MAR 20020011: BAD HEART SANDSTONE

Received date: Nov 22, 2002

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A REPORT AND BACKGROUND INFORMATION PERTINENT TO THE EXPLORATION AND ANALYSIS OF THE BAD HEART SANDSTONE ON PERMITS 9396110003 AND 9396110004

November 14, 2002

Ronald T. Owens

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November 19, 2002

Ronald T. Owens 202 - 5201 - 52 Avenue Ponoka, AB T4J 1H6 Phone: 403-783-6487 Fax: 403-783-6586

Alberta Energy Mineral Operations Division Mineral Tenure Branch 9th Floor, 9945 - 108 St. Edmonton, AB T5K 2G6

Attention: Hazel Hensen, Agreement Administrator

I hereby submit an Assessment Work Report to cover the required expenditures for the following

lands: All of section 21-6-09-079 All of section 22-6-09-079 All of section 26-6-09-079 All of section 27-6-09-079 All of section 34-6-09-079 All of section 35-6-09-079

A total of 3840 acres or 1554.048 hectares

All of section 2-6-09-080 All of section 3-6-09-080 All of section 7-6-09-080 All of section 8-6-09-080 All of section 9-6-09-080 All of section 10-6-09-080 The South-west quarter of section 11-6-09-080 The South one-half of section 16-6-09-080 The South one-half of section 17-6-09-080 The South one-half of section 18-6-09-080 The South one-half of section 18-6-09-080

The balance of the acreage of these two permits (9396110003 and 9396110004) I wish to drop at this time as they are no longer of interest for this project.

I have concentrated efforts on developing a leaching protocol for iron rich ore and comparing the results with a fusion protocol; however, getting a consistent correlation still requires more time and effort.

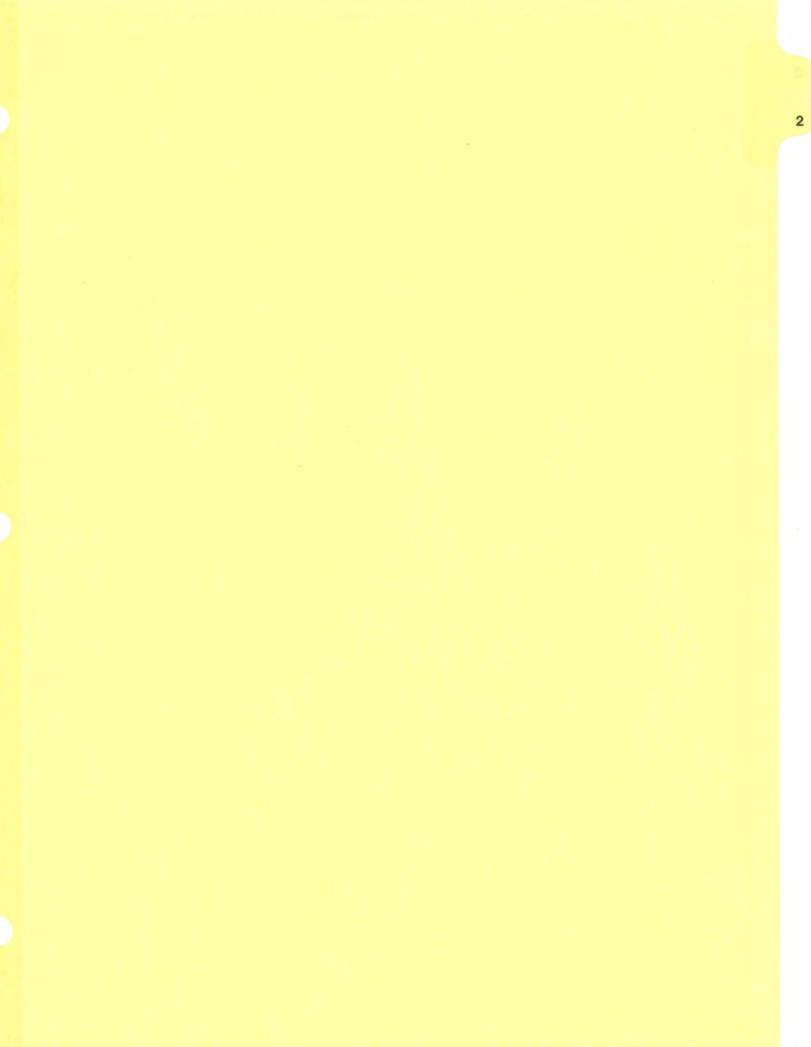
Respectfully yours.

Ronald T. Owens

Authorization to Reproduce or Copy

I hereby give authorization to reproduce or copy this report, after the customary one year delay.

Ronald T. Owens



January 14, 2003

Alberta Energy Mineral Development Division 7th Floor North Petroleum Plaza 9945 - 108 Street Edmonton, AB T5K 2G6

Attention: Susan Carlisle, Director, Mineral Agreements Coal and Mineral Development

Dear Ms. Carlisle:

In response to your letter of December 23, 2002, I will elaborate on the following queries:

- I. Although I believe it necessary to continually up-grade my lab capabilities, I will accept the \$13,500.00 amount that was previously acknowledged by you.
- 2. Although I have found it necessary to travel extensively in acquiring equipment and transporting re-agents as ("hazardous goods regulations" create courier and importation difficulties). Also, the necessity of prompt delivery of leach samples required a great deal of mileage. However, as I realize they are subjective, I will forgo all travel costs.
- 3. The efforts reported here relate to three components of the program of evaluating the Bad Heart Sandstone as a precious metal prospect.

I have worked and spent on this program for over ten years; however, the results obtained were often inconclusive.

For this reason, it appeared necessary to try and identify the causes of the varying results, by a systematic research program of in-house wet chemistry, suggested by an accredited chemist.

Over two hundred separate leach trials were conducted; one hundred and twenty-five are reported here. The balance were either partial or total failures and so are not reported.

Each leach trial required a minimum of six hours, three at a time, dictated by space in the fume cabinet for three stirring hot plates. This, along with the associated preparation of samples (drying, screening and weighing) and the cleaning of necessary glassware, etc. required a minimum total of five hundred hours.

4. The goal of this phase of the program was to try and identify the most suitable pre-treatment and type of leach procedure, for use on a single sample collection of the Bad Heart Sandstone. The reason for this was to eliminate variables that would be introduced, and thus skew the data, if samples taken from multiple locations were used for the initial research.

This standardized procedure would then be used for samples from other sites and depths. This should create an informed decision of the property's potential.

Due to the importance of identifying the procedures required to accurately analyze materials with the characteristics of the Bad Heart Sandstone, the procedures used must remain proprietary, at this time.

3

4. Continued

One other aspect of the program, included in the report, is the field trip of late April, 2001. At this time an experienced geologist and myself, contracted Blackhawk Excavating of Spirit River to re-excavate a test pit at Site one - LSD -06-section 26-06-09-79. The pit was sampled at one foot intervals, to the depth of twelve feet. These samples were then dried, pulverized, screened, split and logged.

A split of each sample was forwarded to Auric Metallurgical Laboratories of Salt Lake City, for fire assay with nickle sulphide collection.

This work required approximately one hundred hours, the results of which are included in the body of the report.

Would you please insert the revised "Statement of Expenditures" and "Allocation of Expenditure" and remove the initial submission in the existing copies of the report.

I am including a list setting forth expenses, as well as a list of consulting and custom services utilized, for which receipts can be provided if required.

Also included is a description of work done and conclusions arrived at for inclusion in the Body of the Report.

Respectfully yours,



Ronald T. Owens

N.B. Correct address is: Suite 202, 5201 - 52 Ave. Ponoka, AB T4J 1H6;

(not suite 201)

Expendables for which receipts can be provided if required

<u>2001</u>

Jan	Bedrock Supplies	\$	211.86
Feb	Bedrock Supplies	Ŷ	92.57
Feb	Bedrock Supplies		67.23
Feb	Bedrock Supplies		462.45
May	Bedrock Supplies		516.21
June	Bedrock Supplies		40.93
Aug	Bedrock Supplies		91.53
Aug	Bedrock Supplies		70.51
Jan	Petrocraft		103.42
May	Petrocraft		16.45
Jan	Franklin Supply		10.48
Mar	Petrocraft		67.41
Feb	Action Mining Supplies		8.51
Feb	Action Mining Supplies		209.01
Mar	Action Mining Supplies		132.82
Mar	Action Mining Supplies		160.67
Jun	Action Mining Supplies		175.32
Jul	Action Mining Supplies		207.44
Feb	High Valley Chemicals		22.86
Feb	High Valley Chemicals		201.28
Feb	Vopak Chemicals		84.26
May	Vopak Chemicals		41.71
May	Mid North Safety Supply		38.95
May	Sample bags		8.63
Jun	Loomis (sample transport)		28.50
Jun	Alfa Aesar		162.77
Jun	Sample bags		16.41
Jun	U.P.S. (transport of re-agents)		40.11
Aug	U.P.S. ""		48.11
Aug	Greyhound ""		7.72
Aug	Fisher Scientific		97.18
2001	De-ionized water		85.00
2001	Heat and electricity for lab		1,224.00
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Total

\$ 4,776.91

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Feb	Loring Laboratories		96.	
Aug	Auric Laboratories		2208.0)4
May	Genalysis		144.0	00
Feb	Alpha Laboratories		218.2	21
Mar	Maxam Analytical		149.3	30
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Dec	Maxam Analytical		149.3	80
Dec	Maxam Analytical		342.4	-
2000				
Apr	Philip Analytical Services		347.1	75
Apr	Philip Analytical Services		160.:	50
2001				
Dec	Philip Analytical Services		615.2	25
Nov	Philip Analytical Services		\$ 612.2	25

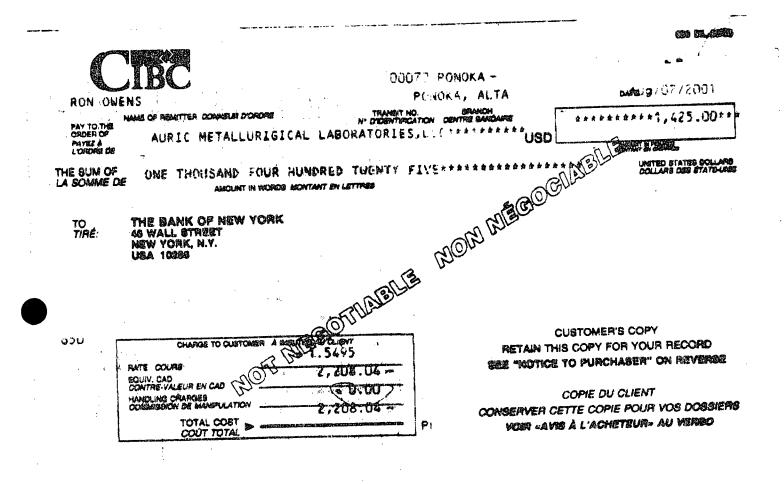
Consulting and Custom Services utilized

2000

Consulting and Custom Services utilized

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Statement of Expenditures

Metallic and Industrial Minerals Permit Nos 9396110003 and 9396110004

Description	Total Cost
Fifty percent of capital investment carried forward from previous period	\$ 13,500.00
Lab materials and reagents	3,733.68
Consulting and Custom Services	6,583.58
Equipment maintenance	
Time spent on project	
	\$ 37,407.95

I certify that these expenditures are valid and were incurred in conducting assessment work on the above permits.

Signed



Ronald T. Owens

KAREN R. DAY aren

For Oaths

Signature/Stamp: Commissioner Exp. 23.07.05

Allocation of Expenditures

Permit No.	Ha.	Expenditure Required	Expenditure Assigned
9396110003	1554.048	\$ 15,540.048	\$ 16,331.18
9396110004	2007.312	20,073.12	21,076.77
Total	3561.36	\$ 35,613.60	\$ 37,394.27

Introduction : Program for the Evaluation of the Bad Heart Sandstone

In November of 2000 it was concluded that much of the prior work and expense related to evaluating this property as a precious metal prospect, was not accomplishing that goal.

An in-house wet-chemistry analysis procedure was begun, under the instruction of an accredited chemist.

The focus of this program was twofold:

- 1. To identify the most suitable pre-treatment and leach procedure for use on sample material containing anomalous iron, nickel, manganese and other potentially interfering elements.
- 2. To evaluate I.C.P. mass spec. as an accurate, economical way of analyzing the pregnant leach samples produced.

Work Performed:

Over two hundred leach trials were conducted; the first several groups were either partial or total failures, and so are not reported.

The protocol followed was "Standard Addition" utilizing a pulp from Nevada, of proven consistency of AU values as the spike.

This spike was used in all samples submitted for instrumental analysis, to which various ratios of Bad Heart Sandstone pulp was added.

In the interest of reducing as many variables as possible, the Bad Heart Sandstone pulp used was a thoroughly mixed sample from between two feet and four feet of an earlier backhoe pit at Site one LSD -06-section 26-06-09-79 (see air photo map)

After a standardized procedure is established, it would then be rigidly applied to samples from other locations and depths of this property.

On April 26, 2002, a second test pit was excavated at Site one - LSD 06-section 26-06-09-79.

Approximately ten pounds of material was collected at one foot intervals, to a depth of twelve feet. As in the previous pit, a two foot horizon of cemented material was encountered at six feet of depth.

Several hundred pounds of this material was retrieved and transported for future analysis. Each one foot horizon was air-dried, pulverized, split, screened and logged. One thousand gram, representative splits of each aforementioned one foot horizon were forwarded to Auric Metallurgical Laboratories, Salt Lake City, Utah. There a fire assay-nickle sulphide collection was conducted. The results are shown in section seven of this report.

1 of 2

1.1

Conclusions:

- 1. Iron interference was a major hurdle in direct I.C.P. analysis of the leaches that were tested.
- 2. Weak acid washes (pre-leach) reduced the problems experienced, somewhat.
- 3. Multi-step wet chemistry is required to obtain repeatable, quantitative results by anyone not having a broad experience in fusion chemistry.
- 4. It is essential that instrumental analysis be done promptly and consistently (within one hundred hours, or the pregnant leaches that were used started to degrade. (partially precipitate).

Summary:

Progress has been made, and more comprehensive in-house work is to be done in the future. This will involve solvent extraction and gravimetric determination, so that all facets of the analysis can be observed. This should help identify sooner, any deviations from the norm.



AMENDED APPENDIX

TO

METALLIC AND INDUSTRIAL MINERALS PERMIT NC. 9396110003

COMMENCEMENT OF TERM:

1996 NOVEMBER 5

DATE OF AMENDMENT:

1998 NOVEMBER 2

AGGREGATE AREA:

4 608 HECTARES

DESCRIPTION OF LOCATION AND PERMITTED SUBSTANCES:

6-09-079: 19-36

METALLIC AND INDUSTRIAL MINERALS

SPECIAL PROVISIONS:

NIL STER OF ENERGY FOR:

AMENDED APPENDIX

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METALLIC AND INDUSTRIAL MINERALS PERMIT NO. 9396110004

COMMENCEMENT OF TERM:

1996 NOVEMBER 5

DATE OF AMENDMENT:

1998 NOVEMBER 2

AGGREGATE AREA:

4 608 HECTARES

DESCRIPTION OF LOCATION AND PERMITTED SUBSTANCES:

6-09-080: 1-18

METALLIC AND INDUSTRIAL MINERALS

SPECIAL PROVISIONS:

NIL STER OF ENERGY FOR:

