10	0.17	0.25	0.50	0.06	2.80	0.05	0.01	0.04	0.01	7.50	0.03	10.00	0.02

NOTE: N.C. denotes "Not "

APPENDIX IV

COMPARATIVE RESULTS OF DUPLICATE SAMPLE PAIRS

CLEAR HILLS IRON DEPOSIT STUDY

APPENDIX IV

COMPARATIVE RESULTS OF DUPLICATE SAMPLE PAIRS
CLEAR HILLS IRON DEPOSIT STUDY

	Precious metals and Platinum Group Elements							Base metals and Pathfinder Elements																				
Sample No.	Au (INAA) ppb	Au (FA) ppb	Ag (INAA) ppm	Ag (ICP) ppm	Pt (FA) ppb	Pd (FA) ppb	Ir (INAA) ppb	As (INAA) ppm	Ba (INAA) ppm	Bi (ICP) ppm	Cd (ICP) ppm	Co (INAA) ppm	Cu (ICP) ppm	Cr (INAA) ppm	Hg (INAA) ppm	Mo (INAA) ppm	Mo (ICP) ppm	Mn (ICP) ppm	Ni (INAA) ppm	Ni (ICP) ppm	Pb (ICP) ppm	Sb (INAA) ppm	Se (INAA) ppm	Sn (INAA) ppm	V (ICP) ppm	W (INAA) ppm	Zn (INAA) ppm	Zn (ICP) ppm
AS010	1	0.5	2.5	0.2	0.2	0.4	2.5	490	480	2.5	0.25	51	8	170	0.5	18	11	853	99	90	41	11	1.5	0.005	1190	0.5	551	467
AS009	1	0.5	2.5	0.2	0.3	0.6	2.5	460	360	5	0.25	50	8	170	0.5	20	10	1011	100	86	37	11	1.5	0.005	1144	0.5	573	521
difference	0	0	0	0	0.1	0.2	0	30	120	2.5	0	1	0	0	0	2	1	158	1	4	4	0	0	0	46	0	22	54
% difference	0%	0%	0%	0%	50%	50%	0%	6%	25%	100%	0%	2%	0%	0%	0%	11%	9%	19%	1%	4%	10%	0%	0%	0%	4%	0%	4%	12%

	Precious metals and Platinum Group Elements							Base metals and Pathfinder Elements																				
Sample No.	Au (INAA) ppb	Au (FA) ppb	Ag (INAA) ppm	Ag (ICP) ppm	Pt (FA) ppb	Pd (FA) ppb	Ir (INAA) ppb	As (INAA) ppm	Ba (INAA) ppm	Bi (ICP) ppm	Cd (ICP) ppm	Co (INAA) ppm	Cu (ICP) ppm	Cr (INAA) ppm	Hg (INAA) ppm	Mo (INAA) ppm	Mo (ICP) ppm	Mn (ICP) ppm	Ni (INAA) ppm	Ni (ICP) ppm	Pb (ICP) ppm	Sb (INAA) ppm	Se (INAA) ppm	Sn (INAA) ppm	V (ICP) ppm	W (INAA) ppm	Zn (INAA) ppm	Zn (ICP) ppm
AS020	11	0.5	2.5	0.2	0.1	0.7	2.5	490	620	2.5	0.25	50	6	160	0.5	5	12	1001	120	101	41	11	1.5	0.01	1286	6	530	506
AS019	3	3	2.5	0.2	0.1	0.3	2.5	450	430	8	0.25	44	5	140	0.5	17	11	1010	170	98	39	10	1.5	0.01	1285	0.5	456	506
difference	8	2.5	0	0	0	0.4	0	40	190	5.5	0	6	1	20	0	12	1	9	50	3	2	1	0	0	1	5.5	74	0
% difference	73%	500%	0%	0%	0%	57%	0%	8%	31%	220%	0%	12%	17%	13%	0%	240%	8%	1%	42%	3%	5%	9%	0%	0%	0%	92%	14%	0%

	Precious metals and Platinum Group Elements							Base metals and Pathfinder Elements																				
Sample No.	Au (INAA) ppb	Au (FA) ppb	Ag (INAA) ppm	Ag (ICP) ppm	Pt (FA) ppb	Pd (FA) ppb	Ir (INAA) ppb	As (INAA) ppm	Ba (INAA) ppm	Bi (ICP) ppm	Cd (ICP) ppm	Co (INAA) ppm	Cu (ICP) ppm	Cr (INAA) ppm	Hg (INAA) ppm	Mo (INAA) ppm	Mo (ICP) ppm	Mn (ICP) ppm	Ni (INAA) ppm	Ni (ICP) ppm	Pb (ICP) ppm	Sb (INAA) ppm	Se (INAA) ppm	Sn (INAA) ppm	V (ICP) ppm	W (INAA) ppm	Zn (INAA) ppm	Zn (ICP) ppm
AW010	2	0.5	2.5	0.2	0.1	0.5	2.5	89	940	2.5	0.25	32	10	49	0.5	12	1	908	53	53	18	3.1	1.5	0.005	397	0.5	316	353
AW009	4	0.5	2.5	0.2	0.2	0.5	2.5	73	860	2.5	0.25	35	9	42	0.5	0.5	1	754	60	60	14	2.8	1.5	0.005	311	0.5	296	337
difference	2	0	0	0	0.1	0	0	16	80	0	0	3	1	7	0	11.5	0	154	7	7	4	0.3	0	0	86	0	20	16
% differenc	100%	0%	0%	0%	100%	0%	0%	18%	9%	0%	0%	9%	10%	14%	0%	96%	0%	17%	13%	13%	22%	10%	0%	0%	22%	0%	6%	5%

	Precious metals and Platinum Group Elements							Base metals and Pathfinder Elements																				
Sample No.	Au (INAA) ppb	Au (FA) ppb	Ag (INAA) ppm	Ag (ICP) ppm	Pt (FA) ppb	Pd (FA) ppb	Ir (INAA) ppb	As (INAA) ppm	Ba (INAA) ppm	Bi (ICP) ppm	Cd (ICP) ppm	Co (INAA) ppm	Cu (ICP) ppm	Cr (INAA) ppm	Hg (INAA) ppm	Mo (INAA) ppm	Mo (ICP) ppm	Mn (ICP) ppm	Ni (INAA) ppm	Ni (ICP) ppm	Pb (ICP) ppm	Sb (INAA) ppm	Se (INAA) ppm	Sn (INAA) ppm	V (ICP) ppm	W (INAA) ppm	Zn (INAA) ppm	Zn (ICP) ppm
MD010	1	0.5	2.5	0.2	0.2	0.4	2.5	130	640	2.5	0.25	37	13	110	0.5	13	9	965	97	62	33	5.3	1.5	0.005	735	0.5	272	298
MD009	1	0.5	2.5	0.2	0.1	0.6	2.5	100	770	7	0.25	33	13	94	0.5	15	9	911	11	61	30	4.8	6	0.005	741	0.5	289	294
difference	0	0	0	0	0.1	0.2	0	30	130	4.5	0	4	0	16	0	2	0	54	86	1	3	0.5	4.5	0	6	0	17	4
% difference	0%	0%	0%	0%	50%	50%	0%	23%	20%	180%	0%	11%	0%	15%	0%	15%	0%	6%	89%	2%	9%	9%	300%	0%	1%	0%	6%	1%

	Precious metals and Platinum Group Elements							Base metals and Pathfinder Elements																				
Sample No.	Au (INAA) ppb	Au (FA) ppb	Ag (INAA) ppm	Ag (ICP) ppm	Pt (FA) ppb	Pd (FA) ppb	Ir (INAA) ppb	As (INAA) ppm	Ba (INAA) ppm	Bi (ICP) ppm	Cd (ICP) ppm	Co (INAA) ppm	Cu (ICP) ppm	Cr (INAA) ppm	Hg (INAA) ppm	Mo (INAA) ppm	Mo (ICP) ppm	Mn (ICP) ppm	Ni (INAA) ppm	Ni (ICP) ppm	Pb (ICP) ppm	Sb (INAA) ppm	Se (INAA) ppm	Sn (INAA) ppm	V (ICP) ppm	W (INAA) ppm	Zn (INAA) ppm	Zn (ICP) ppm
MD020		1 NA		2.5	0.4 NA	NA	2.5	88	740	2.5	0.25	41	13	120	0.5	15	13	891	11	67	35	5.5	1.5	0.005	880	0.5	343	351
MD019		6 NA		2.5	0.2 NA	NA	2.5	84	600	2.5	0.25	39	12	120	0.5	22	12	906	92	66	33	5.2	1.5	0.005	860	0.5	335	340
difference		5 NA		0	0.2 NA	NA	0	4	140	0	0	2	1	0	0	7	1	15	81	1	2	0.3	0	0	20	0	8	11
% difference		500% NA		0%	50% NA	NA	0%	5%	19%	0%	0%	5%	8%	0%	0%	47%	8%	2%	736%	1%	6%	5%	0%	0%	2%	0%	2%	3%

	Precious metals and Platinum Group Elements							Base metals and Pathfinder Elements																				
Sample No.	Au (INAA) ppb	Au (FA) ppb	Ag (INAA) ppm	Ag (ICP) ppm	Pt (FA) ppb	Pd (FA) ppb	Ir (INAA) ppb	As (INAA) ppm	Ba (INAA) ppm	Bi (ICP) ppm	Cd (ICP) ppm	Co (INAA) ppm	Cu (ICP) ppm	Cr (INAA) ppm	Hg (INAA) ppm	Mo (INAA) ppm	Mo (ICP) ppm	Mn (ICP) ppm	Ni (INAA) ppm	Ni (ICP) ppm	Pb (ICP) ppm	Sb (INAA) ppm	Se (INAA) ppm	Sn (INAA) ppm	V (ICP) ppm	W (INAA) ppm	Zn (INAA) ppm	Zn (ICP) ppm
MD030	6	1	2.5	0.2	0.3	0.8	2.5	80	1200	2.5	0.25	16	26	120	0.5	10	2	180	130	41	17	2.2	1.5	0.005	256	0.5	142	130
MD029	1	0.5	2.5	0.7	0.3	0.8	2.5	80	1200	2.5	0.25	14	26	110	0.5	7	2	198	12	43	17	2.1	1.5	0.005	267	0.5	152	136
difference	5	0.5	0	0.5	0	0	0	0	0	0	0	2	0	10	0	3	0	18	118	2	0	0.1	0	0	11	0	10	6
% difference	83%	50%	0%	250%	0%	0%	0%	0%	0%	0%	0%	13%	0%	8%	0%	30%	0%	10%	91%	5%	0%	5%	0%	0%	4%	0%	7%	5%

	Precious metals and Platinum Group Elements							Base metals and Pathfinder Elements																				
Sample No.	Au (INAA) ppb	Au (FA) ppb	Ag (INAA) ppm	Ag (ICP) ppm	Pt (FA) ppb	Pd (FA) ppb	Ir (INAA) ppb	As (INAA) ppm	Ba (INAA) ppm	Bi (ICP) ppm	Cd (ICP) ppm	Co (INAA) ppm	Cu (ICP) ppm	Cr (INAA) ppm	Hg (INAA) ppm	Mo (INAA) ppm	Mo (ICP) ppm	Mn (ICP) ppm	Ni (INAA) ppm	Ni (ICP) ppm	Pb (ICP) ppm	Sb (INAA) ppm	Se (INAA) ppm	Sn (INAA) ppm	V (ICP) ppm	W (INAA) ppm	Zn (INAA) ppm	Zn (ICP) ppm
MD033	1	4	2.5	0.2	0.3	0.8	2.5	210	1000	2.5	0.25	18	22	94	0.5	4	6	162	10	40	18	2.8	1.5	0.005	305	0.5	167	146
MD032	4	0.5	2.5	0.2	0.3	0.7	2.5	300	970	2.5	0.25	21	18	94	0.5	10	5	421	10	36	19	4.2	1.5	0.005	329	0.5	156	148
difference	3	3.5	0	0	0	0.1	0	90	30	0	0	3	4	0	0	6	1	259	0	4	1	1.4	0	0	24	0	11	2
% differenc	300%	88%	0%	0%	0%	13%	0%	43%	3%	0%	0%	17%	18%	0%	0%	150%	17%	160%	0%	10%	6%	50%	0%	0%	8%	0%	7%	1%

	Precious metals and Platinum Group Elements							Base metals and Pathfinder Elements																				
Sample No.	Au (INAA) ppb	Au (FA) ppb	Ag (INAA) ppm	Ag (ICP) ppm	Pt (FA) ppb	Pd (FA) ppb	Ir (INAA) ppb	As (INAA) ppm	Ba (INAA) ppm	Bi (ICP) ppm	Cd (ICP) ppm	Co (INAA) ppm	Cu (ICP) ppm	Cr (INAA) ppm	Hg (INAA) ppm	Mo (INAA) ppm	Mo (ICP) ppm	Mn (ICP) ppm	Ni (INAA) ppm	Ni (ICP) ppm	Pb (ICP) ppm	Sb (INAA) ppm	Se (INAA) ppm	Sn (INAA) ppm	V (ICP) ppm	W (INAA) ppm	Zn (INAA) ppm	Zn (ICP) ppm
MD040	1	5	2.5	0.2	0.3	0.5	2.5	150	870	2.5	0.25	20	16	86	0.5	4	4	456	10	38	19	3.2	1.5	0.005	377	0.5	196	163
MD039	1	4	2.5	0.2	0.2	0.5	2.5	170	760	2.5	0.25	20	16	81	0.5	3	4	828	93	37	21	3.4	1.5	0.005	377	0.5	205	168
difference	0	1	0	0	0.1	0	0	20	110	0	0	0	0	5	0	1	0	372	83	1	2	0.2	0	0	0	0	9	5
% difference	0%	20%	0%	0%	33%	0%	0%	13%	13%	0%	0%	0%	0%	6%	0%	25%	0%	82%	830%	3%	11%	6%	0%	0%	0%	0%	5%	3%

	Precious metals and Platinum Group Elements							Base metals and Pathfinder Elements																				
Sample No.	Au (INAA) ppb	Au (FA) ppb	Ag (INAA) ppm	Ag (ICP) ppm	Pt (FA) ppb	Pd (FA) ppb	Ir (INAA) ppb	As (INAA) ppm	Ba (INAA) ppm	Bi (ICP) ppm	Cd (ICP) ppm	Co (INAA) ppm	Cu (ICP) ppm	Cr (INAA) ppm	Hg (INAA) ppm	Mo (INAA) ppm	Mo (ICP) ppm	Mn (ICP) ppm	Ni (INAA) ppm	Ni (ICP) ppm	Pb (ICP) ppm	Sb (INAA) ppm	Se (INAA) ppm	Sn (INAA) ppm	V (ICP) ppm	W (INAA) ppm	Zn (INAA) ppm	Zn (ICP) ppm
MD051	1	10	2.5	0.2	0.2	0.3	2.5	210	590	2.5	0.25	45	12	140	0.5	12	13	980	83	79	45	9.2	1.5	0.005	1114	0.5	428	464
MD050	5	13	2.5	0.2	0.2	0.3	2.5	180	610	2.5	0.25	40	13	130	0.5	17	13	968	81	80	39	8	1.5	0.005	1127	0.5	373	464
difference	4	3	0	0	0	0	0	30	20	0	0	5	1	10	0	5	0	12	2	1	6	1.2	0	0	13	0	55	0
% difference	80%	23%	0%	0%	0%	0%	0%	17%	3%	0%	0%	13%	8%	8%	0%	29%	0%	1%	2%	1%	15%	15%	0%	0%	1%	0%	15%	0%

	Precious metals and Platinum Group Elements							Base metals and Pathfinder Elements																				
Sample No.	Au (INAA) ppb	Au (FA) ppb	Ag (INAA) ppm	Ag (ICP) ppm	Pt (FA) ppb	Pd (FA) ppb	Ir (INAA) ppb	As (INAA) ppm	Ba (INAA) ppm	Bi (ICP) ppm	Cd (ICP) ppm	Co (INAA) ppm	Cu (ICP) ppm	Cr (INAA) ppm	Hg (INAA) ppm	Mo (INAA) ppm	Mo (ICP) ppm	Mn (ICP) ppm	Ni (INAA) ppm	Ni (ICP) ppm	Pb (ICP) ppm	Sb (INAA) ppm	Se (INAA) ppm	Sn (INAA) ppm	V (ICP) ppm	W (INAA) ppm	Zn (INAA) ppm	Zn (ICP) ppm
MD060	1	2	2.5	0.2	0.2	0.3	2.5	230	490	2.5	0.25	37	10	150	0.5	12	8	853	72	76	47	7.1	1.5	0.01	1230	6	536	457
MD059	5	3	2.5	0.2	0.2	0.3	2.5	240	610	2.5	0.25	39	10	160	0.5	10	7	809	73	71	51	7.2	1.5	0.01	1179	9	640	469
difference	4	1	0	0	0	0	0	10	120	0	0	2	0	10	0	2	1	44	1	5	4	0.1	0	0	51	3	104	12
% difference	400%	50%	0%	0%	0%	0%	0%	4%	24%	0%	0%	5%	0%	7%	0%	17%	13%	5%	1%	7%	9%	1%	0%	0%	4%	50%	19%	3%

	Precious metals and Platinum Group Elements							Base metals and Pathfinder Elements																				
Sample No.	Au (INAA) ppb	Au (FA) ppb	Ag (INAA) ppm	Ag (ICP) ppm	Pt (FA) ppb	Pd (FA) ppb	Ir (INAA) ppb	As (INAA) ppm	Ba (INAA) ppm	Bi (ICP) ppm	Cd (ICP) ppm	Co (INAA) ppm	Cu (ICP) ppm	Cr (INAA) ppm	Hg (INAA) ppm	Mo (INAA) ppm	Mo (ICP) ppm	Mn (ICP) ppm	Ni (INAA) ppm	Ni (ICP) ppm	Pb (ICP) ppm	Sb (INAA) ppm	Se (INAA) ppm	Sn (INAA) ppm	V (ICP) ppm	W (INAA) ppm	Zn (INAA) ppm	Zn (ICP) ppm
MD067	1	NA	2.5	0.2	NA	NA	2.5	1000	610	2.5	0.25	46	8	110	0.5	16	11	1039	53	73	39	19	3	0.005	896	0.5	433	350
MD066	1	NA	2.5	0.2	NA	NA	2.5	74	580	2.5	0.25	49	9	120	0.5	13	8	827	52	68	43	4.4	1.5	0.005	834	0.5	422	332
difference	0	N.C.	0	0	N.C.	N.C.	0	926	30	0	0	3	1	10	0	3	3	212	1	5	4	14.6	1.5	0	62	0	11	18
% difference	0%	N.C.	0%	0%	N.C.	N.C.	0%	93%	5%	0%	0%	7%	13%	9%	0%	19%	27%	20%	2%	7%	10%	77%	50%	0%	7%	0%	3%	5%

	Precious metals and Platinum Group Elements							Base metals and Pathfinder Elements																				
Sample No.	Au (INAA) ppb	Au (FA) ppb	Ag (INAA) ppm	Ag (ICP) ppm	Pt (FA) ppb	Pd (FA) ppb	Ir (INAA) ppb	As (INAA) ppm	Ba (INAA) ppm	Bi (ICP) ppm	Cd (ICP) ppm	Co (INAA) ppm	Cu (ICP) ppm	Cr (INAA) ppm	Hg (INAA) ppm	Mo (INAA) ppm	Mo (ICP) ppm	Mn (ICP) ppm	Ni (INAA) ppm	Ni (ICP) ppm	Pb (ICP) ppm	Sb (INAA) ppm	Se (INAA) ppm	Sn (INAA) ppm	V (ICP) ppm	W (INAA) ppm	Zn (INAA) ppm	Zn (ICP) ppm
MD070	3	NA	2.5	0.2	NA	NA	2.5	320	460	2.5	0.25	50	7	180	0.5	9	10	1346	13.5	93	57	9.4	1.5	0.01	1550	6	614	511
MD069	3	NA	2.5	0.2	NA	NA	2.5	300	470	2.5	0.25	48	7	160	0.5	8	10	1661	64	102	59	8.5	1.5	0.01	1540	8	614	521
difference	0	N.C.	0	0	N.C.	N.C.	0	20	10	0	0	2	0	20	0	1	0	315	50.5	9	2	0.9	0	0	10	2	0	10
% difference	0%	N.C.	0%	0%	N.C.	N.C.	0%	6%	2%	0%	0%	4%	0%	11%	0%	11%	0%	23%	374%	10%	4%	10%	0%	0%	1%	33%	0%	2%

	Precious metals and Platinum Group Elements							Base metals and Pathfinder Elements																				
Sample No.	Au (INAA) ppb	Au (FA) ppb	Ag (INAA) ppm	Ag (ICP) ppm	Pt (FA) ppb	Pd (FA) ppb	Ir (INAA) ppb	As (INAA) ppm	Ba (INAA) ppm	Bi (ICP) ppm	Cd (ICP) ppm	Co (INAA) ppm	Cu (ICP) ppm	Cr (INAA) ppm	Hg (INAA) ppm	Mo (INAA) ppm	Mo (ICP) ppm	Mn (ICP) ppm	Ni (INAA) ppm	Ni (ICP) ppm	Pb (ICP) ppm	Sb (INAA) ppm	Se (INAA) ppm	Sn (INAA) ppm	V (ICP) ppm	W (INAA) ppm	Zn (INAA) ppm	Zn (ICP) ppm
MD080	4	3	2.5	0.7	0.5	1.1	2.5	69	880	2.5	0.25	13	26	100	0.5	3	1	107	10	40	22	1.2	1.5	0.005	243	2	164	124
MD079	7	3	2.5	0.2	0.4	0.9	2.5	45	890	2.5	0.25	12	27	110	0.5	3	2	116	10	44	16	1.2	1.5	0.005	245	0.5	168	128
difference	3	0	0	0.5	0.1	0.2	0	24	10	0	0	1	1	10	0	0	1	9	0	4	6	0	0	0	2	1.5	4	4
% difference	75%	0%	0%	71%	20%	18%	0%	35%	1%	0%	0%	8%	4%	10%	0%	0%	100%	8%	0%	10%	27%	0%	0%	0%	1%	75%	2%	3%

	Precious metals and Platinum Group Elements							Base metals and Pathfinder Elements																				
Sample No.	Au (INAA) ppb	Au (FA) ppb	Ag (INAA) ppm	Ag (ICP) ppm	Pt (FA) ppb	Pd (FA) ppb	Ir (INAA) ppb	As (INAA) ppm	Ba (INAA) ppm	Bi (ICP) ppm	Cd (ICP) ppm	Co (INAA) ppm	Cu (ICP) ppm	Cr (INAA) ppm	Hg (INAA) ppm	Mo (INAA) ppm	Mo (ICP) ppm	Mn (ICP) ppm	Ni (INAA) ppm	Ni (ICP) ppm	Pb (ICP) ppm	Sb (INAA) ppm	Se (INAA) ppm	Sn (INAA) ppm	V (ICP) ppm	W (INAA) ppm	Zn (INAA) ppm	Zn (ICP) ppm
MD090	3	3	2.5	0.4	0.2	0.3	2.5	310	670	2.5	0.25	49	10	130	0.5	13	7	964	110	76	45	9.5	1.5	0.015	1140	0.5	566	469
MD089	5	2	2.5	0.5	0.1	0.2	2.5	270	680	2.5	0.25	53	9	160	0.5	8	9	936	110	79	58	9.9	1.5	0.01	1157	0.5	648	476
difference	2	1	0	0.1	0.1	0.1	0	40	10	0	0	4	1	30	0	5	2	28	0	3	13	0.4	0	0.005	17	0	82	7
% difference	67%	33%	0%	25%	50%	33%	0%	13%	1%	0%	0%	8%	10%	23%	0%	38%	29%	3%	0%	4%	29%	4%	0%	33%	1%	0%	14%	1%

	Precious metals and Platinum Group Elements							Base metals and Pathfinder Elements																				
Sample No.	Au (INAA) ppb	Au (FA) ppb	Ag (INAA) ppm	Ag (ICP) ppm	Pt (FA) ppb	Pd (FA) ppb	Ir (INAA) ppb	As (INAA) ppm	Ba (INAA) ppm	Bi (ICP) ppm	Cd (ICP) ppm	Co (INAA) ppm	Cu (ICP) ppm	Cr (INAA) ppm	Hg (INAA) ppm	Mo (INAA) ppm	Mo (ICP) ppm	Mn (ICP) ppm	Ni (INAA) ppm	Ni (ICP) ppm	Pb (ICP) ppm	Sb (INAA) ppm	Se (INAA) ppm	Sn (INAA) ppm	V (ICP) ppm	W (INAA) ppm	Zn (INAA) ppm	Zn (ICP) ppm
CS005	3	NA	2.5	0.2	NA	NA	2.5	59	590	2.5	0.25	39	6	35	0.5	16.0	15	888	10	52	12	2.1	1.5	0.005	230	0.5	106	107
CS003	3	0.5	2.5	0.2	0.2	0.7	2.5	730	850	8.0	0.50	32	5	62	0.5	12.0	16	1772	66	57	22	17.0	1.5	0.005	580	0.5	143	176
difference	0	N.C.	0	0	N.C.	N.C.	0	671	260	5.5	0.25	7	1	27	0	4	1	884	56	5	10	14.9	0	0	350	0	37	69
% difference	0%	N.C.	0%	0%	N.C.	N.C.	0%	1137%	44%	220%	100%	18%	17%	77%	0%	25%	7%	100%	560%	10%	83%	710%	0%	0%	152%	0%	35%	64%

NOTE: "N.A." denotes "No Analysis (below detection)"; and "N.C." denotes "Not Calculatable".

APPENDIX IV (Cont.)

COMPARATIVE RESULTS OF DUPLICATE SAMPLE PAIRS

Uranium, Thorium, Rare Earth and Selected Other Related Elements																	Rock Forming and Related Trace Elements												Sample Weight (g)		
Sample No.	Be (ICP) ppm	Ce (INAA) ppm	Cs (INAA) ppm	Eu (INAA) ppm	Hf (INAA) ppm	La (INAA) ppm	Lu (INAA) ppm	Nd (INAA) ppm	Sc (INAA) ppm	Sm (INAA) ppm	Ta (INAA) ppm	Tb (INAA) ppm	Th (INAA) ppm	U (INAA) ppm	Y (ICP) ppm	Yb (INAA) ppm	Al (ICP) %	Br (INAA) ppm	Ca (INAA) %	Ca (ICP) %	Fe (INAA) %	K (ICP) %	Mg (ICP) %	Na (INAA) %	P (ICP) %	Rb (INAA) ppm	Sr (INAA) ppm	Sr (ICP) ppm		Ti (ICP) ppm	
AS010		1	57	2	3.8	2	41	0.84	45	13	12	0.25	3.1	14	7.1	85	5.5	2.9	0.25	0.5	1.28	35.8	0.33	0.52	0.14	0.6	7.5	0.07	168	0.08	26.71
AS009		1	62	4	3.5	2	38	0.85	44	13	11	1.2	2.1	13	6.2	82	5.4	2.94	0.25	0.5	1.42	36.1	0.35	0.52	0.12	0.637	7.5	0.025	174	0.08	26.9
difference	0		5	2	0.3	0	3	0.01	1	0	1	0.95	1	1	0.9	3	0.1	0.04	0	0	0.14	0.3	0.02	0	0.02	0.037	0	0.045	6	0	
% difference	0%		9%	100%	8%	0%	7%	1%	2%	0%	8%	380%	32%	7%	13%	4%	2%	1%	0%	0%	11%	1%	6%	0%	14%	6%	0%	64%	4%	0%	

	Uranium, Thorium, Rare Earth and Selected Other Related Elements																Rock Forming and Related Trace Elements														
Sample No.	Be (ICP ppm	Ce (INAA) ppm	Cs (INAA) ppm	Eu (INAA) ppm	Hf (INAA) ppm	La (INAA) ppm	Lu (INAA) ppm	Nd (INAA) ppm	Sc (INAA) ppm	Sm (INAA) ppm	Ta (INAA) ppm	Tb (INAA) ppm	Th (INAA) ppm	U (INAA) ppm	Y (ICP) ppm	Yb (INAA) ppm	Al (ICP) %	Br (INAA) ppm	Ca (INAA) %	Ca (ICP) %	Fe (INAA) %	K (ICP) %	Mg (ICP) %	Na (INAA) %	P (ICP) %	Rb (INAA) ppm	Sr (INAA) ppm	Sr (ICP) ppm	Ti (ICP) ppm	Sample Weight (g)	
AS020	1	53	0.5	3.3	2	35	0.71	36	12	11	0.25	2.4	13	5.9	88	5.2	2.69	0.25	0.5	1.08	34.5	0.27	0.47	0.12	0.577	7.5	0.025	158	0.07	30.11	
AS019	1	52	2	3.2	1	34	0.69	36	11	9.9	0.25	2.3	11	7.4	86	4.5	2.7	0.25	0.5	0.97	32	0.28	0.47	0.11	0.543	7.5	0.025	151	0.07	30.37	
difference	0	1	1.5	0.1	1	1	0.02	0	1	1.1	0	0.1	2	1.5	2	0.7	0.01	0	0	0.11	2.5	0.01	0	0.01	0.034	0	0	7	0		
% difference	0%	2%	300%	3%	50%	3%	3%	0%	8%	10%	0%	4%	15%	25%	2%	13%	0%	0%	0%	10%	7%	4%	0%	8%	6%	0%	0%	4%	0%		

Uranium, Thorium, Rare Earth and Selected Other Related Elements																	Rock Forming and Related Trace Elements													Sample Weight (g)
Sample No.	Be (ICP) ppm	Ce (INAA) ppm	Cs (INAA) ppm	Eu (INAA) ppm	Hf (INAA) ppm	La (INAA) ppm	Lu (INAA) ppm	Nd (INAA) ppm	Sc (INAA) ppm	Sm (INAA) ppm	Ta (INAA) ppm	Tb (INAA) ppm	Th (INAA) ppm	U (INAA) ppm	Y (ICP) ppm	Yb (INAA) ppm	Al (ICP) %	Br (INAA) ppm	Ca (INAA) %	Ca (ICP) %	Fe (INAA) %	K (ICP) %	Mg (ICP) %	Na (INAA) %	P (ICP) %	Rb (INAA) ppm	Sr (INAA) ppm	Sr (ICP) ppm	Ti (ICP) ppm	
AW010	2	68	2	3.7	3	64	0.77	53	6.2	12	0.25	2.4	4.6	19	132	4.7	2.05	2.1	10	11.1	17.3	0.58	0.36	0.22	4.033	49	0.06	623	0.08	36.85
AW009	2	62	2	3.3	3	58	0.59	46	5.3	11	0.25	2.3	4.9	19	128	4.3	1.89	2.2	11	12.46	13.7	0.54	0.32	0.24	4.599	25	0.08	699	0.07	36.98
difference	0	6	0	0.4	0	6	0.18	7	0.9	1	0	0.1	0.3	0	4	0.4	0.16	0.1	1	1.36	3.6	0.04	0.04	0.02	0.566	24	0.02	76	0.01	
% difference	0%	9%	0%	11%	0%	9%	23%	13%	15%	8%	0%	4%	7%	0%	3%	9%	8%	5%	10%	12%	21%	7%	11%	9%	14%	49%	33%	12%	13%	

