The Hydrometallurgical Treatment of Base Metal Sulfide Concentrates Containing Precious and Platinum Group Metals

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Background

Platinum group metals (PGM's)

- platinum, palladium, rhodium, ruthenium, osmium and iridium
- occur with base metal sulfides of copper, nickel and cobalt
- gold is frequent found in association

Conventional Processing of PGM's

- Flotation of a sulfide concentrate
- Smelting to separate iron (slag) and sulfur (off gas), resulting in a PGM rich matte
- Matte slow cooling of sulfur deficient matte produces magnetic PGM concentrate
- Remaining base metal sulfides are pressure leached to produce a residue enriched in PGM's
- Concentrated PGM values are processed through a PGM refinery (HCl/Cl_2) to produce commercial purity metal products

Special Cases Where Conventional Processing is Not Applicable

Lean Concentrates

- Dilute PGM values limits the use of the conventional process

Dirty Concentrates

- Smelting has a limited tolerance for deleterious elements such as Bi, As, Se, Te, Hg.

High Chromium or Magnesium Concentrates

- Chromium and magnesium have reduced solubility in smelting slags at conventional temperatures.

- Special furnace designs required.

- South African concentrates (UG-2) are often very high in Cr content.

Other Options

- Direct oxidative pressure leaching of the concentrate to dissolve the base metals.
- Gold and the PGM's remain in the pressure leach residue.
- Iron and gangue minerals remain in residue
- Dilute PGM concentrations in residue
- HCl/Cl_2 leach process for PGM's not applicable.

Polymet Mining Company

Northmet Property (formerly called Dunka Road) in Minnesota, USA, owned by PolyMet Mining Corp. of Denver, CO.

500 – 1000 Million Tonnes of Ore Containing
~ 0.43% Cu, 0.12% Ni, ~0.009% Co
0.08 g/t Pt, 0.36 g/t Pd, 0.06 g/t Au

Toll smelting of nickel/copper concentrates containing PGM's does not produce acceptable returns.

Construction of a smelter/PGM plant in Minnesota is not economically or environmentally attractive.

Technical breakthrough – the PLATSOL® Process

The rights to the PLATSOL® Process are held by International PGM Technologies

Bulk Concentration Results – Base Metals

	Element				
	Cu %	Ni %	Co %	Fe %	S^{2-} %
Ore	0.43	0.12	0.009	10.8	1.01
Concentrate	15.5	3.69	0.15	28.7	25.6
Recovery, %	93.7	77.1	46.4		

Bulk Concentration Results – Precious Metals

	Element (g/t)			
	Au	Pt	Pd	Total PGMs
Ore	0.06	0.08	0.37	0.59
Concentrate	2.80	2.49	11.1	16.7
Recovery, %	76.6	76.4	75.8	

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Conventional High Temperature Pressure Oxidation (220 C)

Element	Feed	Residue	Ext. (%)
Cu	13.8	0.16	99.3
Ni	3.52	0.23	95.9
Co	0.15	<0.02	>92
Fe	28.7	40.8	11.5
S_T	25.6	4.4	91.5
Au	2.24	3.14	~0
Pt	1.75	2.15	~0
Pd	8.91	5.36	61.1

Precious Metal Recovery from Washed Pressure Oxidation Residue

Concentrated HCl and/or NaCl
NaOCl or Cl_2 additions to potentials of >1000 mV (vs. Ag/AgCl)
Fine grinding to a K_{80} of ~10 microns
Temperatures of up to 80^{o}C.
Au and Pd extractions of >90%
Pt extraction ~30%

VERY HIGH REAGENT CONSUMPTIONS

High pressure, (ambient temperature) intensive cyanidation
99% Au, 90% Pd, 35% Pt extraction

VERY HIGH REAGENT CONSUMPTIONS

New Process Development - PLATSOL®

Addition of Chloride to High Temperature Pressure Oxidation to Promote

Leaching of Precious and Base Metals

Chalcopyrite Oxidation/Iron Hydrolysis:

$$CuFeS_2 + 17/4O_2 + H_2O \rightarrow CuSO_4 + 1/2Fe_2O_3 + H_2SO_4$$

Pyrite Oxidation:

$$FeS_2 + 15/4O_2 + 2H_2O \rightarrow 1/2Fe_2O_3 + 2H_2SO_4$$

Pyrrhotite Oxidation:

$$FeS + 9/4O_2 + H_2O \rightarrow 1/2Fe_2O_3 + H_2SO_4$$

Nickel Sulfide Oxidation:

$$NiS + 2O_2 \rightarrow NiSO_4$$

Gold Oxidation/Chlorocomplex Formation:

$$\mathrm{Au} + 3/4\mathrm{O}_2 + 3/2\,\mathrm{H_2SO_4} + 4\mathrm{NaCl} \rightarrow \mathrm{NaAuCl_4} + 3/2\,\mathrm{Na_2SO_4} + 3/2\,\mathrm{H_2O}$$