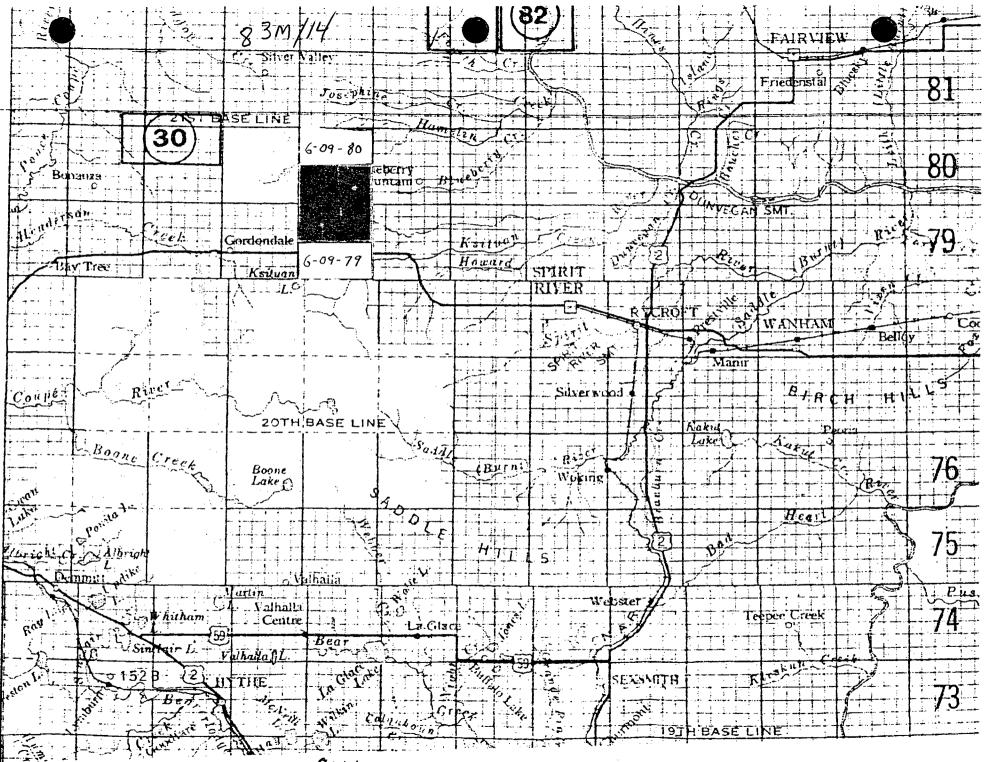
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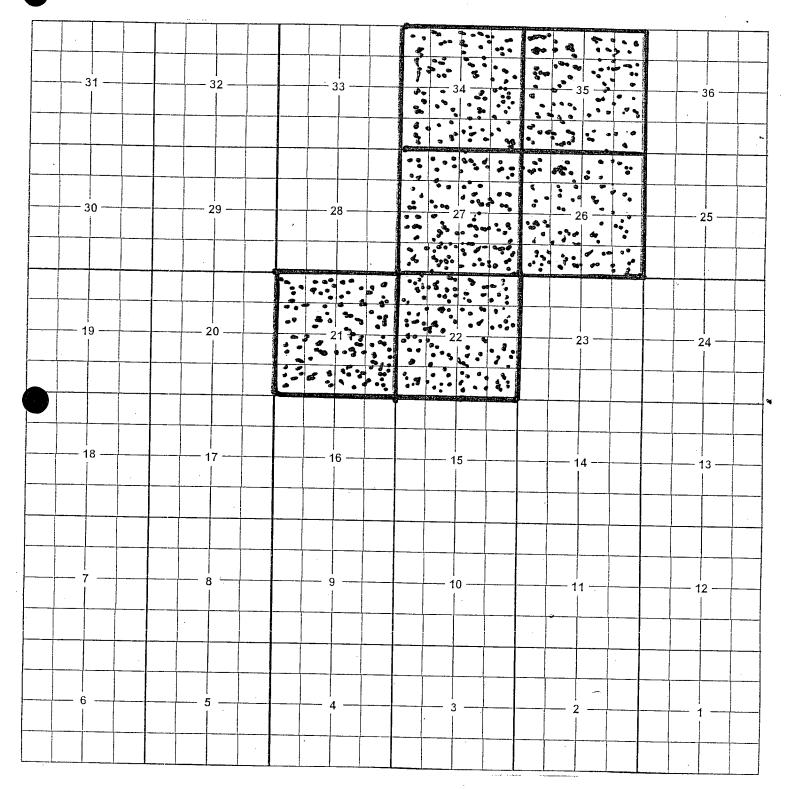


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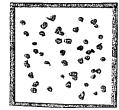
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METALLIC MINERALS PERMIT NO. 9396110003

6-09-079

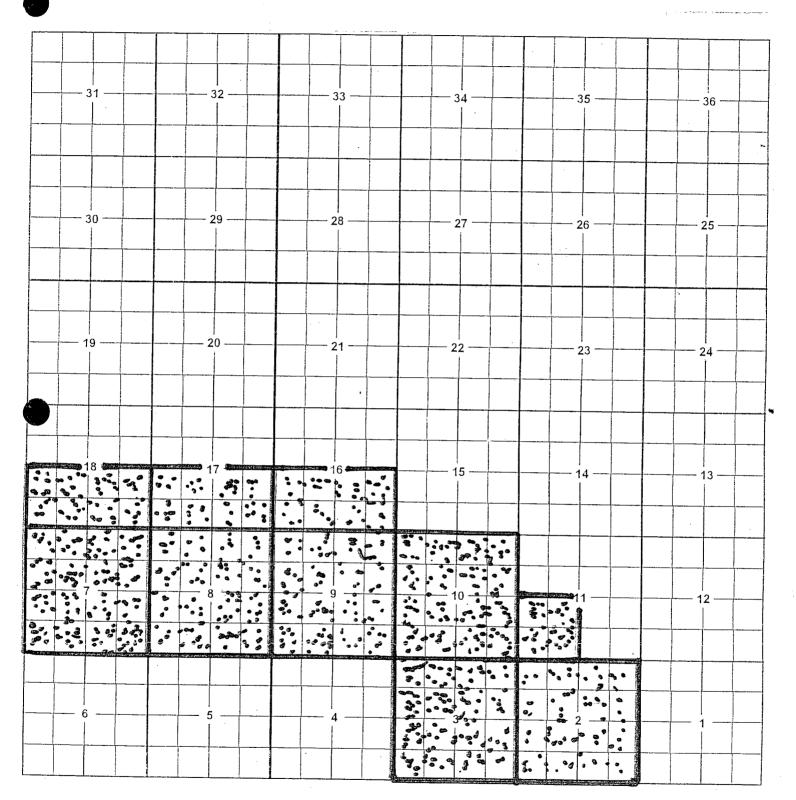


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METALLIC MINERALS PERMIT NO. 9396110004

6-09-080



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Body of Report

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A Chemex Labs Alberta/NC/VAMANN International Partnership

9331 - 48 Street Edmonton, Alberta, Canada T6B 2R4

FAX COVER SHEET

Please Deliver the Following Pages To:

NAME: Ron Owens, Mineral Recovery Systems

FAX: 1-403-783-6586

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 Maxxem Edm.

 TELEPHONE:
 (780)
 468-3500

 FAX:
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Report Distribution Invoice(s) 1 Report(s) Ron Owens

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Supervisory Approval Industrial Division

Signature

Mon, Jan 22, 2001 Date of Issue

Ponoka, AB

C/C Mineral Recovery

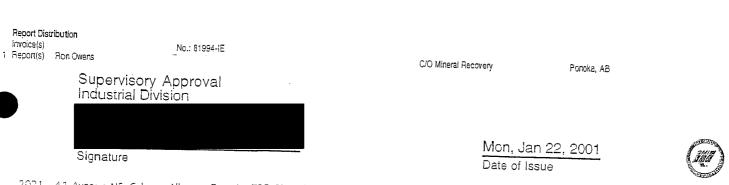


2021 - 41 Avenue NE, Calgary, Alberta, Canada T2E 6P2 Tel: (403) 291-3077 Toll free: 800-386-7247 Fax: (403) 291-9468 Website: www.maxxam.ca 9331 - 48 Street, Edmonton, Alberta, Canada T68 2R4 Tel: (780) 468-3500 Toll-free: 800-386-7247 Fax: (780) 466-2222 Website:



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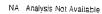
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ontainer Identity	Sample Point I.D. Clie	ent I.D.				01-23406-02
·	Complex on the Che	an 1.1.		Meter i lumber		Laboratory Numoer
Сотралу		·····				
teil / Plani	<u></u>			Name of Sampler		Company
amole Description				· · · · · · · · · · · · · · · · · · ·		
IN-001B				Pressures kPa		Temperatures 'C
ample Point			N/A Source	N/A	<u>N/A</u>	N/A
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## CERTIFICATE OF ANALYSIS

Glass Bottle							
Container Identity	Sample Point I.D.	Client I.D.			Meter Number		01-23406-03 Laboratory Number
отралу							
ell / Plant							
1					Name of Sampler		Company
mple Description		·····					
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Results relate only to items tested

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## CERTIFICATE OF ANALYSIS

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ample Description					
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/eil / Plant				Name of Sampler	Compeny
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ample Description N-008A			Gauge P	ressures kPa	- Tomografiyan iC
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Results relate only to items tested

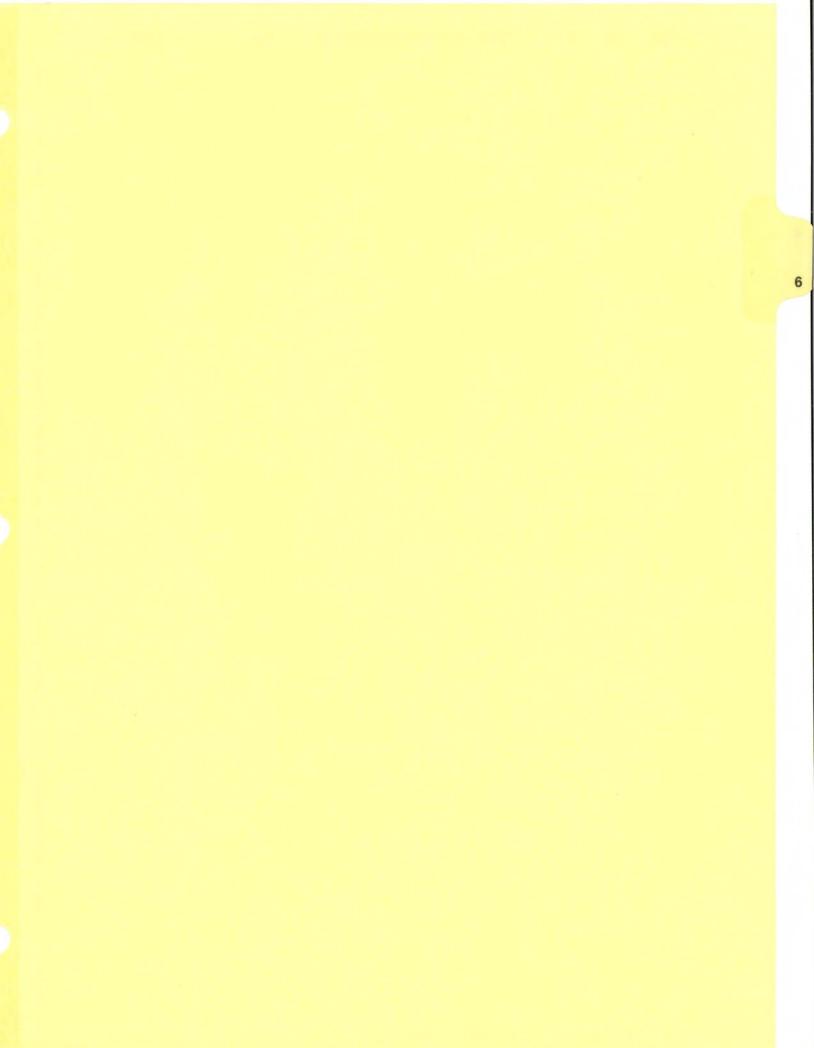
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Container laentity	Sample Foint I.D. Client I.D.			Meter Number		01-23406-07
Сотралу				Meter NDNDer		Laboratory Number
Junpariy						
Vell / Plant						
				Name of Sampler		Company
Sample Description						
N-009A	·			Pressures kPa		Temperatures 'C
ample Point			N/A Source	N/A	<u>N/A</u>	N/A
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^{Remarks:} * No Sample Date



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Vell / Plant						
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ampie Descriptian	······					
N-008B				Pressures kPa		Temperatures 'C
Imple Point			N/A Source	- <u>- N/A</u>	<u>N/A</u>	N/A
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PHILIP SERVICES									
PHILIP ANALYTICAL 07-Dec-00 Page 2 of 7	AN	IAL Y For	TICAL R m 420077	eport 82					
Client :	Philip Clien	ID: ID:	30007984 RO-031A 2/2	30007985 RO-030T1 1/2		07986 4031B 2/2	30007987 RO-031CT1 2/2	30007988 RO-03471 1/2	30007989 RO-035 2/3
Sparcode Parameter	Uait h	1DL	•						
METALS TOTAL Au-TMS42 Gold	mg/L 0	0001	0.0037	0.0027	0.	©043	0.0016	0.0008	0.0139
	Metri Samp		Suil 00/12/04	Soil 00/12/04	5oi 00.'	2/04	50년 00/12/04	Soit 00/12/04	Soil 00/12/04
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PHILIP SERVICES						
PHILIP ANALYTICAL						
07-Dec-00 Page 3 of 7	E	UPLICATE Form 4200:	SUMMA) 782	RY		
Parameter	Client ID	Philip ID	Sample Cong.	Duplicate Cope.	MDL Unit	Relativ & Diff
Gold	RO-030T1 1/2	30007985	0.0027	0 0024	0.0001 mg/L	11.76
					••••••••••••••••••••••••••••••••••••••	
	ar man a sha a sh					

PHILIP ANALYTICAL 07-Dec-00 Page 4 of 7	SP F	IKE SUMN form 42007	MARY 782				
Paraspeter	Client ID	Philip ID	Sampie Conc.	Sampie & Spike Conc.	Spike Amount	Unir	Perce Reco
Gold Gold	Blank Spike. Batch : RO-030T1 1/2	04201862 30007985.	< 0.0001 0.0027	0.0184 0.441	.02 .5	mg/L mg/L	9 <u>2</u> 88

29/1995 19:22 00			4		F¢	4GE 41
PHILIP SERVICES						
PHILIP ANALYTICAL 04-Dec-00 Page 2 of 10	ANAI	YTICAL R	EPORT			
Client : Project :		Philip ID : Client ID :	30007867 RC-024B	30907868	30007869	30007870
Sparcode Parameter	Unit	MDL	RC-024B	RO-024A	RO-025A	RO-025B
METALS TOTAL Au-TMS42 Gold	mg/L	0.0001	< 0.0010 (1)	< 0.0010 (1)	< 0.0010 (1)	< 0.0010 (1)
		Matrix : Sampled on:	Soil 00/11/28 16:00	Soil 90/11/28 15:90	Šoil 00/11/28 16:00	Soil
Result comments and/or text rest	ults :					
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PHILIP SERVICES								
PHILIP ANALYTICAL 04-Dec-00 Page 3 of 10	rond to the second s	ANAL	YTICAL P	EPORT				
Client : Praject :								
Sparcode Parameter		Unit	Pallip ID : Clear ID : MDL	30007871 RC-026		30007872 RO-027 TI	30007873 RO-027 T2	30007874 RG-027 T3
METALS TOTAL Au-TMS42 Gold		mg/[_	0.0001	< 0.0010 (1	1)	0.0001	0.0009	0.0002
			Matrix : Sampled on:	Soil 00/11/28 16:	00	Soil 00/11/28 15:00	Sail	
Result comments and/or text	esults :						00/11/29 16:00	00/11/28 16:00
I) MDL RAISED DUE TO								
	5							
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•	PHILIP SE							
•	PHILIP ANA 04-Dec-CO Page 4 of 10	LYTICAL	ANALY	TICAL RI	EPORT			
	Client : Project :	ану сф. б. н ни и и стехни		Philip ID : Client ID :	30007875 RO-027 T6	30007876 RO-028 72	30007877 RO-029 T1	30007878 RO-029 T2
	Sparcode	Parameter	Unit	MDL				MUTUE7 [ E
	METALS TO Au-TMS42	ral Gold	mg/L	0.0001	< 0.0001	0.0032	0.0012	0.0011
				Matrin : Sampled on:	Soil 00/11/28 15 00	Soll 00/11/28 16:00	Soil 00/11/28 16:00	Soil 00/11/28 16:00
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PHILIP SERVICES			
PHILIP ANALYTICAL 04-Dec-50 Page 5 of 10	ANALYTICAL REPORT		
Client : Project : .		Philip ID : Client ID :	30007879 RO-022B
Sparcode Pareneter	tiaU	MEL	
METALS TOTAL Au-TMS42 Gold	mg/L	0.0001	0.0060
		Matrix : Sampled on:	Soil 00/11/28 15:00

1/29/1995 19:22 00	3					PA	GE 45
PHILIP SERVICES							
PHILIP ANALYTICAL 04-Dec-00 Page 6 of 10		DUPLICATE	SUMMA	RY			
Parameter	Client ID	Philip ID	Sample Conc.	Duplicate Conc.	MDL	Unit	Relativ % Diff
Gold	RO-027 T1	30007872	0.0001	0.0001	0.0001	mg/L	0.00
	<ul> <li>A set of the set of</li></ul>						
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Conc.         Spike Conc.         Amount           Gold         Blank Spike. Batch :         04201836         < 0.6001         Q.0205         .02	Unit Per Re mg/L 10 mg/L 80
Conc.         Spike Conc.         Amount           Gold         Blank Spike. Butch :         04201836         < 0.0001         Q.0205         .02	Re- mg/L 10

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HILIP SERVICES						
PHILIP ANALYTICAL 02-Nov-00 Page 2 of 16	ANAL	YTICAL RI	EPORT			
Client : Praject :		Philip ID : Client ID :	30006630 R0-008(;	30906631 R0-008D	30006632 RO-008E	30006633 RO-008G
Spurcode Parameter	Unit	MDL				
METALS TOTAL Au-TM542 Gold	mg/L	0.0001	0.0146	0.0043	0.0034	0.0040
		Mairix Sampled on	: Soll : 00/10/30 15:0	Soil 0 00/10/30 16:0	Sail 0 00/10/30 16:00	Soil 00/10/30 16:00
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PHILIP SERVICES						
PHILIP ANALYTICAL 02-Nov-00 Page 3 of 16	ANALY	TICAL RE	PORT			
Client : Project :		Philip ID : Client ID :	30006634 RO-008F	30006635 RQ-908H	30005636 B3	30006637 RO-0081 T1
Spurcode Parameter	Unit	MEL				
METALS TOTAL Au-TMS42 Gold	mg/L	0.0001	0.0028	0.0007	0.305	0.0011
			Soil 00/10/30 16:00	Soil 00/10/30 16:00	Seil 06/10/30 16:00	Soii 00/10/30 16:00

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HILIP SERVICES							
02-Nov-00 Fage 4 of 16	ANAL	FTICAL RI	eport				
Client : Project :		Philip ID : Client ID :			30006639 Bl	30006640 RG-006	30006641 RO-008J T2
Sparcode Parameter	Unk	MDL				n Maria da M	
METALS TOTAL Au-TMS42 Gold	mg/L	0.0001	0.0149		0.0014	0.0040	0.0019
		Matrix Sampled on	: Soil : 00/10/30 16:0	90	Soil 00/10/30 16:00	Soli 00/10/30 16:00	Soli 00/10/30 16:00