	Uranium, Thorium, Rare Earth and Selected Other Related Elements																Rock Forming and Related Trace Elements														
Sample No.	Be (ICP) ppm	Ce (INAA) ppm	Cs (INAA) ppm	Eu (INAA) ppm	Hf (INAA) ppm	La (INAA) ppm	Lu (INAA) ppm	Nd (INAA) ppm	Sc (INAA) ppm	Sm (INAA) ppm	Ta (INAA) ppm	Tb (INAA) ppm	Th (INAA) ppm	U (INAA) ppm	Y (ICP) ppm	Yb (INAA) ppm	Al (ICP) %	Br (INAA) ppm	Ca (INAA) %	Ca (ICP) %	Fe (INAA) %	K (ICP) %	Mg (ICP) %	Na (INAA) %	P (ICP) %	Rb (INAA) ppm	Sr (INAA) ppm	Sr (ICP) ppm	Ti (ICP) ppm	Sample Weight (g)	
MD010	2	42	2	2	3	27	0.56	22	11	6.4	0.25	1.5	9.8	4.3	49	3.6	3.64	0.25	5	4.84	25.1	0.76	0.76	0.13	0.381	44	0.025	206	0.13	32.96	
MD009	1	46	2	2.1	3	27	0.54	26	11	6.4	0.25	1.6	9.5	3.8	50	3.6	3.54	0.25	4	3.92	24.9	0.74	0.77	0.12	0.395	52	0.025	192	0.13	29.2	
difference	1	4	0	0.1	0	0	0.02	4	0	0	0	0.1	0.3	0.5	1	0	0.1	0	1	0.92	0.2	0.02	0.01	0.01	0.014	8	0	14	0		
% difference	50%	10%	0%	5%	0%	0%	4%	18%	0%	0%	0%	7%	3%	12%	2%	0%	3%	0%	20%	19%	1%	3%	1%	8%	4%	18%	0%	7%	0%		

	Uranium, Thorium, Rare Earth and Selected Other Related Elements																Rock Forming and Related Trace Elements													
Sample No.	Be (ICP) ppm	Ce (INAA) ppm	Cs (INAA) ppm	Eu (INAA) ppm	Hf (INAA) ppm	La (INAA) ppm	Lu (INAA) ppm	Nd (INAA) ppm	Sc (INAA) ppm	Sm (INAA) ppm	Ta (INAA) ppm	Tb (INAA) ppm	Th (INAA) ppm	U (INAA) ppm	Y (ICP) ppm	Yb (INAA) ppm	Al (ICP) %	Br (INAA) ppm	Ca (INAA) %	Ca (ICP) %	Fe (INAA) %	K (ICP) %	Mg (ICP) %	Na (INAA) %	P (ICP) %	Rb (INAA) ppm	Sr (INAA) ppm	Sr (ICP) ppm	Ti (ICP) ppm	Sample Weight (g)
MD020	1	47	2	2.2	3	29	0.64	27	12	6.9	0.25	1.7	11	3.8	56	4.3	4.06	0.25	3	3.38	26.1	0.81	0.9	0.14	0.363	54	0.025	195	0.15	32.4
MD019	1	47	3	2.3	3	29	0.62	29	12	7.1	0.25	1.6	11	5	56	4.4	3.68	0.25	5	4.67	27.7	0.75	0.88	0.11	0.481	65	0.025	243	0.13	31.89
difference	0	0	1	0.1	0	0	0.02	2	0	0.2	0	0.1	0	1.2	0	0.1	0.38	0	2	1.29	1.6	0.06	0.02	0.03	0.118	11	0	48	0.02	
% difference	0%	0%	50%	5%	0%	0%	3%	7%	0%	3%	0%	6%	0%	32%	0%	2%	9%	0%	67%	38%	6%	7%	2%	21%	33%	20%	0%	25%	13%	

	Uranium, Thorium, Rare Earth and Selected Other Related Elements																Rock Forming and Related Trace Elements														
Sample No.	Be (ICP) ppm	Ce (INAA) ppm	Cs (INAA) ppm	Eu (INAA) ppm	Hf (INAA) ppm	La (INAA) ppm	Lu (INAA) ppm	Nd (INAA) ppm	Sc (INAA) ppm	Sm (INAA) ppm	Ta (INAA) ppm	Tb (INAA) ppm	Th (INAA) ppm	U (INAA) ppm	Y (ICP) ppm	Yb (INAA) ppm	Al (ICP) %	Br (INAA) ppm	Ca (INAA) %	Ca (ICP) %	Fe (INAA) %	K (ICP) %	Mg (ICP) %	Na (INAA) %	P (ICP) %	Rb (INAA) ppm	Sr (INAA) ppm	Sr (ICP) ppm	Ti (ICP) ppm	Sample Weight (g)	
MD030	1	72	8	1.7	6	43	0.62	36	15	5.6	0.7	0.25	11	3.6	26	3.6	7.12	1.3	2	1.54	5.14	2.01	0.79	0.33	0.091	60	0.025	126	0.33	24.48	
MD029	1	67	8	1.7	5	43	0.54	34	15	5.5	0.02	0.25	11	3.7	30	3.8	7.36	1.4	0.5	1.49	5.12	2.1	0.81	0.34	0.093	140	0.025	130	0.36	24.62	
difference	0	5	0	0	1	0	0.08	2	0	0.1	0.68	0	0	0.1	4	0.2	0.24	0.1	1.5	0.05	0.02	0.09	0.02	0.01	0.002	80	0	4	0.03		
% difference	0%	7%	0%	0%	17%	0%	13%	6%	0%	2%	97%	0%	0%	3%	15%	6%	3%	8%	75%	3%	0%	4%	3%	3%	2%	133%	0%	3%	9%		

	Uranium, Thorium, Rare Earth and Selected Other Related Elements																Rock Forming and Related Trace Elements														
Sample No.	Be (ICP) ppm	Ce (INAA) ppm	Cs (INAA) ppm	Eu (INAA) ppm	Hf (INAA) ppm	La (INAA) ppm	Lu (INAA) ppm	Nd (INAA) ppm	Sc (INAA) ppm	Sm (INAA) ppm	Ta (INAA) ppm	Tb (INAA) ppm	Th (INAA) ppm	U (INAA) ppm	Y (ICP) ppm	Yb (INAA) ppm	Al (ICP) %	Br (INAA) ppm	Ca (INAA) %	Ca (ICP) %	Fe (INAA) %	K (ICP) %	Mg (ICP) %	Na (INAA) %	P (ICP) %	Rb (INAA) ppm	Sr (INAA) ppm	Sr (ICP) ppm	Ti (ICP) ppm	Sample Weight (g)	
MD033	1	56	5	1.7	5	36	0.42	20	12	5.6	1.3	0.9	10	3.1	28	3	5.5	0.25	0.5	0.94	7.68	1.61	0.59	0.25	0.223	87	0.025	118	0.25	29.17	
MD032	1	54	5	1.6	4	33	0.48	24	11	5.3	0.25	1.1	9.2	4.8	34	3.1	4.74	2	4	3.85	9.18	1.38	0.6	0.24	0.444	98	0.025	174	0.21	27.44	
difference	0	2	0	0.1	1	3	0.06	4	1	0.3	1.05	0.2	0.8	1.7	6	0.1	0.76	1.75	3.5	2.91	1.5	0.23	0.01	0.01	0.221	11	0	56	0.04		
% differenc	0%	4%	0%	6%	20%	8%	14%	20%	8%	5%	81%	22%	8%	55%	21%	3%	14%	700%	700%	310%	20%	14%	2%	4%	99%	13%	0%	47%	16%		

	Uranium, Thorium, Rare Earth and Selected Other Related Elements																Rock Forming and Related Trace Elements													
Sample No.	Be (ICP) ppm	Ce (INAA) ppm	Cs (INAA) ppm	Eu (INAA) ppm	Hf (INAA) ppm	La (INAA) ppm	Lu (INAA) ppm	Nd (INAA) ppm	Sc (INAA) ppm	Sm (INAA) ppm	Ta (INAA) ppm	Tb (INAA) ppm	Th (INAA) ppm	U (INAA) ppm	Y (ICP) ppm	Yb (INAA) ppm	Al (ICP) %	Br (INAA) ppm	Ca (INAA) %	Ca (ICP) %	Fe (INAA) %	K (ICP) %	Mg (ICP) %	Na (INAA) %	P (ICP) %	Rb (INAA) ppm	Sr (INAA) ppm	Sr (ICP) ppm	Ti (ICP) ppm	Sample Weight (g)
MD040	1	50	4	1.6	5	30	0.49	28	10	5.2	0.25	0.25	9.2	3.4	34	2.8	4.32	0.25	3	2.77	8.14	1.21	0.62	0.21	0.206	80	0.025	140	0.18	31.89
MD039	1	49	3	1.7	4	30	0.51	28	9.7	5.6	0.25	1.2	8.7	4	37	3.4	4.02	0.25	5	4.66	8.91	1.1	0.62	0.19	0.258	76	0.025	165	0.17	26.58
difference	0	1	1	0.1	1	0	0.02	0	0.3	0.4	0	0.95	0.5	0.6	3	0.6	0.3	0	2	1.89	0.77	0.11	0	0.02	0.052	4	0	25	0.01	
% difference	0%	2%	25%	6%	20%	0%	4%	0%	3%	8%	0%	380%	5%	18%	9%	21%	7%	0%	67%	68%	9%	9%	0%	10%	25%	5%	0%	18%	6%	

	Uranium, Thorium, Rare Earth and Selected Other Related Elements																Rock Forming and Related Trace Elements													
Sample No.	Be (ICP) ppm	Ce (INAA) ppm	Cs (INAA) ppm	Eu (INAA) ppm	Hf (INAA) ppm	La (INAA) ppm	Lu (INAA) ppm	Nd (INAA) ppm	Sc (INAA) ppm	Sm (INAA) ppm	Ta (INAA) ppm	Tb (INAA) ppm	Th (INAA) ppm	U (INAA) ppm	Y (ICP) ppm	Yb (INAA) ppm	Al (ICP) %	Br (INAA) ppm	Ca (INAA) %	Ca (ICP) %	Fe (INAA) %	K (ICP) %	Mg (ICP) %	Na (INAA) %	P (ICP) %	Rb (INAA) ppm	Sr (INAA) ppm	Sr (ICP) ppm	Ti (ICP) ppm	Sample Weight (g)
MD051	1	49	4	2.8	3	33	0.68	33	13	8.7	0.25	2	12	5.5	74	5.1	4.03	0.25	4	4.07	24	0.73	0.94	0.11	0.516	38	0.025	206	0.13	33.38
MD050	1	46	3	2.5	3	29	0.61	26	12	7.7	0.7	2	11	5.4	73	4.6	4.06	0.25	3	3.79	22.1	0.72	0.98	0.13	0.499	34	0.025	197	0.13	36.02
difference	0	3	1	0.3	0	4	0.07	7	1	1	0.45	0	1	0.1	1	0.5	0.03	0	1	0.28	1.9	0.01	0.04	0.02	0.017	4	0	9	0	
% difference	0%	7%	33%	12%	0%	14%	11%	27%	8%	13%	64%	0%	9%	2%	1%	11%	1%	0%	33%	7%	9%	1%	4%	15%	3%	12%	0%	5%	0%	

	Uranium, Thorium, Rare Earth and Selected Other Related Elements																Rock Forming and Related Trace Elements													
Sample No.	Be (ICP) ppm	Ce (INAA) ppm	Cs (INAA) ppm	Eu (INAA) ppm	Hf (INAA) ppm	La (INAA) ppm	Lu (INAA) ppm	Nd (INAA) ppm	Sc (INAA) ppm	Sm (INAA) ppm	Ta (INAA) ppm	Tb (INAA) ppm	Th (INAA) ppm	U (INAA) ppm	Y (ICP) ppm	Yb (INAA) ppm	Al (ICP) %	Br (INAA) ppm	Ca (INAA) %	Ca (ICP) %	Fe (INAA) %	K (ICP) %	Mg (ICP) %	Na (INAA) %	P (ICP) %	Rb (INAA) ppm	Sr (INAA) ppm	Sr (ICP) ppm	Ti (ICP) ppm	Sample Weight (g)
MD060	1	48	2	2.8	2	31	0.68	30	13	9.7	0.25	2	12	6.6	83	5.6	3.7	0.25	1	2.53	31	0.58	0.54	0.13	0.562	57	0.025	170	0.12	28.36
MD059	1	59	2	3.2	3	36	0.73	30	14	10	0.25	2.5	13	6.8	82	5.7	3.81	0.25	2	2.45	33.3	0.61	0.54	0.17	0.602	52	0.09	167	0.13	27.92
difference	0	11	0	0.4	1	5	0.05	0	1	0.3	0	0.5	1	0.2	1	0.1	0.11	0	1	0.08	2.3	0.03	0	0.04	0.04	5	0.065	3	0.01	
% difference	0%	23%	0%	14%	50%	16%	7%	0%	8%	3%	0%	25%	8%	3%	1%	2%	3%	0%	100%	3%	7%	5%	0%	31%	7%	9%	260%	2%	8%	

	Uranium, Thorium, Rare Earth and Selected Other Related Elements																Rock Forming and Related Trace Elements													
Sample No.	Be (ICP) ppm	Ce (INAA) ppm	Cs (INAA) ppm	Eu (INAA) ppm	Hf (INAA) ppm	La (INAA) ppm	Lu (INAA) ppm	Nd (INAA) ppm	Sc (INAA) ppm	Sm (INAA) ppm	Ta (INAA) ppm	Tb (INAA) ppm	Th (INAA) ppm	U (INAA) ppm	Y (ICP) ppm	Yb (INAA) ppm	Al (ICP) %	Br (INAA) ppm	Ca (INAA) %	Ca (ICP) %	Fe (INAA) %	K (ICP) %	Mg (ICP) %	Na (INAA) %	P (ICP) %	Rb (INAA) ppm	Sr (INAA) ppm	Sr (ICP) ppm	Ti (ICP) ppm	Sample Weight (g)
MD067	1	44	0.5	2.2	2	27	0.5	21	11	7.3	0.25	1.5	10	5.1	59	4.2	3.18	0.25	2	3.25	28.5	0.63	1.18	0.08	0.492	73	0.025	168	0.11	31.37
MD066	1	55	3	2.4	2	31	0.5	27	12	8.2	0.25	1.8	11	3.9	60	4.4	3.43	0.25	3	3.78	26.5	0.73	1.18	0.1	0.497	52	0.06	212	0.12	30.47
difference	0	11	2.5	0.2	0	4	0	6	1	0.9	0	0.3	1	1.2	1	0.2	0.25	0	1	0.53	2	0.1	0	0.02	0.005	21	0.035	44	0.01	
% difference	0%	25%	500%	9%	0%	15%	0%	29%	9%	12%	0%	20%	10%	24%	2%	5%	8%	0%	50%	16%	7%	16%	0%	25%	1%	29%	140%	26%	9%	

	Uranium, Thorium, Rare Earth and Selected Other Related Elements																Rock Forming and Related Trace Elements													
Sample No	Be (ICP) ppm	Ce (INAA) ppm	Cs (INAA) ppm	Eu (INAA) ppm	Hf (INAA) ppm	La (INAA) ppm	Lu (INAA) ppm	Nd (INAA) ppm	Sc (INAA) ppm	Sm (INAA) ppm	Ta (INAA) ppm	Tb (INAA) ppm	Th (INAA) ppm	U (INAA) ppm	Y (ICP) ppm	Yb (INAA) ppm	Al (ICP) %	Br (INAA) ppm	Ca (INAA) %	Ca (ICP) %	Fe (INAA) %	K (ICP) %	Mg (ICP) %	Na (INAA) %	P (ICP) %	Rb (INAA) ppm	Sr (INAA) ppm	Sr (ICP) ppm	Ti (ICP) ppm	Sample Weight (g)
MD070	1	58	0.5	3.6	2	37	0.85	28	15	12	0.8	2.2	14	11	100	6.5	3.24	3.7	2	1.8	37.7	0.4	0.49	0.08	0.741	53	0.025	141	0.09	27.79
MD069	1	53	0.5	3.3	2	34	0.8	29	14	11	0.25	2.4	14	10	96	6.1	3.31	3.1	1	1.73	35.5	0.43	0.5	0.09	0.708	7.5	0.025	138	0.09	32.3
difference	0	5	0	0.3	0	3	0.05	1	1	1	0.55	0.2	0	1	4	0.4	0.07	0.6	1	0.07	2.2	0.03	0.01	0.01	0.033	45.5	0	3	0	
% difference	0%	9%	0%	8%	0%	8%	6%	4%	7%	8%	69%	9%	0%	9%	4%	6%	2%	16%	50%	4%	6%	7%	2%	13%	4%	86%	0%	2%	0%	

	Uranium, Thorium, Rare Earth and Selected Other Related Elements																Rock Forming and Related Trace Elements													
Sample No.	Be (ICP) ppm	Ce (INAA) ppm	Cs (INAA) ppm	Eu (INAA) ppm	Hf (INAA) ppm	La (INAA) ppm	Lu (INAA) ppm	Nd (INAA) ppm	Sc (INAA) ppm	Sm (INAA) ppm	Ta (INAA) ppm	Tb (INAA) ppm	Th (INAA) ppm	U (INAA) ppm	Y (ICP) ppm	Yb (INAA) ppm	Al (ICP) %	Br (INAA) ppm	Ca (INAA) %	Ca (ICP) %	Fe (INAA) %	K (ICP) %	Mg (ICP) %	Na (INAA) %	P (ICP) %	Rb (INAA) ppm	Sr (INAA) ppm	Sr (ICP) ppm	Ti (ICP) ppm	Sample Weight (g)
MD080	1	72	8	1.4	6	42	0.49	27	14	5.7	0.25	0.25	11	4.2	29	3.7	7.25	2	1	0.44	3.64	2.08	0.72	0.41	0.077	140	0.025	144	0.35	25.13
MD079	1	68	7	1.4	6	40	0.47	27	13	5.5	1.3	0.7	11	3.7	28	3.8	7.3	2	0.5	0.4	3.42	2.09	0.73	0.4	0.076	130	0.025	144	0.35	23.86
difference	0	4	1	0	0	2	0.02	0	1	0.2	1.05	0.45	0	0.5	1	0.1	0.05	0	0.5	0.04	0.22	0.01	0.01	0.01	0.001	10	0	0	0	0
% difference	0%	6%	13%	0%	0%	5%	4%	0%	7%	4%	420%	180%	0%	12%	3%	3%	1%	0%	50%	9%	6%	0%	1%	2%	1%	7%	0%	0%	0%	0%

	Uranium, Thorium, Rare Earth and Selected Other Related Elements																Rock Forming and Related Trace Elements													
Sample No.	Be (ICP) ppm	Ce (INAA) ppm	Cs (INAA) ppm	Eu (INAA) ppm	Hf (INAA) ppm	La (INAA) ppm	Lu (INAA) ppm	Nd (INAA) ppm	Sc (INAA) ppm	Sm (INAA) ppm	Ta (INAA) ppm	Tb (INAA) ppm	Th (INAA) ppm	U (INAA) ppm	Y (ICP) ppm	Yb (INAA) ppm	Al (ICP) %	Br (INAA) ppm	Ca (INAA) %	Ca (ICP) %	Fe (INAA) %	K (ICP) %	Mg (ICP) %	Na (INAA) %	P (ICP) %	Rb (INAA) ppm	Sr (INAA) ppm	Sr (ICP) ppm	Ti (ICP) ppm	Sample Weight (g)
MD090	1	57	2	2.9	2	34	0.64	31	13	10	0.25	2.5	13	4.9	79	5.5	3.82	1.5	3	5.18	26.2	0.62	1.43	0.1	0.606	7.5	0.025	185	0.12	30.18
MD089	1	56	2	3	3	34	0.66	28	13	10	0.8	2.4	14	7.4	78	5.9	3.57	0.25	4	4.92	26.7	0.63	1.43	0.1	0.594	7.5	0.025	197	0.12	33.12
difference	0	1	0	0.1	1	0	0.02	3	0	0	0.55	0.1	1	2.5	1	0.4	0.25	1.25	1	0.26	0.5	0.01	0	0	0.012	0	0	12	0	
% difference	0%	2%	0%	3%	50%	0%	3%	10%	0%	0%	220%	4%	8%	51%	1%	7%	7%	83%	33%	5%	2%	2%	0%	0%	2%	0%	0%	6%	0%	

	Uranium, Thorium, Rare Earth and Selected Other Related Elements																Rock Forming and Related Trace Elements													
Sample No	Be (ICP) ppm	Ce (INAA) ppm	Cs (INAA) ppm	Eu (INAA) ppm	Hf (INAA) ppm	La (INAA) ppm	Lu (INAA) ppm	Nd (INAA) ppm	Sc (INAA) ppm	Sm (INAA) ppm	Ta (INAA) ppm	Tb (INAA) ppm	Th (INAA) ppm	U (INAA) ppm	Y (ICP) ppm	Yb (INAA) ppm	Al (ICP) %	Br (INAA) ppm	Ca (INAA) %	Ca (ICP) %	Fe (INAA) %	K (ICP) %	Mg (ICP) %	Na (INAA) %	P (ICP) %	Rb (INAA) ppm	Sr (INAA) ppm	Sr (ICP) ppm	Ti (ICP) ppm	Sample Weight (g)
CS005	1	36	1.0	1.6	2	28	0.24	15	5.1	4.7	0.25	1.2	3.3	2.7	34	1.5	1.62	0.25	15.0	16.54	10.10	0.46	0.80	0.12	0.774	29.0	0.025	387	0.07	38.51
CS003	1	54	1.0	2.4	2	36	0.44	27	8.7	7.6	0.25	1.5	5.0	3.2	62	3.2	1.92	0.25	5.0	4.96	27.50	0.39	1.08	0.12	0.949	7.5	0.025	239	0.06	46.38
difference	0	18	0	0.8	0	8	0.2	12	3.6	2.9	0	0.3	1.7	0.5	28	1.7	0.3	0	10	11.58	17.4	0.07	0.28	0	0.175	21.5	0	148	0.01	
% difference	0%	50%	0%	50%	0%	29%	83%	80%	71%	62%	0%	25%	52%	19%	82%	113%	19%	0%	67%	70%	172%	15%	35%	0%	23%	74%	0%	38%	14%	

NOTE: "N.A

APPENDIX V

**COMPARATIVE RESULTS BETWEEN THE INAA AND FIRE
ASSAY OR ICP METHODS FOR GOLD (Au), SILVER (Ag),
MOLYBDENUM (Mo), NICKEL (Ni), ZINC (Zn) AND CALCIUM (Ca)**

CLEAR HILLS IRON DEPOSIT STUDY

APPENDIX V

COMPARATIVE RESULTS BETWEEN THE INAA AND FIRE ASSAY OR ICP METHODS
FOR GOLD (Au), SILVER (Ag), MOLYBDENUM (Mo), NICKEL (Ni), ZINC (Zn) AND CALCIUM (Ca)

Assigned	Duplicates	Au in ppb		Difference		Ag in ppm		Difference		Mo in ppm		Difference		Ni in ppm		Difference		Zn in ppm		Difference		Ca in %		Difference		
Sample No.		INAA	FA	Actual	Percentage	INAA	ICP	Actual	Percentage	INAA	ICP	Actual	Percentage	INAA	ICP	Actual	Percentage	INAA	ICP	Actual	Percentage	INAA	ICP	Actual	Percentage	
RAMBLING RIVER (SWIFT CREEK) SAMPLES WHICH WERE COLLECTED BY THE ALBERTA GEOLOGICAL SURVEY																										
AS028	D	1.0	1.0	0.0	0.0%	2.5	0.6	1.9	76.0%	12.0	11.0	1.0	8.3%	110.0	87.0	23.0	20.9%	453.0	509.0	56.0	-12.4%	0.5	2.32	1.82	-364.0%	
AS027		10.0	0.5	9.5	95.0%	2.5	0.7	1.8	72.0%	15.0	11.0	4.0	26.7%	94.0	91.0	3.0	3.2%	461.0	554.0	93.0	-20.2%	0.5	1.85	1.35	-270.0%	
AS026		3.0	2.0	1.0	33.3%	2.5	1.0	1.5	60.0%	10.0	12.0	2.0	-20.0%	110.0	97.0	13.0	11.8%	457.0	505.0	48.0	-10.5%	0.5	1.70	1.20	-240.0%	
AS025		1.0	1.0	0.0	0.0%	2.5	0.5	2.0	80.0%	16.0	11.0	5.0	31.3%	100.0	100.0	0.0	0.0%	451.0	487.0	36.0	-8.0%	2.0	1.46	0.54	27.0%	
AS024		1.0	0.5	0.5	50.0%	2.5	0.7	1.8	72.0%	19.0	11.0	8.0	42.1%	110.0	92.0	18.0	16.4%	475.0	504.0	29.0	-6.1%	1.0	1.90	0.90	-90.0%	
AS023		5.0	5.0	0.0	0.0%	2.5	0.2	2.3	92.0%	9.0	12.0	3.0	-33.3%	13.0	94.0	81.0	-623.1%	505.0	524.0	19.0	-3.8%	0.5	1.54	1.04	-208.0%	
AS022		1.0	0.5	0.5	50.0%	2.5	0.7	1.8	72.0%	18.0	11.0	7.0	38.9%	110.0	97.0	13.0	11.8%	455.0	528.0	73.0	-16.0%	0.5	1.60	1.10	-220.0%	
AS021		4.0	0.5	3.5	87.5%	2.5	0.7	1.8	72.0%	6.0	12.0	6.0	-100.0%	210.0	93.0	117.0	55.7%	475.0	513.0	38.0	-8.0%	0.5	1.22	0.72	-144.0%	
AS020		11.0	0.5	10.5	95.5%	2.5	0.2	2.3	92.0%	5.0	12.0	7.0	-140.0%	120.0	101.0	19.0	15.8%	530.0	506.0	24.0	4.5%	0.5	1.08	0.58	-116.0%	
AS019		D	3.0	3.0	0.0	0.0%	2.5	0.2	2.3	92.0%	17.0	11.0	6.0	35.3%	170.0	98.0	72.0	42.4%	456.0	506.0	50.0	-11.0%	0.5	0.97	0.47	-94.0%
AS018		1.0	0.5	0.5	50.0%	2.5	0.8	1.7	68.0%	10.0	11.0	1.0	-10.0%	120.0	106.0	14.0	11.7%	545.0	538.0	7.0	1.3%	0.5	1.06	0.56	-112.0%	
AS017		1.0	0.5	0.5	50.0%	2.5	0.8	1.7	68.0%	14.0	11.0	3.0	21.4%	100.0	94.0	6.0	6.0%	513.0	512.0	1.0	0.2%	0.5	1.70	1.20	-240.0%	
AS016		4.0	11.0	7.0	-175.0%	2.5	0.2	2.3	92.0%	7.0	12.0	5.0	-71.4%	100.0	100.0	0.0	0.0%	533.0	513.0	20.0	3.8%	0.5	1.20	0.70	-140.0%	
AS015		1.0	0.5	0.5	50.0%	2.5	0.8	1.7	68.0%	13.0	11.0	2.0	15.4%	90.0	92.0	2.0	-2.2%	434.0	497.0	63.0	-14.5%	0.5	1.28	0.78	-156.0%	
AS014		4.0	0.5	3.5	87.5%	2.5	0.2	2.3	92.0%	17.0	12.0	5.0	29.4%	91.0	93.0	2.0	-2.2%	507.0	495.0	12.0	2.4%	0.5	1.34	0.84	-168.0%	
AS013		5.0	0.5	4.5	90.0%	2.5	0.7	1.8	72.0%	15.0	11.0	4.0	26.7%	83.0	81.0	2.0	2.4%	521.0	494.0	27.0	5.2%	0.5	1.04	0.54	-108.0%	
AS012	1.0	0.5	0.5	50.0%	2.5	0.6	1.9	76.0%	19.0	12.0	7.0	36.8%	100.0	90.0	10.0	10.0%	478.0	509.0	31.0	-6.5%	0.5	0.92	0.42	-84.0%		
AS011	1.0	1.0	0.0	0.0%	2.5	0.2	2.3	92.0%	18.0	11.0	7.0	38.9%	88.0	83.0	5.0	5.7%	535.0	493.0	42.0	7.9%	1.0	1.14	0.14	-14.0%		
AS010	D	1.0	0.5	0.5	50.0%	2.5	0.2	2.3	92.0%	18.0	11.0	7.0	38.9%	99.0	90.0	9.0	9.1%	551.0	467.0	84.0	15.2%	1.0	1.28	0.28	-28.0%	
AS009	D	1.0	0.5	0.5	50.0%	2.5	0.2	2.3	92.0%	20.0	10.0	10.0	50.0%	100.0	86.0	14.0	14.0%	573.0	521.0	52.0	9.1%	1.0	1.42	0.42	-42.0%	
AS008	1.0	0.5	0.5	50.0%	2.5	0.2	2.3	92.0%	14.0	9.0	5.0	35.7%	110.0	101.0	9.0	8.2%	516.0	467.0	49.0	9.5%	1.0	1.43	0.43	-43.0%		
AS007	8.0	0.5	7.5	93.8%	2.5	0.4	2.1	84.0%	12.0	7.0	5.0	41.7%	120.0	118.0	2.0	1.7%	488.0	477.0	11.0	2.3%	4.0	3.25	0.75	18.8%		
AS006	5.0	0.5	4.5	90.0%	2.5	0.6	1.9	76.0%	0.5	8.0	7.5	-1500.0%	96.0	91.0	5.0	5.2%	483.0	438.0	45.0	9.3%	3.0	1.72	1.28	42.7%		
AS005	1.0	1.0	0.0	0.0%	2.5	0.7	1.8	72.0%	89.0	92.0	3.0	-3.4%	250.0	215.0	35.0	14.0%	808.0	795.0	13.0	1.6%	3.0	2.32	0.68	22.7%		
AS004	1.0	0.5	0.5	50.0%	2.5	0.5	2.0	80.0%	7.0	6.0	1.0	14.3%	93.0	88.0	5.0	5.4%	439.0	452.0	13.0	-3.0%	0.5	2.52	2.02	-404.0%		
AS003	8.0	1.0	7.0	87.5%	2.5	0.5	2.0	80.0%	17.0	7.0	10.0	58.8%	100.0	81.0	19.0	19.0%	491.0	446.0	45.0	9.2%	2.0	1.34	0.66	33.0%		
AS002	5.0	0.5	4.5	90.0%	2.5	0.2	2.3	92.0%	11.0	4.0	7.0	63.6%	83.0	81.0	2.0	2.4%	435.0	388.0	47.0	10.8%	0.5	2.74	2.24	-448.0%		
AS001	10.0	1.0	9.0	90.0%	2.5	0.2	2.3	92.0%	11.0	5.0	6.0	54.5%	93.0	93.0	0.0	0.0%	425.0	443.0	18.0	-4.2%	2.0	2.09	0.09	-4.5%		
WORSLEY PIT SAMPLES WHICH WERE COLLECTED BY THE ALBERTA GEOLOGICAL SURVEY																										
AW013	D	8.0	0.5	7.5	93.8%	2.5	0.4	2.1	84.0%	7.0	6.0	1.0	14.3%	85.0	85.0	0.0	0.0%	385.0	417.0	32.0	-8.3%	0.5	0.86	0.36	-72.0%	
AW012		4.0	0.5	3.5	87.5%	2.5	0.2	2.3	92.0%	13.0	3.0	10.0	76.9%	71.0	76.0	5.0	-7.0%	504.0	564.0	60.0	-11.9%	5.0	5.20	0.20	-4.0%	
AW011		5.0	1.0	4.0	80.0%	2.5	0.2	2.3	92.0%	0.5	1.0	0.5	-100.0%	85.0	67.0	18.0	21.2%	265.0	270.0	5.0	-1.9%	2.0	1.43	0.57	28.5%	
AW010		2.0	0.5	1.5	75.0%	2.5	0.2	2.3	92.0%	12.0	1.0	11.0	91.7%	53.0	53.0	0.0	0.0%	316.0	353.0	37.0	-11.7%	10.0	11.10	1.10	-11.0%	
AW009		4.0	0.5	3.5	87.5%	2.5	0.2	2.3	92.0%	0.5	1.0	0.5	-100.0%	60.0	60.0	0.0	0.0%	296.0	337.0	41.0	-13.9%	11.0	12.46	1.46	-13.3%	
AW008		3.0	0.5	2.5	83.3%	2.5	0.2	2.3	92.0%	15.0	10.0	5.0	33.3%	100.0	89.0	11.0	11.0%	533.0	547.0	14.0	-2.6%	0.5	1.32	0.82	-164.0%	
AW007		1.0	0.5	0.5	50.0%	2.5	0.6	1.9	76.0%	13.0	6.0	7.0	53.8%	78.0	74.0	4.0	5.1%	714.0	648.0	66.0	9.2%	2.0	1.49	0.51	25.5%	
AW006		3.0	0.5	2.5	83.3%	2.5	0.6	1.9	76.0%	0.5	3.0	2.5	-500.0%	100.0	94.0	6.0	6.0%	571.0	559.0	12.0	2.1%	3.0	2.10	0.90	30.0%	
AW005		2.0	1.0	1.0	50.0%	2.5	0.2	2.3	92.0%	22.0	15.0	7.0	31.8%	87.0	83.0	4.0	4.6%	434.0	470.0	36.0	-8.3%	0.5	2.42	1.92	-384.0%	
AW004		1.0	1.0	0.0	0.0%	2.5	0.2	2.3	92.0%	7.0	5.0	2.0	28.6%	65.0	55.0	10.0	15.4%	374.0	346.0	28.0	7.5%	0.5	1.69	1.19	-238.0%	
AW003		1.0	0.5	0.5	50.0%	2.5	0.2	2.3	92.0%	4.0	1.0	3.0	75.0%	62.0	66.0	4.0	-6.5%	340.0	337.0	3.0	0.9%	1.0	0.83	0.17	17.0%	
AW002		1.0	0.5	0.5	50.0%	2.5	0.6	1.9	76.0%	10.0	4.0	6.0	60.0%	10.0	7.0	3.0	30.0%	25.0	27.0	2.0	-8.0%	0.5	0.26	0.24	48.0%	
AW001		1.0	2.0	1.0	-100.0%	2.5	0.2	2.3	92.0%	8.0	5.0	3.0	37.5%	10.0	13.0	3.0	-30.0%	78.0	52.0	26.0	33.3%	0.5	0.29	0.21	42.0%	
WORSLEY PIT SAMPLE COLLECTED BY MARUM																										
MW001		3.0	0.5	2.5	83.3%	2.5	0.2	2.3	92.0%	16.0	13.0	3.0	18.8%	94.0	90.0	4.0	4.3%	504.0	560.0	56.0	-11.1%	2.0	1.08	0.92	46.0%	
WORSLEY PIT SAMPLES COLLECTED BY TOM BRYANT																										
BW011		1.0	0.5	0.5	50.0%	2.5	0.2	2.3	92.0%	7.0	7.0	0.0	0.0%	86.												