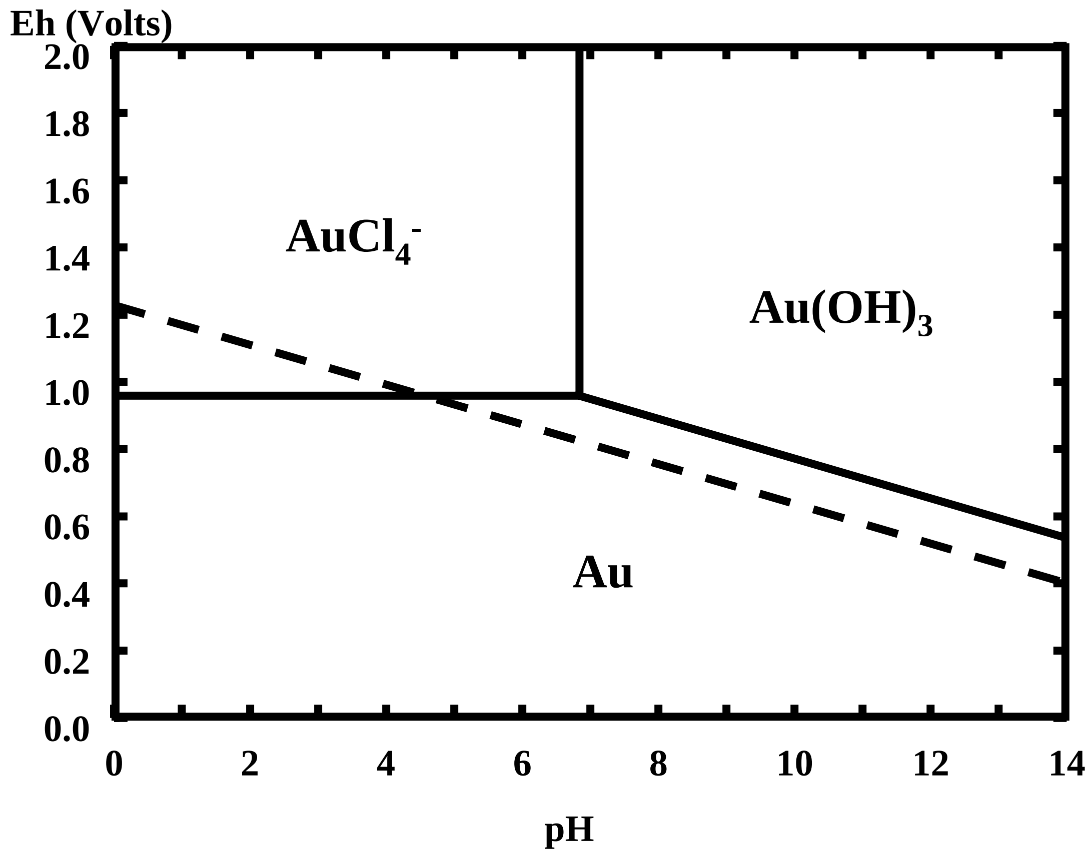
Platinum Oxidation/Chlorocomplex Formation:

$$Pt + O_2 + 2H_2SO_4 + 6NaCl \rightarrow Na_2PtCl_6 + 2Na_2SO_4 + 2H_2O$$

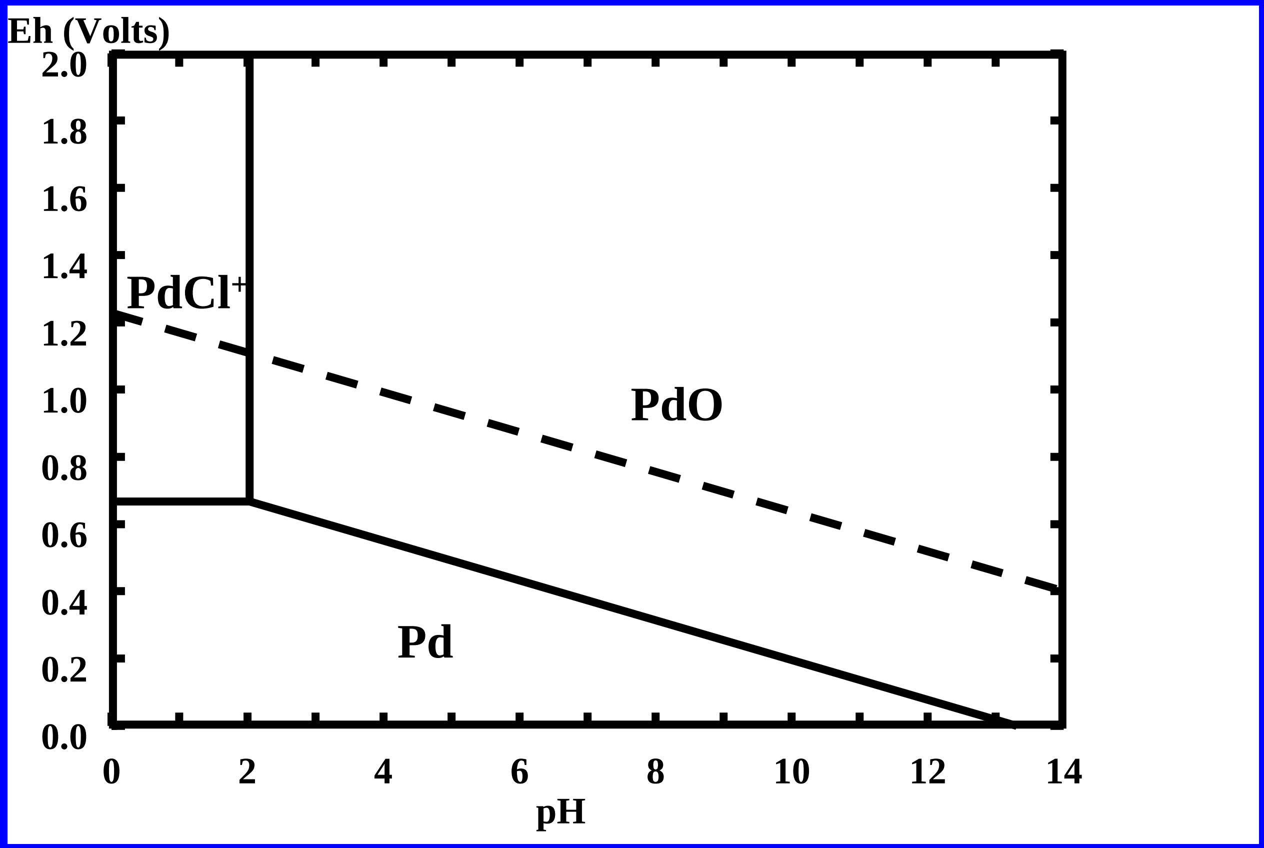
Palladium Oxidation/Chlorocomplex Formation:

$$Pd + 1/2O_2 + H_2SO_4 + 4NaCl \rightarrow Na_2PdCl_4 + Na_2SO_4 + H_2O$$

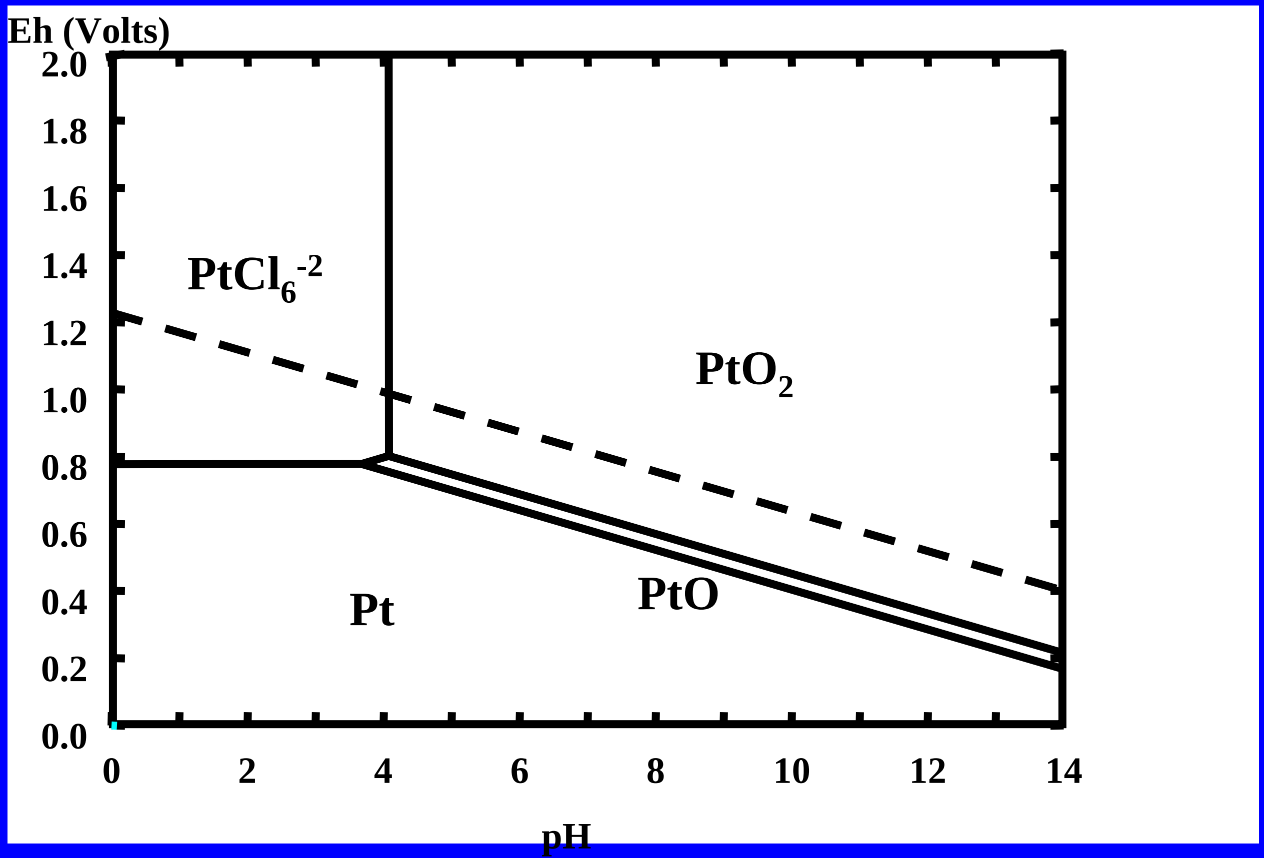
Eh – pH Diagram for the Au-Cl system at 25 C.
[Au] = 0.00001 M. [Cl] = 0.2 M.



Eh – pH Diagram for the Pt-Cl system at 25 C.
[Pt] = 0.00001 M. [Cl] = 0.2 M.



Eh – pH Diagram for the Pd-Cl system at 25 C.
[Pd] = 0.00001 M. [Cl] = 0.2 M.



Batch Leach Conditions

Test No.	Conc. Reground	Feed K_{80} µm	Media	Temp °C	$P(O_2)$ psi	Time h	NaCl g/L
1	No	32	nil	220	100	2	0
2	No	32	nil	220	100	2	10
3	Yes	15-20	steel	220	100	2	10
4	Yes	15-20	steel	220	100	2	5
5	Yes	15-20	steel	200	100	2	10
6	Yes	15-20	ceramic	220	100	2	10
7	Yes	15-20	ceramic	220	100	2	10

Batch Leach Results

Test No.	Cu Conc %	Cu Rec %	Ni Conc %	Ni Rec %	Au Conc g/t	Au Rec %	Pt Conc g/t	Pt Rec %	Pd Conc g/t	Pd Rec %
Feed	13.8		3.52		2.24		1.75		8.91	
1	0.16	99.3	0.23	97.7	3.32	~0	2.15	~0	5.36	61
2	0.05	99.7	0.31	93.4	0.27	91	0.49	79	1.37	88
3	0.14	99.3	0.21	95.7	0.74	79	0.18	93	0.47	96
4	0.12	99.4	0.27	94.3	0.64	79	0.16	93	1.01	92
5	0.28	98.3	0.38	90.8	2.71	~0	1.97	4	10.9	~0
6	0.11	99.4	0.31	93.3	0.13	96	0.06	98	0.72	94
7	0.10	99.4	0.26	94.3	0.13	96	0.06	98	0.64	95

Base Metal Recovery

Copper

- **Copper Solvent Extraction and Electrowinning**
  - **LME Grade Cathode**

Nickel/Cobalt

- **Variety of Processes Possible**
- **Direct SX/EW (Bulong, INCO Processes)**
- **Hydroxide Precipitation/Releach SX/EW (Cawse Process)**
- **Sulfide Precipitation/Releach/SX-EW or Reduction (Anaconda Process)**

NaSH Precipitation of Precious Metals

	Cu	Ni	Fe	Au	Pt	Pd
Preg solution mg/L	17000	19900	1550	0.32	0.34	1.23
Barren solution mg/L	14300	18200	1340	0.01	0.00	0.01
Precipitate (% or g/t)	61.8	0.19	0.37	92	102	484
Precipitation Efficiency %	16	<0.1	1	97	~100	99