01/29/1995 19:22 00	ł		PAGE 09
PHILIP SERVICES PHILIP SERVICES PHILIP ANALYTICAL 02-Nov-00 Page 5 of 16 Client : Project : Sparcode Parame	ANALYTICAL REPORT	Philip ID : Cliest ID : MDL	30006642 RO-0087 T3
METALS TOTAL Au-TM542 Gold	mg/L	ბ.0001	0.0012
		himrix : Sampled on:	Soil 00/10/30 16:00



#### DUPLICATE SUMMARY

02-Nov-00 Page 6 of 16

Page 6 of 16						
Parameter	Client ID	Philip ID	Sample Conc.	Duplicate Conc.	MDL Unit	Relative % Diff.
Gold	RO-008E	30006632	0.0034	0.0031	0.0001 . mg/L	9.23

81/29/1995 19:22 00 PAGE 11 10037 vat a PHILIP SERVICES PHILIP ANALYTICAL SPIKE SUMMARY 02-Nov-00 Page 7 of 16 Percent Unit Spike Sample & Philip ID Sample Client ID Parameter Recovery Amouni Spike Conc. Cone. 109 ,02 mg/L < 0.0001 0.0218 04201591 Blank Spike. Batch : Gold 111 \$.53 5 mg/L 0.0034 30006632 RO-008E Gold

(79(1990-19:57 RR				a tradition for the second	P;	46E 14
HILIP SERVICES						
HILIP ANALYTICAL 14-Nov-00 Page 2 of 13	ANALY For	TICAL RE m 4200777	PORT			
Clieat :		Phillip ID : Cilent ID :	30607191 RO-009D	30007192 RO-013	30007193 RO-011F	30007194 RO-010A
Sparcode Persmeter	Ualt	MDL	000 D		an a	
METALS TOTAL ALI-TMS42 Gold	mg/L	0.0001	0.0256	0.0159	0.0392	0.812
			Soil 2 00/11/07 16:00	Soil 00/11/07 15:00	Soil 00/11/07 16:00	Soil 00/11/07 16:0
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PHILIP SERVICES						
PHILIP ANALYTICAL 14-Nov-00 Page 3 of 13	ANAL Fo	YTICAL R rm 420077	EPORT 75			
Client		Failip ID : Client ID ;	30007195 RO-010B T2	30007196 RO-010B T4	30007197 RO-009E	30007198 R0-012
Sparcode Parameter	Unit	MDL				
METALS TOTAL Au-TM542 Gold	mg/L	0.0001	0-79 0.132	0-34 0.0575	0.0512	0.140
		Matrix Sampled or	: Soil : 00/11/07 16:0	Soil 0 00/11/07 16:00	Soil 00/11/07 16:00	Səil 00/11/07 16:0
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PHILIP SERVICES		~		
PHILIP ANALYTICAL 14-Nov-00 Page 4 of 13 Client :	ANALYTICAL RI Form 4200777	EPORT		
Sparcode Paramotes	Undt	Philip ID Client ID MDL	30007199 RO-011B	30007200 RO-011D
METALS TOTAL Au-TMS42 Gold	mg/L	0.000	0.0459	0.0339
		Matrix Sampled ou:	Soi) 00/11/07 16:00	Soil 06/11/07 18:00
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14-Nov-00 Page 5 of 13

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#### DUPLICATE SUMMARY Form 42007775

Client ID	Philip ID	Sampic Conc.		Duplicate Conc.	MDL	Unit	Relative % Diff.
RO-011F	30007193	0.0392		0.0383	0.0001	mg/L	1.03
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		RO-011F 30007193	Cone. RO-011F 30007193 0.0392	Conc. RO-011F 30007193 0.0392	Cone.         Cone.           RO-011F         30007193         0.0392         # .0383	Conc. Conc. Conc. R0-011F 30007193 0.0392 9.0383 0.0001	Cone.         Cone.           RO-011F         30007193         0.0392         0.0383         0.0001 mg/L

PHILIP SERVICES PHILIP ANALYTICAL 14-Nov-00 Page 5 of 13	SPI F	KE SUMN orm 42007	1ARY 775				
Parameter	Client ID	Philip ID	Sample Conc.	Sample & Spike Conc.	Spike Amount	Unit	Percent Recover
Geid Gold	Blank Spike, Batch : RQ-011F	04201693 30007193	< 0.0001 0.0392	0.0207 0.502	.02 .5	mg/L mg/L	104 93

/29/1995 19:22 00					₩4	4GE 20
PHILIP SERVICES						
PHILIP ANALYTICAL 22-Nov-00 Page 2 of 13	ANAL Fo	YTICAL RI rm 420077	EPORT			
Client :		Philip ID : Client ID :	30007524 RO-014 T1	30007525 RO-014 T3	30007526 RO-016A T1	30007527 RO-016A T3
Sparcode Parameter	Uait	MDL				
METALS TOTAL Au-TMS42 Gold	mg/L	0.0001	0.0011	0.0093	0.865	0.108
		Matrix : Sampled on:	Soil 60/11/17 16:00	Soil 00/11/17 16:00	Soll 00/11/17 16:00	Soli 00/11/17.16:0
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HILIP SERVICES						
HILIP ANALYTICAL 22-Nov-00 Page 3 of 13	ANALY For	TICAL RE m 4200777	PORT			
Client :		Phillp ID : Client ID :	30CD7528 RO-011-i	00007529 RO-011 K	30007530 RO-015 A	30007531 RO-016B T1
Spartode Parameter	Unit	MDL				
METALS TOTAL Au-TMS42 Gold	mg/L	0.0001	0.952	0.113	0.9606	0.152
			Soil : 00/11/17 16:00	Soil 00/11/17 16:0(	Soli ) 00/11/17 16:00	Søil 00/11/17 16:0
1912) 1914 - 1914 1914 - 1914 - 1914 - 1914 - 1914 - 1914 - 1914 - 1914 - 1914 - 1914 - 1914 - 1914 - 1914 - 1914 - 1914 - 1914 - 1914 - 1914 - 1914 - 1914 - 1914 - 1914 - 1914 - 1914 - 1914 - 1914 - 1914 - 1914 - 1914 - 1914 - 1914 - 1914 - 1914 - 1914 - 1914 - 1914 - 1914 - 1914 - 1914 - 1914 - 1914 - 1914 - 1914 - 1914 - 1914 - 1914 - 1914 - 1914 - 1914 - 1914 - 1914 - 1914 - 1914 - 1914 - 1914 - 1914 - 1914 - 1914 - 1914 - 1914 - 1914 - 1914 - 1914 - 1914 - 1914 - 1914 - 19						

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PHILIP SERVICES				
22-Nov-00 Page 4 of 13	ANALYT Form	ICAL REPORT 42007776		
Client :			Philip ID ; Client ID ;	30007532 RO-016E T2
Sparcode Pai	*2.542 CT	Unit	MDL.	
METALS TOTAL Au-TMS42 Gold		mg/L	0.6001	0.0304
			Matrix : Sampled on:	Soil 00/11/17 16:00



22-Nov-00 Page 5 of 13

#### DUPLICATE SUMMARY Form 42007776

	1.01111 .496.64						
Client ID	Philip ID	Sample Conc.	I	Duplicate Conc.	MDL	Unit	Relative S Diff.
RO-014 73	30007525	0.0093		0 0106	0.0001	mg/L	+13.07
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and a second							
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		Client ID Philip ID	Client ID Philip ID Sample Conc.	Client ID Philip ID Sample I Cone. C	Client ID         Philip ID         Sample Conc.         Duplicate Conc.           RO-014 T3         30007525         0.0093         0 0106	Client ID Philip ID Sample Duplicate MDL Conc. Conc.	Conc. Conc. Conc. R0-014 T3 30007525 0.0093 010106 0.0001 mg/L

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PHILIP SERVICES							
	- Commentation (1999)						
PHILIP ANALYTICAL							
22-Nex-00 Page 6 of 13	SP. F	IKE SUMI form 42007	MARY 7776				
Parameter	Client ID	Philip (D	Sample Cons.	Sample & Spike Conc.	Spike Amount	Unit	Perc
Goid Goid	Blank Spike, Batch : RO-014 T3	04201745 30007 <u>52</u> 5	< 0.0001 0.0093	0.0198	.02	mg/L	99
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HILIP SERVICES								
MILIP ANALYTICAL 29-Nov-00 Page 2 of 10	9 - 14 - 14 - 14 - 14 - 14 - 14 - 14 - 1	ANALY	fical re	PORT				
Client : Projeci :			Philip ID : Clica: ID :	30007638 R0-015C		30007639 17B	30007640 RO-017C	30007641 RO-015D
Sparcode Paramet	er	Unit	MDL					
METALS TOTAL Au-TM S42 Gold		mg/L	0.0001	0.0051		0.0822	0.0013	0.0013
				Soil : 00/11/22 1	5 00	Soil 00/11/22 16:00	Soil 00/11/22 16:00	Soil 00/11/22 16:00

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PHILIP SERVICES							
PHILIP ANALYTICAL 29-Nov-00 Page 3-of 10	ANALY	TICAL RE	PORT				
Client : Project :		Philip ID : Client ID :	30007642 RO-018A		30007643 RO-017A	30007644 RO-20	30007645 RO-015B.2 T2
Spercode Parameter	Unit	MDL					
METALS TOTAL Au-TMS42 Gold	mg/L	6.0001	0.0013		6.0004	0.0013	0.0022
			: Soli h: 00/11/22	16 00	Soli 00/11/22 16:00	Soil 00/11/22 16:00	Soil 00/11/22 16:00
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PHILIP SERVICES							
PHILIP ANALYTICAL 29-Nov-00 Page 4 of 10	ANAL	YTICAL R	eport				
Client : Project : .		Philip ID :	30007646		30007647	30007648	30007649
Sparcode Parameter	Unit	Client ID : MDL	RO-019A 1		RO-019A 72	RO-021	RO-023
METALS TOTAL Au-TMS42 Gold	നള/്	0.0001	0.0005		0.0003	0.0041	0.0012
SPECIAL INORGANICS MTSPMTSP Metals Special Analy	None					(1)	(2)
			50il 90/11/22 1	6:00	Soil 00/11/22 16:00	Soll 00/11/22 16:00	Soll 00/11/22 1
Result comments and/or text results :	and the second secon	an a					
(1) Text results for sample 90007648	sparcode MT	SPMTSP falle	NS/ ·				
Rh = <0.0001 ng/L							
(2) Text results for sample 10007649	sparcode MT.	SPMTSP follo	w :				
Pd = 0.0056  mg/L							
Pt = 0.0103 mg/L							
N N							

/29/1995 13:22 00	۱ ف	: 1		PAGE 29
PHILIP SERVICES PHILIP ANALYTICAL 25-Nov-00				
Denov-00 Page 5 of 10 Client : Project :	ANALY	NCAL REPORT		
Sparcode Pera	ter	Unit	Pailip ID : Client ID : MDL	30007630 RO-010A
SPECIAL INORGANICS MTSPMTSP Metais 3	pocial Analy	None		(1)
			Matrix : Sampised on:	Soil 00/11/22 16:00
Result comments and/or text	esults :			میں اور
(1) Text results for sample	0007650 sparcode MTSP	MTSP follow :		
	DIGESTED, Au IS <			
	17-135-121-14-1			
	Print and Print			
	new Zan Calabara			
1	l			



29-Nov-00 Page 6 of 10

## DUPLICATE SUMMARY

1 May 2 OF 10							
Darameter	Client (D	Philip ID	Sample Conc.	Duplicate Conc.	MDL	Unic	Reibiive % Diff.
61d	RO-021	30007648	0.0041	0.0039	0.0001	mg/L	5.90



29-Nov-00 Page 7 of 10

#### SPIKE SUMMARY

Parameter	Clien ID	Philip ID	Sample Conc.	Sample & Spike Conc.	Spike Amount	Unit	Percent Recovery
Gold	Blank Spike, Eatch :	04201772	< 0.0001	9.0201	.02	mg/L	101
Gold	RO-021	30007648	0.0041	9.0464	.05	mg/L	85
Gold	Blank Spike, Batch :	04201807	< 0.0001	9.0201	.02	mg/L	101



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### Dete: August 3, 2001

### ANALYSIS CERTIFICATE:

#### Mr. Ron Owens 10: Mineral Recovery Systems 201-5201-52 Ave Ponoka, Alberta, Canada T41 1HD

Sample No:	Customer Sample ID No.	Method Code1 Code2	Goid Tr ozhon	Silver Trioz/ton	Pletinum Trorton	Palladium Trozhon
3498	4	FANFAA	0.010	0.084	0.012	0.004
3499		FAN/FAA	0.008	N/D	0.001	0.003
No. of Concession, name	3	FANFAA	0.006	0.009	0.003	0.004
3500		FANFAA	0.005	N/D	0.002	0.005
3501		FANTAA	0.007	N/D	0.003	0.006
3502	<u> </u>	FANFAL	0.005	N/D	N/D	0.004
3503	9	FANTAA	0.008	N/D	N/D	0.005
3504	0	FANFAA	0.007	0.001	0.003	0.005
3505	<u> </u>	FANFAA	0.008	N/D	N/D	0.004
3508	10	FANTAA	0.007	N/D	0.008	0.006

#### Analysis method:

Code 1 Procedure for Decomposition ( Propersition of Syster Statements	AUSIASIS HIGH ON	Procedure for Decomposition / Preparation of Solid Seconds
		Processing and a standard
AUn Auid Decomposition (n: the number of acide used)		
FAI I're Assay with Lead button Collection	FAL	tire Assay with Lead Bullion Collection
FAN Fire Assay with Nickel Sulfide Collection	FAN	Fire Assay with Nickel Sulfide Collection
FAT Fire Assay with Tin Button Collection	FAT	Fire Assay with Tin Button Collection

Code 2	Pricedure for Measurement
VOL.	Volumetry or Thrimetry
GRV	Cirevimetry
1 AA	Hame Alumic Absorption Spectrophotometry
GAA	Graphite Humace Atomic Absurption Spectrophotometry
ICPE	Inductively Coupled Plasma Spectrophotometry

### GENERAL DISCLUMER:

the results reparties anove are based on well-known, accepted analytical procedure, used solely on the sample submitted by the customer. No werranty as to the reproducibility or example billing of the material other than the sample is given. AllRK: Metallurg.cal I aborgatories, LLC makes an representation express or implied on the insuring inter that represented by the assayed sample.

#### NEVADALEGISLATIVA DASCLAIGER

The results of this event were based solely upon the control of the strangic schmitting. Any decision to invest should be made only after the potential involument value of the claim or deposit has been determined based on the results of assays of multiple samples of geological materials collected by the prospective investor or by a qualified person scienced by him grid based on an evaluation of sit ungineuring data available concerning any proposed project.

Anmet B. Altinay Metellussical Engineer



2000 West Directors Roll, Sell Labo City, Uten 84164 USA • Ph; 601-676-7677 • Fax: 601-874-8656 AuRIC Listellurgiasi Laboratorios (s a Listing Listatly Company

and a second 


Data: August 3, 2001

### ANALYSIS CERTIFICATE:

#### Mr. Ron Owens To: Mineral Recovery Systems 201-5201-52 AV@ Ponoka, Albana, Canada Taj 145

Sample No:	Customer Sample ID No:	Method Code1 Code2	Gold Tr os/ton	Silver Troz/ton	Platinum Tr oz/ton	Pelledium Troz/ton 0.004	
3508	11	FANFAA	0.008	N/D N/D	N/D N/D	0.004	
3509	12	FAN/FAA FAN/FAA	0.006	0.047	N/D	0.003	
3510	15	FAN/FAA	0.004	N/D	N/D 0.017	0.003	1
3512	17	FAN/FAA FAN/FAA	0.027	N/D N/D	0.018	0.007	
3513	18	FAN/FAA	0.022	0.034	0.037	0.007	
3514		a			0.012	0.009	j
2118	1	AD2/GRV	0.013		0.012	0.044	
2117	17	IL ADZIGRV	0.010		- Province and the second		تعير

### Analysis method:

Analysis method:	
Custa 1	Procedure for Decommittion / Preparation of Solid Samales

- Acid Decomposition (n: the number of acids used) ADn
- Fire Assay with Load button Collection FAL
- Fire Assay with Nickel Suffide Collection FAN
- Fire Assay with Tin Button Collection FAT

Code 2	Prosidure for Massurement Volumetry or Titrimetry
VOL	Volumetry or Titrimetry

VOL	Volumetry or a

- ÜRV Gravimenty
- Flame Atomic Absorption Spectrophotometry FAA
- Graphile Furnace Atomic Absorption Spectrophotometry GAA
- Inductively Coupled Plasma Spectrophotometry ICPE

GEASEAL DISCLAINER: The results reported above are based on well-known, accepted analytical procedures used solely on the sample submitted by the customer. No wereanty as to the reproducibility or extructebility of the material other than the sample is given. AukiC Metallurgical t shoresones, LLC makes an expresentation express or lesplied on the material other than that represented by the assayed sample

The results of this assay were based solely upon the content of the sample sammined. Any decision to invest should be made only after the potential investment value of the claim or deposit has been determined based on the results of essays of multiple samples of reconstruction internation class in the original internation was a seried on the result of internation of puttypic sumplies of peological magnats collected by the prospective measure or by a qualified person velected by him and based on an evaluation of all engineering data as slighte concerning my proposed project.