APPENDIX V

COMPARATIVE RESULTS BETWEEN THE INAA AND FIRE ASSAY OR ICP METHODS
FOR GOLD (Au), SILVER (Ag), MOLYBDENUM (Mo), NICKEL (Ni), ZINC (Zn) AND CALCIUM (Ca)

Assigned	Duplicates	Au in ppb		Difference		Ag in ppm		Difference		Mo in ppm		Difference		Ni in ppm		Difference		Zn in ppm		Difference		Ca in %		Difference	
Sample No.		INAA	FA	Actual	Percentage	INAA	ICP	Actual	Percentage	INAA	ICP	Actual	Percentage	INAA	ICP	Actual	Percentage	INAA	ICP	Actual	Percentage	INAA	ICP	Actual	Percentage
DRILL HOLE CUTTINGS FROM HOLES DRILLED BY MARUM NEAR WORSLEY PIT																									
MD093		1.0	0.5	0.5	50.0%	2.5	0.2	2.3	92.0%	9.0	5.0	4.0	44.4%	100.0	89.0	11.0	11.0%	507.0	428.0	79.0	15.6%	3.0	4.02	1.02	-34.0%
MD092		1.0	1.0	0.0	0.0%	2.5	0.2	2.3	92.0%	16.0	4.0	12.0	75.0%	95.0	56.0	39.0	41.1%	421.0	331.0	90.0	21.4%	12.0	9.88	2.12	17.7%
MD091		1.0	2.0	1.0	-100.0%	2.5	0.2	2.3	92.0%	13.0	8.0	5.0	38.5%	60.0	84.0	24.0	-40.0%	532.0	490.0	42.0	7.9%	2.0	3.13	1.13	-56.5%
MD090	D	3.0	3.0	0.0	0.0%	2.5	0.4	2.1	84.0%	13.0	7.0	6.0	46.2%	110.0	76.0	34.0	30.9%	566.0	469.0	97.0	17.1%	3.0	5.18	2.18	-72.7%
MD089	D	5.0	2.0	3.0	60.0%	2.5	0.5	2.0	80.0%	8.0	9.0	1.0	-12.5%	110.0	79.0	31.0	28.2%	648.0	476.0	172.0	26.5%	4.0	4.92	0.92	-23.0%
MD088		2.0	4.0	2.0	-100.0%	2.5	0.2	2.3	92.0%	0.5	2.0	1.5	-300.0%	11.0	38.0	27.0	-245.5%	227.0	164.0	63.0	27.8%	2.0	1.48	0.52	26.0%
MD087		1.0	0.5	0.5	50.0%	2.5	0.2	2.3	92.0%	11.0	4.0	7.0	63.6%	11.5	39.0	27.5	-239.1%	141.0	126.0	15.0	10.6%	8.0	8.96	0.96	-12.0%
MD086		1.0	5.0	4.0	-400.0%	2.5	0.2	2.3	92.0%	6.0	6.0	0.0	0.0%	10.0	44.0	34.0	-340.0%	222.0	159.0	63.0	28.4%	3.0	3.29	0.29	-9.7%
MD085		3.0	4.0	1.0	-33.3%	2.5	0.2	2.3	92.0%	6.0	2.0	4.0	66.7%	10.0	42.0	32.0	-320.0%	136.0	126.0	10.0	7.4%	0.5	0.49	0.01	2.0%
MD084		1.0	6.0	5.0	-500.0%	2.5	0.2	2.3	92.0%	3.0	1.0	2.0	66.7%	94.0	41.0	53.0	56.4%	133.0	121.0	12.0	9.0%	0.5	0.71	0.21	-42.0%
MD083		3.0	4.0	1.0	-33.3%	2.5	0.6	1.9	76.0%	4.0	1.0	3.0	75.0%	10.0	42.0	32.0	-320.0%	148.0	126.0	22.0	14.9%	0.5	0.37	0.13	26.0%
MD082		1.0	3.0	2.0	-200.0%	2.5	0.5	2.0	80.0%	2.0	1.0	1.0	50.0%	10.0	36.0	26.0	-260.0%	88.0	115.0	27.0	-30.7%	0.5	0.38	0.12	24.0%
MD081		1.0	4.0	3.0	-300.0%	2.5	0.2	2.3	92.0%	5.0	1.0	4.0	80.0%	10.0	35.0	25.0	-250.0%	154.0	106.0	48.0	31.2%	1.0	1.19	0.19	-19.0%
MD080	D	4.0	3.0	1.0	25.0%	2.5	0.7	1.8	72.0%	3.0	1.0	2.0	66.7%	10.0	40.0	30.0	-300.0%	164.0	124.0	40.0	24.4%	1.0	0.44	0.56	56.0%
MD079	D	7.0	3.0	4.0	57.1%	2.5	0.2	2.3	92.0%	3.0	2.0	1.0	33.3%	10.0	44.0	34.0	-340.0%	168.0	128.0	40.0	23.8%	0.5	0.40	0.10	20.0%
MD078		4.0	NA	NA	NA	2.5	0.2	2.3	92.0%	7.0	2.0	5.0	71.4%	10.0	28.0	18.0	-180.0%	127.0	103.0	24.0	18.9%	0.5	0.61	0.11	-22.0%
MD077		4.0	NA	NA	NA	2.5	0.2	2.3	92.0%	9.0	4.0	5.0	55.6%	70.0	57.0	13.0	18.6%	278.0	223.0	55.0	19.8%	0.5	0.47	0.03	6.0%
MD076		1.0	NA	NA	NA	2.5	0.2	2.3	92.0%	4.0	5.0	1.0	-25.0%	80.0	147.0	67.0	-83.8%	575.0	565.0	10.0	1.7%	2.0	3.79	1.79	-89.5%
MD075		1.0	4.0	3.0	-300.0%	2.5	0.2	2.3	92.0%	11.0	5.0	6.0	54.5%	70.0	110.0	40.0	-57.1%	559.0	490.0	69.0	12.3%	2.0	2.99	0.99	-49.5%
MD074		1.0	3.0	2.0	-200.0%	2.5	0.2	2.3	92.0%	9.0	6.0	3.0	33.3%	63.0	81.0	18.0	-28.6%	574.0	518.0	56.0	9.8%	1.0	2.80	1.80	-180.0%
MD073		1.0	4.0	3.0	-300.0%	2.5	0.2	2.3	92.0%	14.0	10.0	4.0	28.6%	51.0	71.0	20.0	-39.2%	464.0	405.0	59.0	12.7%	2.0	3.86	1.86	-93.0%
MD072		1.0	NA	NA	NA	2.5	0.2	2.3	92.0%	5.0	2.0	3.0	60.0%	10.0	39.0	29.0	-290.0%	110.0	102.0	8.0	7.3%	0.5	0.82	0.32	-64.0%
MD071		1.0	NA	NA	NA	2.5	0.2	2.3	92.0%	7.0	2.0	5.0	71.4%	10.0	46.0	36.0	-360.0%	250.0	261.0	11.0	-4.4%	7.0	9.56	2.56	-36.6%
MD070	D	3.0	NA	NA	NA	2.5	0.2	2.3	92.0%	9.0	10.0	1.0	-11.1%	13.5	93.0	79.5	-588.9%	614.0	511.0	103.0	16.8%	2.0	1.80	0.20	10.0%
MD069	D	3.0	NA	NA	NA	2.5	0.2	2.3	92.0%	8.0	10.0	2.0	-25.0%	64.0	102.0	38.0	-59.4%	614.0	521.0	93.0	15.1%	1.0	1.73	0.73	-73.0%
MD068		7.0	NA	NA	NA	2.5	0.2	2.3	92.0%	10.0	7.0	3.0	30.0%	63.0	79.0	16.0	-25.4%	563.0	538.0	25.0	4.4%	3.0	3.22	0.22	-7.3%
MD067		1.0	NA	NA	NA	2.5	0.2	2.3	92.0%	16.0	11.0	5.0	31.3%	53.0	73.0	20.0	-37.7%	433.0	350.0	83.0	19.2%	2.0	3.25	1.25	-62.5%
MD066		1.0	NA	NA	NA	2.5	0.2	2.3	92.0%	13.0	8.0	5.0	38.5%	52.0	68.0	16.0	-30.8%	422.0	332.0	90.0	21.3%	3.0	3.78	0.78	-26.0%
MD065		2.0	NA	NA	NA	2.5	0.6	1.9	76.0%	4.0	1.0	3.0	75.0%	50.0	27.0	23.0	46.0%	176.0	114.0	62.0	35.2%	12.0	12.66	0.66	-5.5%
MD064		2.0	NA	NA	NA	2.5	0.2	2.3	92.0%	3.0	3.0	0.0	0.0%	10.0	45.0	35.0	-350.0%	192.0	134.0	58.0	30.2%	2.0	1.42	0.58	29.0%
MD063		6.0	NA	NA	NA	2.5	0.2	2.3	92.0%	0.5	2.0	1.5	-300.0%	80.0	44.0	36.0	45.0%	221.0	135.0	86.0	38.9%	0.5	0.66	0.16	-32.0%
MD062		1.0	NA	NA	NA	2.5	0.2	2.3	92.0%	10.0	2.0	8.0	80.0%	78.0	47.0	31.0	39.7%	206.0	136.0	70.0	34.0%	0.5	0.56	0.06	-12.0%
MD061		1.0	2.0	1.0	-100.0%	2.5	0.2	2.3	92.0%	18.0	9.0	9.0	50.0%	94.0	79.0	15.0	16.0%	593.0	521.0	72.0	12.1%	2.0	2.40	0.40	-20.0%
MD060		1.0	2.0	1.0	-100.0%	2.5	0.2	2.3	92.0%	12.0	8.0	4.0	33.3%	72.0	76.0	4.0	-5.6%	536.0	457.0	79.0	14.7%	1.0	2.53	1.53	-153.0%
MD059		5.0	3.0	2.0	40.0%	2.5	0.2	2.3	92.0%	10.0	7.0	3.0	30.0%	73.0	71.0	2.0	2.7%	640.0	469.0	171.0	26.7%	2.0	2.45	0.45	-22.5%
MD058		1.0	4.0	3.0	-300.0%	2.5	0.2	2.3	92.0%	11.0	5.0	6.0	54.5%	43.0	72.0	29.0	-67.4%	475.0	375.0	100.0	21.1%	2.0	2.35	0.35	-17.5%
MD057		3.0	2.0	1.0	33.3%	2.5	0.2	2.3	92.0%	0.5	4.0	3.5	-700.0%	70.0	83.0	13.0	-18.6%	576.0	508.0	68.0	11.8%	3.0	4.09	1.09	-36.3%
MD056		3.0	2.0	1.0	33.3%																				

APPENDIX V

COMPARATIVE RESULTS BETWEEN THE INAA AND FIRE ASSAY OR ICP METHODS
FOR GOLD (Au), SILVER (Ag), MOLYBDENUM (Mo), NICKEL (Ni), ZINC (Zn) AND CALCIUM (Ca)

Assigned Sample No.	Duplicates	Au in ppb		Difference		Ag in ppm		Difference		Mo in ppm		Difference		Ni in ppm		Difference		Zn in ppm		Difference		Ca in %		Difference	
		INAA	FA	Actual	Percentage	INAA	ICP	Actual	Percentage	INAA	ICP	Actual	Percentage	INAA	ICP	Actual	Percentage	INAA	ICP	Actual	Percentage	INAA	ICP	Actual	Percentage
MD028		1.0	0.5	0.5	50.0%	2.5	0.2	2.3	92.0%	3.0	1.0	2.0	66.7%	11.5	42.0	30.5	-265.2%	162.0	127.0	35.0	21.6%	0.5	0.34	0.16	32.0%
MD027		4.0	0.5	3.5	87.5%	2.5	0.2	2.3	92.0%	23.0	14.0	9.0	39.1%	14.5	80.0	65.5	-451.7%	355.0	396.0	41.0	-11.5%	3.0	1.79	1.21	40.3%
MD026		4.0	3.0	1.0	25.0%	2.5	0.2	2.3	92.0%	10.0	7.0	3.0	30.0%	13.0	46.0	33.0	-253.8%	237.0	222.0	15.0	6.3%	0.5	1.32	0.82	-164.0%
MD025		3.0	0.5	2.5	83.3%	2.5	0.4	2.1	84.0%	7.0	4.0	3.0	42.9%	11.5	41.0	29.5	-256.5%	211.0	173.0	38.0	18.0%	0.5	1.01	0.51	-102.0%
MD024		1.0	2.0	1.0	-100.0%	2.5	0.4	2.1	84.0%	8.0	6.0	2.0	25.0%	190.0	33.0	157.0	82.6%	118.0	133.0	15.0	-12.7%	2.0	1.79	0.21	10.5%
MD023		3.0	1.0	2.0	66.7%	2.5	0.2	2.3	92.0%	6.0	2.0	4.0	66.7%	11.5	45.0	33.5	-291.3%	123.0	122.0	1.0	0.8%	0.5	0.68	0.18	-36.0%
MD022		1.0	1.0	0.0	0.0%	2.5	0.7	1.8	72.0%	0.5	1.0	0.5	-100.0%	11.0	36.0	25.0	-227.3%	154.0	109.0	45.0	29.2%	0.5	0.46	0.04	8.0%
MD021		3.0	NA	NA	NA	2.5	0.2	2.3	92.0%	13.0	5.0	8.0	61.5%	230.0	88.0	142.0	61.7%	482.0	451.0	31.0	6.4%	4.0	4.06	0.06	-1.5%
MD020	D	1.0	NA	NA	NA	2.5	0.4	2.1	84.0%	15.0	13.0	2.0	13.3%	11.0	67.0	56.0	-509.1%	343.0	351.0	8.0	-2.3%	3.0	3.38	0.38	-12.7%
MD019	D	6.0	NA	NA	NA	2.5	0.2	2.3	92.0%	22.0	12.0	10.0	45.5%	92.0	66.0	26.0	28.3%	335.0	340.0	5.0	-1.5%	5.0	4.67	0.33	6.6%
MD018		1.0	NA	NA	NA	2.5	0.2	2.3	92.0%	17.0	10.0	7.0	41.2%	140.0	60.0	80.0	57.1%	318.0	320.0	2.0	-0.6%	4.0	4.52	0.52	-13.0%
MD017		1.0	NA	NA	NA	5.0	0.2	4.8	96.0%	10.0	7.0	3.0	30.0%	10.0	41.0	31.0	-310.0%	230.0	192.0	38.0	16.5%	0.5	1.31	0.81	-162.0%
MD016		1.0	NA	NA	NA	2.5	0.8	1.7	68.0%	5.0	1.0	4.0	80.0%	110.0	43.0	67.0	60.9%	125.0	128.0	3.0	-2.4%	0.5	0.36	0.14	28.0%
MD015		1.0	NA	NA	NA	2.5	0.4	2.1	84.0%	5.0	2.0	3.0	60.0%	75.0	44.0	31.0	41.3%	170.0	123.0	47.0	27.6%	0.5	0.72	0.22	-44.0%
MD014		1.0	NA	NA	NA	2.5	0.5	2.0	80.0%	0.5	3.0	2.5	-500.0%	10.0	44.0	34.0	-340.0%	135.0	125.0	10.0	7.4%	0.5	0.50	0.00	0.0%
MD013		1.0	NA	NA	NA	2.5	0.7	1.8	72.0%	7.0	2.0	5.0	71.4%	10.0	43.0	33.0	-330.0%	142.0	122.0	20.0	14.1%	0.5	0.60	0.10	-20.0%
MD012		4.0	2.0	2.0	50.0%	2.5	0.6	1.9	76.0%	7.0	1.0	6.0	85.7%	10.0	41.0	31.0	-310.0%	137.0	104.0	33.0	24.1%	0.5	1.10	0.60	-120.0%
MD011		1.0	0.5	0.5	50.0%	2.5	0.4	2.1	84.0%	11.0	2.0	9.0	81.8%	11.5	74.0	62.5	-543.5%	334.0	338.0	4.0	-1.2%	5.0	5.45	0.45	-9.0%
MD010	D	1.0	0.5	0.5	50.0%	2.5	0.2	2.3	92.0%	13.0	9.0	4.0	30.8%	97.0	62.0	35.0	36.1%	272.0	298.0	26.0	-9.6%	5.0	4.84	0.16	3.2%
MD009	D	1.0	0.5	0.5	50.0%	2.5	0.2	2.3	92.0%	15.0	9.0	6.0	40.0%	11.0	61.0	50.0	-454.5%	289.0	294.0	5.0	-1.7%	4.0	3.92	0.08	2.0%
MD008		1.0	0.5	0.5	50.0%	2.5	0.7	1.8	72.0%	8.0	9.0	1.0	-12.5%	10.0	64.0	54.0	-540.0%	270.0	269.0	1.0	0.4%	3.0	3.42	0.42	-14.0%
MD007		3.0	0.5	2.5	83.3%	2.5	0.5	2.0	80.0%	4.0	1.0	3.0	75.0%	10.0	19.0	9.0	-90.0%	87.0	84.0	3.0	3.4%	0.5	0.30	0.20	40.0%
MD006		1.0	0.5	0.5	50.0%	2.5	0.7	1.8	72.0%	7.0	3.0	4.0	57.1%	10.0	19.0	9.0	-90.0%	85.0	59.0	26.0	30.6%	2.0	2.14	0.14	-7.0%
MD005		1.0	7.0	6.0	-600.0%	2.5	0.6	1.9	76.0%	5.0	2.0	3.0	60.0%	10.0	54.0	44.0	-440.0%	166.0	166.0	0.0	0.0%	1.0	0.56	0.44	44.0%
MD004		3.0	0.5	2.5	83.3%	2.5	0.5	2.0	80.0%	6.0	1.0	5.0	83.3%	10.0	46.0	36.0	-360.0%	194.0	142.0	52.0	26.8%	0.5	0.47	0.03	6.0%
MD003		1.0	NA	NA	NA	2.5	0.7	1.8	72.0%	4.0	1.0	3.0	75.0%	10.0	41.0	31.0	-310.0%	148.0	131.0	17.0	11.5%	1.0	0.40	0.60	60.0%
MD002		1.0	NA	NA	NA	2.5	0.2	2.3	92.0%	7.0	3.0	4.0	57.1%	63.0	22.0	41.0	65.1%	75.0	74.0	1.0	1.3%	3.0	3.22	0.22	-7.3%
MD001		1.0	NA	NA	NA	2.5	0.4	2.1	84.0%	5.0	1.0	4.0	80.0%	65.0	39.0	26.0	40.0%	145.0	116.0	29.0	20.0%	0.5	0.41	0.09	18.0%
SMOKY RIVER SAMPLES WHICH WERE COLLECTED BY C. COLLOM																									
CS005	D	3.0	NA	NA	NA	2.5	0.2	2.3	92.0%	16.0	15.0	1.0	6.3%	10.0	52.0	42.0	-420.0%	106.0	107.0	1.0	-0.9%	15.0	16.54	1.54	-10.3%
CS003	D	3.0	0.5	2.5	83.3%	2.5	0.2	2.3	92.0%	12.0	16.0	4.0	-33.3%	66.0	57.0	9.0	13.6%	143.0	176.0	33.0	-23.1%	5.0	4.96	0.04	0.8%
CS004		1.0	31.0	30.0	-3000.0%	2.5	0.2	2.3	92.0%	160.0	264.0	104.0	-65.0%	18.0	9.0	9.0	50.0%	25.0	2.0	23.0	92.0%	0.5	0.06	0.44	88.0%
CS002		3.0	0.5	2.5	83.3%	2.5	0.4	2.1	84.0%	19.0	14.0	5.0	26.3%	70.0	52.0	18.0	25.7%	122.0	100.0	22.0	18.0%	20.0	17.44	2.56	12.8%
CS001		1.0	0.5	0.5	50.0%	2.5	0.2	2.3	92.0%	18.0	9.0	9.0	50.0%	40.0	39.0	1.0	2.5%	97.0	73.0	24.0	24.7%	8.0	8.74	0.74	-9.3%
Average		4.4	3.1	1.4	30.9%	2.5	0.4	2.2	85.9%	11.4	8.8	2.6	23.0%	63.4	63.9	0.6	-0.9%	331.0	315.3	15.6	4.7%	2.6	2.95	0.37	-14.3%

NOTE: "N.A." denotes "Not Analyzed" due to budgetary restraints.

APPENDIX VI

GEOCHEMICAL DISTRIBUTION HISTOGRAMS FOR SELECTED ELEMENTS, CLEAR HILLS IRON DEPOSITS STUDY

VI.1 Precious Metals and Platinum Group Elements

VI.2 Base Metals and Pathfinder Elements

VI.3 Uranium, Thorium, Rare Earths and Related Elements

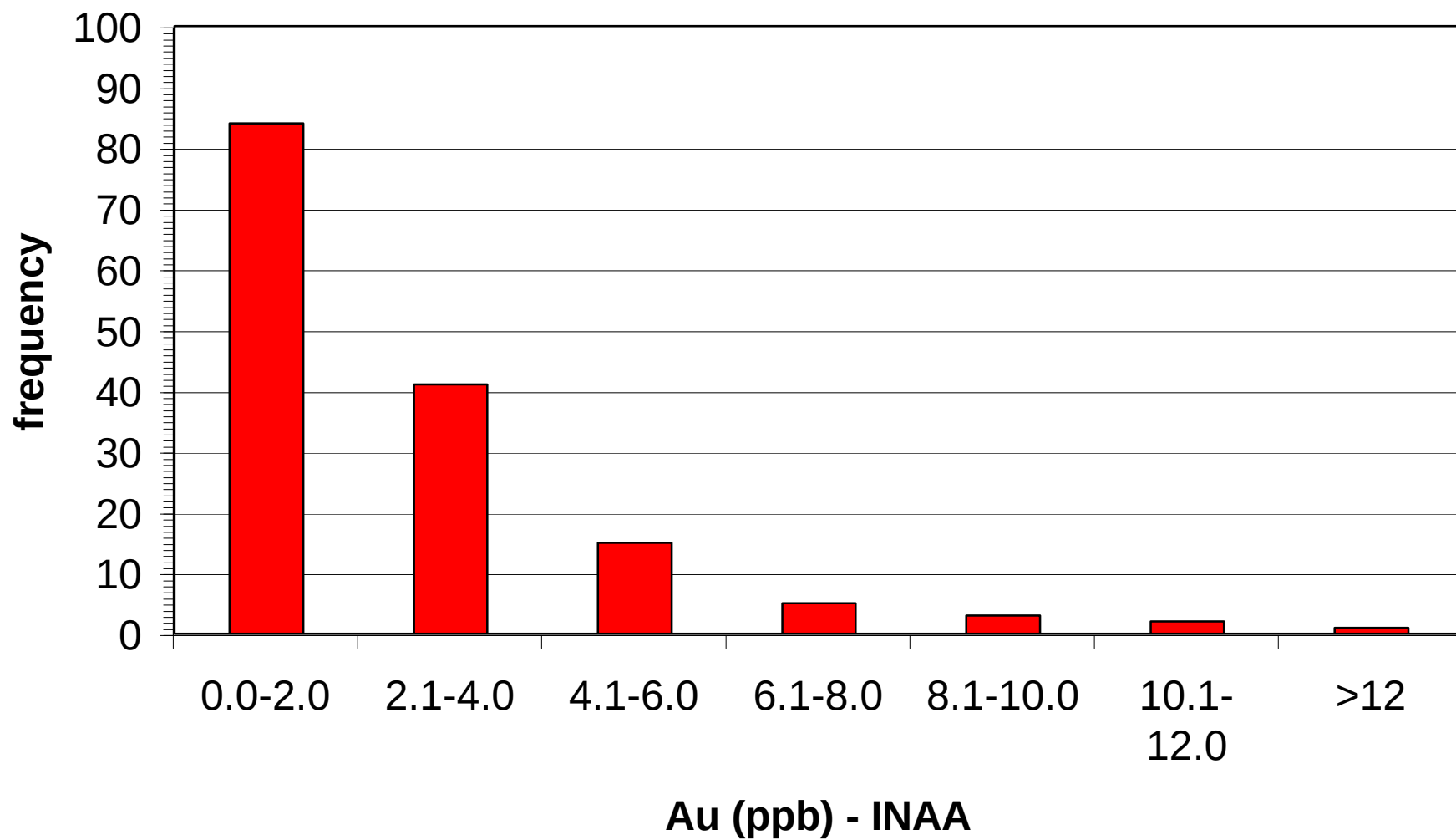
VI.4 Rock Forming and Related Trace Elements

APPENDIX VI.1

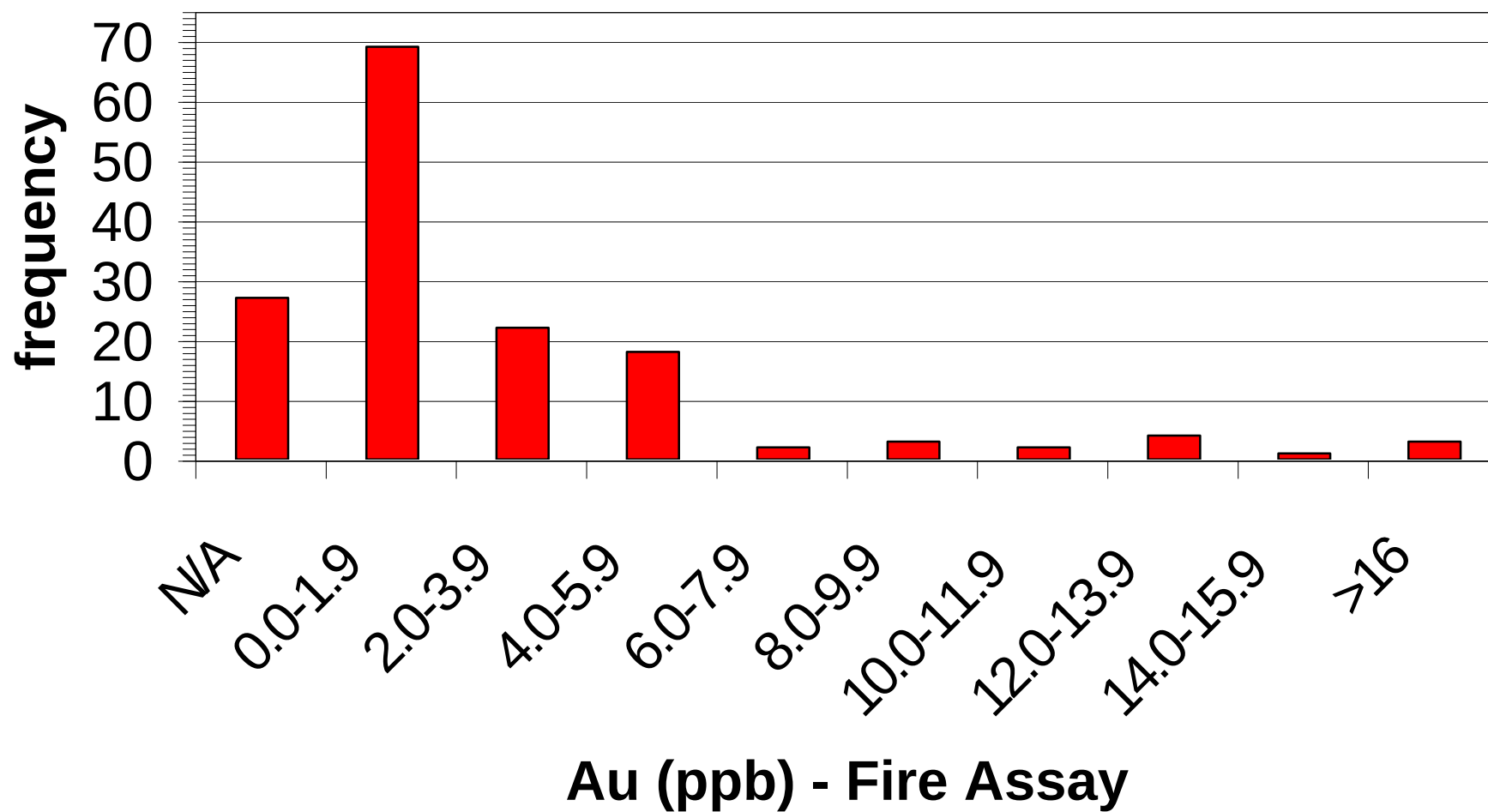
**GEOCHEMICAL DISTRIBUTION HISTOGRAMS FOR SELECTED ELEMENTS,
CLEAR HILLS IRON DEPOSITS STUDY**