### Ahmet B. Altinay

Metallurgical Engineer

5250 West Directors Rest, Best Lake City, Jian 64104 UBA • Ph; 601-074-7677 • Fax: 001-074-0056 AUGHC Matchingtest Laborstories to a Littlical Listelling Company



Date: February 28, 2001

### ASSAY REPORT:

To: Mr. Ron Owens Mineral Recovery Systems 201-5201-52 Ave Ponoka, Alberta Canada T4J 1HD

AURIC Sample No.	Customer Sample ID No:	Gold Tr oz/ton	Silver Tr oz/ton	Platinum Tr oz/ton	Palladium Trioz/ton	Rhodium Trioz/ton
1643 C	ROA - 04	0.012	0.102	0.064	0.004	N/D
3365 A	ROA - 04	0.014	0.174	0.049	0.003	N/C
				[		
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** <b>#**************</b> ***				L		
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				1		ļ
· · · <u>- · · · · · · · · · · · · · · · ·</u>	1					

Analysis method: (for AuRIC Sample No.'s anding with A - FA/AA) (for AuRIC Sample No 's anding with C: Chemical Assay/ SX/ GFAA spectrophotometer finish)

The results reported above are based on well known, accepted analytical procedures used solely on the sample sammined by the easternet. No warranty as to the reproducibility or extractability of the material other than the sample is given. AuRIC Metallurgical Laboratories, LLC, makes no representation express or implied on the material other than that represented by the assayed sample.

Ahmet B. Altinay Metallurgical Engineer



3280 West Diractons Row, Balt Lake City, Utah 84104 USA • Ph: 801-974-7577 • Fax: 691-974-9668 Au88C Matshuples Laboratorias is a Limited Liability Company



### ANALYSIS REPORT:

Date: September 12, 2002

1

Mineral	n Owens I Recovery Systems		
•	01-52 Ave a, Alberta, Canada T4J 1HD		
	AuRIC Sample No.:	3926	
	Customer Sample ID No.:	Bead	•
	Weight: (Bead)	1.969 mg	
	Method (Code 1 / Code 2)	AD2/FAA	
	Units:	ppm	
	Aluminum		
	Bismuth		
	Chromium		1
	Cobalt	······	
	Copper	······	1
	Gold	812.60	-> 0.002 mg
	Iridium	N/A	
	Iron		1
	Lead		1
	Molybdenum		1
	Nickel		
	Osmium	N/A	
	Palladium	304.72	1→0001 mg
	Platinum	Trace	0
	Rhodium	N/A	
	Ruthenium	N/A	1
	Silver	996,476.38	-> 1.962 mg
	Tin		1 0
	Titanium		1
	Vanadium		
	Zinc		
_	Procedure for Decomposition / Prep Acid Decomposition (n: the number of Fire Assay with Lead button Collection Fire Assay with Nickel Sulfide Collection Fire Assay with Tin Button Collection Procedure for Measurement Volumetry or Titrimetry Gravimetry Fiame Atomic Absorption Spectrophoto Graphite Furnace Atomic Absorption S Inductively Coupled Plasma Spectroph	acids used) on ometry pectrophotometry	r <u>2195</u>

The results reported above are based on well-known, accepted analytical procedures used solely on the sample submitted by the customer. No warranty as to the reproducibility or extractability of the material other than the sample is given. AuRIC Metallurgical Laboratories, LLC makes no representation express or implied on the material other than that represented by the assayed sample.

Ahmet B. Altinay

Analysis method: Code 1 ADn FAL FAN FAT Code 2 VOL GRV FAA GAA ICPE

Metalurgical Engineer

3260 West Directors Row, Salt Lake City, Utah 84104 USA · Ph: 801-974-7677 · Fax: 801-974-9656 AuRIC Metallurgical Laboratories is a Limited Liability Company

P. 02



To : MR. RON OWENS 201, 5201 - 52nd Avenue Ponoka, Alberta T4J 1H6



File No : **4 4 1 2 7** Date : September 6, 2001 Samples : Project : P.O.#

### Certificate of Assay Loring Laboratories Ltd.

629 Beaverdam Road, NE Calgary Alberta T2K 4W7 Tel: (403)274-2777 Fax: (403)275-0541

Sample No.	Au mg/i	Pd mg/l	Pt mg/l	Rh mg/l	
"PGM Analysis"					
01-03-01	< 0.01	< 0.01	< 0.01	< 0.01	
01-03-02	1.12	< 0.01	< 0.01	< 0.01	
	NOTE: High iron conter some wavelengt		ns caused ir	nterferences at	
I HEREBY CERTIFY that th	e above results are those assays				
made by me upon the here	n described samples :		A	ssayer <i>)</i>	

Rejects and pulps are retained for one month unless specific arrangements are made in advance.



# FULLERTON

Department of Chemistry and Biochemistry (714) 278-3621 / Fax (714) 278-5316



February 18, 2002

Ron Owen Mineral Recovery Systems 201-5201-52 Ave Ponoka, Alberta T4J1H6 Phone: 403 783 6487 Fax? 403 783 6586 Mobil: 403 783 0656

Dear Ron,

As I mentioned on the phone, I have completed the assay on the sample you submitted. The analysis is shown below:

	Gold	Platinum	Palladium	Rhodium
<u>Sample ID</u>	<u>Oz/Ton</u>	<u>Oz/Ton</u>	<u>Oz/Ton</u>	<u>Oz/Ton</u>
5080	less than 0.02	ess than 0.02	less than 0.02	less than 0.02

This assay is for the sample labeled "Site 01, sample # 03, 3-4 feet. As we discussed, I am now running sample 01, 1-2 feet and will report to you as soon as I have finished. If you have any questions, please feel free to call me at (714) 278 2641.

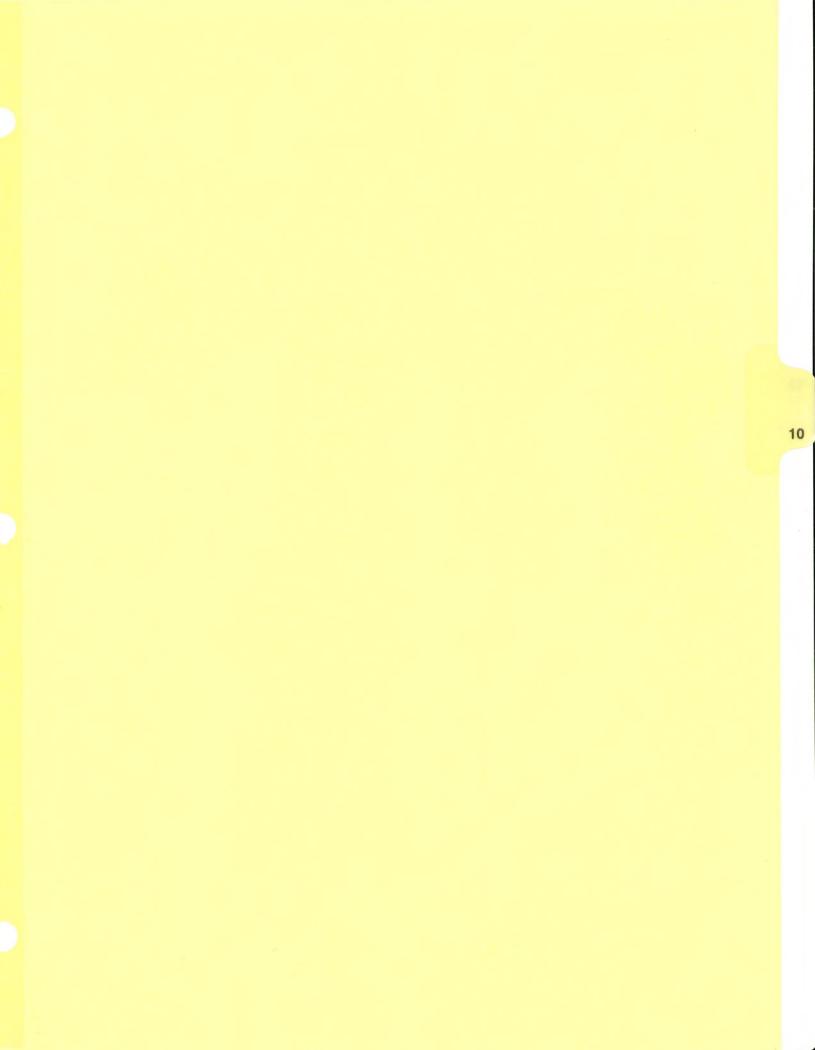
Sincerely Yours,

Dr. Joseph L. Thomas Associate Professor of Chemistry

CALIFORNIA STATE UNIVERSITY, FULLERTON P.O. Box 6866, Fullerton, CA 92834-6866

The California State University: Bakersfield / Channel Islands / Chico / Dominguez Hills / Fresno / Fullerton / Hayward / Humboldt / Long Beach / Los Angeles / Maritime Academy / Monterey Bay / Northridge / Pomona / Sacramento / San Bernardino / San Diego / San Francisco / San Jose / San Luis Obispo / San Marcos / Sonoma / Stanislaus

Alter A. May



# Genalysis Laboratory Services Pty. Ltd.

ANALYSTS AND CONSULTING CHEMISTS ABN: 32 008 787 237

# Analytical Report

### COMMENTS

1. ATTENTION: ROWEN

### JOB INFORMATION

JOB CODE	1	6.3/0103205
NO. OF SAMPLES	:	3
No. of ELEMENTS	:	7
CLIENT O/N	;	R OWENS
SAMPLE SUBMISSION No.	;	
PROJECT	:	
STATE	:	Pulp
DATE RECEIVED	1	08/08/2001
DATE COMPLETED	:	
DATE PRINTED	1	\$1/07/2001

### LEGEND

'X'	= LESS THAN DETECTION LIMIT
'N/R'	SAMPLE NOT RECEIVED
181	= RESULT CHECKED
'() [*]	= RESULT STILL TO COME
'VS'	= INSUFFICIENT SAMPLE FOR ANALYSIS
'E <del>0</del> '	= RESULT X 1,000,000
'UA'	= LINABLE TO ASSAY

#### MAIN OFFICE AND LABORATORY

15 Davison Street, Mandington 6109, Wostorn Australia PO Box 144, Gosnells 8990, Western Australia Tel: +61 8 9459 9011 Fax: +61 8 9458 5343 Email: genalysis@gonalysis.com.au Web Page: www.gensiyals.com.su

#### KALGOORLIE SAMPLE PREPARATION DIVISION

12 Keogh Way, Kalgoorlie 8430, Western Australia PO Box 388, Kalgoorile 6430, Western Australia Tel: +61 8 9021 6057 Fax: +61 8 9021 3476

#### ADELAIDE SAMPLE PREPARATION DIVISION

124 Mooringe Avenue, North Plympton 5037, South Australia PO Box 2078, South Plympton 5038, South Australia Tel: +61 8 8376 7122 Fax: +61 8 8376 7144



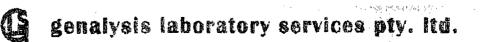
### genalysis laboratory services pty. Itd.

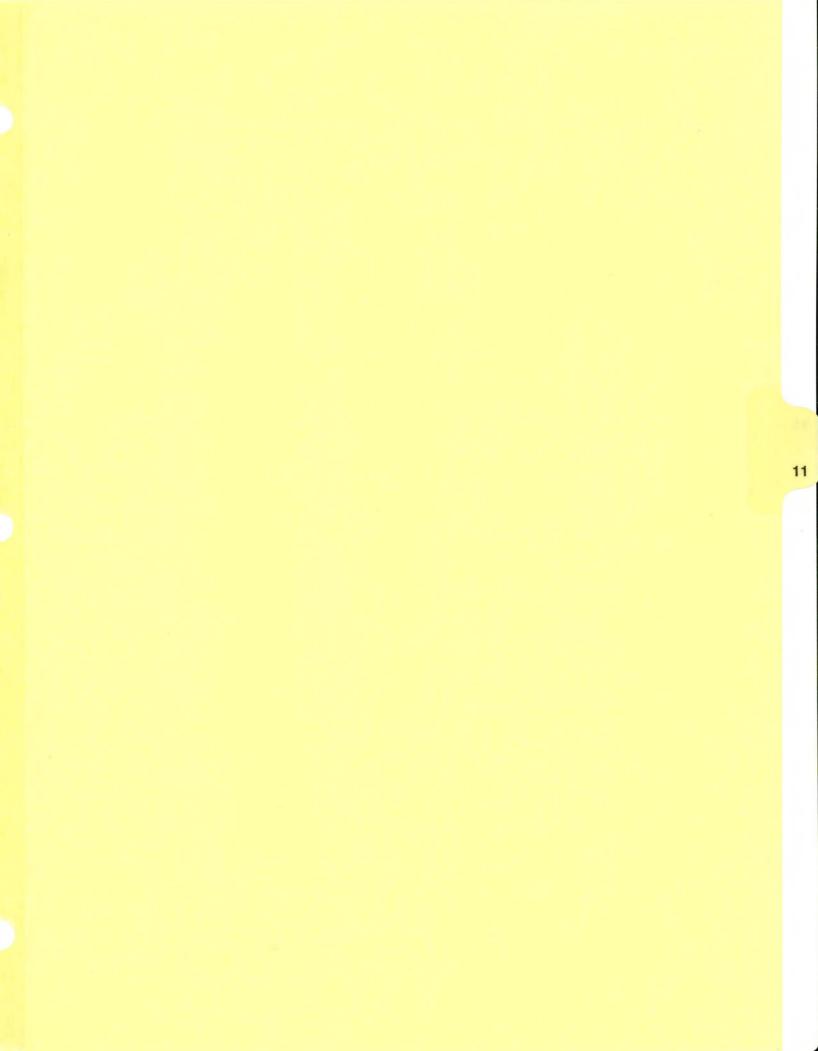
. 6.3/0103205 (11/07/2001) CLIENT O/N: R OWENS

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### ANALYSIS

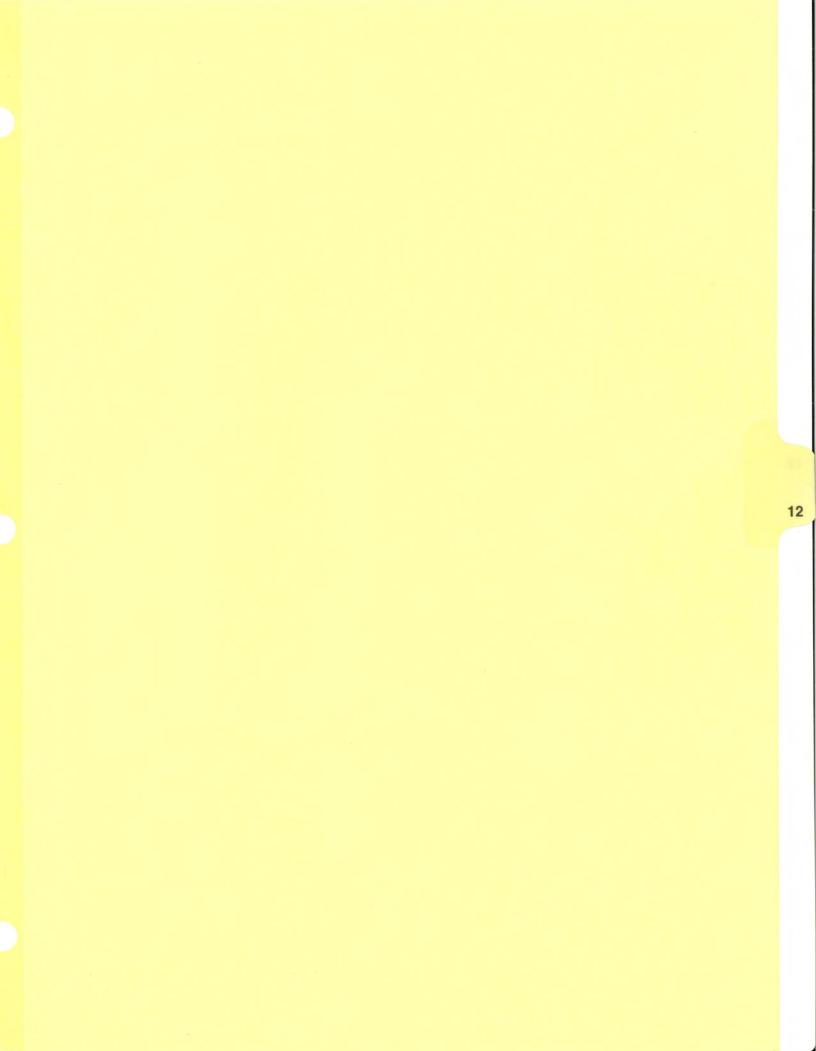
ELEMENTS	Au	lr	٥s	Pd	• Pt	Rh	Ru
UNITS	ppb	ppb	ppb	pp <b>b</b>	ppb	ppb	ppb
DETECTION	5	2	2	2	2	1	2
METHOD	NIS/*MS	NIS/MS	NIS/MS	NIS/*MS	NIS/*MS	NIS/MS	NIS/MS
SAMPLE NUMBERS							
0001 03	10	x	x	4	2	х	2
0002 03 DUP	10	x	x	4	Х	х	X
0003 03 TRIP	10	x	×	4	2	x	2
STANDARDS							
0001 HGMN.1	144	76	118	710	258	86	252
BLANKS							·
0001 Control Blank	Х	×	X	2	x	х	х





### SILVER INQUART METHOD

- 1. Thoroughly mix ore with flux. (chould be done in a metal mixing box)
  - 5 grams Ore 20 grams borax 70 grams Htharge 1 gram silver 15 grams flour
- 2. Put in furnace in acortfying dish at 2,000° F for 46 minutes.
- 3. Pour and cool. Break sizg from lead and cupsi lead button at 1,700° F.
- 4. Weigh Ag button.
- 5. Part in 1:6 HNO, to distilled water. Warm until button is in solution.
- 6. Leave on hot plate until dry. Put crucible in furnace for two hours at 600° F.
- 7. Remove from furnace and cool. Add 80 to 100 ml distilled water and warm.
- 8. Fliter and wash three times with het distilled water.
- 9. Burn filter until ash free and add 25% sulfuric acid and heat for one hour.
- 10. Filter and wash with hot water.
- 11. Burn fliter until free of ash, cool and weigh.
- 12. Colculate mixture of metals and enalyze on instrument.