Precious Metals and Platinum Group Elements

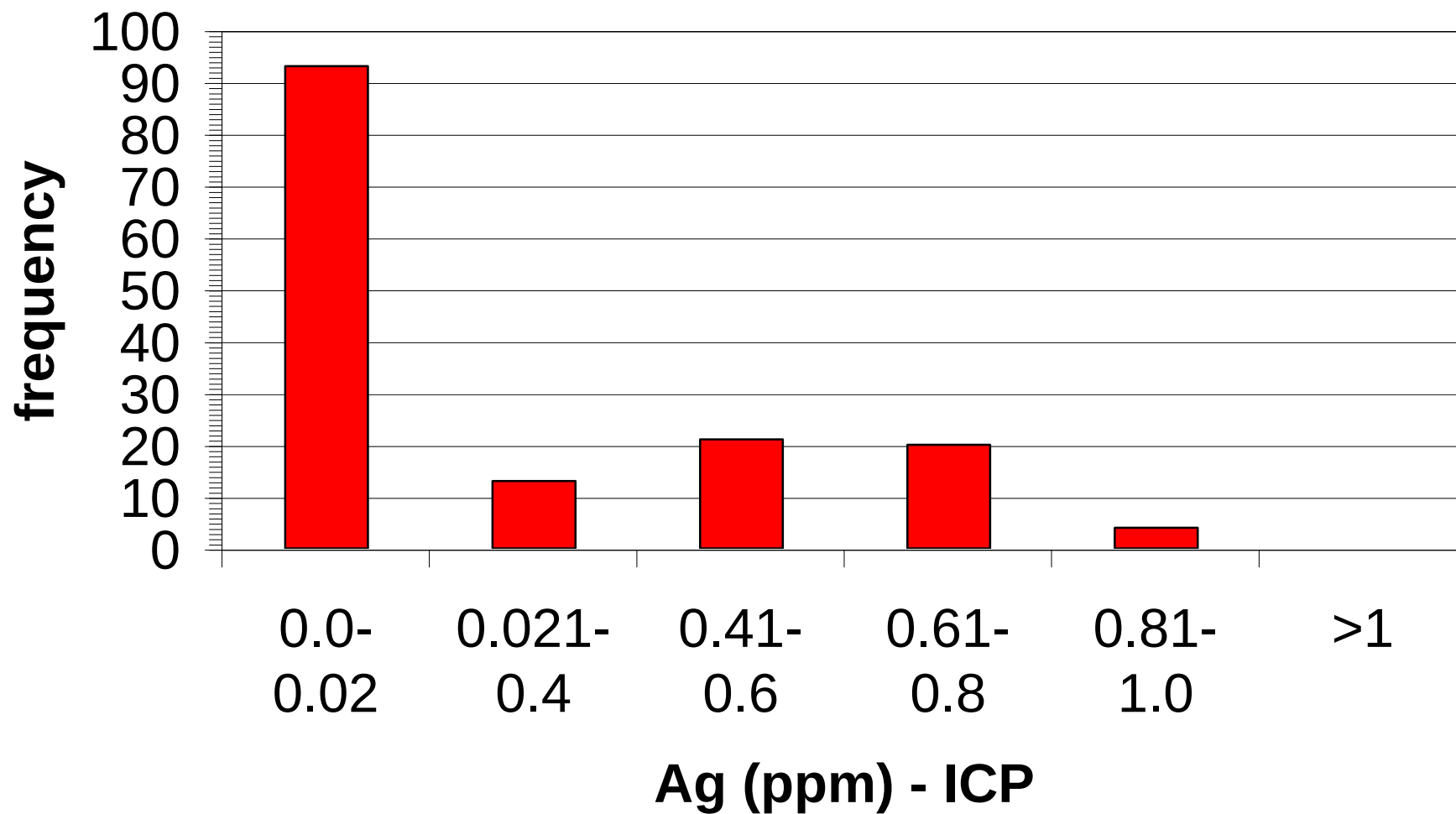
Assay vs. Frequency



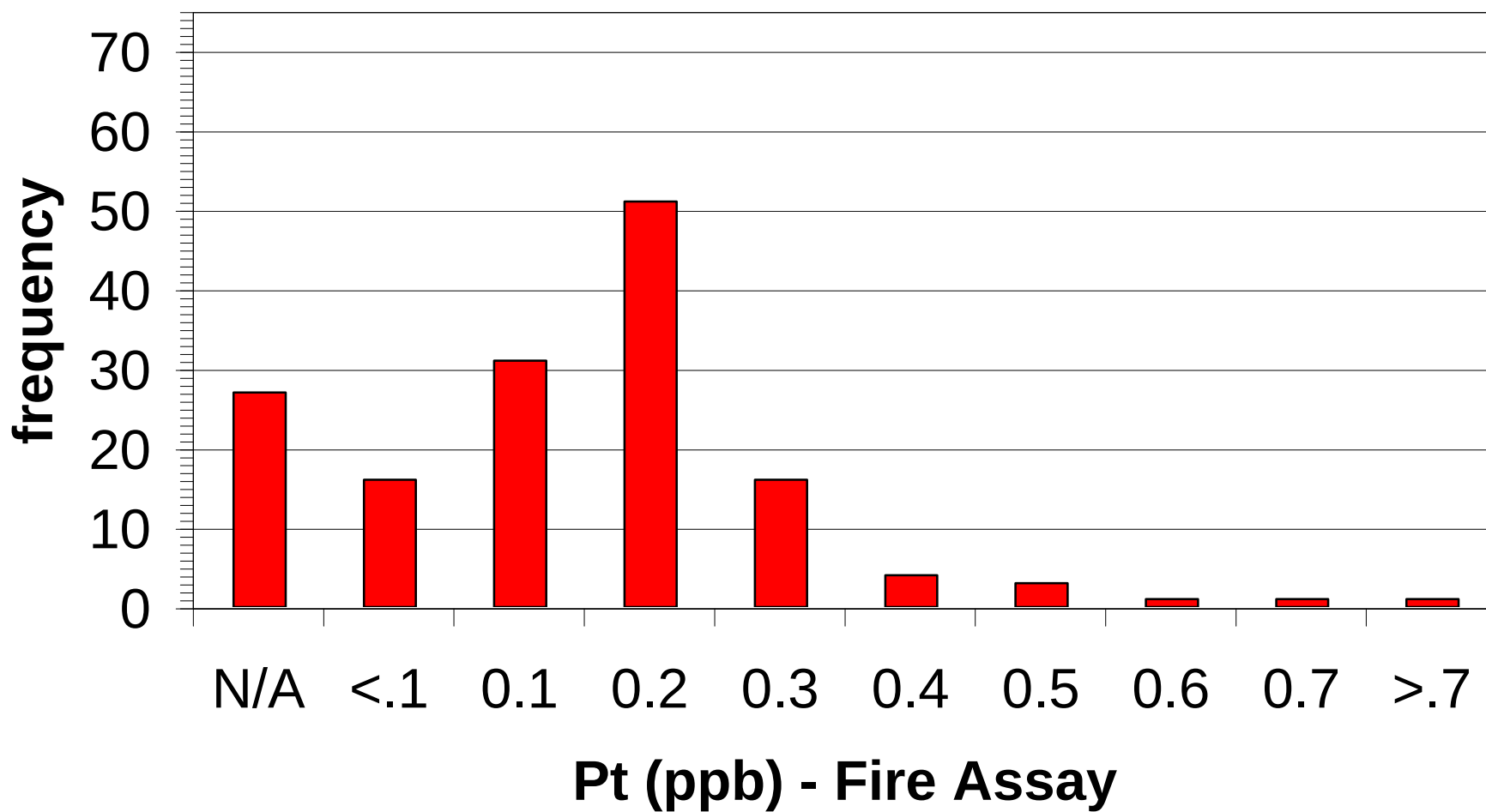
Assay vs. Frequency



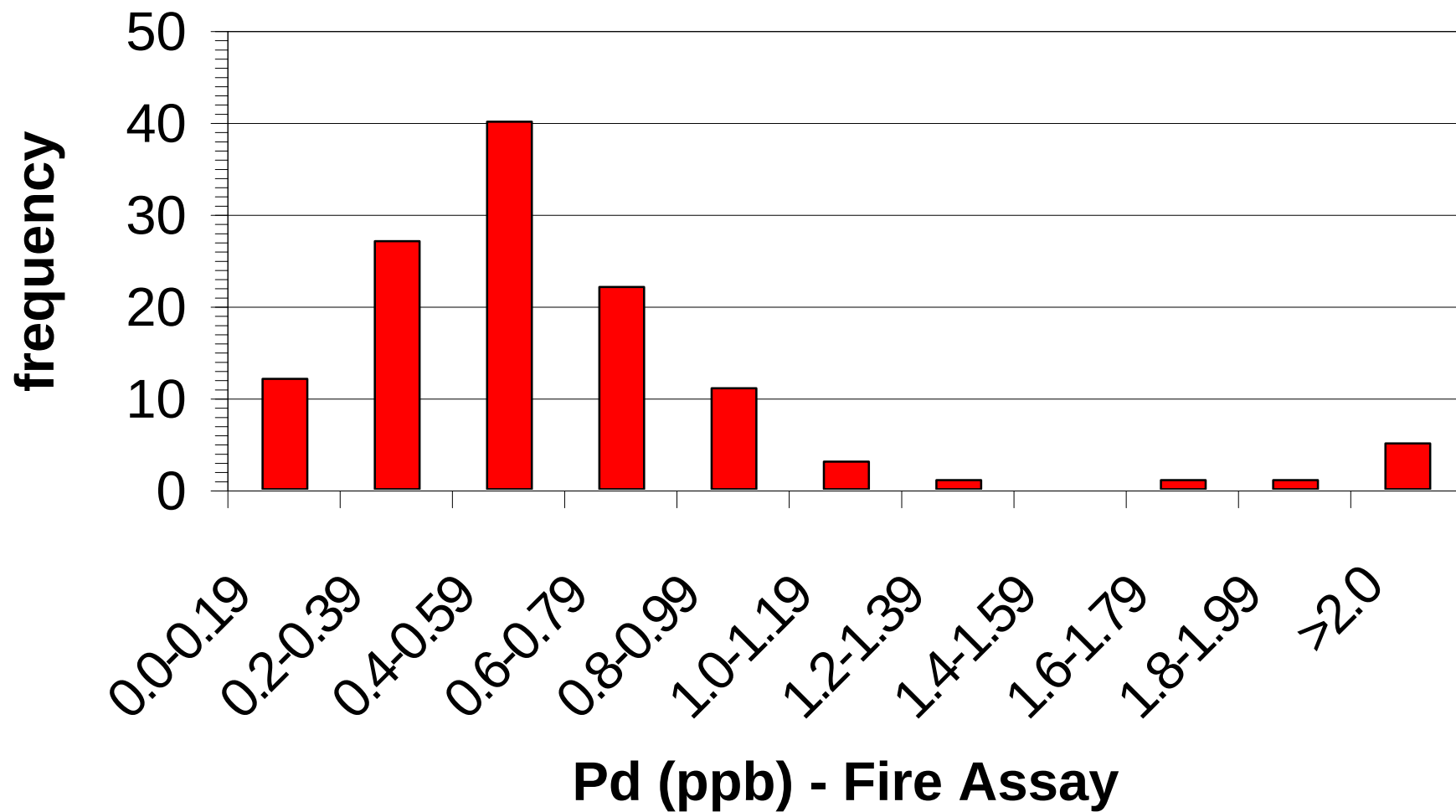
Assay vs. Frequency



Assay vs. Frequency



Assay vs. Frequency

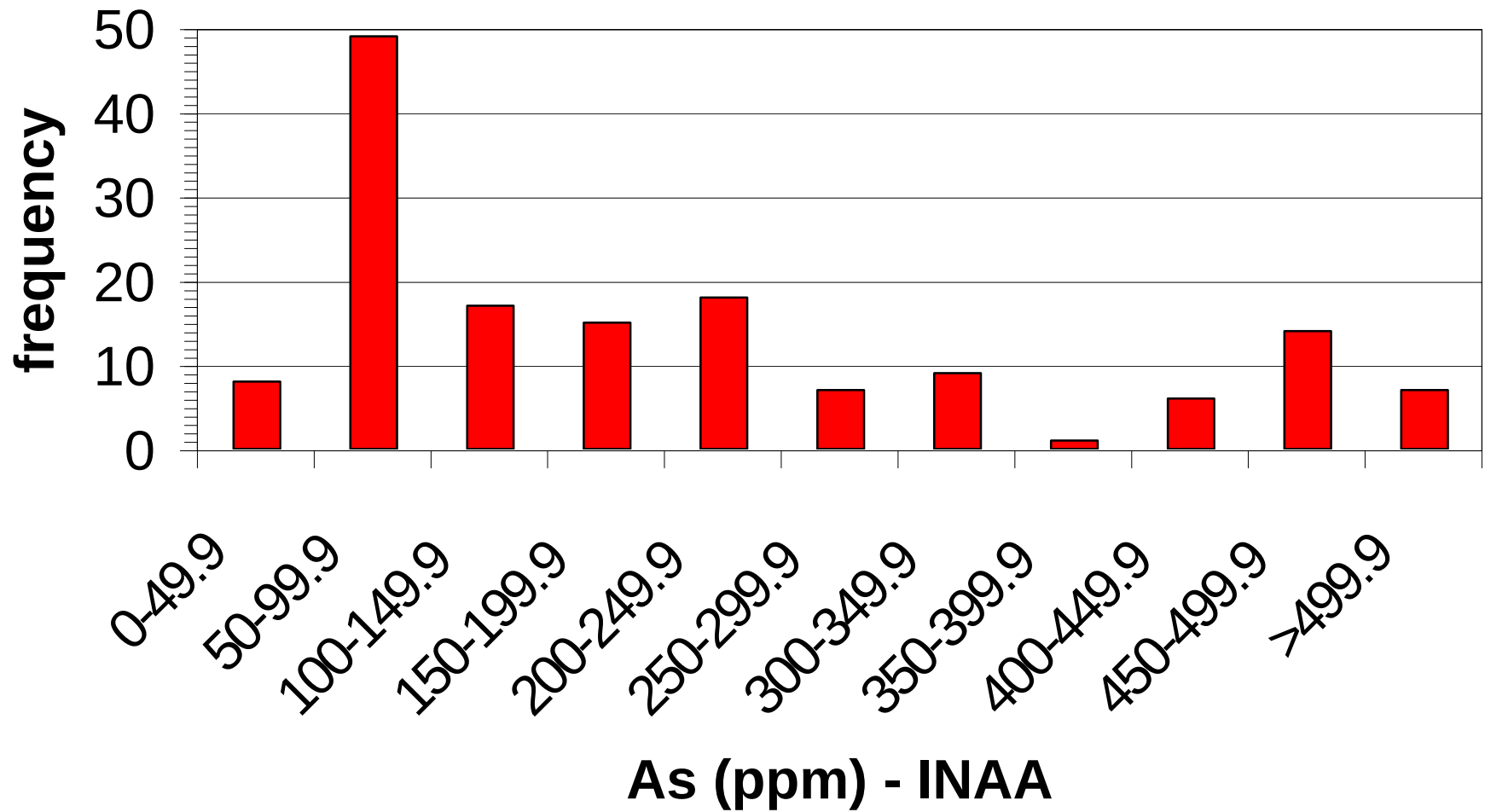


APPENDIX VI.2

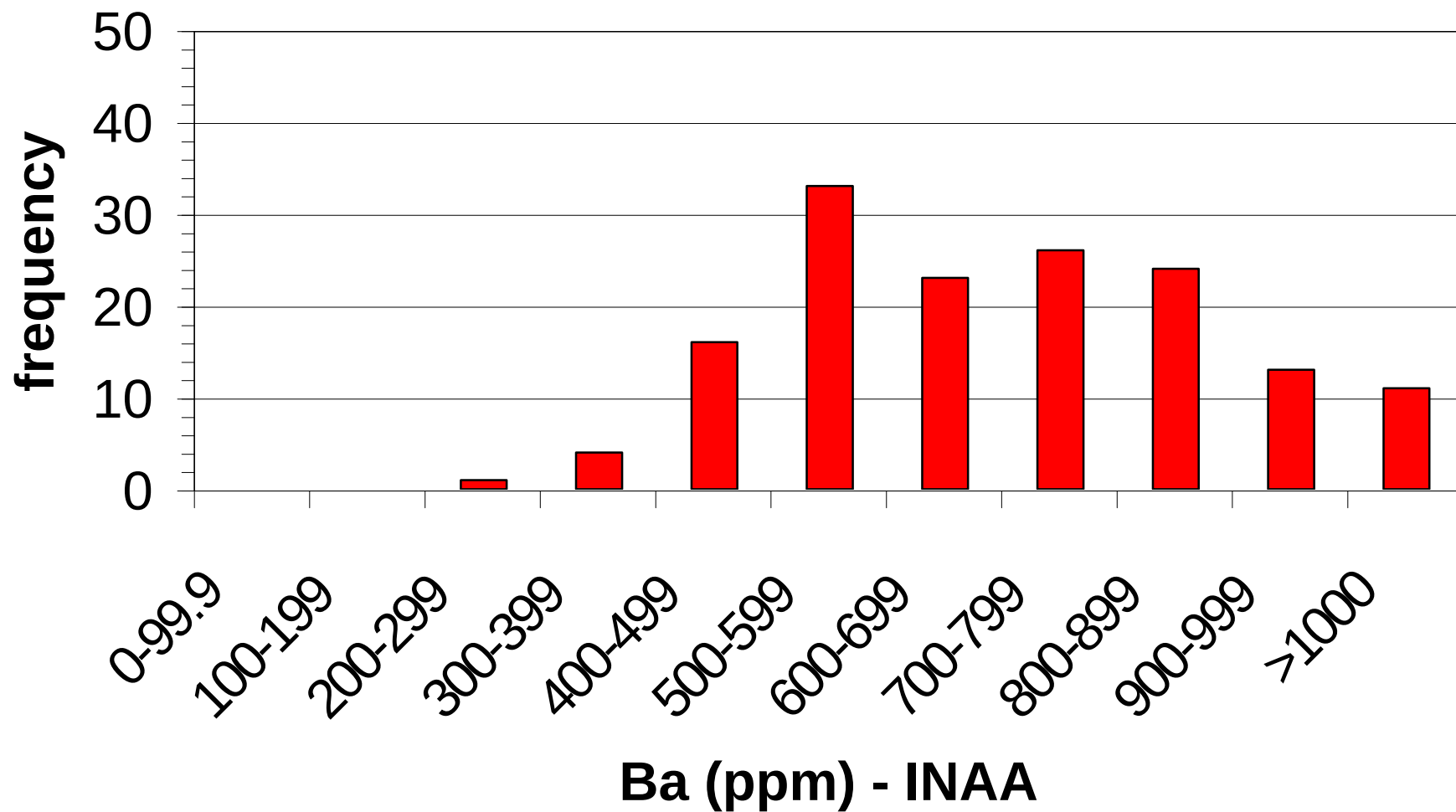
**GEOCHEMICAL DISTRIBUTION HISTOGRAMS FOR SELECTED ELEMENTS,
CLEAR HILLS IRON DEPOSITS STUDY**