1. Grind 100 grams of the ore to -100 mesh. Thoroughly mix with 70 grams of borax and 30 grams of sodium carbonate. Place in an unused 40 gram? clay crucible and fuse this mixture for approximately 90 minutes at 1,150C. Pour into a cast iron mold being careful to recover as much of the fusion as possible. Save the crucible. Grind the fusion to -100 mesh.

2. Carefully separate the metallic particles from the glass matrix. This may be done by using one of the following methods:

a. Place the ground fusion into a gold pan and carefully pan away as much of the glass as possible. Remove the concentrate from the gold and dry. There should be approximately 5 grams of dried concentrates remaining.

b. Using a hand magnet, carefully remove the magnetic particles from the ground fusion. Place the non-magnetic fraction into a gold pan and, using normal panning procedures, discard as much of the "lights" as possible. Remove the concentrates from the pan and dry. Combine these concentrates with the magnetics.

3. Weigh the concentrates. Add approximately the same weight of a mixture of one-half sodium nitrate and one-half sodium peroxide. Mix thoroughly and place in the above saved clay crucible. Furnace at 1,000C for 30 minutes. It should be noted that sodium peroxide is a strong oxidizer which should be handled with care. Any osmium or ruthenium that is present in the sample may, at this stage, be oxidized and volatized from the roast. Remove from the furnace and, while still hot, add the following premixed flux:

- 1. 60 grams litharge
- 2. 8 grams flour
- 3. 50 grams borax glass
- 4. 35 grams sodium carbonate
- 5. 5 grams silica
- 6. 1 gram analytical-grade silver chloride

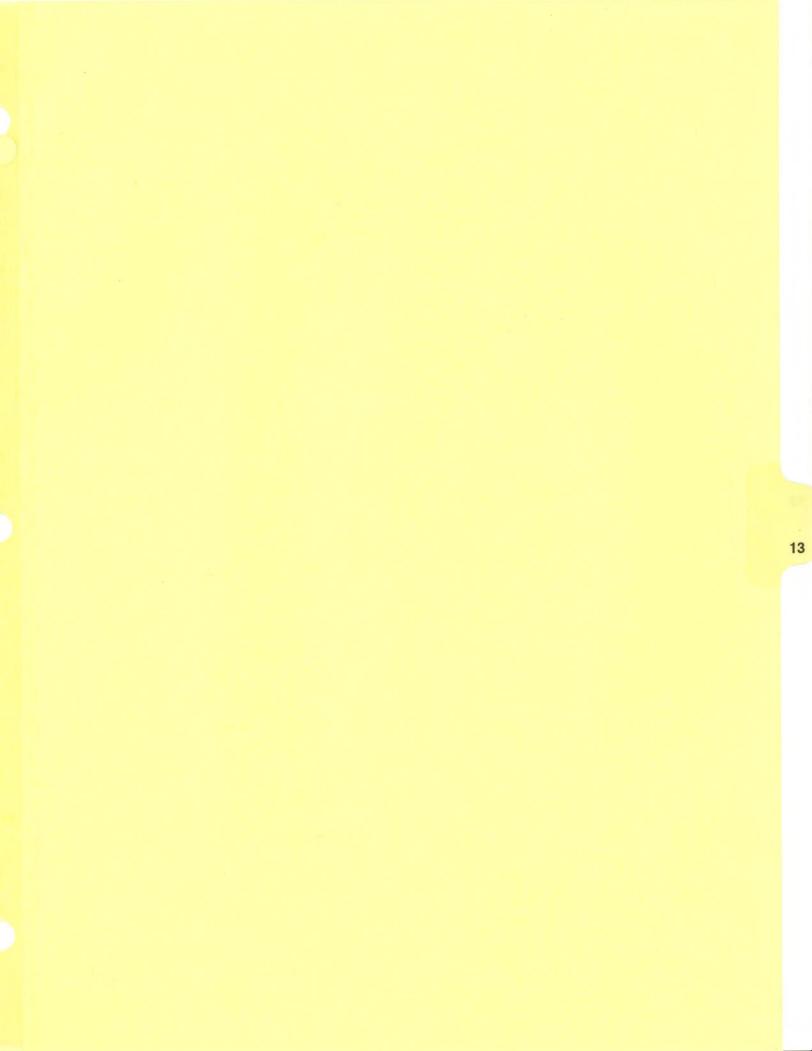
Place in furnace and fuse for approximately one hour at 1,150C. Pour into a cast iron mold and let cool. Carefully break away the slag from the Pb button. Save any metal fragments that are removed during the cleaning process. Grind the slag and smelt under the above conditions using the same flux and crucible; do not add additional silver.

4. Place the Pb buttons and recovered matal fragments in a suitably-sized scorifying dish (3.5 inch diameter), cover with borax glass and a small amount of sodium carbonate, and scorify to approximately one-half of the original weight of the Pb buttons. Pour into a cast iron mold.

5. Cupel the Pb button at approximately 950C. If the cupel is discolored, suggesting the presence of small amounts of precious metals, wrap approximately 100 mg of silver in 5 grams of lead foil and "re-cupel".

6. Using standard spectographic procedures the prill(s) may be analyzed for the Au content and the data calculated to Troy ounces of Au per head one ton. It is recommended that the method of standard additions be used for background correction. The resulting prill(s) may also (again using standard procedures) be parted with dilute nitric acid and the residue annealed and weighed. The above procedure can be modified to analyze either larger or smaller one samples.

2





Shale-hosted Nickle Zinc Moly PGE - Mineral Deposit Profiles, B.C. Geological Survey

SHALE-HOSTED Ni-Zn-Mo-PGE E16



by David V. Lefebure* and R.M. Coveney Jr.# * British Columbia Geological Survey # University of Missouri - Kansas City, Kansas City, Missouri

Lefebure, D.V. and Coveney, R.M. Jr.(1995): Shale-hosted Ni-Zn-Mo-PGE, in Selected British Columbia Mineral Deposit Profiles, Volume 1 - Metallics and Coal, Lefebure, D.V. and Ray, G.E., Editors, British Columbia Ministry of Energy of Employment and Investment, Open File 1995-20, pages 45-48.

### IDENTIFICATION

SYNONYMS: Sediment-hosted Ni-Mo-PGE, Stratiform Ni-Zn-PGE.

COMMODITIES (BYPRODUCTS): Ni, Mo, (Zn, Pt, Pd, Au).

**EXAMPLES (British Columbia - Canada/International)**: Nick (Yukon, Canada); mining camps of Tianeshan, Xintuguo, Tuansabao and Jinzhuwoin and Zunyi Mo deposits, Dayong-Cili District (China).

### **GEOLOGICAL CHARACTERISTICS**

**CAPSULE DESCRIPTION**: Thin layers of pyrite, vaesite (NiS2), jordisite (amorphous MoS2) and sphalerite in black shale sub-basins with associated phosphatic chert and carbonate rocks.

**TECTONIC SETTING(S)**: Continental platform sedimentary sequences and possibly successor basins. All known deposits associated with orogenic belts, however, strongly anomalous shales overlying the North American craton may point to as yet undiscovered deposits over the stable craton.

DEPOSITIONAL ENVIRONMENT / GEOLOGICAL SETTING: Anoxic basins within clastic sedimentary (flysch) sequences containing black shales.

AGE OF MINERALIZATION: Post Archean. Known deposits are Early Cambrian and Devonian, however, there is potential for deposits of other ages.

HOST/ASSOCIATED ROCK TYPES: Black shale is the host; associated limestones, dolomitic/ limestones, calcareous shale, cherts, siliceous shale, siliceous dolomite, muddy siltstone and tuffs. Commonly associated with phosphate horizons. In the Yukon at base of a 10 to 20 m thick phosphatic shale bed and in China the Ni-Mo beds are in black shales associated with phosphorite.

**DEPOSIT FORM**: Thin beds (0 to 15 cm thick, locally up to 30 cm) covering areas up to at least 100 ha and found as clusters and zones extending for tens of kilometres.

**TEXTURE/STRUCTURE**: Semimassive to massive sulphides as nodules, spheroids, framboids and streaks or segregations in a fine-grained matrix of sulphides, organic matter and nodular phosphorite or phosphatic carbonaceous chert. Mineralization can be rhythmically laminated; often has thin discontinuous laminae. Brecciated clasts and spheroids of pyrite, organic matter and phosphorite. In China nodular textures (~ 1 mm diameter) grade to coatings of sulphides on tiny 1-10 mm spherules of organic matter. Fragments and local folding reflect soft sediment deformation. Abundant plant fossils in Nick mineralization and abundant fossils of microorganisms (cyanobacteria) in the Chinese ores.

**ORE MINERALOGY (Principal and** *subordinate*): Pyrite, vaesite (NiS2), amorphous molybdenum minerals (jordisite, MoS2), bravoite, *sphalerite, wurtzite, polydimite, gersdorffite, violarite, millerite, sulvanite, pentlandite, tennanite and as traces native gold, uranitite, tiemannite, arsenopyrite, chalcopyrite and covellite.* Discrete platinum group minerals may be unusual. Some ore samples are surprisingly light because of abundant organic matter and large amount of pores.

**GANGUE MINERALOGY (Principal and** *subordinate*): Chert, amorphous silica, phosphatic sediments and bitumen. Can be interbedded with pellets of solid organic matter (called stone coal in China). Barite laths are reported in two of the China deposits.

**ALTERATION MINERALOGY**: Siliceous stockworks and bitumen veins with silicified wallrock occur in the footwall units. Carbonate concretions up to 1.5 m in diameter occur immediately below the Nick mineralized horizon in the Yukon.

**WEATHERING**: Mineralized horizons readily oxidize to a black colour and are recessive. Phosphatic horizons can be resistant to weathering.

**ORE CONTROLS**: The deposits developed in restricted basins with anoxic conditions. Known deposits are found near the basal contact of major formations. Underlying regional unconformities and major basin faults are possible controls on mineralization. Chinese deposits occur discontinuously in a 1600 km long arcuate belt, possibly controlled by basement fractures.

**GENETIC MODEL**: Several genetic models have been suggested reflecting the limited data available and the unusual presence of PGEs without ultramafic rocks. Syngenetic deposition from seafloor springs with deposition of metals on or just beneath the seafloor is the most favoured model. Siliceous venting tubes and chert beds in the underlying beds in the Yukon suggest a hydrothermal source for metals.

**ASSOCIATED DEPOSIT TYPES**: Phosphorite layers (F07?), stone coal, SEDEX Pb-Zn (E14), Sediment-hosted barite (E17), vanadian shales, sediment-hosted Ag-V, uranium deposits.

**COMMENTS**: Ag-V and V deposits hosted by black shales have been described from the same region in China hosted by underlying late Precambrian rocks.

### **EXPLORATION GUIDES**

**GEOCHEMICAL SIGNATURE**: Elevated values of Ni, Mo, Au, PGE, C, P, Ba, Zn, Re, Se, As, U, V and S in rocks throughout large parts of basin and derived stream sediments. In China average regional values for host shales of 350 g/t Mo, 150 g/t Ni, several wt % P2O5 and 5 to 22% organic matter. Organic content correlates with metal contents for Ni, Mo and Zn.

GEOPHYSICAL SIGNATURE: Electromagnetic surveys should detect pyrite horizons.

**OTHER EXPLORATION GUIDES**: Anoxic black shales in sub-basins within marginal basins. Chert or phosphate-rich sediments associated with a pyritiferous horizon. Barren, 5 mm to 1.5 cm thick, pyrite layers (occasionally geochemically anomalous) up to tens of metres above mineralized horizon.

### **ECONOMIC FACTORS**

**TYPICAL GRADE AND TONNAGE**: The thin sedimentary horizons (not economic) represent hundreds of thousands of tonnes grading in per cent values for at least two of Ni-Mo-Zn with significant PGEs. In China, Zunyi Mo mines yield ~ 1000 t per year averaging ~4 % Mo and containing up to 4 % Ni, 2 % Zn, 0.7 g/t Au, 50 g/t Ag, 0.3 g/t Pt, 0.4 g/t Pd and 30 g/t Ir. The ore is recovered from a number of small adits using labour-intensive mining methods.

**ECONOMIC LIMITATIONS**: In China the Mo-bearing phase is recovered by roasting followed by caustic leaching to produce ammonium molybdate. Molybedenum-bearing phases are fine grained and dispersed, therefore all ore (cutoff grade 4.1% Mo) is direct shipped to the smelter after crushing.

**IMPORTANCE**: Current world production from shale-hosted Ni-Mo-PGE mines is approximately 1000 t of ore with grades of approximately 4 % Mo. Known deposits of this type are too thin to be economic at current metal prices, except in special conditions. However, these deposits contain enormous tonnages of relatively high grade Ni, Mo, Zn and PGE which may be exploited if thicker deposits can be found, or a relevant new technology is developed.

### REFERENCES

**ACKNOWLEDGEMENTS**: Larry Hulbert of the Geological Survey of Canada introduced the senior author to this deposit type and provided many useful comments. Rob Carne of Archer, Cathro and Associates Limited reviewed a draft manuscript.

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## New Chloride Leaching Process for Gold Extraction from Refractory Ores

From certain gold ores, known as refractory gold ores, the gold cannot be fully recovered by direct cyanide leaching. A major cause of this is the occurrence of much of the gold in such ores in highly disseminated form in sulfide, arsenide and sometimes antimonide minerals. Three methods have been developed for treatment of such refractory ores, each of which involves breaking down the sulfide and arsenide minerals by oxidation before cyanide extraction.

In one method, the sulfide and related minerals containing the gold are recovered by flotation, and roasted. The residues (S- and As-free) are then leached with cyanide. In a second, recently developed process, the flotation concentrates are aerated in slurry form in a medium containing Sand As-oxidizing microorganisms before being leached with cyanide. In the third method, breakdown of the S- and As-minerals is achieved by oxidative treatment of the concentrate in an autoclave, followed by cyanide leaching.

Method 1 is gradually being abandoned because of environmental pollution problems, and new plants in the USA, South Africa, Australia and elsewhere tend to employ Method 2 or Method 3, which produce less severe problems of this type.

Over the past 10 years, however, there have been a number of publications which indicate that the direct oxidative chloride leaching of gold from refractory gold ores may prove to be an improvement on the methods now in use.

These new developments were reviewed by F K Letowski of the University of Witwaterstand in Johannesburg, at the International Conference on the Science and Technology of Gold at Hanau in Germany in June 1996 (1). They include:

### 1 The use of less volatile 'chloride ion carriers'

In the past, HCl has been used as the main chloride ion carrier in leaching solutions and HNO₃ (or Cl₂) as the oxidant. This has limited leaching temperatures because high partial pressures of HCl lead to loss of Cl⁻ from the leaching solution. Partial substitution of HCl by AlCl₃ or ZnCl₂ has been found to decrease dramatically these partial pressures of HCl, apparently as a result of the formation of Al and Zn chlorocomplexes. This has made the attainment of higher leaching temperatures and higher efficiencies possible. Decomposition of the refractory sulfides and arsenides occurs in the chloride leach solutions and their gold content made susceptible to cyanide leaching.

## 2 The regeneration, in process, of nitric acid used as oxidant

In the chloride leaching reaction, the nitric acid is reduced to NO, the conversion of which back to  $HNO_3$  is costly by conventional methods. A 'leaching in froth' (L/F) process has been devised, however, which has been successfully applied on a laboratory scale for mineral graphite purification (2), zinc concentrate processing (3) and more recently for gold extraction from refractory gold ores.

In this process, oxygen and oxides of nitrogen are the flotation carriers and a chloride solution containing  $HNO_3$  is the reactive medium in which the hydrophobic particles of the ore are suspended. In operation, the outer walls of the froth cells are quickly saturated with oxygen and oxides of nitrogen, entering them from both their sides.

Instantaneous hydrolysis and disproportionation of  $NO_2$  through intermediate species regenerates a substantial fraction of the HNO₃ fed to the system, which implies that the main oxidant in the process is oxygen.

Gold is recoverable by adsorption on carbon from the chloride leach solutions, which can be recycled.

The foundations appear to have been laid for a pilot plant evaluation of this process.

WS Rapson

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### Issues Concerning the Quality of Assay Results

### Phillip L Hellman¹

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"It is necessary that the assayer who is testing ore or metals should be prepared and instructed in all things necessary in assaying, and that he should close the doors of the room in which the assay furnace stands, lest anyone coming at an inopportune moment might disturb his thoughts when they are intent on the work." Agricola²

### Abstract

It should not be assumed that assays of samples collected during activities associated with mineral exploration, drilling and metallurgical testwork will be either accurate or precise. The onus of responsibility of monitoring quality should be on those who submit samples.