Base Metals and Pathfinder Elements

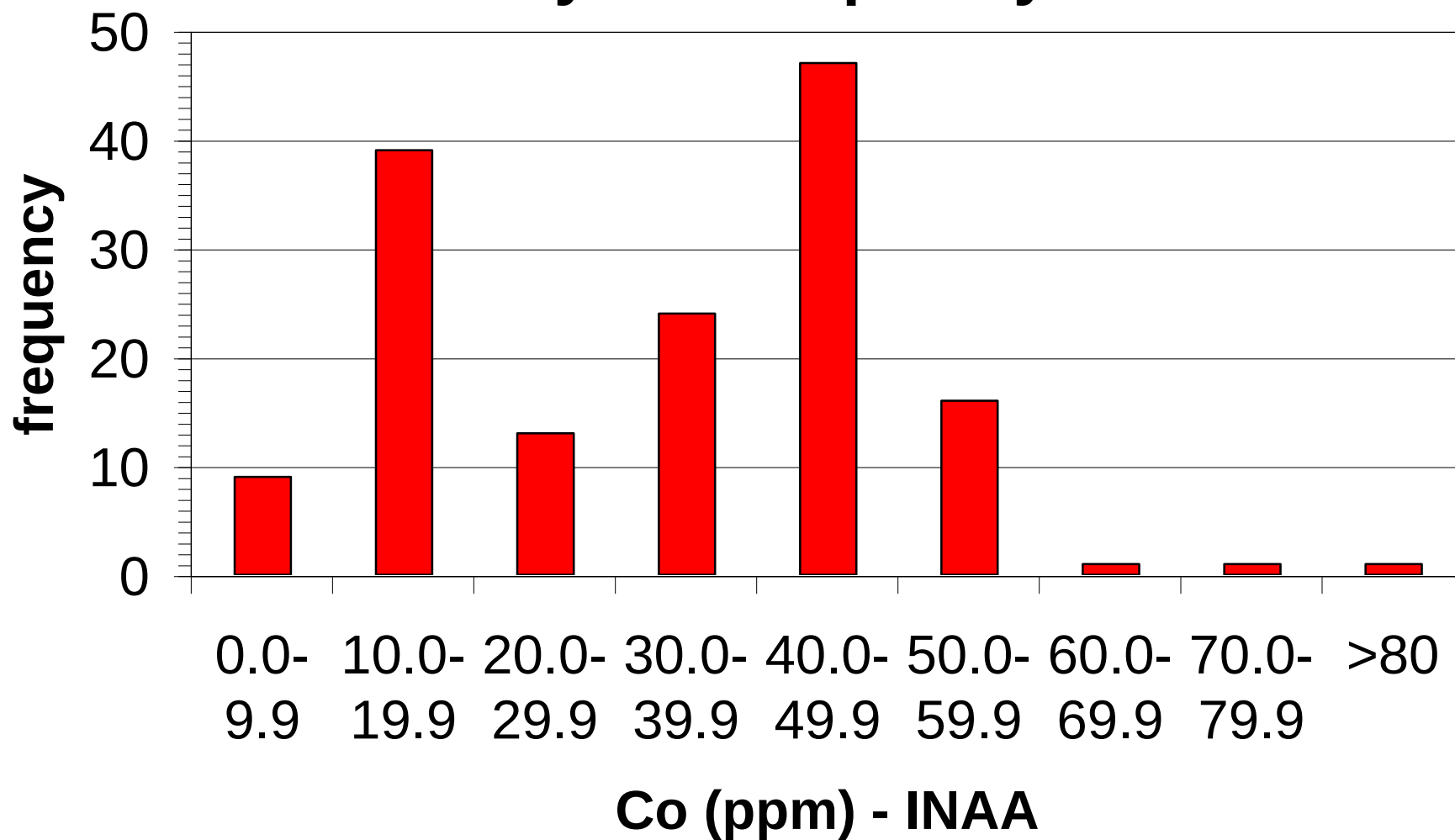
Assay vs. Frequency



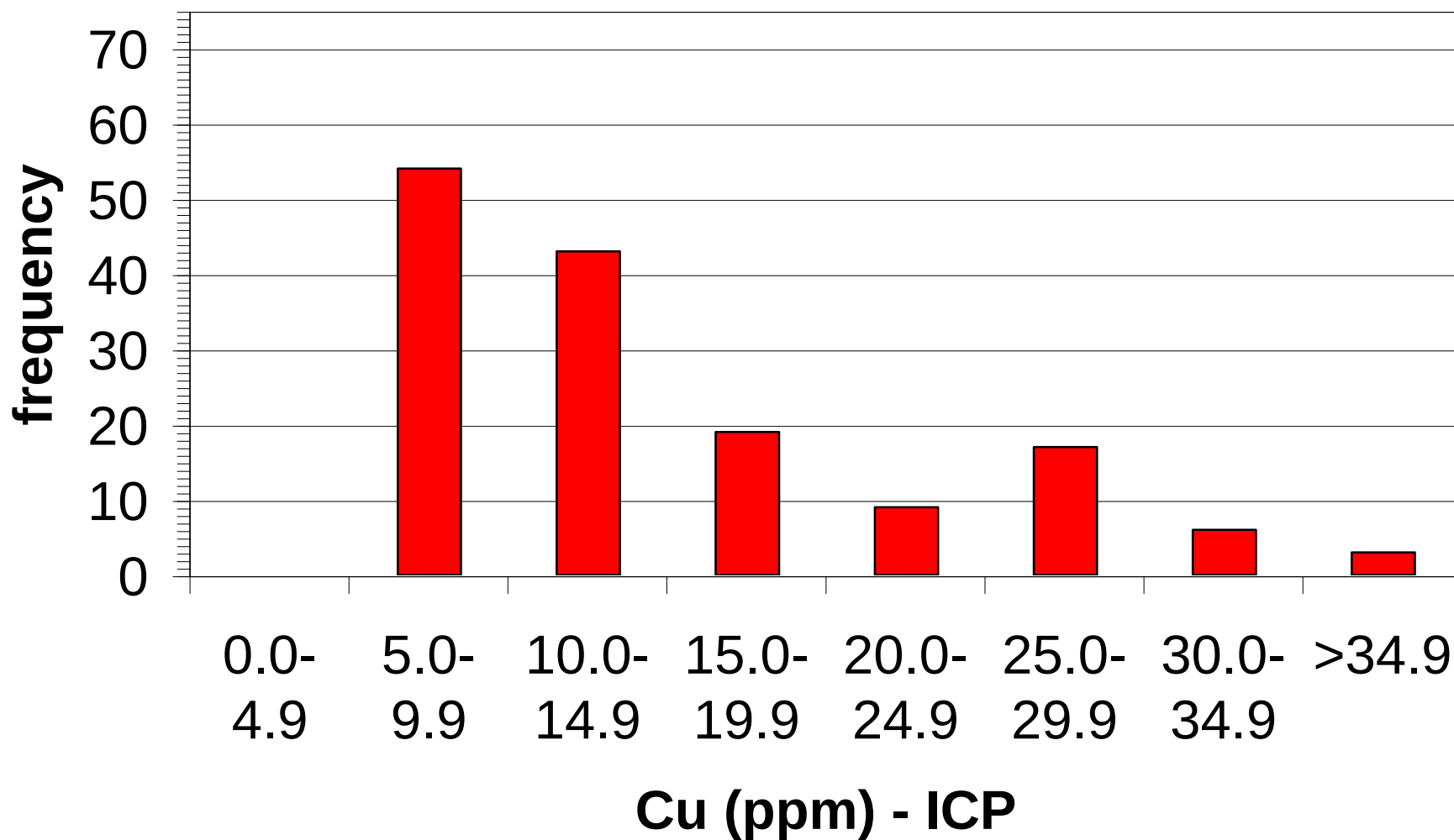
Assay vs. Frequency



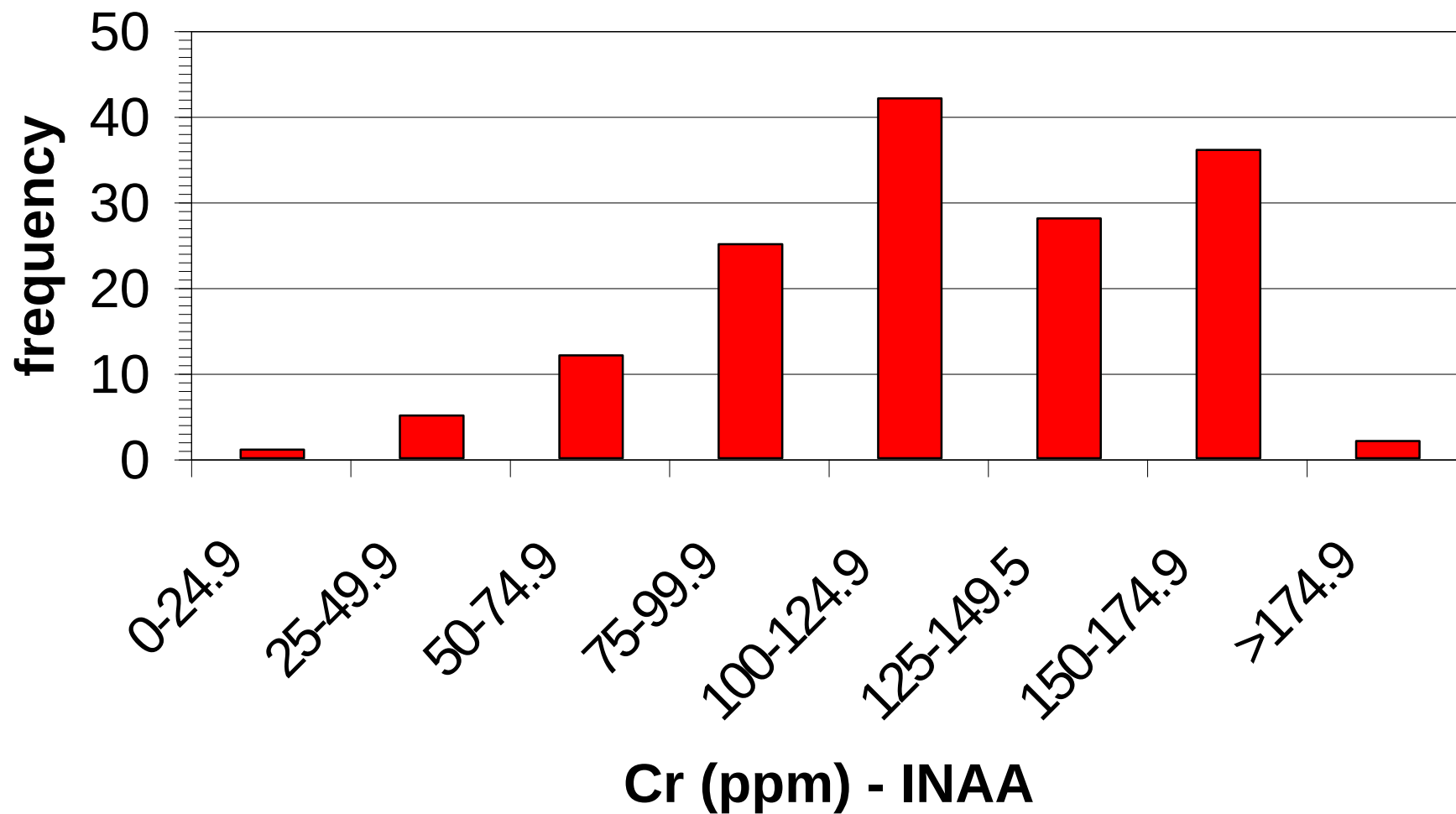
Assay vs. Frequency



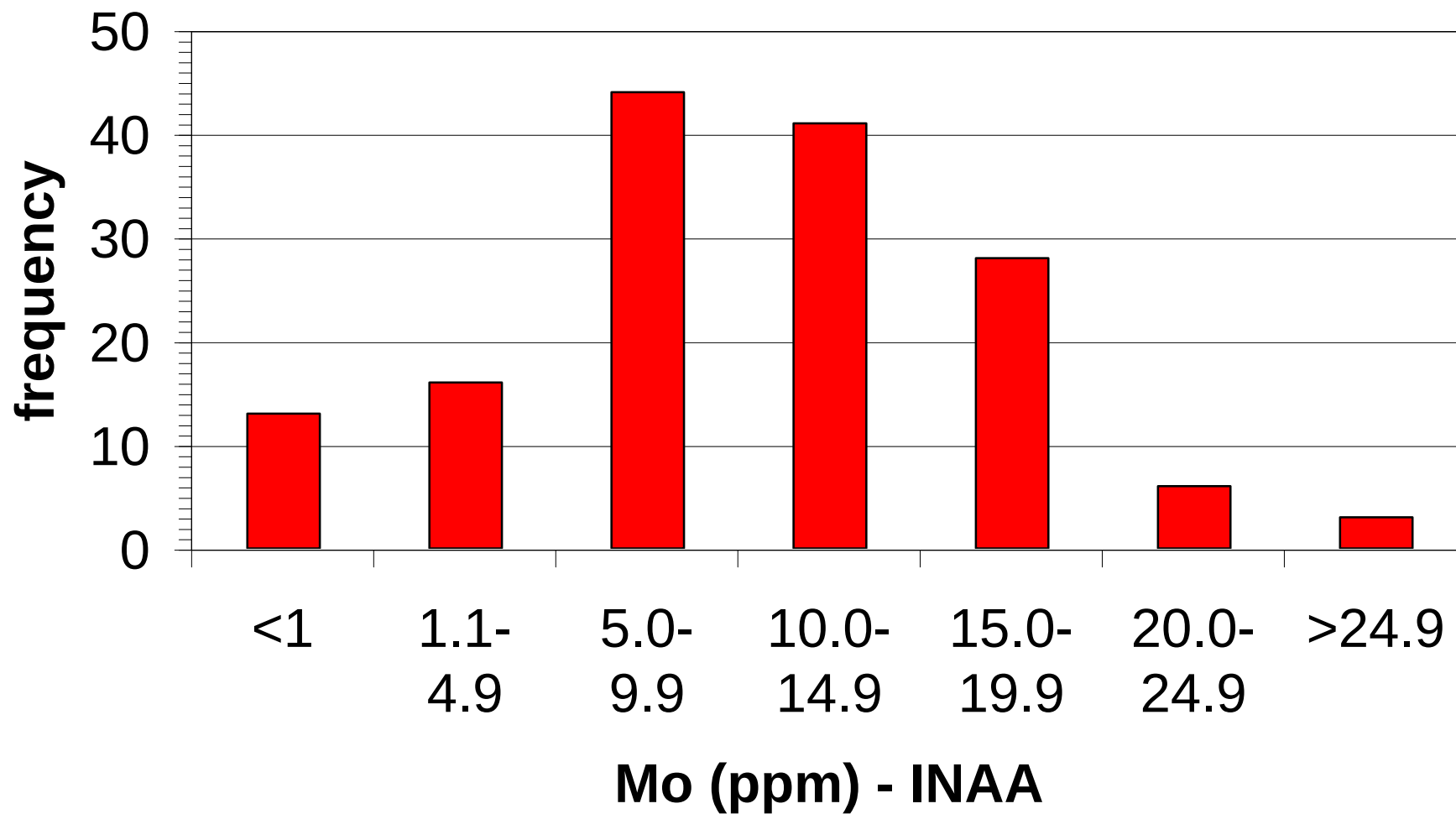
Assay vs. Frequency



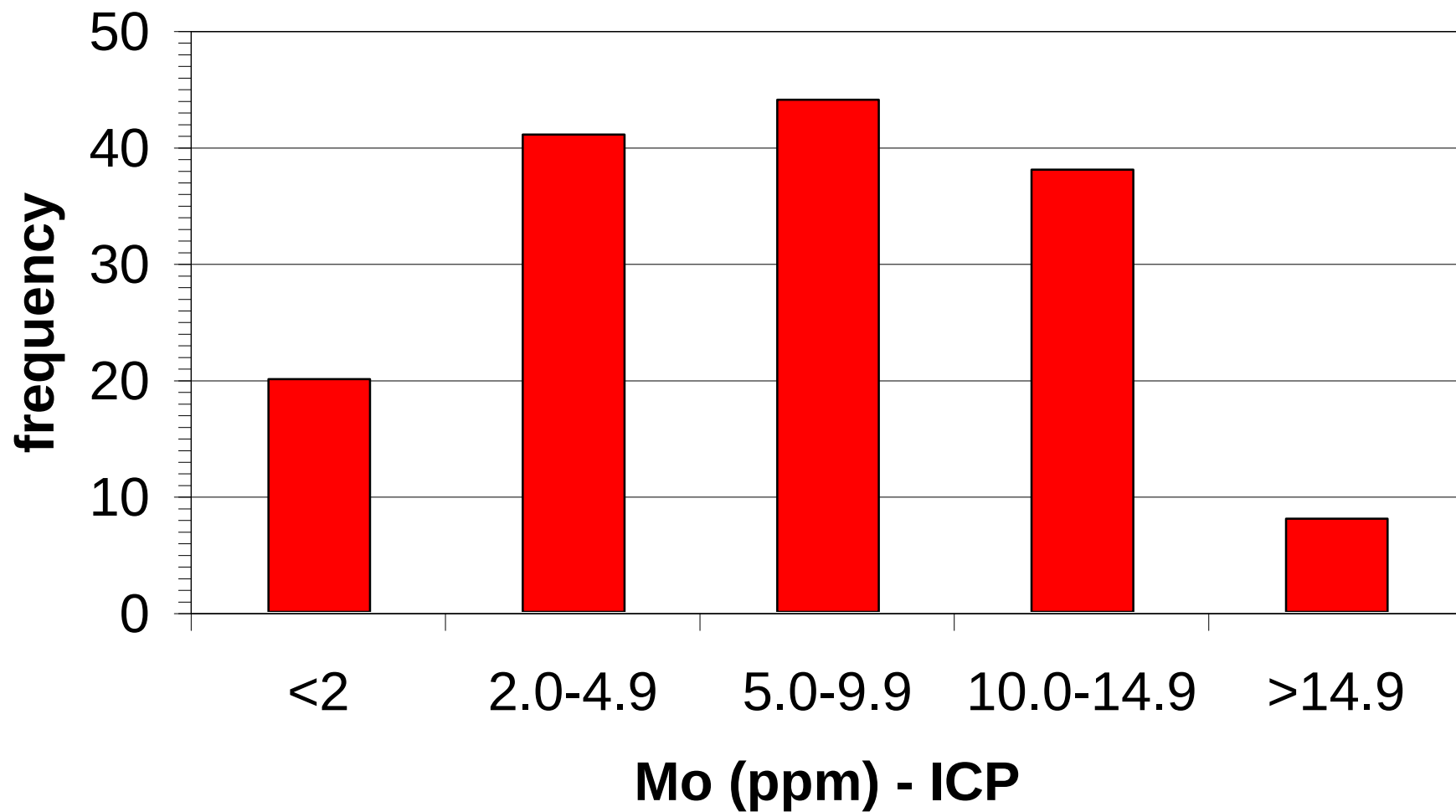
Assay vs. Frequency



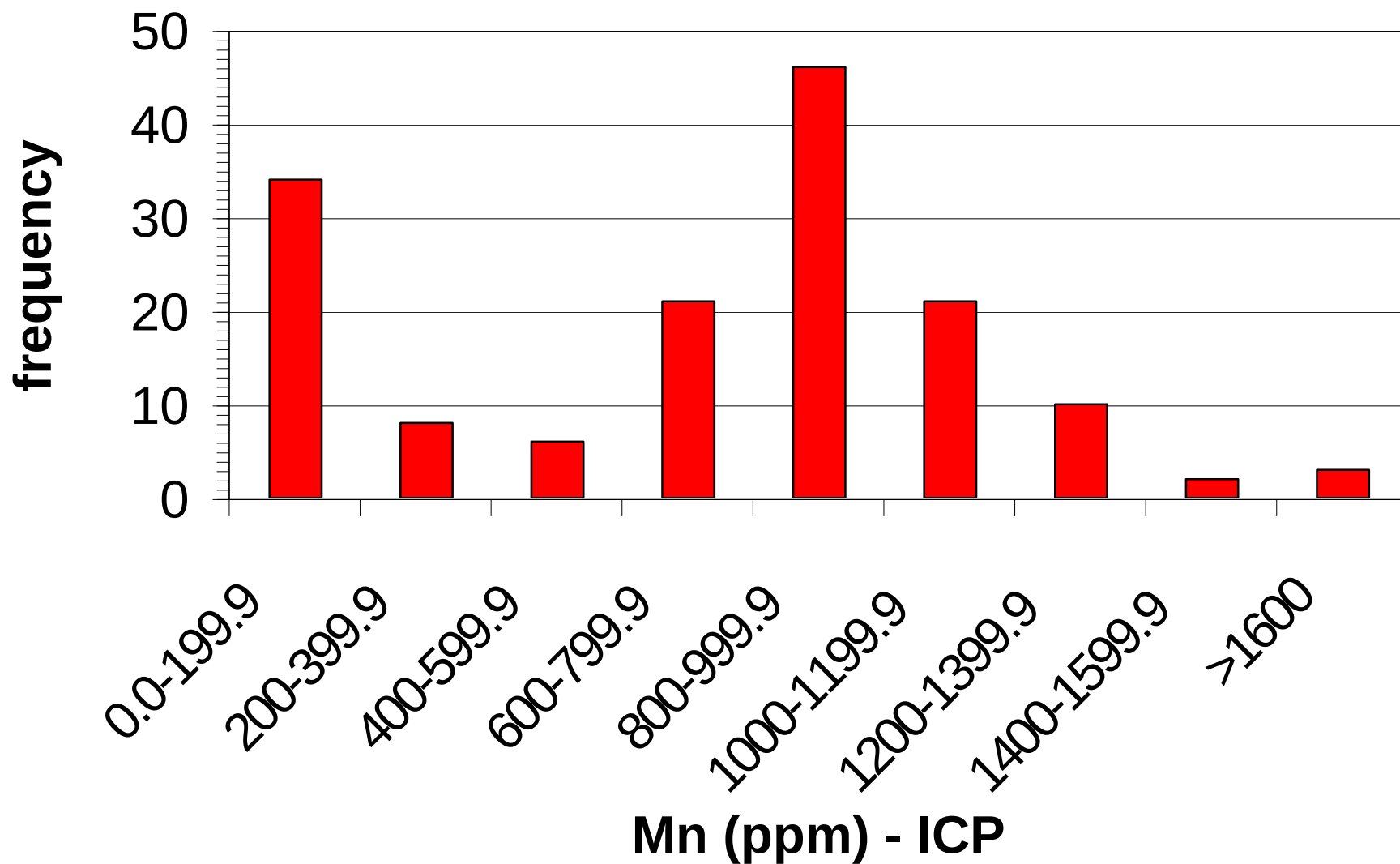
Assay vs. Frequency



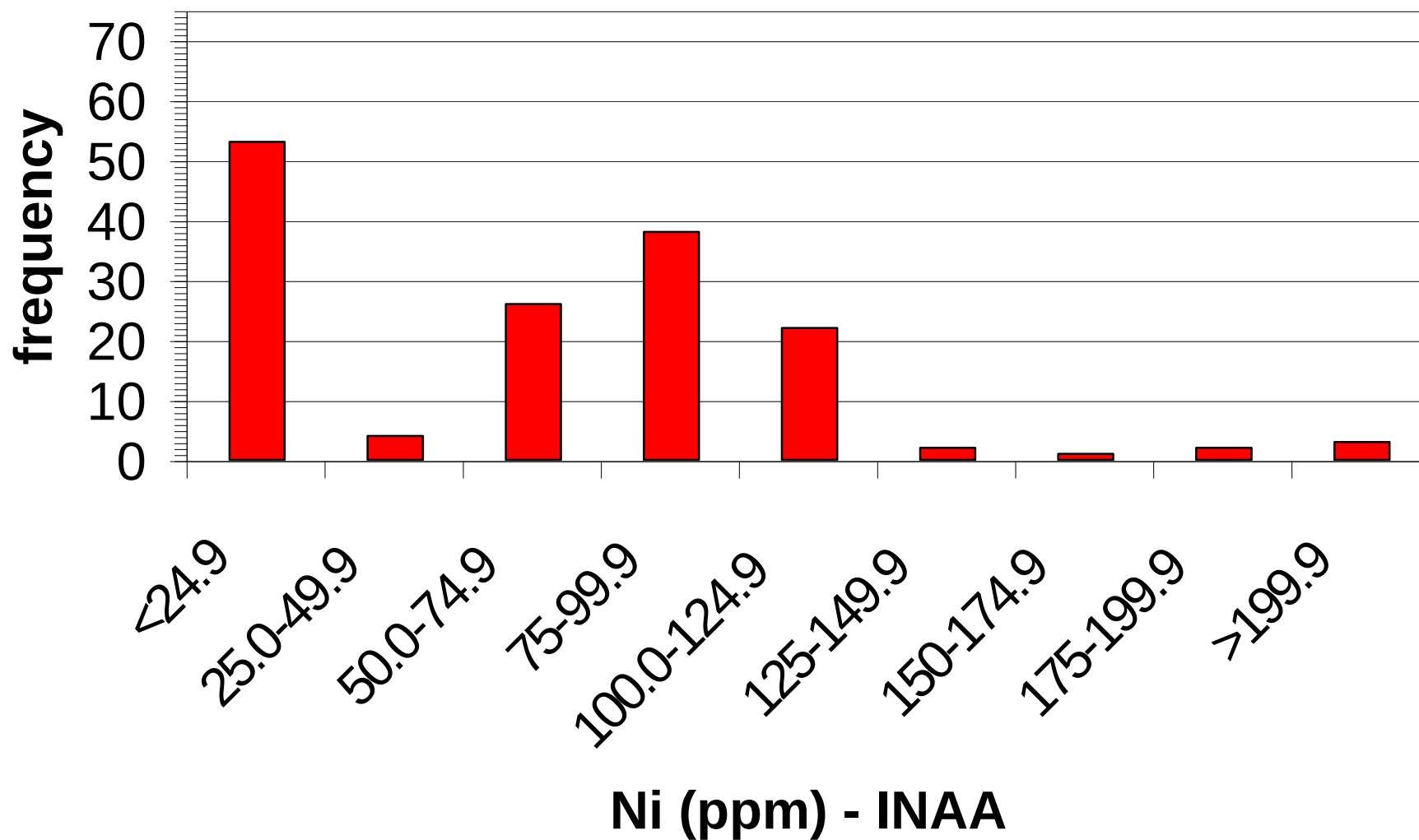
Assay vs. frequency



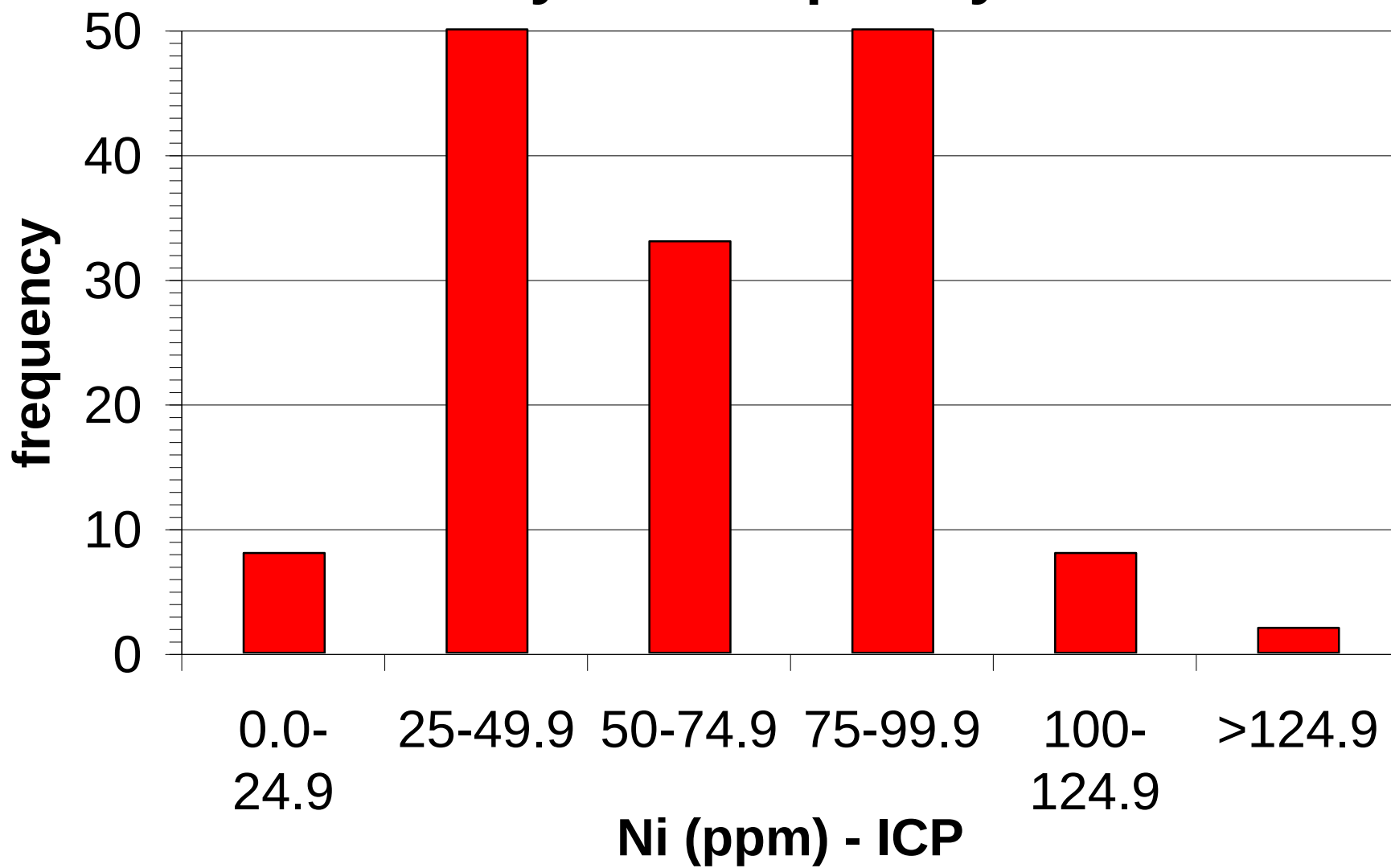
Assay vs. Frequency



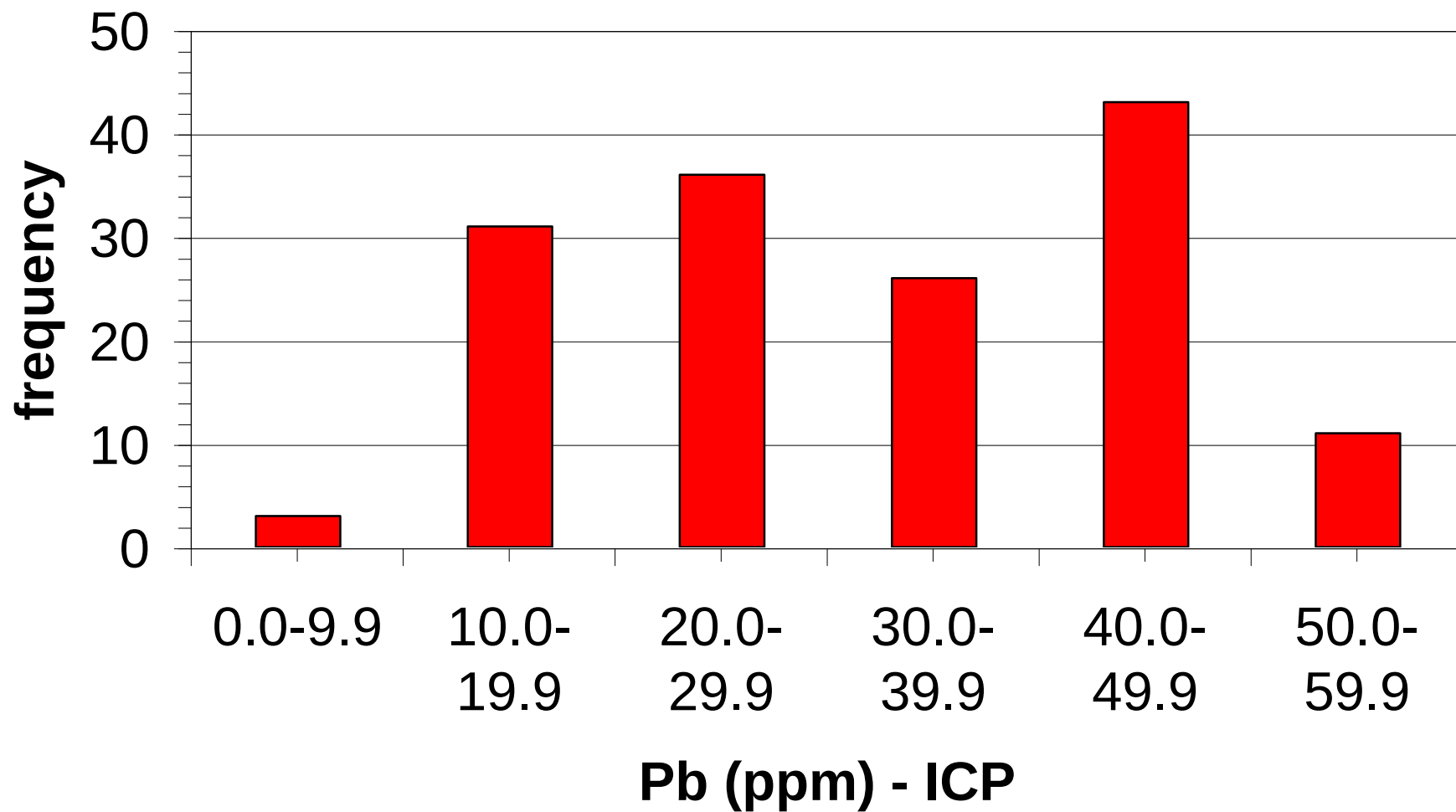
Assay vs. Frequency



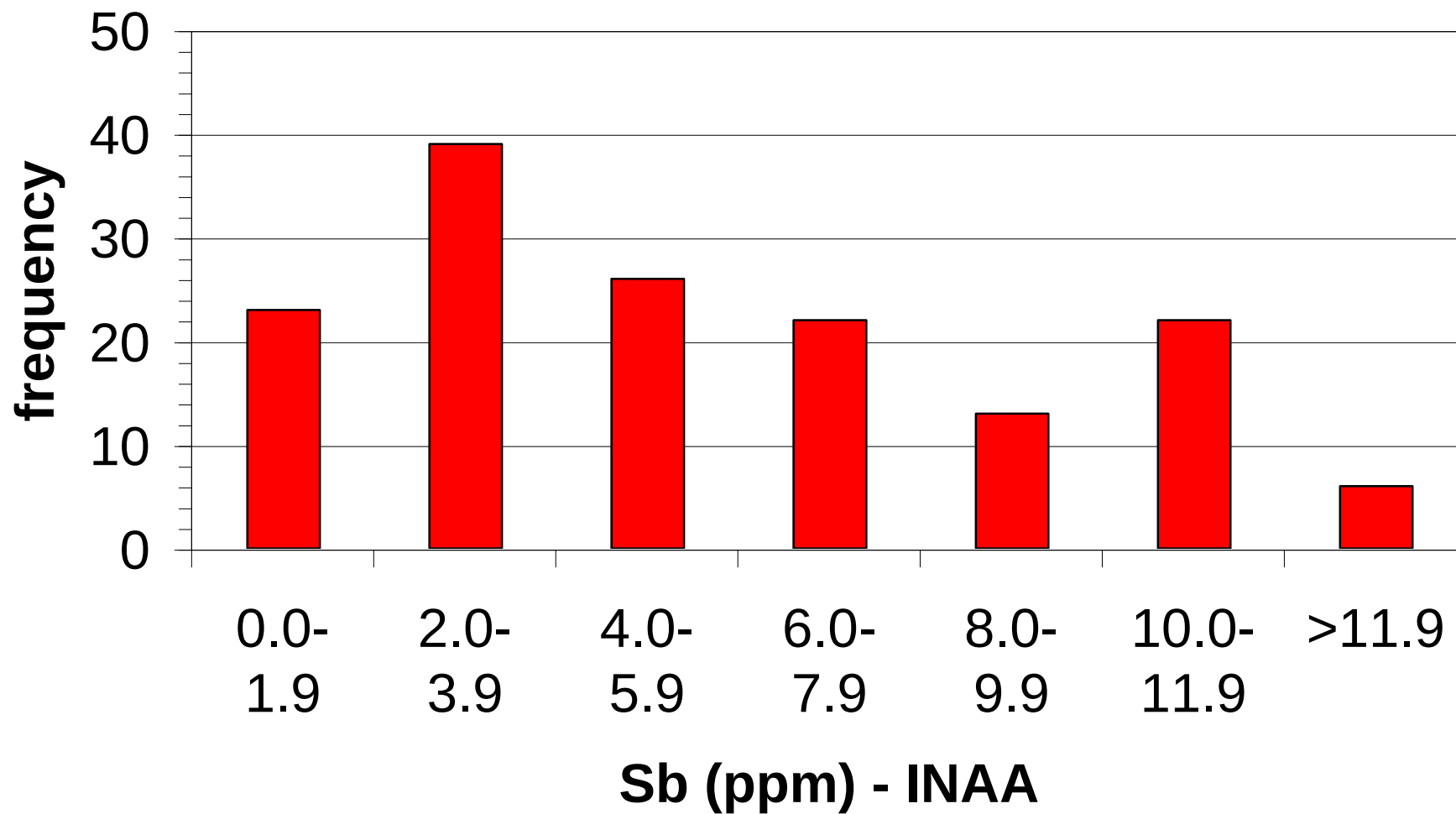
Assay vs. Frequency



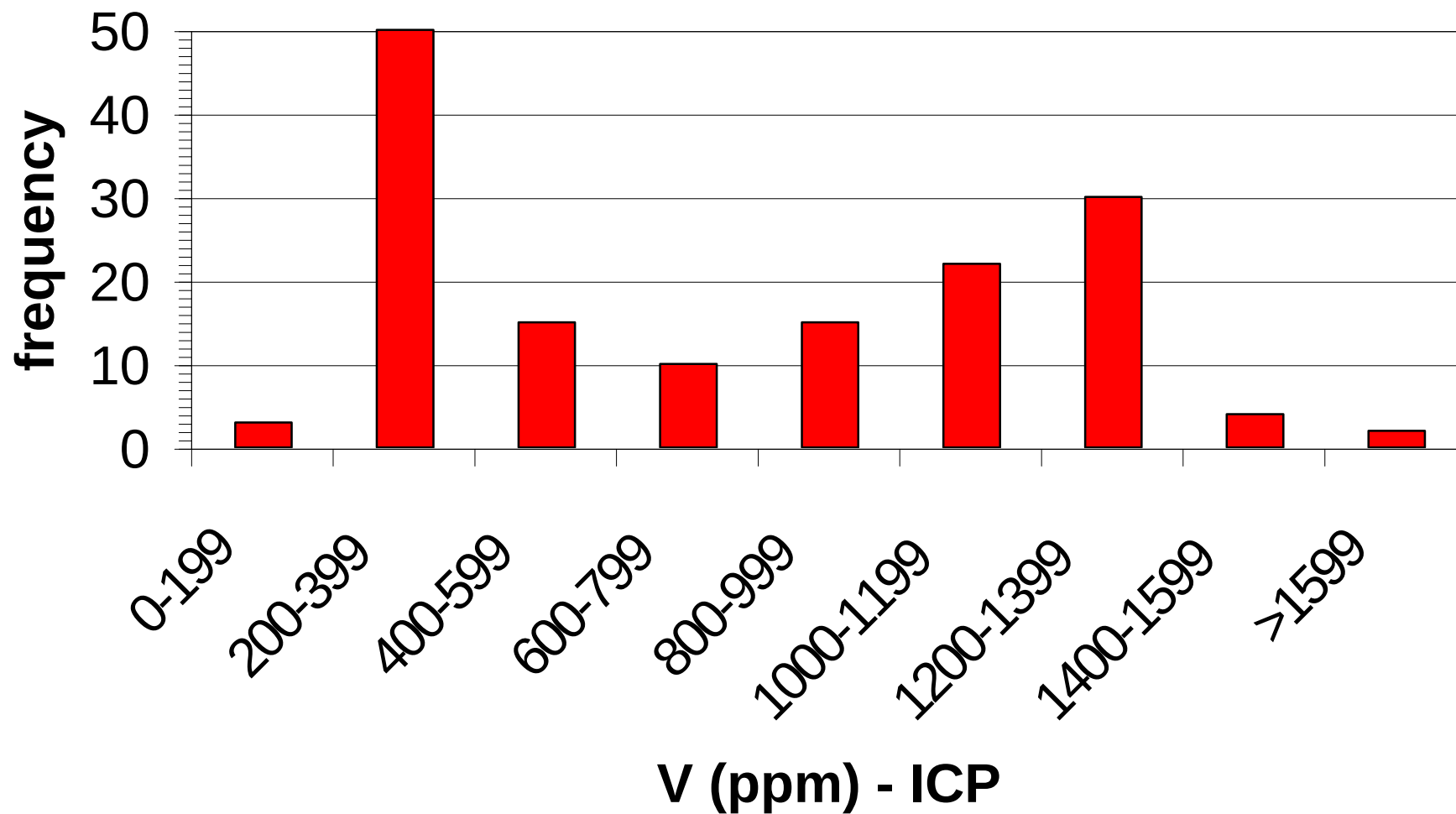
Assay vs. Frequency



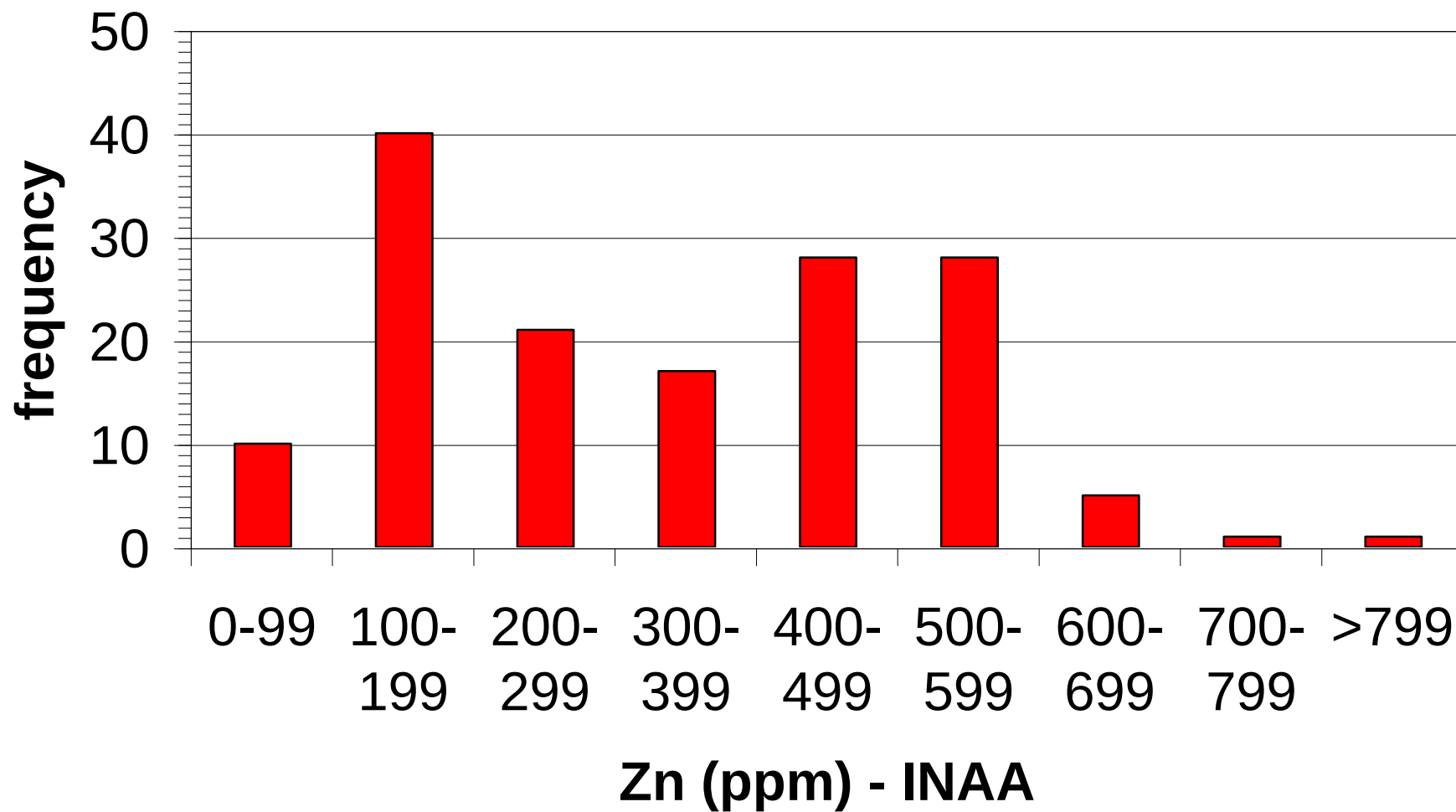
Assay vs. Frequency



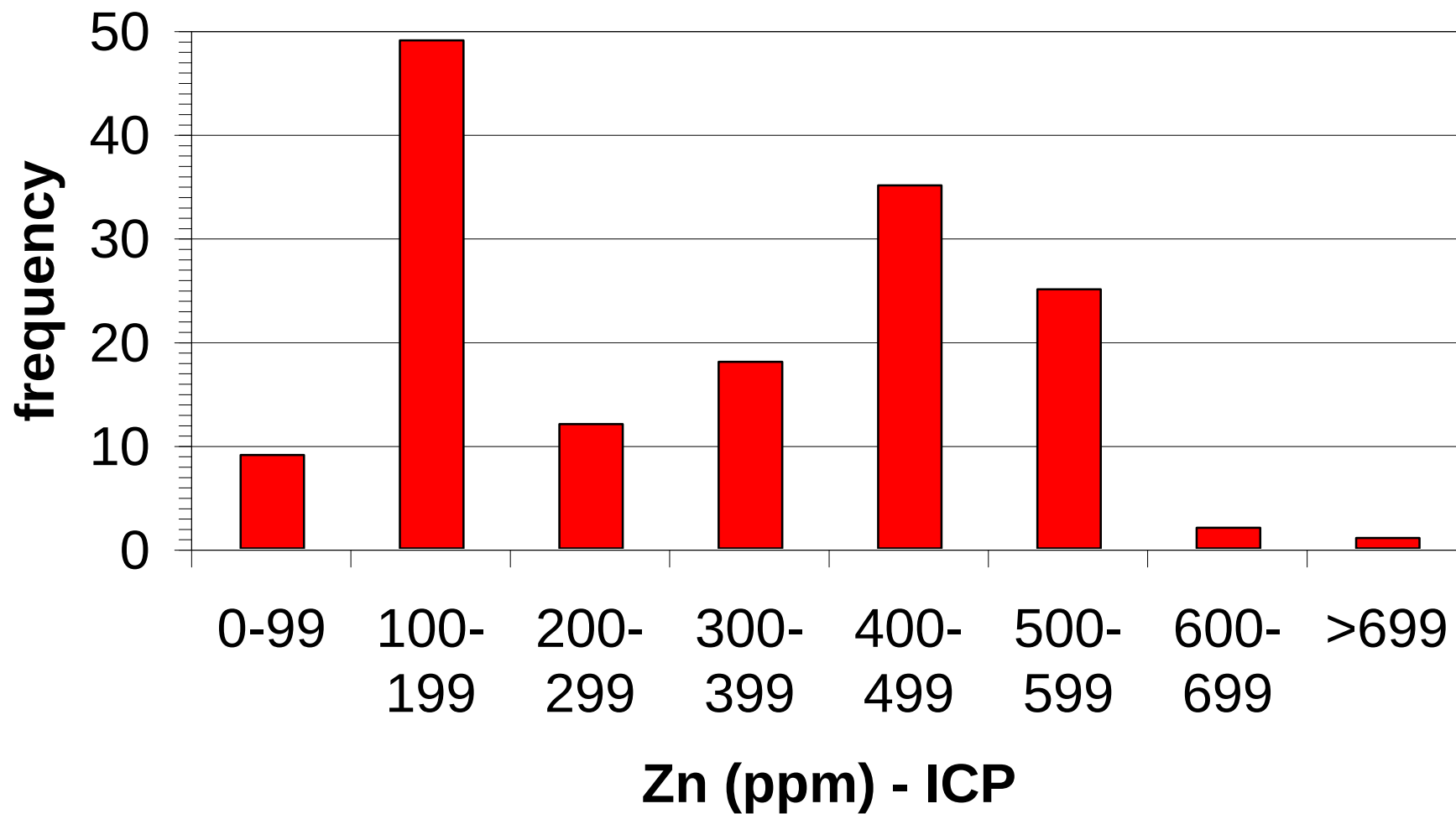
Assay vs. Frequency



Assay vs. Frequency



Assay vs. Frequency

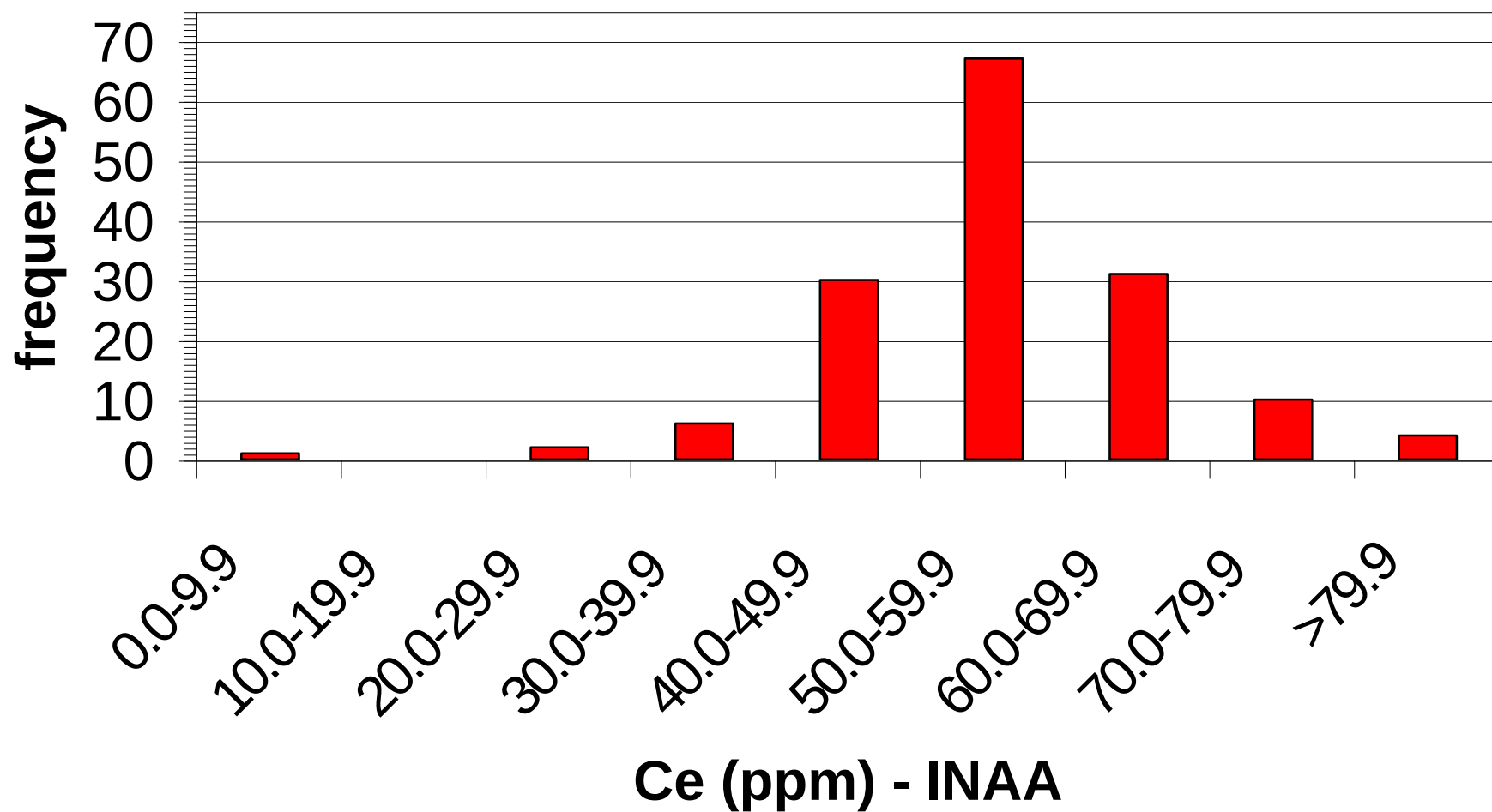


APPENDIX VI.3

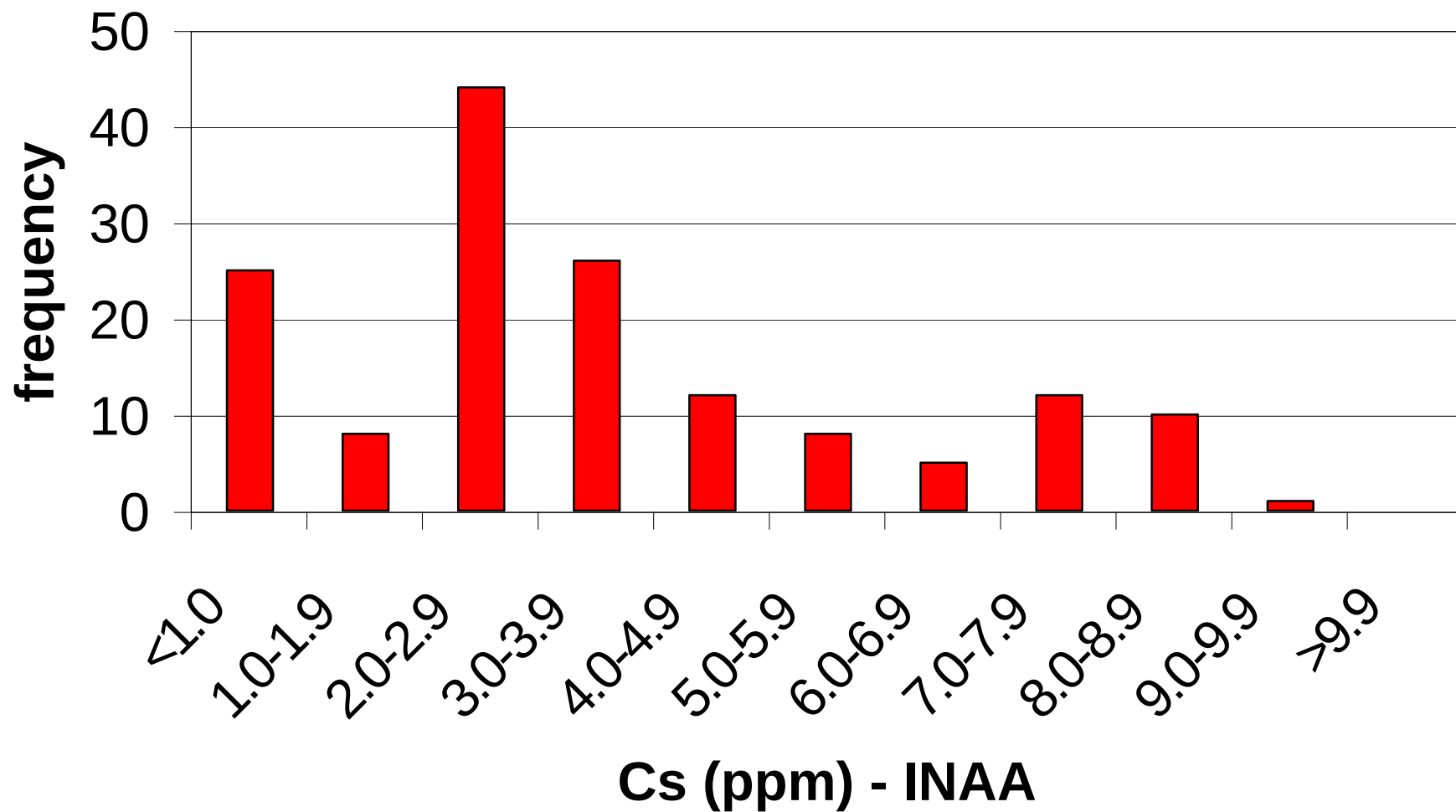
**GEOCHEMICAL DISTRIBUTION HISTOGRAMS FOR SELECTED ELEMENTS,
CLEAR HILLS IRON DEPOSITS STUDY**