Assumptions of quality that depend upon, inter alia:

- certification or affiliation of the laboratory,
- use of internal standards by the laboratory,
- apparent accuracy of internal standards as reported by the laboratory,
- agreement between original assays and repeat assays by a second, third or subsequent laboratory,

• agreement between Calculated Heads and Head Assays in metallurgical testwork should not be made.

Numerous examples are presented highlighting problems such as:

- cross contamination of gold,
- incorrect assay technique leading to under-statement of gold,
- background analytical error resulting in delineation of waste as ore,
- assay bias induced by lithology and presence of coarse gold and
- incorrect calibrations.

These issues reinforce the need for the submission of control samples such as blanks and standards, as well as properly designed check assay campaigns, to:

- provide proof of accuracy and precision,
- provide early warning signals of assay problems,
- identify or eliminate the source of error when issues arise such as poor reconciliations (eg between resource model vs grade control, grade control vs mill),
- minimise risks associated with resource development.

### Introduction

The areas of exploration, resource delineation and mine development that come under the general responsibility of geologists and are subject to the greatest risk are, in decreasing importance³:

- resource estimation,
- · sampling and

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² Agricola (1556) pp 223-224

³ In the experience of Hellman & Schofield Pty Ltd

• assaying.

The potential for **resource estimates** to be seriously in error is enormous. It is not uncommon for different estimates using the same data to vary by over 30% in grade and/or in tonnes⁴. **Sampling bias** will directly impact on both resource estimates and on the discrimination between ore and waste in the production environment. Issues of **assay quality** affect all steps from exploration to production and include environmental monitoring. They also impinge directly on areas subject to the responsibility of metallurgists both at the Feasibility testing stage and also during production.

### Importance of Quality Control

A recent example⁵ of the importance of Quality Control comes from a gold mine. The mine geology department had been complaining that the resource model was over-estimating grade. A detailed inspection of several months of blast hole assay results from the mine laboratory showed few assays less than 0.5 g/t. The author then submitted a blank pulp and a standard pulp with known gold concentration to the laboratory.

The blank returned an assay of 0.6 g/t. It should have returned a "less-than-detection" value. The standard returned a value of 1.6 g/t and had a recommended value of 0.9 g/t. Ore zones were being defined on the basis of a 1.5 g/t cut-off. Thus whole "ore blocks" with a true grade of between 0.9 and 1.5 g/t were being mined on the assumption that they exceeded 1.5 g/t. The identification of assay bias in the mine laboratory ended a cycle of confusion and blame of the innocent. The view that Quality Control is the responsibility of the laboratory, and not also of those who submit the samples, is a common justification for not using control samples such as standards or blanks.

Mines that are generally the only source of cash generation for mining companies usually have no effective Quality Control systems for monitoring assay accuracy in their laboratories. Paradoxically, the accounting firms that audit these companies, however, have sophisticated systems, often ISO stamped, to audit the books and financial results.

In the production environment where there is ineffective quality control there is no basis for taking informed remedial action when problems anse. A typical example⁶ of how unsolved problems compound follows:

- the metallurgical department complains to the mine geology department the gold head grade is lower than predicted in the ore being delivered to the plant,
- the mine geology department replies that they are probably losing gold in the tails or in plant lock-up,
- the tanks are cleaned out to find the gold,
- the mine geologists point out that the hard ore that contains the good grade is not being processed,
- management becomes suspicious that gold is being stolen,
- a large batch of samples is sent to another laboratory
- extra security is placed in the gravity circuit,
- an "audit" of the laboratory commences,
- the mineralisation is regarded as being unique and hostile to resource estimation,

Good Project - Wrong Assays, Getting Sample Preparation and Assaying Right

⁴ For example, V Snowden (1994, p335) discusses Snowden Associates' re-estimation of the resources at the Girilambone copper deposit, NSW, Australia and reports a doubling of the reserve tonnage at a similar grade to previous estimates.

²Further discussed in Example 2, below.

⁶ Based on several real examples.

### Issues Concerning the Quality of Assay Results

- the results of the check assays are received but they are so different from the original results that there is a big debate about which laboratory is correct,
- the resource model is re-run to try to better control the spatial variability of the high grades with the same result as before,
- private investigators are called in to detect fraud,
- an audit of the grade-control procedures is commissioned,
- everyone is suspicious that the external consultant has delivered a defective resource model but because terms such as "sequential indicator kriging" or "uniform conditioning" are used (that few understand) they feel powerless to argue,
- management requests all resource estimation and ore blocking to be undertaken by polygonal methods
- an audit of the resource estimate commences,
- the new polygonal estimates clearly do not match reality,
- still there is no answer,

All of the above possibilities for explaining why the mill feed grade is below the predicted grade may be true, but without having credible assays of unbiased samples, there is no basis for coming to any firm conclusion as to what is the cause (s) of the problem. There is also no basis for quickly eliminating possible causes for the short-fall in gold production.⁷

### Terminology

In this paper the term "*standard*(s)" is used instead of the more technically correct term "*standard reference material*" (or "SRM"). Sometimes, the *term "house reference material*" (or "HRM") is used to refer to standards made for particular internal purposes by a company or laboratory. The term "*precision*" is used to denote the spread of assay data obtained from replicate determinations and is often used synonymously with "*relative standard deviation*." ("RSD" = standard deviation/mean) and "*coefficient of variation*" or "CV". These terms are often expressed as a percentage.

If commercial laboratories quote a precision, it only relates to a concentration level above some multiple of the "*Jower detection limit*" ("LD" or "LLD"). This multiple is usually 20 to 50 and refers to a level above which the precision is reasonably stable. The precision value usually refers to twice the RSD expressed as a percentage based on multiple analyses. A quoted precision of 10% for base-metal analysis and 15% for fire-assay gold are typical quoted levels. In reality these obviously depend upon many factors such as difficulty of matrix, element (it cannot be assumed that silver for example will have the same precision as copper), etc. Assays become more imprecise as the lower detection limit is approached. Precision levels from actual examples are provided in this paper.

The "*upper detection limit*" ("UD" or "ULD") is a level beyond which the analysis is recommended to be repeated by a more appropriate technique usually because the concentration is beyond the normal limits of calibration.

The term "*precision*"⁸ is also commonly applied to the spread of assay data as determined by duplicate pairs. This information is usually more readily available than replicate analyses of individual samples. Pairs of assay results, such as two determinations of gold from the same pulp, that comes out of a pulveriser provide estimates of one type of precision whereas an

⁷ It is the experience of H&S that, despite audits and reviews of operations and Feasibility Studies by high profile consulting groups, fundamental flaws may remain undiscovered.

⁸ The precision value that appears in the figures in this paper refers to  $\sigma(A-B)/(\sqrt{2} \times m(A))$  where A & B refer to original and repeat assays and m(A) is the mean of A.

original assay paired to a check assay of a split of the same pulp carried out by a different laboratory provides another type of precision. In these cases the absolute value of the difference between the two results divided by the pair mean⁹ is often used to estimate precision and is commonly expressed as a percentage. This has been referred to as the "Absolute Mean Percent Difference" or AMPD (eg Bumstead, 1984). The average of these values for a number of pairs is often reported.

AMPDs from duplicate determinations of pulps by different laboratories are recommended by Francois-Bongarcon et al (1996) to be better than 10% (ie the value returned from duplicate of assays of 1.000 and 0.905 g/t). This level increases to 20% when assays from coarse rejects¹⁰ are considered. These levels are somewhat arbitrary and depend upon the commodity of interest (eg silver typically returns higher AMPDs than base-metals) and concentration level. AMPDs from concentrations near the LLD will obviously be considerably higher than at higher concentrations.

"Accuracy" of phalyses or assays refers to closeness to the true value. Consistent and significant departure from accuracy is termed "bias" and can be expressed in a variety of ways such as an absolute difference or as a percentage. Thus an average value of 0.8 g/t from several assays of a standard with a "Recommended Value" (RV) of 1.0 g/t indicates a negative bias of 20%. Positive bias refers to results from unknowns that are consistently higher than accepted values. Bias is phly "relative" unless results from samples are referenced against results for which there is proof of accuracy.

Benchmark papers that discuss this terminology in relation to geochemical analysis include Howarth & Thompson (1976), Thompson & Howarth (1978), Thompson (1992) and Ramsey, et al (1992).

A number of actual examples from exploration, feasibility studies and grade control are described below. The Walker Lake data set has been used to depict a mining bench to illustrate the impact that sampling and assay errors may have on resource estimates and mining operations. This approach has been used here rather than by using actual sections or bench plans from operations or prospects to preserve anonymity.

The Walker Lake data consists of 78,000 data points from a digital elevation model and has been studied in getail by Isaaks and Srivastava (1989). The distribution of the "U" variable in the data set has close similarities with natural gold distributions (eg skewed shape, high coefficient of variation of 1.8). One hundredth of its value is used in this paper to achieve a mean "grade" of 2.66 g/t (with a standard deviation of 4.88, minimum of 0 and maximum of 95). Data points closest to the nodes of a 10 metre grid have been used as a reduced data set.

### Examples of Bias

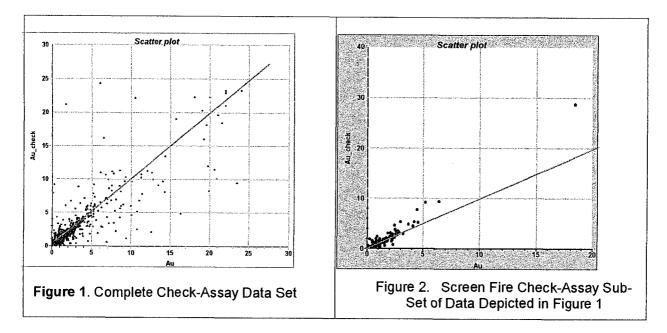
### Example 1. Low grades biased high and high grades biased low

Cause: Poor sample preparation procedures with samples containing coarse gold leading to cross contamination as well as the wrong choice of assay technique

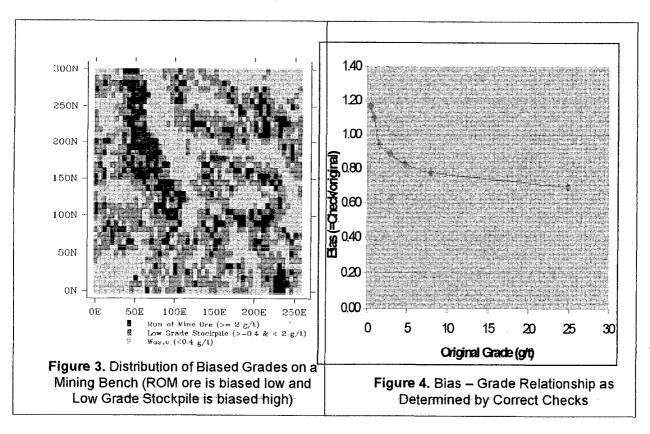
The evaluation of this deposit was flawed due to a choice of assay technique that proved to be imprecise and partial rather than near-total as would have been achieved by the use of fire assay. The interpretation of check assay results was made difficult by the presence of coarse gold resulting in a considerable scatter when original and check assays are plotted (Figure 1). The use of a sub-set of the check assays that had been performed by screen fire assays from a

⁹ie [assay1 – assay2]/[avgē] or as 200[assay1 – assay2]/[assay1 + assay2] (expressed as a percentage) ¹⁰ Eg RC chips

proven laboratory revealed an interesting feature depicted in Figure 2. The increasing bias with increasing grade is obvious.



Approximately one third of the check assays from the data set in Figure 2, however, were of low grade assays less than 0.5 g/t. There is little value in check assaying such a high proportion of low grade samples. An examination of the check assays that followed samples with high amounts of free gold indicated that low grade (less than 1 g/t) were being significantly contaminated with gold that had plated on the pulverising equipment. This caused the positive bias at low grades that are evident in Figure 4.



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The impact of the variable bias on the spatial distribution of grades is depicted in Figure 3 by using the bias-grade relationship of Figure 4.

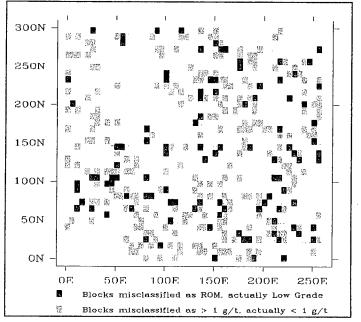
The presence of coarse gold requires a careful consideration of sampling and assaying protocols. The use of large bowl pulverisers to obtain the largest possible fine sample before splitting off the sample for assaying is commendable. Even this process, however, may induce bias (Johansen, 1997) in mineralisation containing coarse gold such as is found in Bendigo, Victoria, Australia. Scoops taken from the top of the mound of pulp in the pulveriser for conventional fire assaying having an average 30% less than gold assays determined by either cyanidation of the whole pulp or by screen fire assaying of a large sample. In this case, assaying the whole sample effectively eliminates any possibility of bias resulting from "extraction error". The low bias of the fire assays, however, had not arisen due their low (50 grams) sample weights, *per se*, compared to the larger weights employed by the other techniques but rather because the samples were intrinsically biased due to segregation of gold particles in the pulveriser.

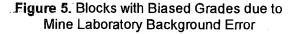
The situation is not helped by laboratories taking short-cuts in their screen-fire methodologies. The author has found it necessary to specify that the sieve cloth used in screening be assayed. This was once accepted practice. It is also necessary to specify that the wash (eg felspar) used between samples to clean the pulveriser bowl be assayed to weight-average with the unknown in order to prevent assays being diminished by gold plating onto the discarded wash. Melnbardis (1991) documented the loss of up to 50% of gold on to disk pulveriser plates and 15% on to ring pulverisers from 1/8 inch crushed samples containing visible gold.

### Example 2. All grades biased high

Cause:

Assay error arising from poor checking of standard solutions





This example was referred to in the Introduction (above). 24% of the tonnage with a true grade less than 1.5 g/t has been mis-classified as ROM (blocks marked with filled squares, Figure 5). 22% of the tonnage with a true grade less than 1.0 g/t has been mis-classified as having a grade

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exceeding 1.0 g/t. As with many reconciliation issues (resource or grade control vs mill) the identification of the major component of the problem was hindered by the presence of both assay bias and also sampling bias. The most likely explanation for the constant "background error" is the detenoration of standard solutions used to calibrate the AAS readings.

### Example 3. Assay bias exacerbated by lithology and presence of coarse gold

Cause: Presence of clay causing dispersion problems and solubility problems of gold grains

Discrepancies between grade prediction from mine grade control procedures and backcalculated mill head grades at a gold mine with a significant level of gravity-recoverable gold led to a number of check assaying campaigns. The check assay results, however, were equivocal when doubt was cast on the veracity of the assays due to serious data handling errors and an inconsistent explanation for some of the assay discrepancies. The absence of included standards did not help establish which laboratory should be believed.

This example was interesting because the cyanide-soluble assays from the grade control samples were positively biased (of the order of 10%) compared to a number of checks by aqua regia and a smaller number of checks by fire assay. The mineralisation, however, has no known characteristics that should prove problematical for aqua regia (eg presence of electrum, high sulphide contents, carbonate, etc). Intuitively, the cyanide results should have been lower than the aqua regia assays: Coincidentally¹¹, the magnitude of the bias between the cyanide results and the aqua regia corresponded to the mismatch between milled grade and grade control predicted grade.

The mine laboratory used "off-the-shelf" standard pulps that had an uncertain relevance to the mineralisation sp it was felt that the quality of the assaying should be re-investigated. The following course of action was taken in collaboration with mine staff:

- 1. Several hundred kilograms from a range of rock types and grades were comminuted, blended and homogenised.
- 2. A set (10 pulps in each set) of approximately 70 gram samples were dispatched to two laboratories for fire assay (30g) of gold in duplicate, a third set of 20 pulps (with included standards) were sent for analysis by neutron activation to establish homogeneity.

· · · · · · · · · · · · · · · · · · ·	As	saying of (	Candidate S	Standards		
Standard	Lab 1 (n=20)		Lab 2 (n=20)		NAA Lab (n=20)	
	Mean	CV%	Mean	CV%	Mean	CV%
LG	1.19	4.3	1.39	2.2	1.24	1.3
MG	2.59	7.0	3.06	3.3	2.92	1.6
HG	8.70	3.5	10.17	3.1	9.14	1.3

3. The results from all three laboratories were examined:

 Table 1: Homogeneity check assaying of standards

The variation between the three laboratories in the author's experience is typical with an average 17% difference between the lowest and the highest average for each standard. This variation is, however, unacceptable by any reasonable criteria. The two laboratories that returned the lowest and highest value have good reputations and were advised that the samples represent potential standards so it is assumed that particular care was taken with their assay.

¹¹⁻This remained a coincidence

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Assaying of Certified Standards					
Standard	Recommended Value (g/t)	NAA Result (N = 3)			
2PA	0.85	0.85			
7PA	3.00	3.00			
10P	6.81	6.82			
6PA	1.65	1.66			

The results for the certified standards supplied to the NAA laboratory are:

Table 2: Assaying of included standards by NAA

The results in Table 2 are within 1% of Recommended Values and indicate that the values from the NAA laboratory in Table 1 can be used with confidence.

- 4. The three standards were then provided to the mine geology department as large samples (~800 g) to use with the large grade control samples for cyanide soluble gold and as smaller samples (100 g) for use as controls for conventional assaying by fire assay and aqua regia.
- 5. Blank pulps and coarse blanks were also prepared.
- 6. To resolve the historic and ongoing assay discrepancies a retrospective check assay program commenced using approximately 200 previously assayed residue pulps in combination with the newly prepared standards and blanks.
- 7. Several coarse gold standards were made by using high purity separates from the gravity plant. These were weighed and added to selected standard samples. Coarse blanks (several grams) prepared to mimic typical +106 micron fractions obtained during screening (for screen fire assay) were also added to the standards that had spiked gold. The coarse blank was also added to several blank pulps submitted for screen fire assaying.
- 8. The prepared batch was submitted to a different laboratory from those tabulated above for cyanide-soluble gold analysis and screen fire assay (~800 grams, 150 mesh, two 30 gram fire assay undersize and fire assay of oversize, sieve cloth assayed). The "whole" submitted sample was assayed.

Standards and Blanks						
Standard (g/t)	Recommended Value (g/t)	Assay Method	Mean	CV%	Ň	
Blank	<0.01	SFA	0.03		4	
Blank	<0.01	CN	0.03		4	
				<u></u>		
LG	1.24	SFA	1.25	6.1	7	
MG	2.92	SFA	2.80	4.1	6	
HG	9.14	SFA	8.98	1.87	7	
LG	1.24	CN	1.25	0.7	7	
MG	2.92	CN	2.70	12.2	6	
HG	9.14	CN	8.82	1.95	5	

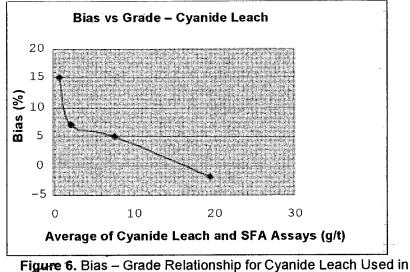
9. The results of the control samples were examined:

Table 3: Summary statistics for the assaying of standards

These results compare well with recommended values. Although the laboratory was not informed that the batch contained standards, it performed better than the two other laboratories whose results are reported in Table 1. The cyanide-soluble results are lower than the RVs for the MG and HG standards (by 92% & 97% respectively).

### issues Concerning the Quality of Assay Results

- 10. The results from the spiked samples were useful despite potential inaccuracies in weighing in small amounts of physical gold into the standard samples. The CN-soluble results were consistently low (average of 78% of predicted values) whilst the SFA results were, on average, within 10% of the predicted values. The average predicted grade for the spiked samples assayed by SFA is 17.4 g/t and the average for the CN-soluble assays is 13.5 g/t. Thus at higher grades, in the presence of coarse gold, there is evidence that the CN-soluble grades are significantly low.
- 11. An examination of the assay results of the unknowns commenced. The original pulps of the samples had previously been assayed twice at different times using the mine laboratory's CN-soluble methodology. Thus for each sample there were two original assays. There were also two new assays a screen fire assay and a CN-soluble assay, by the check laboratory. It quickly became clear that one set of the earlier CN-soluble results were biased high by an overall 6% compared to the check laboratory's CN results. The other set had a close agreement with the check laboratory. When the grade ranges were considered, however, by sub-setting the grades into intervals from 0-1, 1-5, 5-10 and 10-50 g/t a positive bias at low grades and a negative bias at higher grades became apparent (Figure 6):



Assaying of Grade Control Samples.

This result was consistent with previously acquired internal check assay data.

12. The reason for the bias grade relationships became clear when the data was split on the basis of lithology. The lithologies containing the highest amounts of layer silicates had the highest positive biases suggesting that problems of dispersion in the pregnant solution were contributing to the problem. The check laboratory commented that the dispersion problems were extreme for some of the samples with settling of the solutions for hours required in some cases.

The presence of high clay contents is a well known contributor to high bias for both aqua regia and cyanide gold determinations.

The procedures outlined above for preparation of standards have proved effective over many years. Unless every batch of samples submitted to a laboratory contains a standard sample there is no means to determine the accuracy of the results. This applies to stream sediments, BLEG samples, soils, ferruginous Jags, rock chips, drill core, reverse circulation

chips, grade control samples, waters, metallurgical samples and any other samples. The common assumption that assay results are in some way guaranteed because the laboratory uses its own standards is clearly unsupported and unjustified .

Useful papers describing the use and preparation of standards are James and Radford (1988) and Davis and Windham (1995).

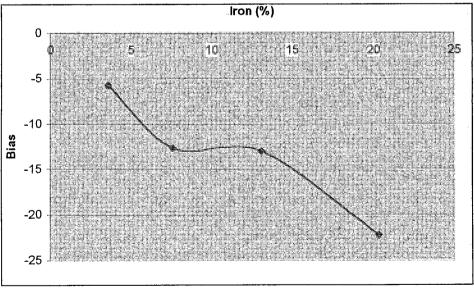
# Example 4. Low bias in copper-rich but high iron samples from Girilambone, NSW.

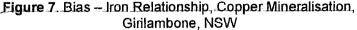
Cause: Incorrect gas mixture resulting in inadequate temperature in flame for AAS determinations.

The evaluation¹² that led to the successful development of the Girilambone Copper Mine, N.S.W. took place from 1989 to 1992. As part of the drilling program a number of pulps were prepared from the actual mineralisation and were distributed to ten Australian laboratories to check the copper content of oxide and chalcocite samples with a variable Fe content. It became immediately apparent that the results formed two populations. Seven laboratories agreed on a lower set of Cu values, three gave results variably higher.

The view that the majority is likely to be right is a common¹³ but flawed approach when dealing with check assays. In this case the majority was wrong and the exercise resulted in the identification of a poor choice of AAS gas mixture resulting in an incorrect flame temperature by the majority of the laboratories. A re-assay program of samples with high Fe¹⁴ contents (~> 5% Fe) and low copper contents (~> 0.3 - < 1.5% Cu) resulted in an average 15.4% lift in copper grade of the re-assayed samples. The relationship between bias and iron content is depicted in Figure 7.

An earlier check assay program had not revealed any bias but had supported the original laboratory's results. Such is the danger of check assay programs uncontrolled by appropriate standard pulps.





¹² By Nord Resources (Pacific) Pty Ltd

¹³ Not only in the mining industry but in most areas of human endeavour. A recent example of this concerned results for a nickel laterite from three laboratories two of which agreed and the third differed by reporting lower concentrations of Ni and Mg. The results from the third were unjustifiably rejected.

concentrations of Ni and Mg. The results from the third were unjustifiably rejected. ¹⁴ The identification of high iron samples for re-assay was made possible by the diligent, detailed and quantitative geological logging that was available as a computerised database.

### Example 5. Fire assay with AAS finish

Cause: Incorrectly calibrated AAS procedure

Five standards with various grades were made up of Lebong Tandai (Bengkulu Province, Sumatera, Indonesia) ore in the early 1980s. These were submitted with underground channel samples and drill core to an Australian laboratory for fire assay (followed by AAS) gold determinations. The results from submitted standards in numerous batches indicated a 15% tow bias. A check laboratory with included standards was also used. A simple scatter plot of gold concentration of the two laboratories with the results of the standards was sufficient to convince the laboratory to re-assay, at their expense, all samples from the previously assayed batches. The use of included standards prevented arguments between the two laboratories as to which laboratory was correct.

The original laboratory maintained that the problem arose from the AAS equipment though no other laboratory had this problem with the same equipment. It appears that a fundamental problem existed either with standardisation or with the actual fire assay technique. This laboratory was subsequently sold to another group. If that low bias carried through to other projects how many projects may have been similarly undervalued?

## **Examples of Incorrect Assay Techniques**

#### Example 6. Disappearance of grade

Cause: Unconvincing explanation from the branch laboratory that "we forgot to add the acid"—the wrong technique was used.

The spectacular example of a whole batch of silver results reporting low as is depicted in Figure 8 was discovered by the routine use of blind standards. The curious feature of this example is that lead and zinc assays performed in the same batch as the silver assays showed close to expected values. Rather than having discovered a new Ag-poor Pb/Zn-rich ore type the results from the standards demonstrated that the silver assays had considerably been undervalued. The laboratory (a branch laboratory of a major international minerals analytical company) initially indicated that the results were as reported. The standard results were then shown to the laboratory which then conceded that a mistake had been made. The forthcoming explanation of forgetting to add acid was, however, less than convincing due to the fact that the Pb and Zn assays are derived from the same solution.

The check assays for Pb are, on average, 8% lower than the originals (Figure 9) and illustrate a convincing uniform bias. The Zn repeats show a close agreement with the originals.

The samples in this example constitute approximately 170 metres of drilled intervals from two holes. If undiscovered, the low grades (mean of 3 g/t) in the original batch would have resulted in a significantly understated resource estimate compared to the re-assayed batch (mean of 47 g/t). In a preliminary exploration setting the low results could conceivably have led to the down-grading of a promising prospect.

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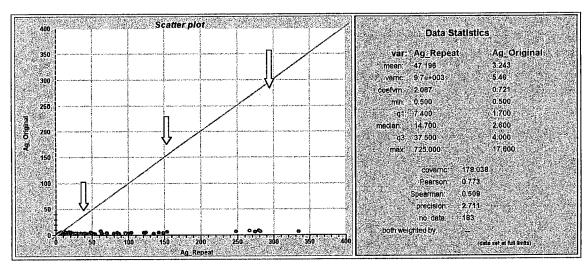


Figure 8. Original vs Repeat Silver Assays – Entire Batch of Results (arrows mark position of standards)

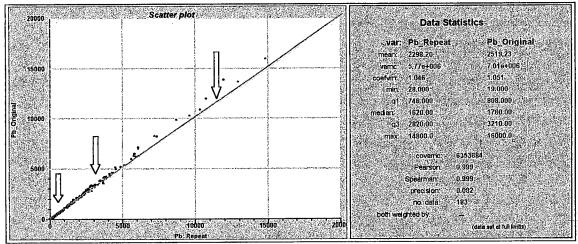
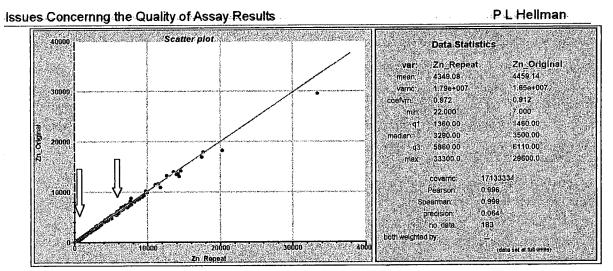


Figure 9. Original vs Repeat Lead Assays – Entire Batch of Results (arrows mark standards)



**Figure 10.** Original vs Repeat Zinc Assays – Entire Batch of Results (arrows mark standards)

A more considered explanation of the disappearance of the silver in the original batch came from the laboratory where the actual analysis was performed. The branch laboratory acted as a receiving depot and forwarded the pulps to the main laboratory for analysis. A partial leach was stated to have been mistakenly used instead of a multi-acid digestion that would have involved HCI, HNO3, HCID4 and HF resulting in a "total" result. This second explanation is still hard to understand in view of the "partial" results for Pb and Zn having higher mean results than the repeats.

## Example 7. Inappropriate ICP technique for iron-rich laterite samples

Cause: Inappropriate assay technique that failed to report As and Sb resulting from iron-rich nature of matrix

An example of the complete failure of an ICP technique for analysis of Sb and biased results for As comes from a laterite sampling survey in West Africa. Sb results from all the initial batches of results for surface laterite samples were reported by the laboratory as being "less-than-detection" by a large sample aqua regia technique. Prior to selecting the technique the laboratory had been contacted to check the appropriateness of the particular technique.

Checking by INAA showed these results to be clearly in error with the true results returning values in excess of 10 times the detection limit. Repeat analyses by the same laboratory using a larger ratio of solution to sample resulted in more acceptable results.

## Examples of Cross Contamination

## Example 8. Cross contamination of an entire batch of samples

Cause: Previously assayed metallurgical test products and failure by client and laboratory to assay coarse blanks

The formative experience by the author early in his career of a whole batch of surface rock chips having suffered irreversible laboratory contamination from coarse gold originating from previously assayed metallurgical samples in the laboratory has left a lasting memory. With such

exciting results there was keen interest in following15 up the initial samples. This led to a new batch of submitted samples returning values less than detection.

### Example 9. Cross contamination tails

Cause: High amounts of coarse gold reporting to oversize in screened assays

An examination of successive assays following high grade intercepts was carried out to test the extent of cross contamination that may have resulted during the fine pulverising stage. Two examples are provided in Figure 11.

¹⁵ One week of field-work in mid summer

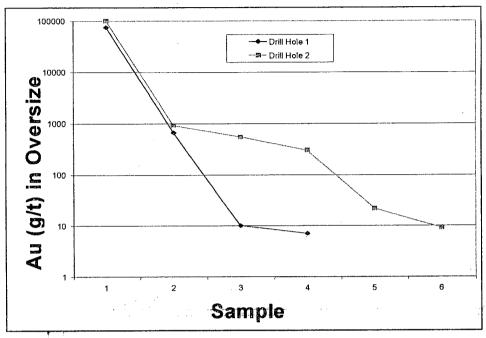


Figure 11. Diminution of grades in screened oversize following a high grade intercept.

The fall off in grade following the intervals with exceptionally high gold in the coarse fraction is a testimony to the ability of gold to plate on to pulverising equipment and carry-over to subsequent samples. Evidence for such effects can be found by closely examining the behaviour of gold grades following high grade intervals either by assessing the amount of gold that reports to the oversize in the gase of screened assays (eg screen fire assays) or by looking for decay-type diminution of grade.

Coarse blanks (eg waste gravel, coral, limestone, etc) should be submitted as anonymous samples especially after suspected high grade mineralisation to test for cross contamination. Cross contamination in samples containing coarse gold may be severe and may have the effect in resource evaluation drilling of falsely enhancing lower grades to levels above cutoffs of interest.

A useful practice is to find out how many pulverisers are being used in the laboratory and what order the samples are being processed. The same number of coarse blanks should then be placed at the start of every submitted batch. This ensures that, if the previously prepared batch at the laboratory contained unusually high concentrations of elements (eg Mo, Au) that have a tendency to plate onto pulverisers, early detection of the problem is likely.

A recent inspection of a laboratory revealed the selective non-use of inter sample cleaning agents (such as quartz wash). This was justified by the laboratory manager on the basis of the visual impression by laboratory assistants that the pulveriser bowls appear clean. It is impossible, however, to visually detect gold plated onto pulverising equipment that may contribute parts per million cross contamination.

Cross contamination of gold in the context of resource estimation will result in exaggerated mineralised intercepts leading to the impression that mineralised widths are wider than reality. This will, in tum, affect geostatistical studies of spatial continuity resulting in artificially induced

measures of continuity. Blanks cost nothing and are easily obtainable and may provide indispensable information regarding the quality of sample preparation.

Blanks that by-pass the sample preparation system are also valuable. These are typically prepulverised material (eg silica flour or residue pulps) and yield information relating to background analytical levels and the possibility of cross contamination by virtue of solution carry-over or other sources of non-sample-preparation-type contamination.

### Example of Re-Calibration

Cause:

# Example 10. Discrepancy between Zn assays by different techniques from the same laboratory

Incorrect calculation of assays due to incorrect calibration

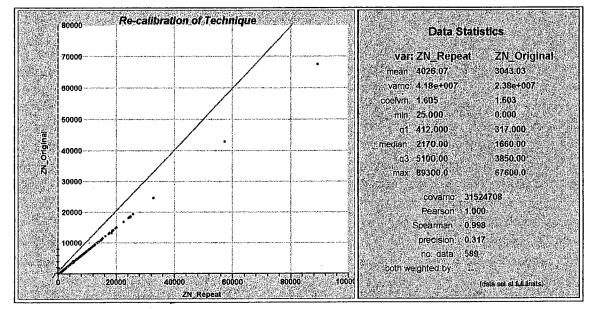


Figure 12. Effect of Recalibration upon Repeat Assays

This is an unusual example and was discovered by standards submitted by the client being used to document discrepancies between assays based on different methods. The result was pleasing with an approximate lift by 33% of zinc grades.

## Importance of Detection Limits

# Example 11. Illustration of the wisdom of taking note of laboratory's guidelines for assay method's upper limits

Many laboratory Schedules of Services quote Upper Detection Limits ("UD") in addition to Lower Detection Limits ("LD"). These should be taken seriously as the example depicted in Figure 13 illustrates. In this case the laboratory's Schedule of Services specifies a LD between 2-5 ppm and an UD of approximately 80 - 120¹⁶ ppm.