Uranium, Thorium, Rare Earths and Related Elements

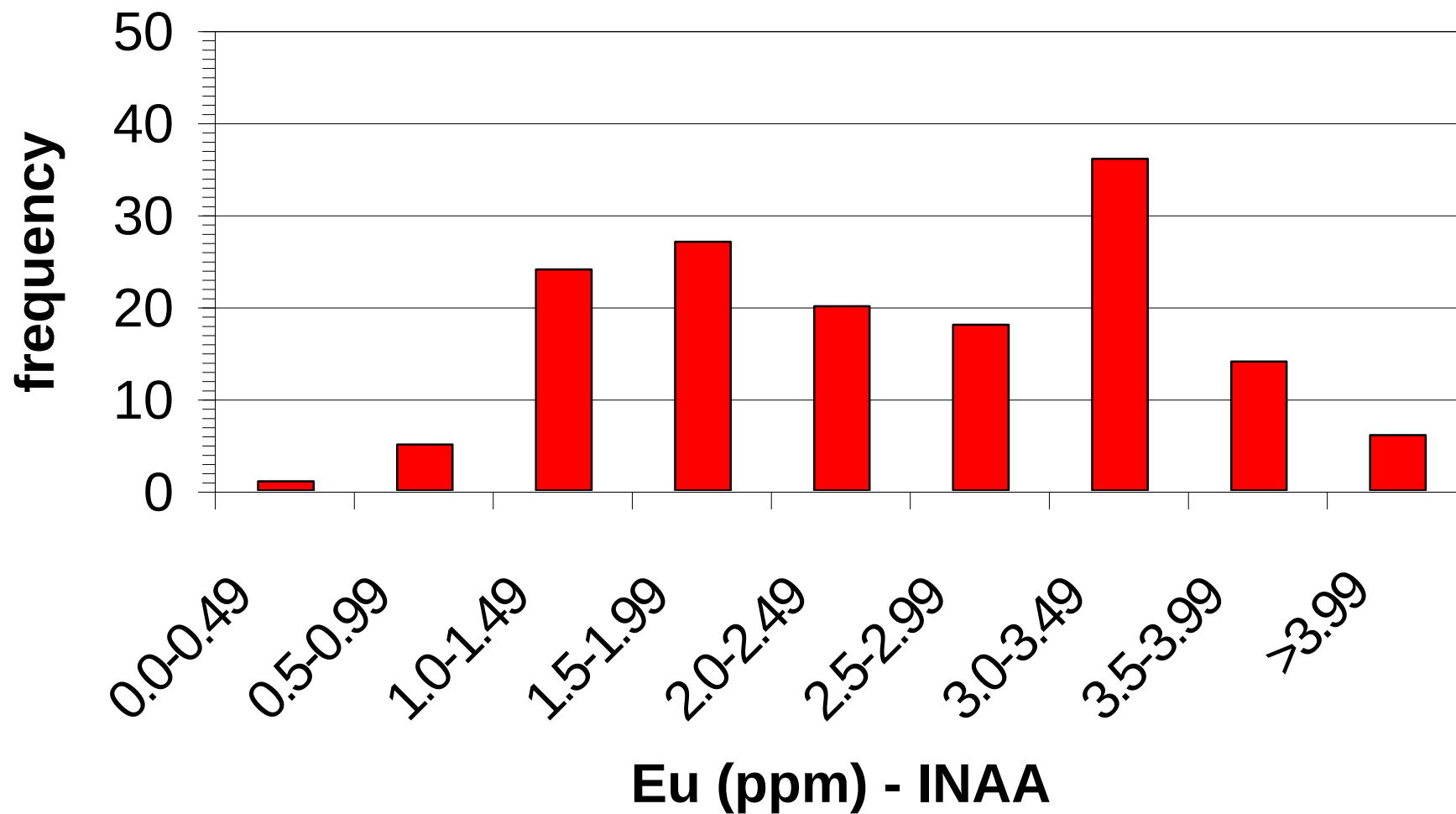
Assay vs. Frequency



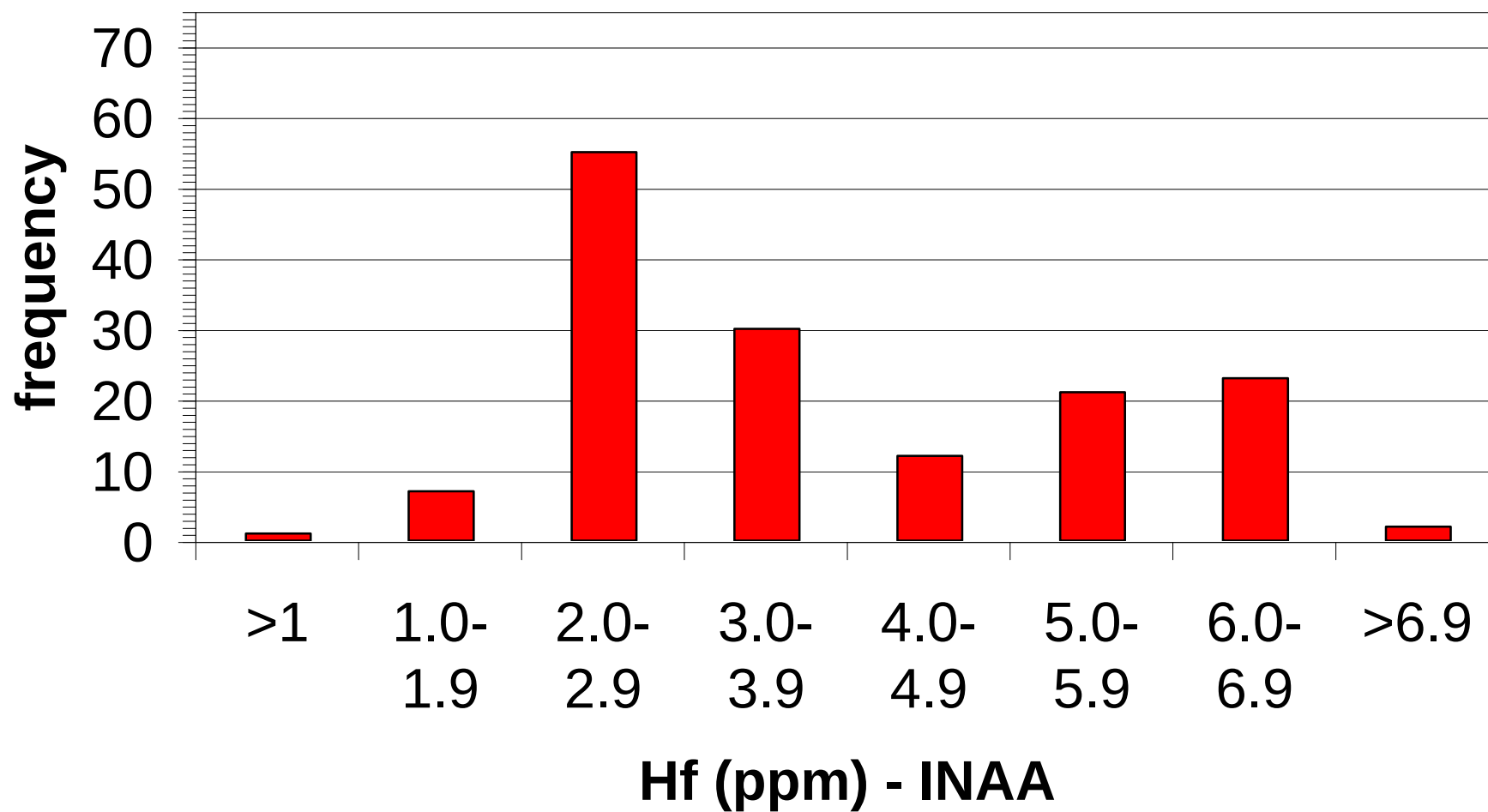
Assay vs. Frequency



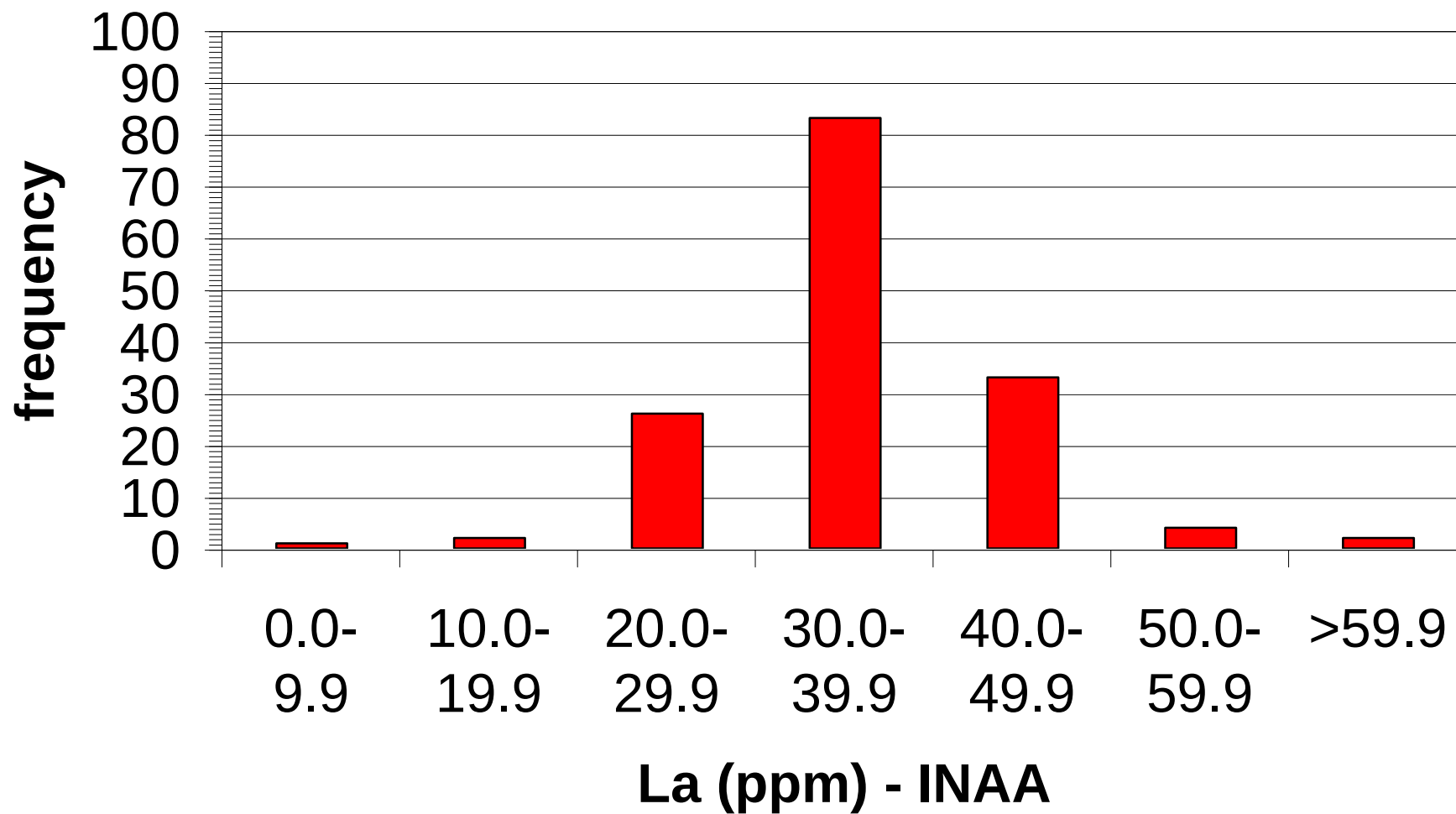
Assay vs. Frequency



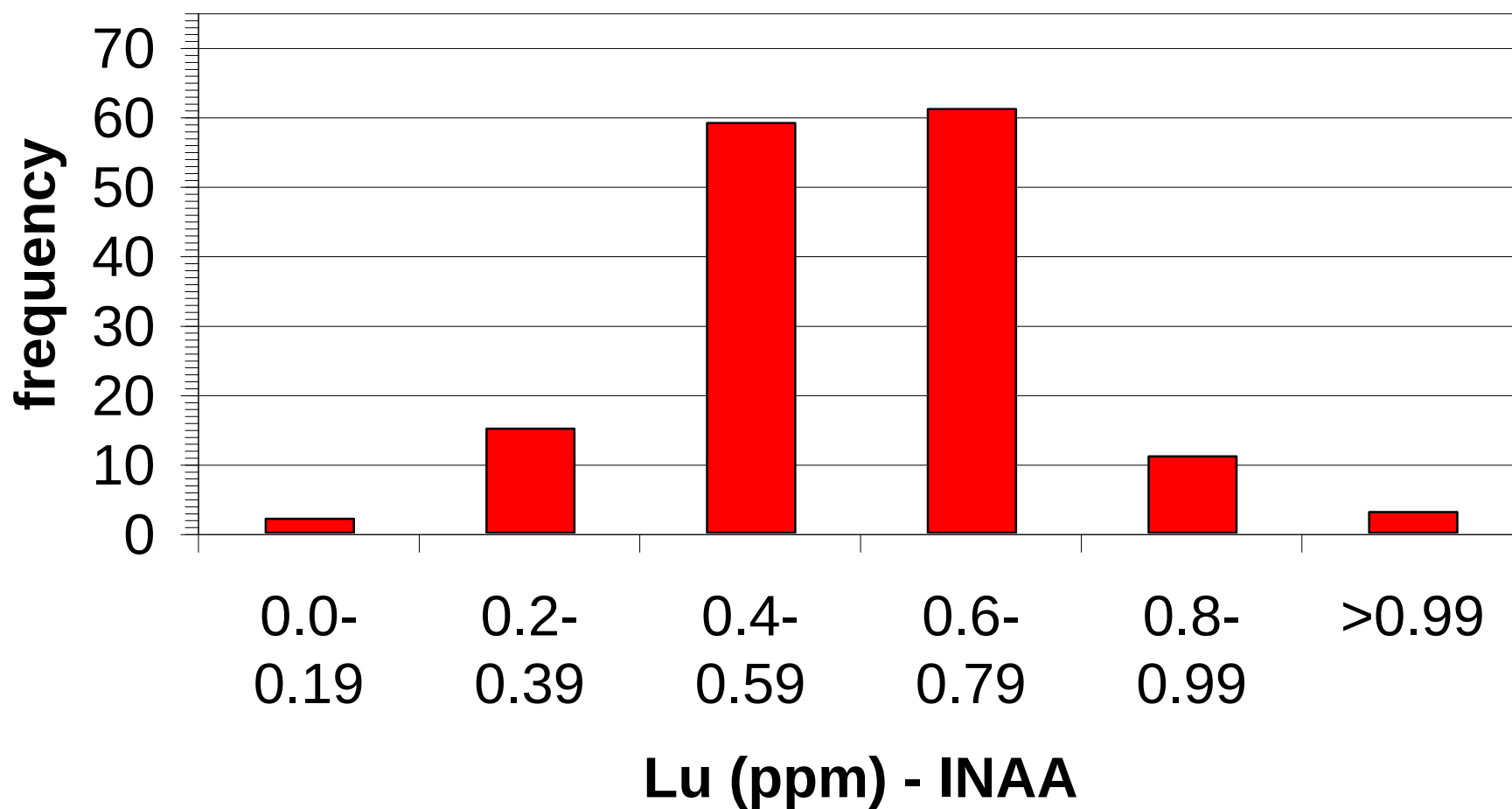
Assay vs. Frequency



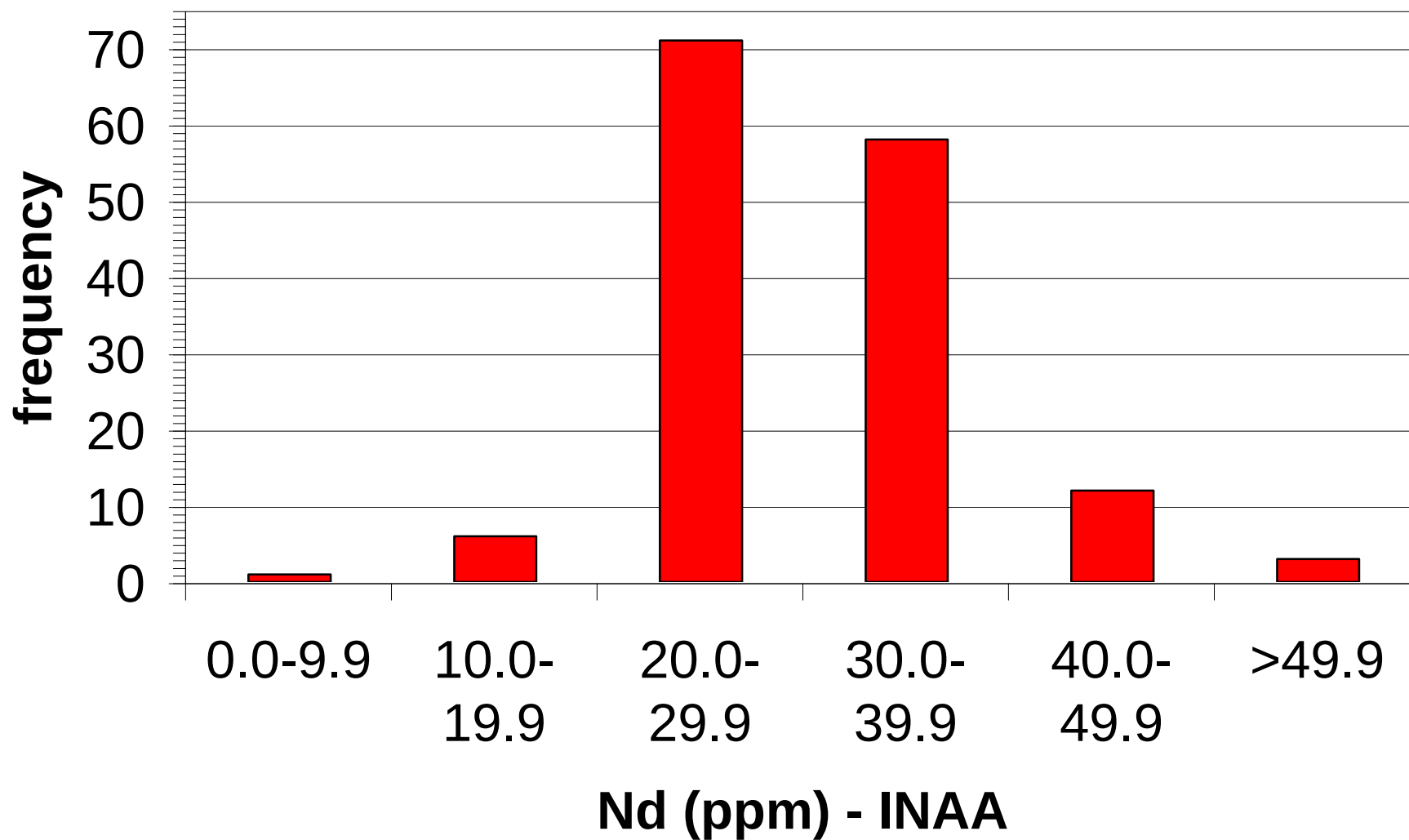
Assay vs. Frequency



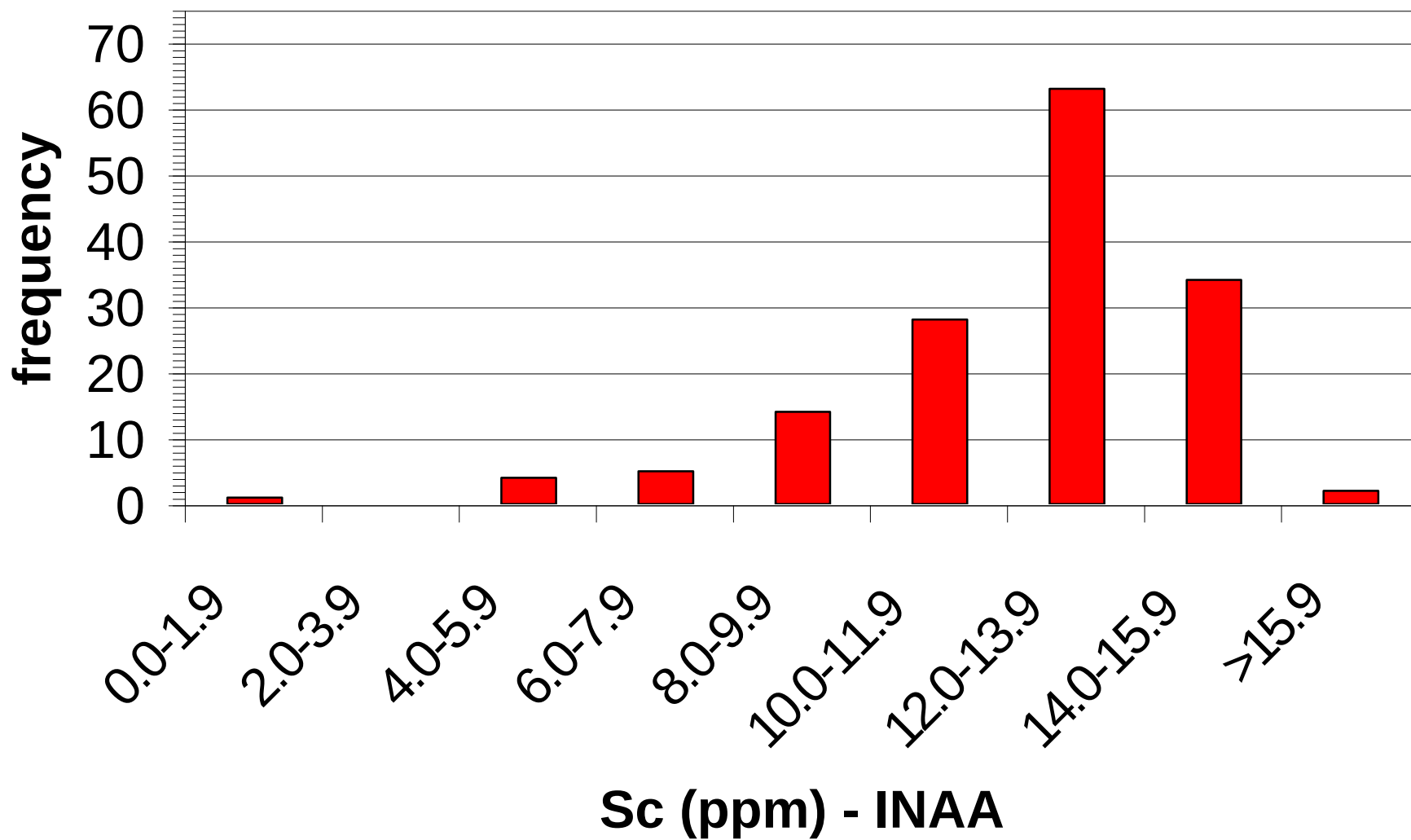
Assay vs. Frequency



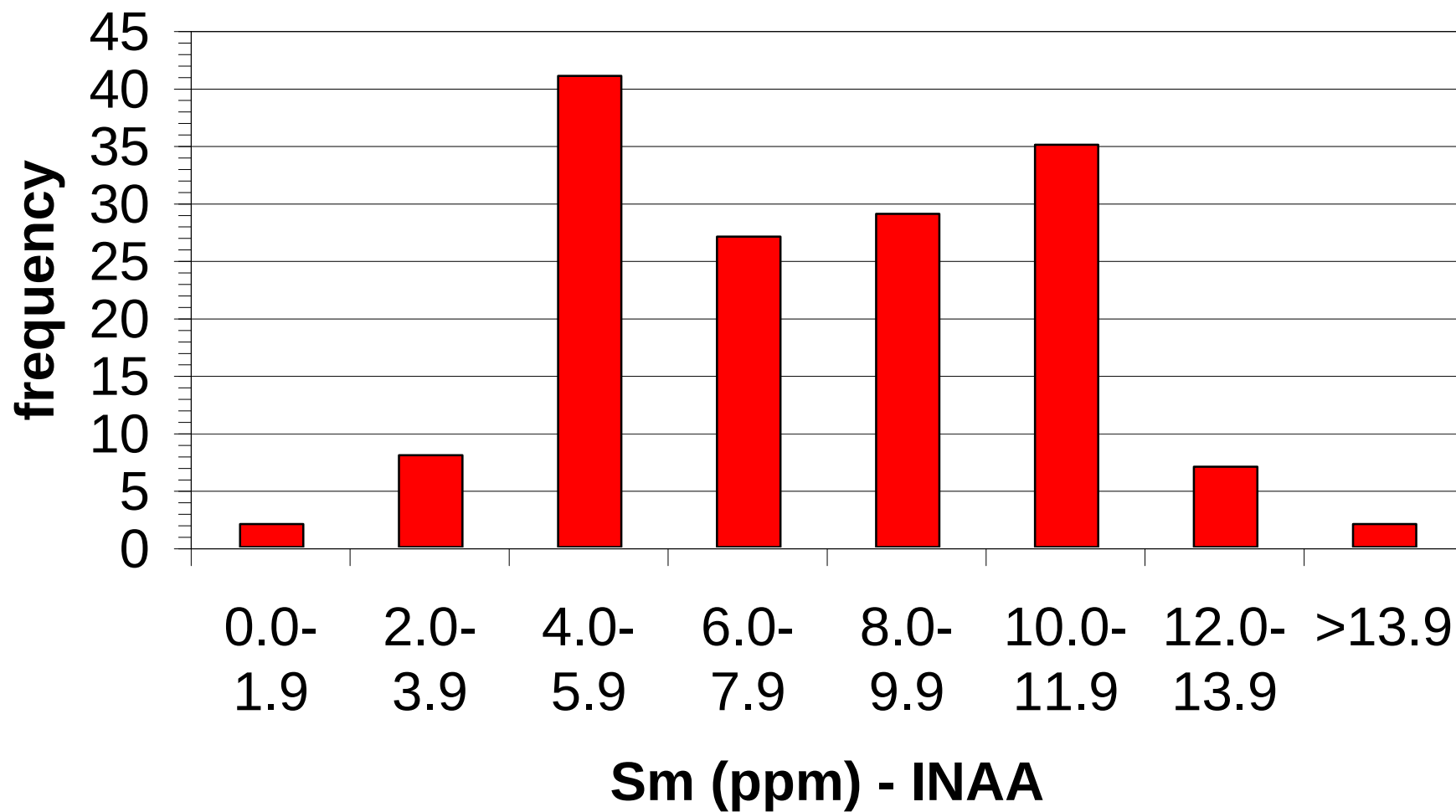
Assay vs. Frequency



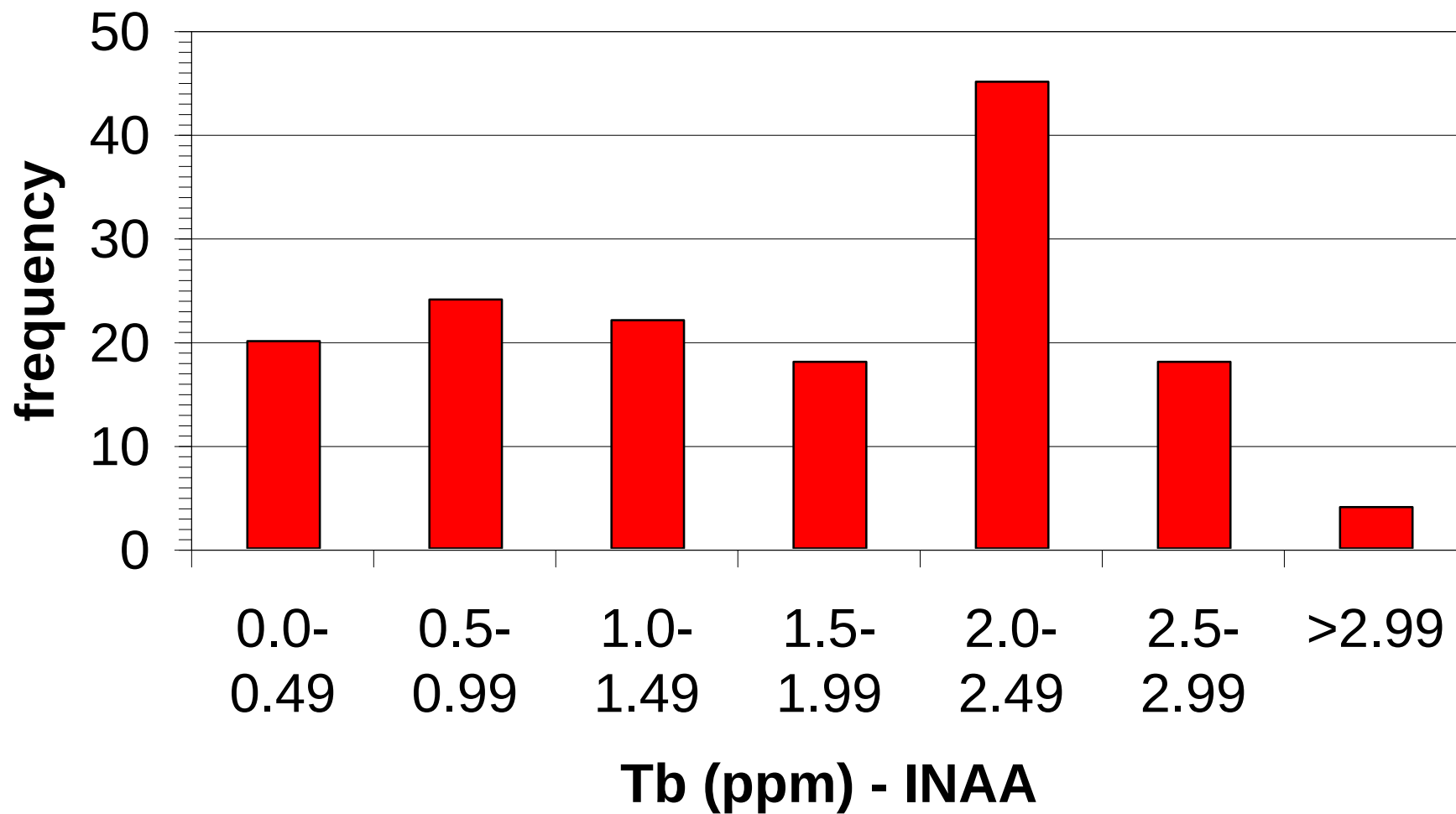
Assay vs. Frequency



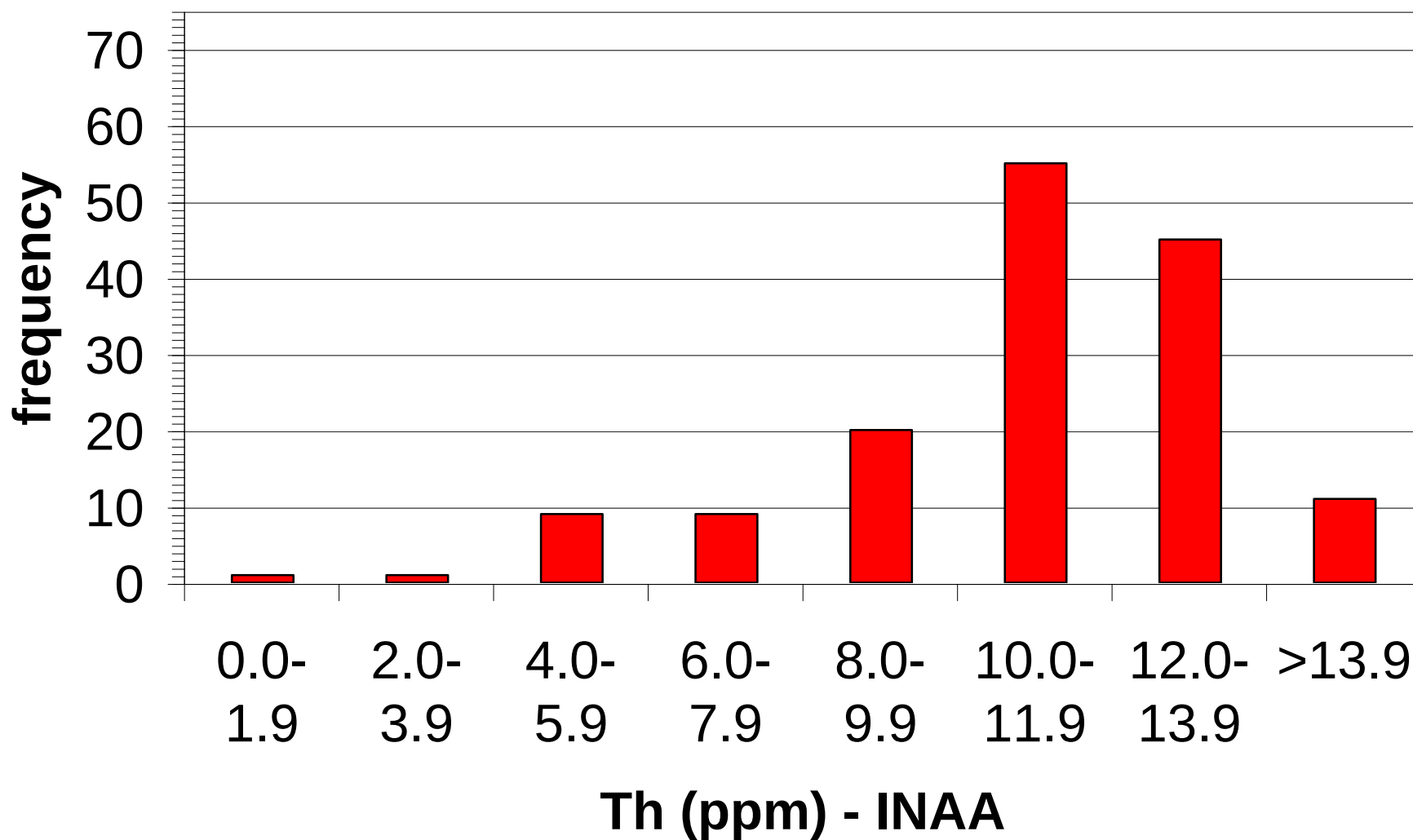
Assay vs. Frequency



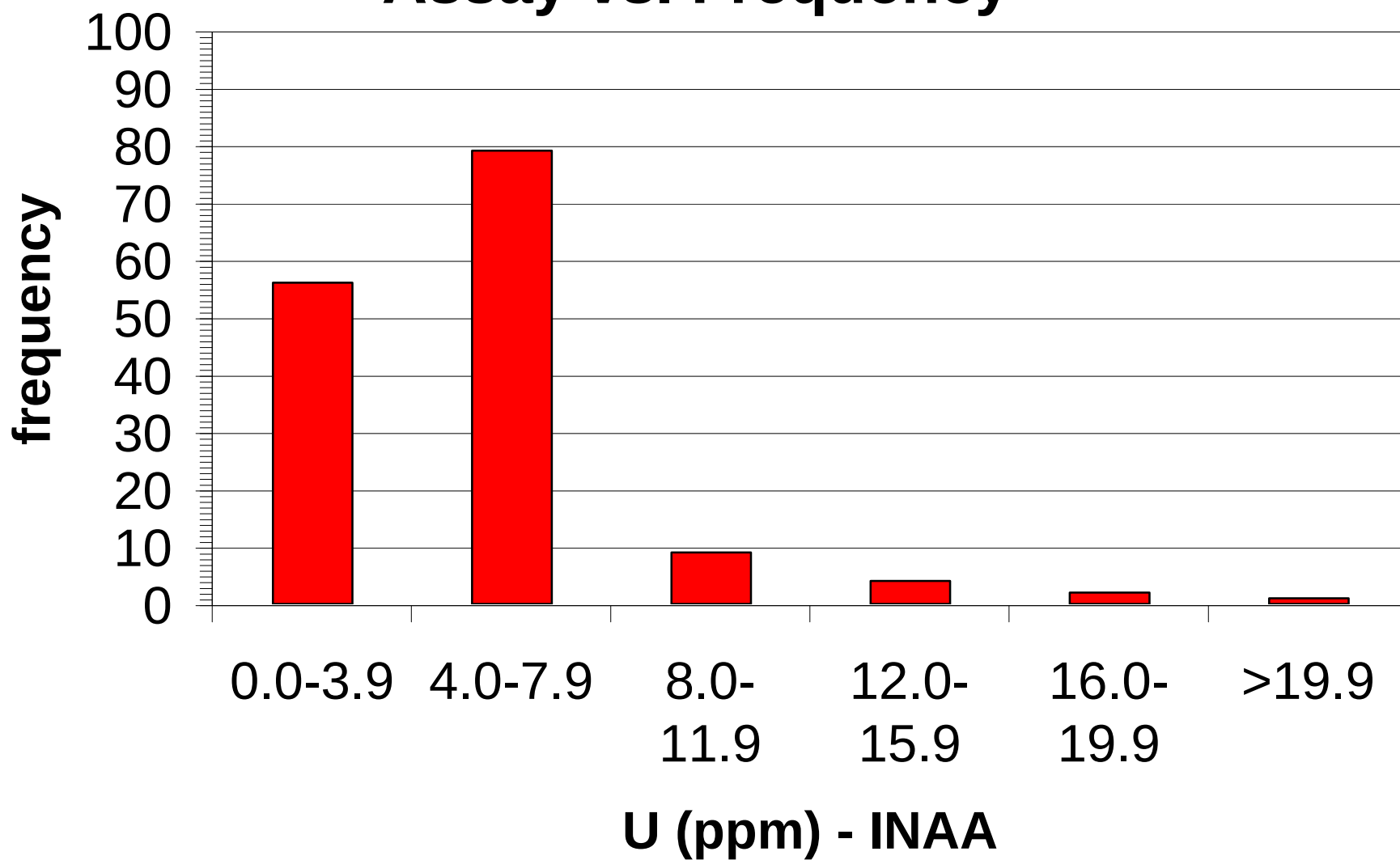
Assay vs. Frequency



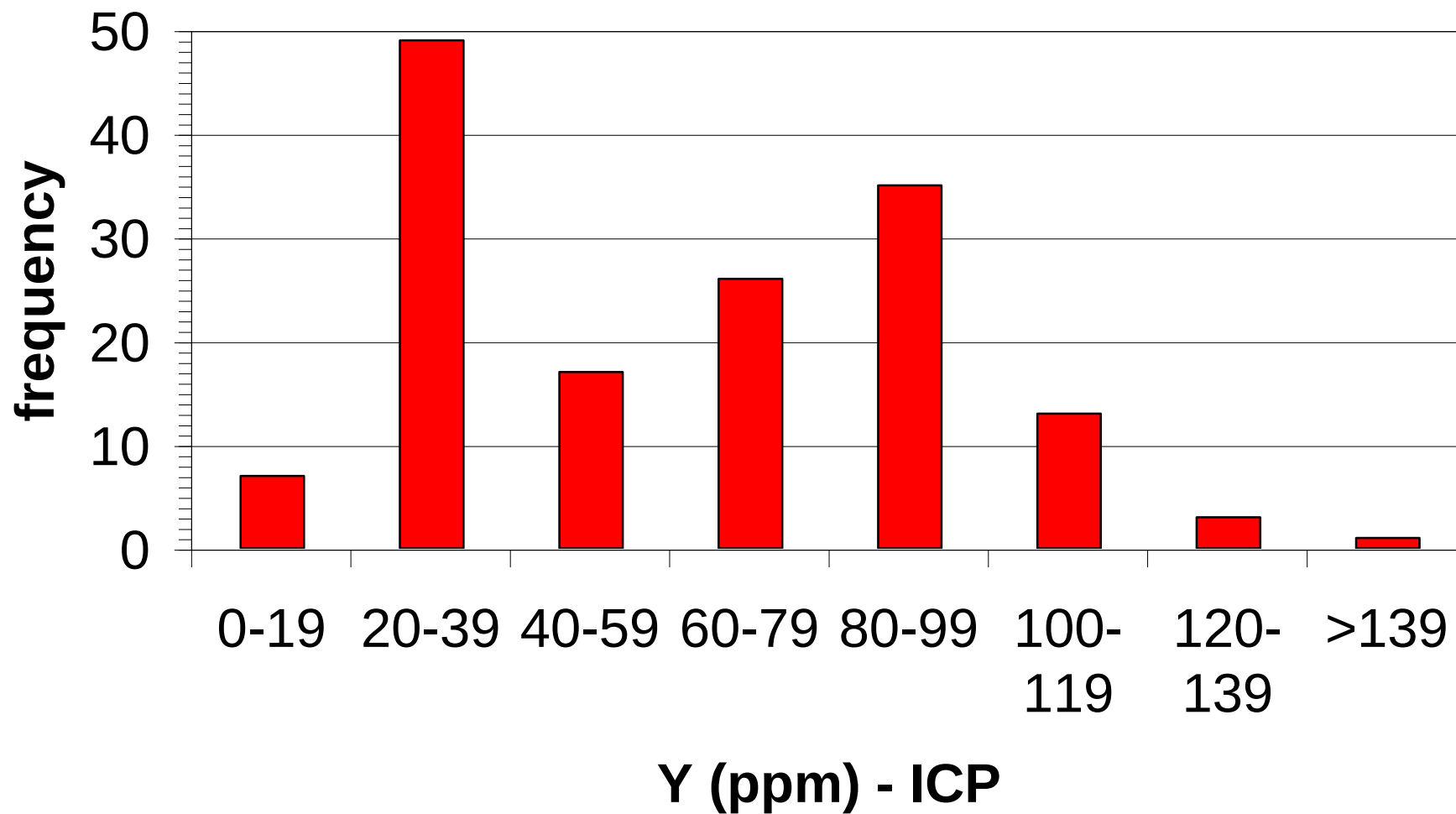
Assay vs. Frequency



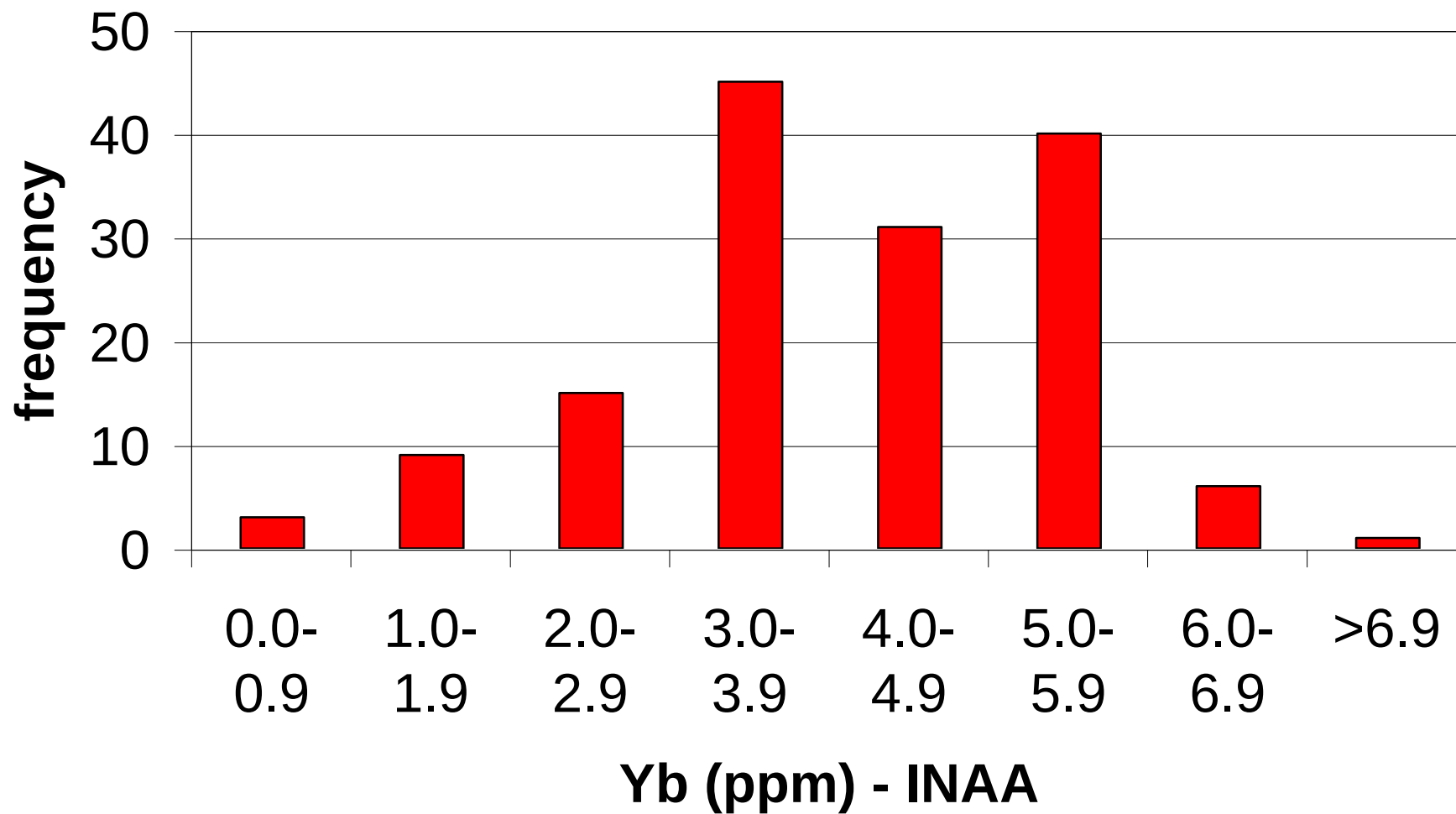
Assay vs. Frequency



Assay vs. Frequency



Assay vs. Frequency

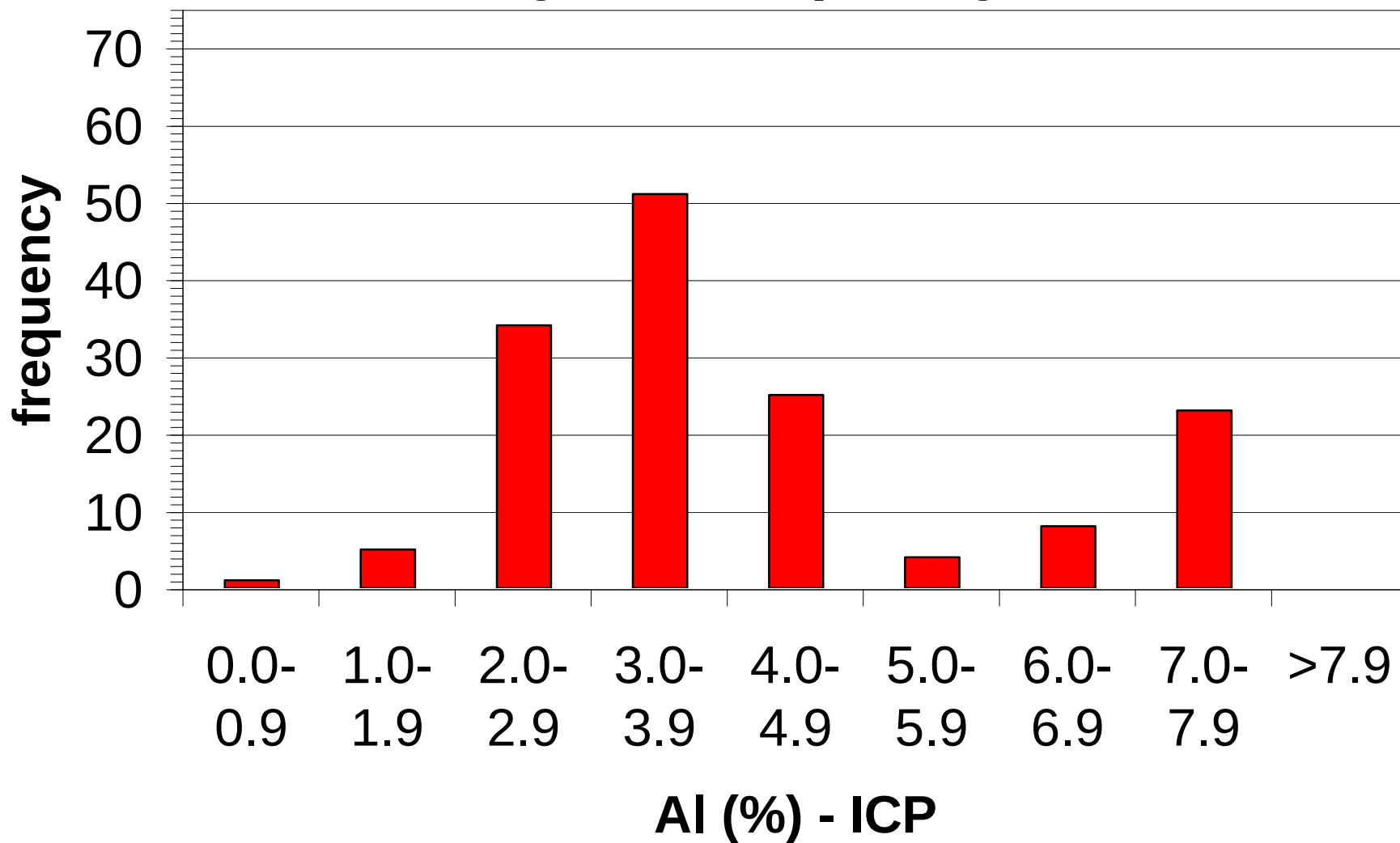


APPENDIX VI.4

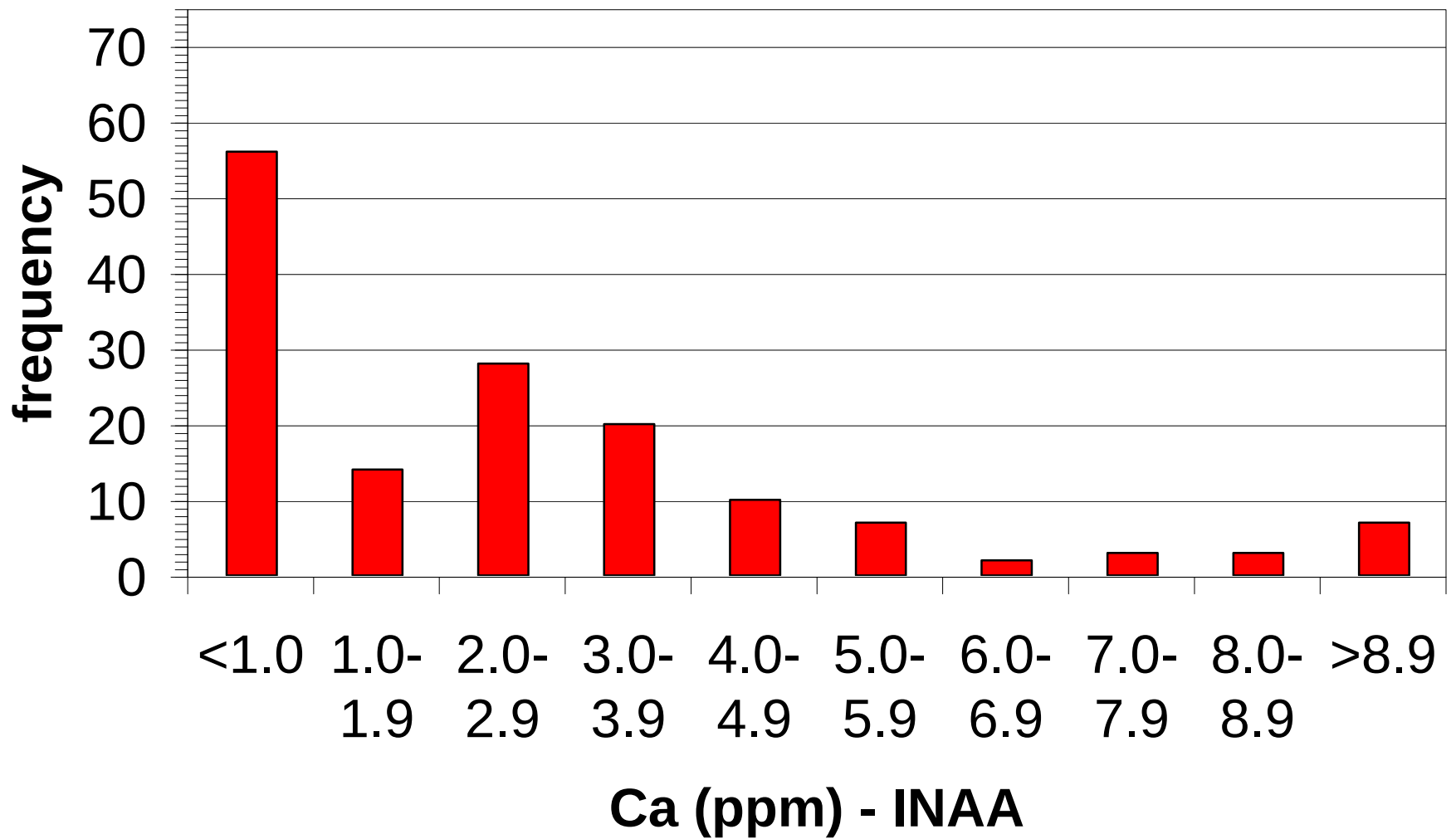
**GEOCHEMICAL DISTRIBUTION HISTOGRAMS FOR SELECTED ELEMENTS,
CLEAR HILLS IRON DEPOSITS STUDY**

Rock Forming and Related Trace Elements

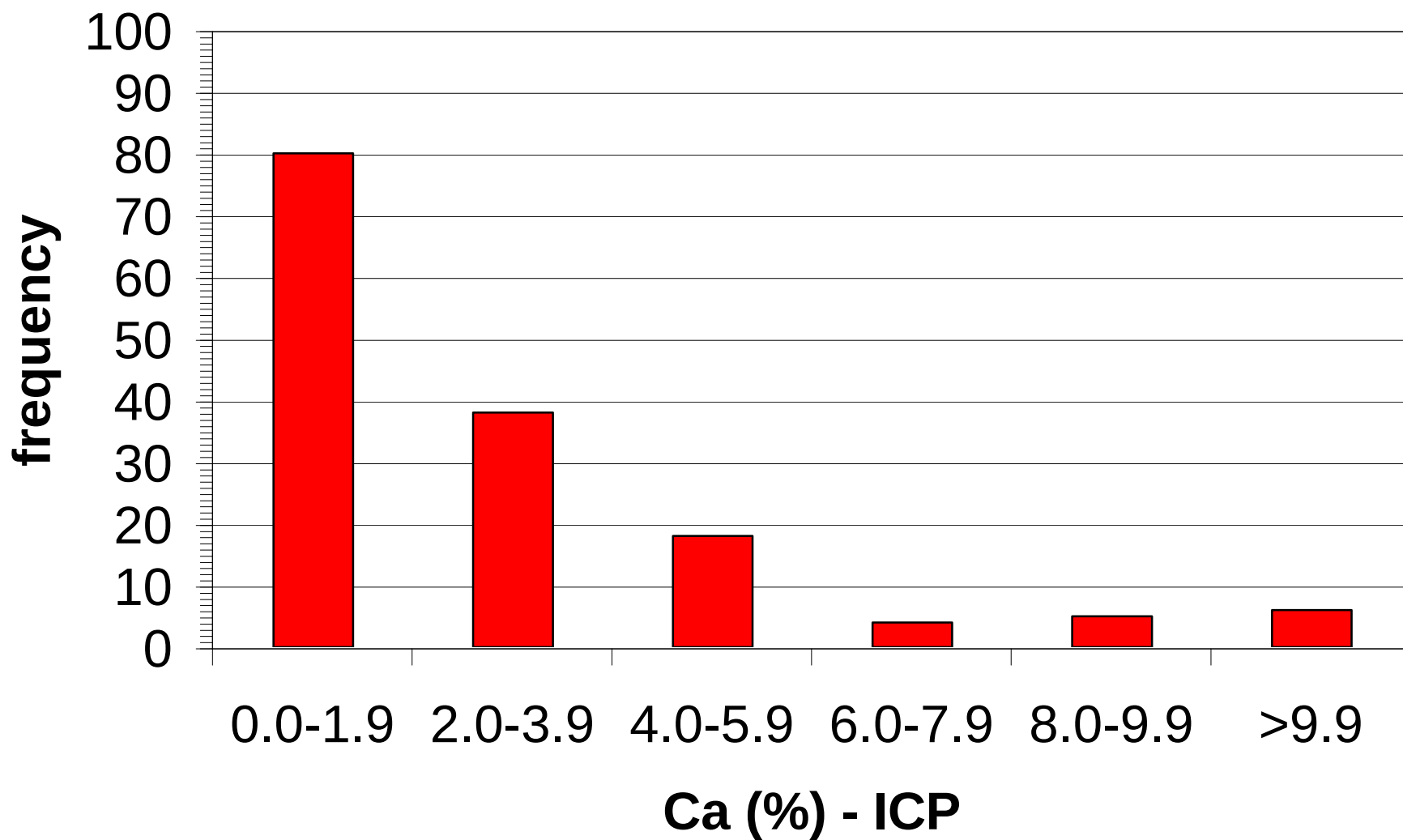
Assay vs. Frequency



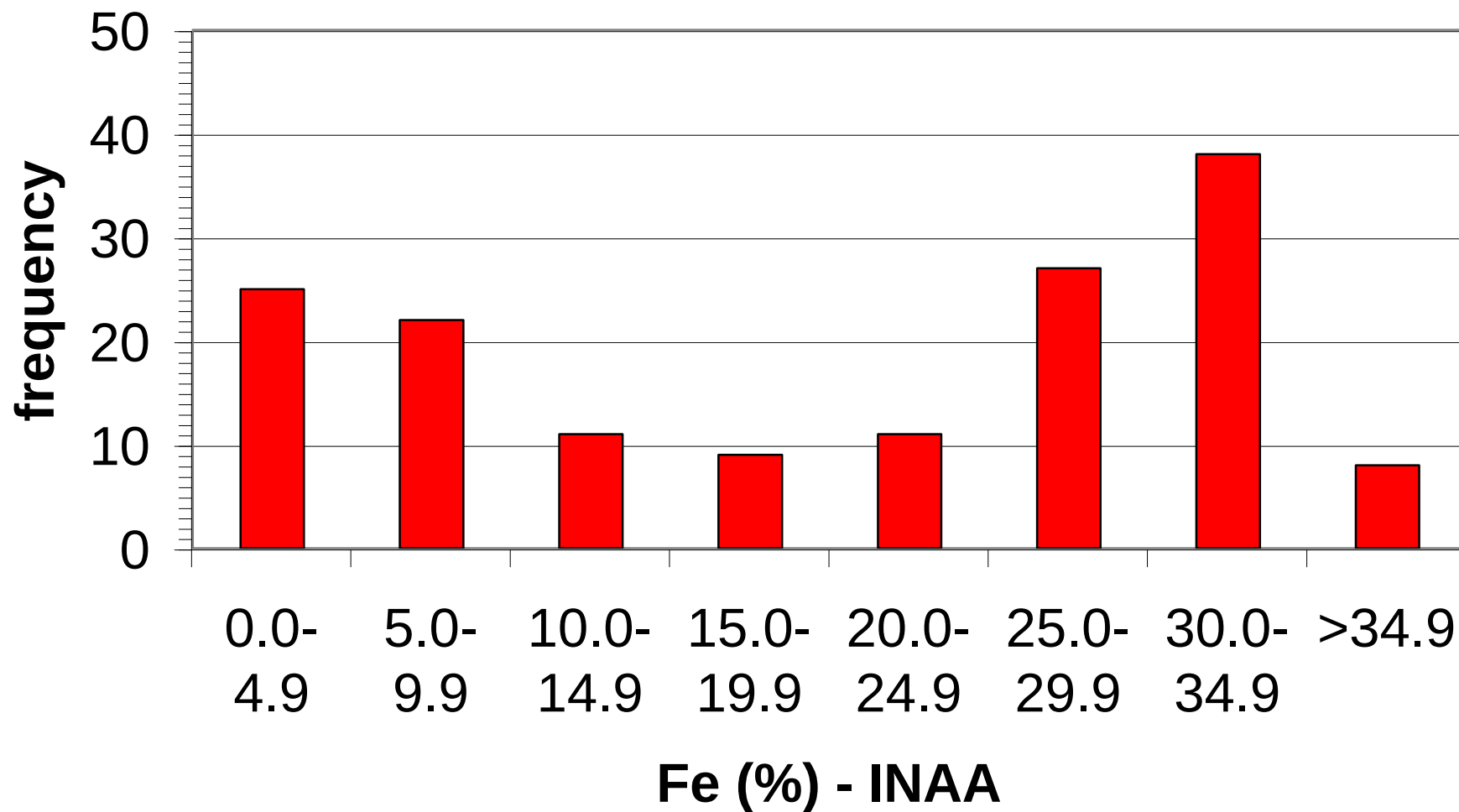
Assay Vs. Frequency



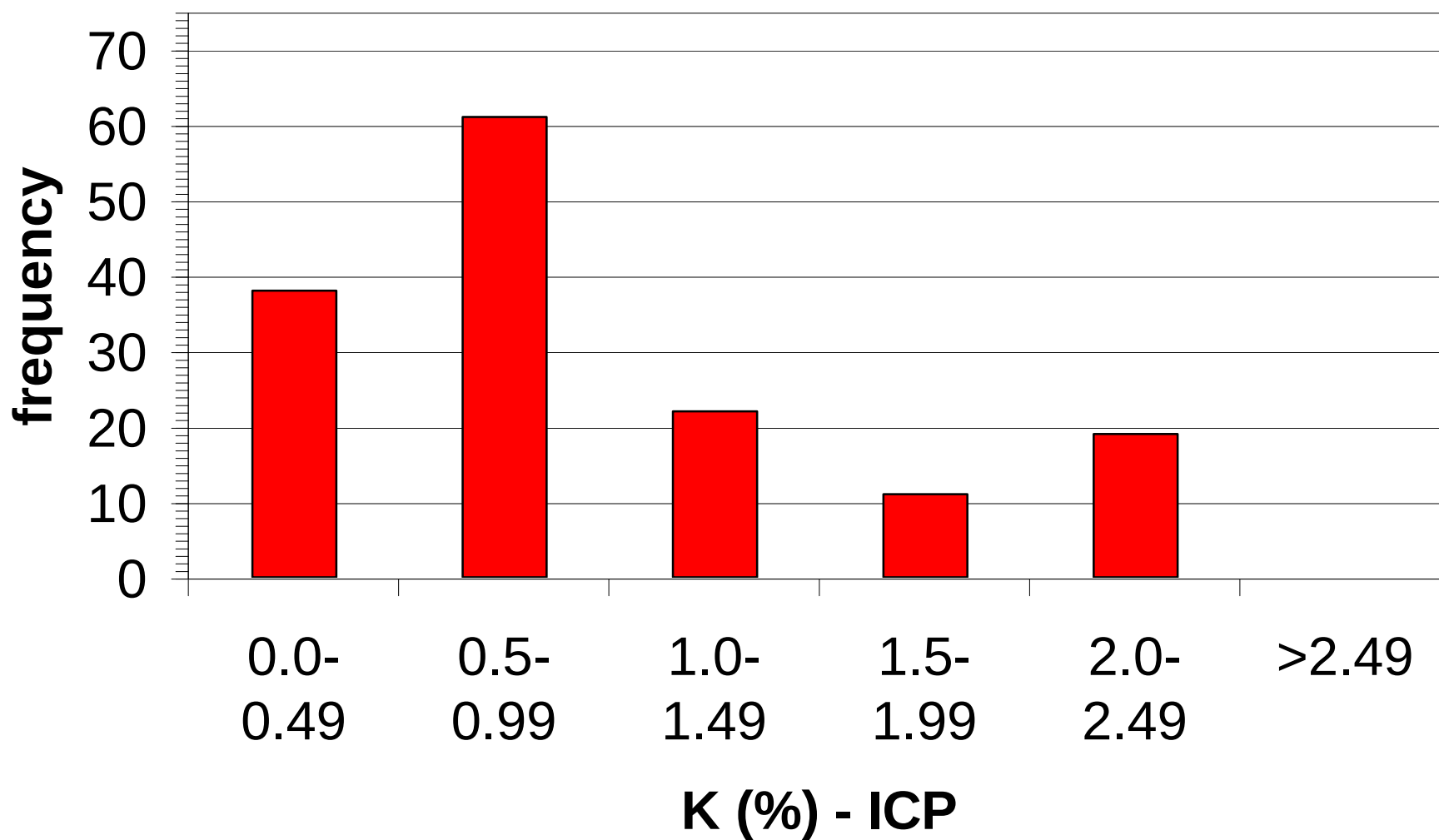
Assay vs. Frequency



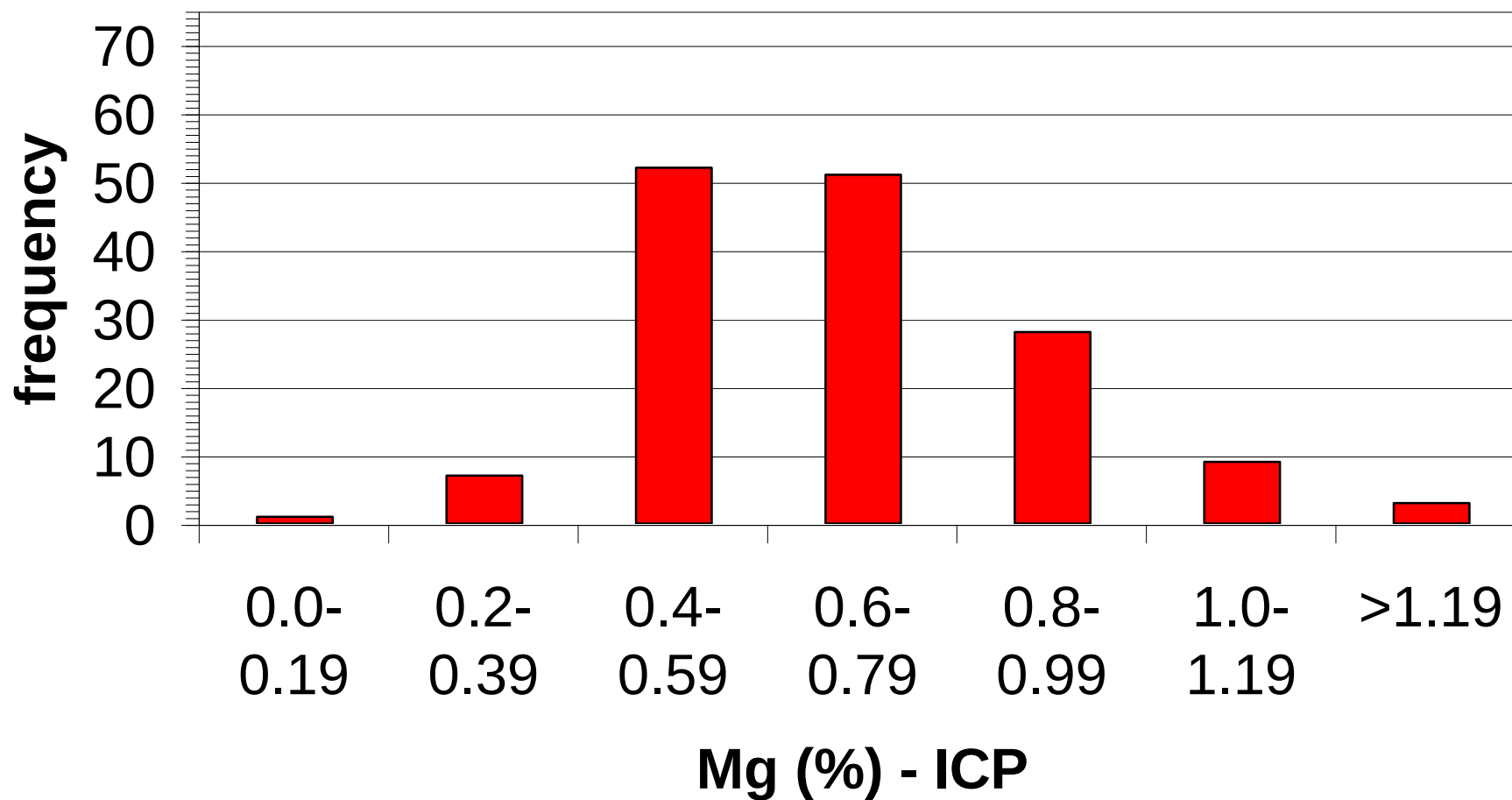
Assay vs. Frequency



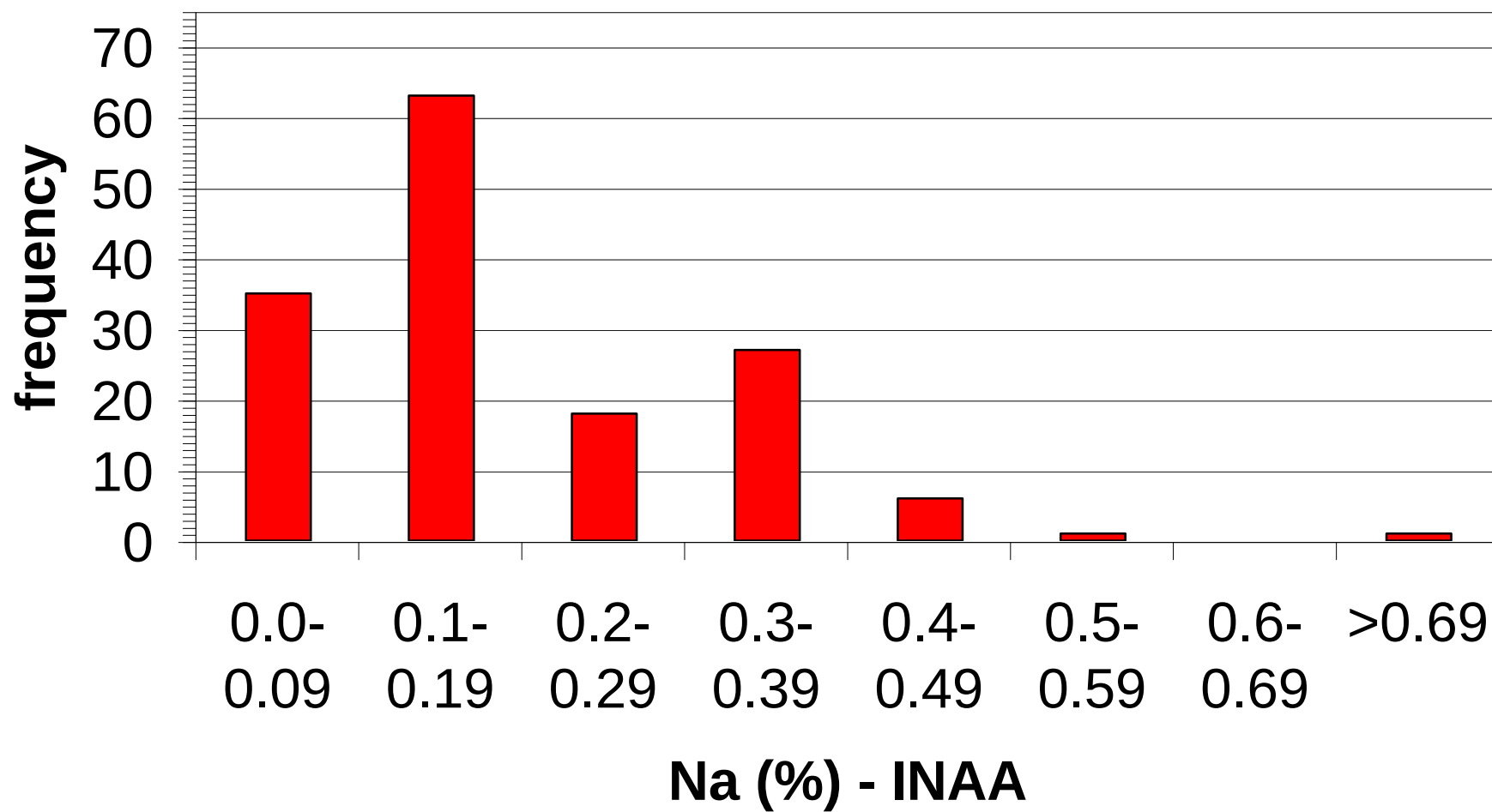
Assay vs. Frequency



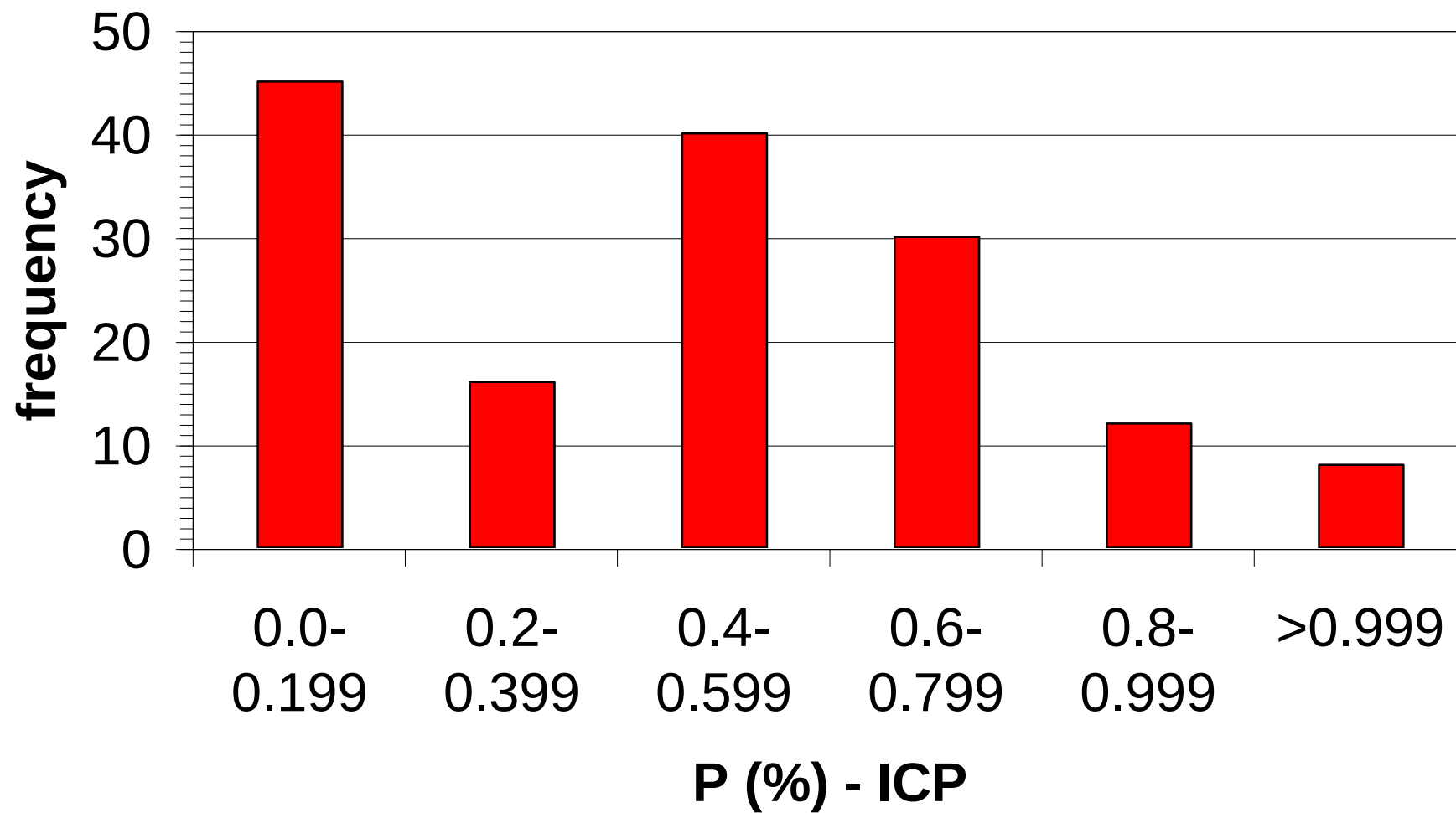
Assay vs. Frequency



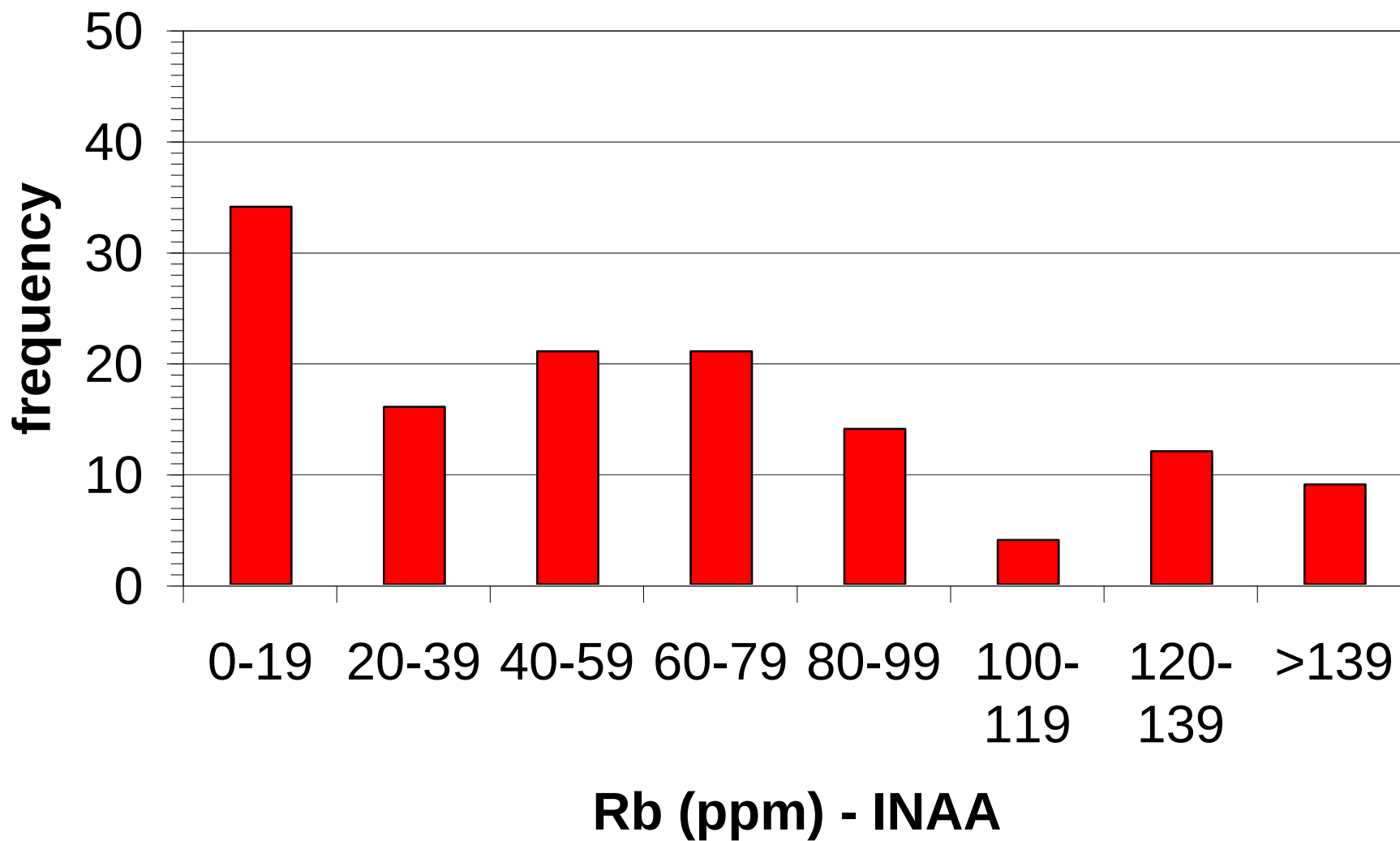
Assay vs. Frequency



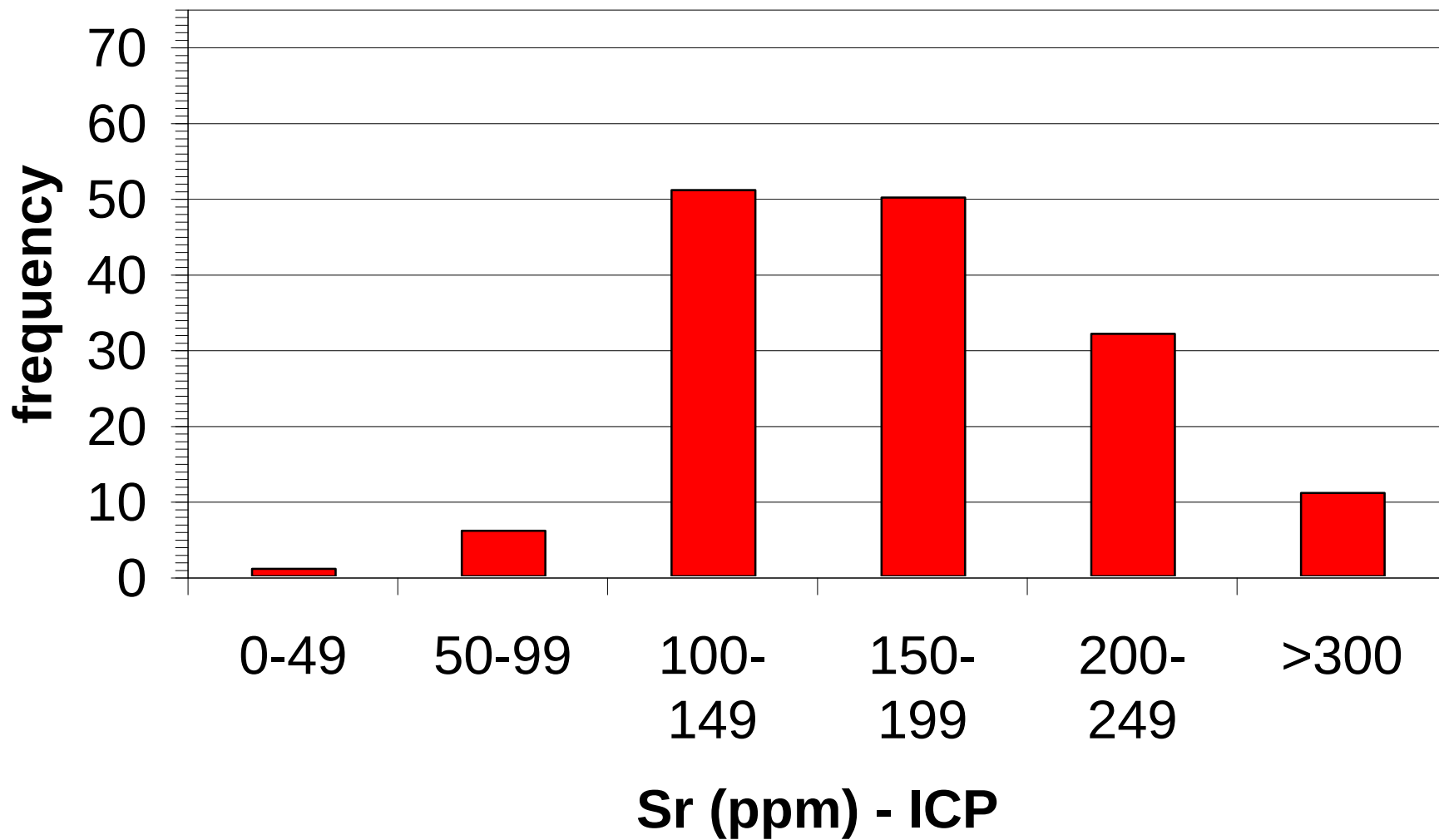
Assay vs. Frequency



Assay vs. Frequency



Assay vs. Frequency



Assay vs. Frequency