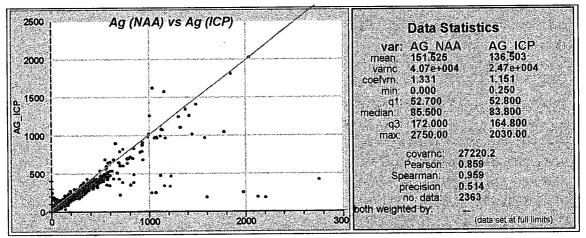


Figure 13. Scatter Plot of Silver by Neutron Activation (x axis) vs ICP

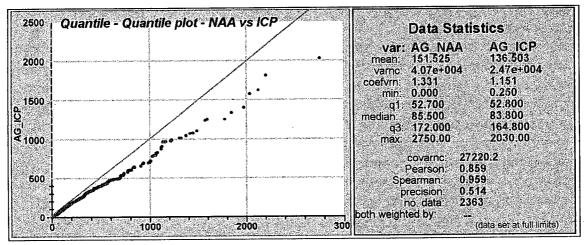


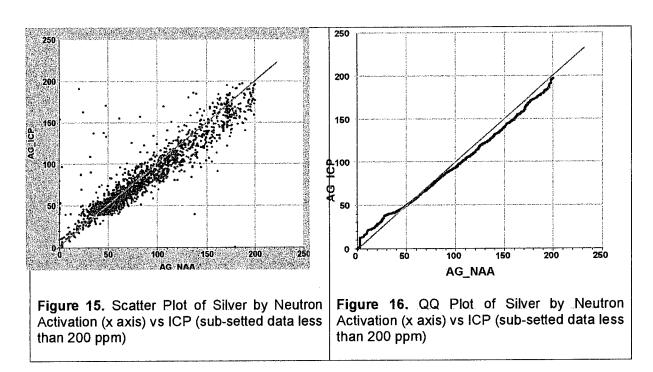
Figure 14. QQ Plot of Silver by Neutron Activation (x axis) vs ICP

Inspection of a scatter plot of the data at lower concentrations (Figure 15) shows a trend of negative bias of the ICP results compared to the NAA results with increasing grade. The QQ plot highlights this more distinctly (Figure 16) and indicates that the quoted UD is in fact too high, on the basis that the NAA results are more accurate at these levels and that the ICP results deteriorate from about 75 ppm rather than the higher UD indicated by the laboratory. This assumption is supported by included silver standards that demonstrated the accuracy of NAA at

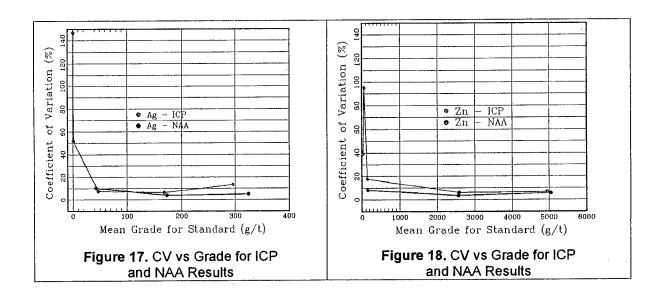
¹⁶ Actual guoted detection limits are not provided in order to preserve anonymity.

levels above 100 g/t. As indicated by Figure 16 there is a positive bias in the ICP results at grades below  $\sim$ 50 g/t compared to NAA. This accords with results from a standard with a RV of 48 ppm for which the ICP results average 48 and the NAA results average 41. This bias is reversed at grades in excess of  $\sim$ 70 g/t Ag.

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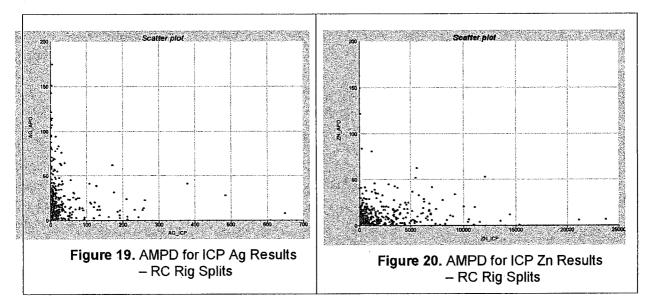


Further evidence for the performance of the ICP and NAA techniques at various concentration levels can usefully be obtained by a consideration of the variation of precision with concentration level. Results from two blanks (a pulp and a coarse blank) as well as three standards are available from numerous batches assayed over a period of two years. In addition to these, results from duplicate pulps and duplicate rig splits (in the case of reverse circulation drill samples) are also available. The relationship between CV and concentration is provided in Figure 17 and Figure 18 for the two methods for silver and zinc. The asymptotic relationship between the two is typical and is a reflection of the rapid deterioration of precision at low concentration levels and only a modest gain in precision at higher levels. The deterioration in the ICP results for silver in Figure 17 in the standard at the ~300 ppm level is consistent with the bias at these levels noted above and reflects the instability of the method above the UD. In contrast, the precision of zinc remains stable at elevated concentrations (Figure 18).



Good Project - Wrong Assays Getting Sample Preparation and Assaying Right.

The results from duplicate rig splits analysed in various batches over a period of two years are provided in Figure 19 and Figure 20.



It is immediately obvious that the comparison of duplicate pairs based on different splits of coarse RC chips introduces a significant deterioration in precision as illustrated by the average AMPD for Ag values over 20 g/t being 19.8% and that of Zn being 12.4%. The CVs from the standards for these two elements are illustrated in Figure 17 and Figure 18. The poorer precision is due to the introduction of a sampling error which was minimal in the case of the results based on splits of finely pulverised standards. This illustrates the importance of ensuing that discussions of analytical precision are based on samples that have minimal sampling error.

### Multiple Problems Within a Laboratory

# Example 12. Poor precision of low level gold determinations using aqua regia digestion

Cause: 1ncorrect calibration at gold levels over 100 ppb and no corrections used for actual sample weights in cases when low weight samples were submitted.

Precise low level gold determinations are required for geochemical exploration techniques that utilise media such as stream sediments, soils and laterite. Aqua regia¹⁷ digestion followed by AAS is ideally suited to these requirements by virtue of its lower cost compared to fire assay and its ability to achieve low limits of detection that are usually quoted at the part-per-billion level. The media quoted above are usually oxidised and lack high levels of problematical components such as sulphides and carbonate that preclude the technique as a general method for resource delineation. Aqua regia assaying for resource-type levels of interest invariably report lower average results with greater variability when compared with "total" techniques such as neutron activation or fire assay. At low levels, however, aqua regia may achieve good precision.

The results depicted in Figure 21 were a disaster to both the laboratory and client. Suitable standards had been routinely submitted to the laboratory along with the soil and stream sediment samples. The client had assumed, however, that there was something wrong with the submitted standard after having been reassured by the laboratory that the internal laboratory standards

¹⁷ For a discussion of its relative performance refer to Hall et al (1989, 1990)

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were effective monitors of accuracy and thus guaranteed acceptable quality of assaying. The internal standards used by the laboratory showed no bias.

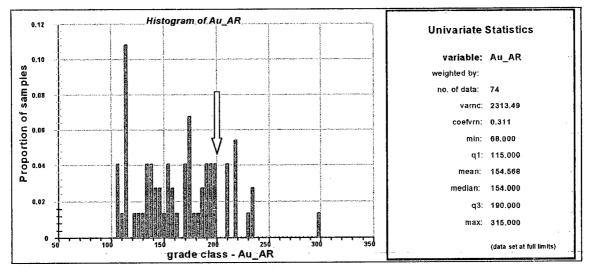


Figure 21. Aqua regia assays for gold of low level gold standard (same standard as in Figure 22)

H&S had been responsible for setting up the original sampling and QC system and were approached to resolve the situation. The first step was to submit approximately 15 splits of the same standard sample to three laboratories for replicate assaying by NAA, aqua regia and fire assay. A histogram of the NAA results is provided in Figure 22. The coefficient of variation (CV) is 2.3% which is an excellent precision and could only be achieved if the original sample splits reflected a homogeneous parent. Furthermore, the mean of 195 is within 1.5% of the Recommended Value of 200 ppb. The CV of the same standard depicted in

Figure 21 is 31.1%, approximately 20 times the NAA result¹⁸. The mean of 155 ppb would be acceptable in the context of discovering anomalies provided some semblance of acceptable precision was achieved.

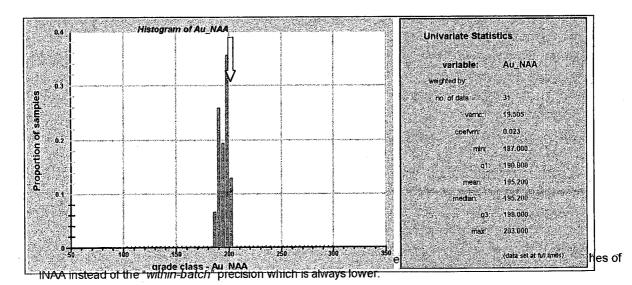


Figure 22. Homogeneity check by INAA of low level gold standard with Recommended Value of 200 ppb (marked by arrow)

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The homogeneity tests using aqua regia and fire assay by an independent laboratory showed CVs of 3% and 4%, respectively. These NAA, AR and FA results prompted the laboratory to investigate the spurce of the poor precision. This led to the discovery of two problems:

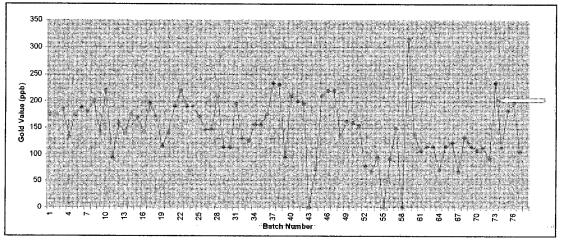
*Firstly*, the results of samples with weights less than 30 grams had a low bias in proportion to the sample weight (eg a 10 gram sample had one third of the correct concentration). The use of small (ie less than 30 grams) samples of –200# hand sieved stream sediments may be common in samples from streams of high relief (due to the rapid loss of fine silt due to high energy drainages). *Secondly*, since the purchase of a new AAS unit, suppression of results by 30% occurred due to incorrect calibration at gold levels above approximately 100 ppb.

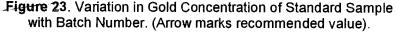
Actual original and repeat gold values (ppb) in pairs of samples analysed by the same laboratory are:

	30 grams	30 grams	<30 gram	<30 gram
Original	130	108		.28
Repeat	217	180	270	280

(Weights refer to original submitted sample weight)

A plot of gold concentration vs Batch Number is provided in Figure 23. These types of plots are useful in highlighting deterioration of quality with time, bad batches within discrete time intervals and overall performance. It is clear that the quoted precision of 10% for the technique was never achieved over the entire period.





This example demonstrates the inadequacy of relying on the performance of a laboratory's own internal standards as a guide to assaying accuracy. In this case a false sense of security would have resulted due to a fixed weight of 30 grams being used by the laboratory for the standards. Many of the unknowns, however, had weights less than 30 grams and therefore had understated grades due to the lack of the weight correction factor.

The laboratory was obliged to have over 1000 exploration samples re-assayed and, due to the lack of confidence of the client in the laboratory, an independent laboratory was, justifiably, requested. The results of the re-assays are depicted in Figure 24, Figure 25 and Figure 26. Bias is particularly pronounced in the soil re-assays at levels above about 75 ppb. Better agreement in the –200 mesh stream sediments is presumably related to the "cleaner" matrix and particulate nature of the gold in the sediments compared to the soils.

The -80 stream sediments (Figure 26) show poor agreement due both to the poor quality of the original assays and also to the sampling errors associated with particulate gold. The high sampling error associated with the -80 mesh sediments is reflected in an AMPD of 47%, the -200 mesh sediments have an AMPD of 16% and the soils an AMPD of 27% (all for values over 20 ppb).

The cost of the laboratory's errors is not simply confined to the cost of re-assaying all the samples which in this case was borne by the original laboratory. The poor precision of the original analyses resulted in considerable mis-classification of geochemical anomalies. Imprecisely understated stream sediment results will result in the down grade of potentially large drainage basin areas (to several square kilometres). The occasional artificial anomaly (see Figure 23) causes the unnecessary follow-up of falsely high results. The combined costs of helicopter hire and logistical support to follow-up-laboratory-induced anomalies is considerable.

The detection of bias and poor precision of either original or check assays is difficult to impossible in samples that have high sampling errors due to particulate gold. In these cases, inserted standards are the only means by which quality of assaying can be unambiguously assessed.

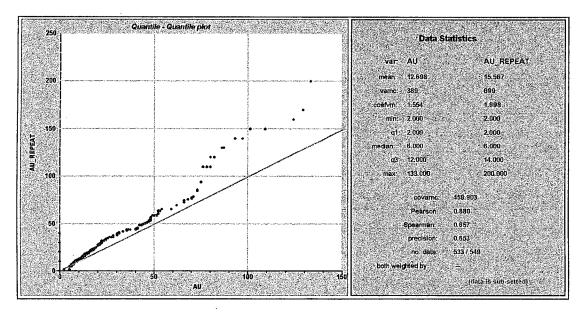


Figure 24. QQ Plot of Original vs Repeat Gold Analyses in Soils.

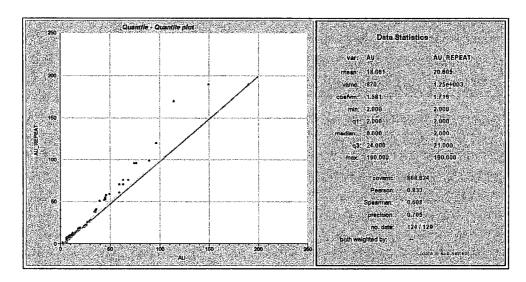
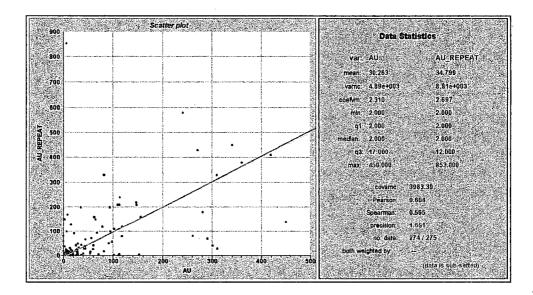


Figure 25. QQ Plot of Original vs Repeat Gold Analyses in -200 Mesh Stream Sediments.



**Figure 26.** Scatter Plot of Original vs Repeat Gold Analyses in –80 Mesh Stream Sediments.

## Assaying of Metallurgical Samples

# Example 13. Interpretation of assay results of metallurgical samples by multiple laboratories using typical criteria

**Cause:** Reliance on agreement between Calculated Heads and Actual Heads as an indicator of accuracy without having submitted standards.

Interpretation of metallurgical results is often difficult as a consequence of the absence of effective QC protocols. Metallurgical test products are susceptible to problems of precision and accuracy resulting from the partitioning nature of the actual testwork which produces extremes in

element concentrations. Inclusion of appropriate control samples is mandatory in such work due to the high cost of the testwork and significance of the results to the evaluation of mineral projects.

Samples were submitted to five laboratories. The results in Table 4 (below) concern silver and are based on the same metallurgical sample and come from two of the five laboratories:

Assay Results of Metallurgical Sample from Laboratory 1			
	Weight (%)	Ag (ppm)	Ag (%)
Product 1	0.49	3900	33.9
Product 2	0.65	2500	28.7
Product 3	0.66	340	4.0
Product 4	4.56	35	2.8
Product 5	1.62	100	2.9
Tail	92.02	17	27.7
Total	100.0		100.0
Calc Head		56.6	
Actual Head	······································	199	

Assay Results of Metallurgical Sample from Laboratory 2			
	Weight (%)	Ag (ppm)	Ag (%)
Product 1	0.49	35125	78.8
Product 2	0.65	3115	9.2
Product 3	0.66	303	0.9
Product 4	4.56	33	0.7
Product 5	1.62	. 94	0.7
Tail	92.02	23	9.6
Total	100.0		99.90
Calc Head		219	
Actual Head	· .	207	·····

Table 4: Assay results of the same metallurgical products by two laboratories

Assays for the tails by five laboratories varied from 14 to 27 ppm and for Product 1 varied from 2800 to 37,700 ppm. Excluding Laboratory 1, assays of Ag for the tails varied from 18 to 27 ppm and for Product 1 from 32,300 to 37,700 ppm.

Results for internal standards assayed in the same batches as the metallurgical samples were reported by the laboratories. Laboratory 1 reported these results:

	Recommended Value (ppm)	Reported Value (ppm)
Standard 1	138	138
Standard 2	626	600
Standard 3	70	68

The apparent good performance of these results is inconsistent with the total failure of the laboratory's performance with respect to the samples of interest. This illustrates the inadequacy of using laboratories' own internal standard data as a monitor of accuracy.

Agreement between calculated heads and actual heads is a common method used to validate assays in metallurgical tests. It is easy to demonstrate that the introduction of a variable bias (eg

assays at high levels too low and assays at low levels too high) will produce a close agreement (within 5%) between these two values. The results from Table 4 have been used to generate a set of biased assays from a hypothetical laboratory:

Hypothetical Laboratory 3				
		Factored	Bias	
	Weight (%)	Ag (ppm)	Factor	Ag (%)
Product 1	0.49	30,000	0.854	74.7
Product 2	0.65	2660	0.854	8.1
Product 3	0.66	333	1.10	1.12
Product 4	4.56	39.6	1.20	0.92
Product 5	1.62	105	1.15	0.86
Tail	92.02	30.6	1.35	14.3
Total	100.0			100.0
Calc Head		198		
Actual Head		207		

Table 5: Artificially introduced variable bias to assay results

The agreement between the Calculated and Actual Heads for the artificially biased results is actually better than the real results provided in Table 4. This feature may lead to the erroneous conclusion that the biased results given in Table 5 are superior to to the real results in Table 4.

The early detection of bias without the time consuming submission of residue samples to check laboratories is only possible by the use of control samples such as internal standards and blanks. The consequences of having no control samples may include the following:

- discrepancies between Calculated vs Actual Heads being blamed on sampling problems such as "spotty" gold rather than assay error,
- incorrect estimation of metallurgical recoveries leading to over- or under-valuation of the project,
- extra expense associated with numerous check assays that may produce equivocal results,
- masking of assay bias by poor precision.

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