Carbon Adsorption Results

Conditions					Solution Assays (mg/L)			Carbon Assays (g/t, %)				
Temp °C	Time h	$Na_2S_2O_5$ g/L	EMF mV		Au	Pt	Pd	Au	Pt	Pd	Cu	Ni
20	24	0	575	Preg	0.21	0.19	1.08					
				Barren	<0.01	0.03	0.07	14	31	197	0.72	0.54
20	24	36	582	Preg	0.24	0.21	1.12					
			328	Barren	0.09	0.13	0.85	12	14	46	1.67	0.44
60	24	10		Preg	0.32	0.24	1.23					
			363	Barren	0.05	0.12	0.23	1	13	35	1.62	0.38

EMF is referenced to Ag/AgCl Electrode

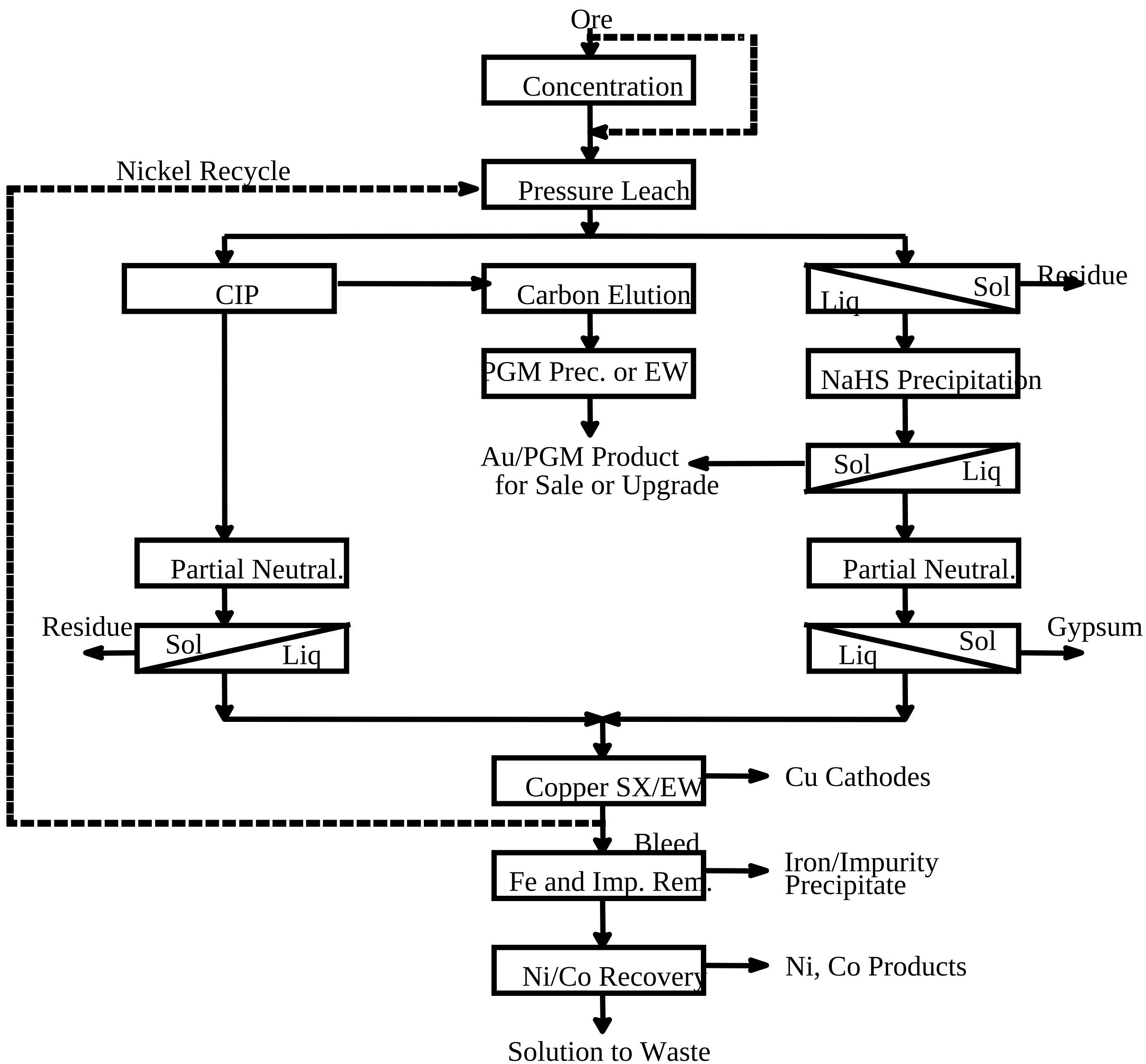
Carbon Elution Results (Cyanide)

	Carbon Analyses (g/t, %)					
Product	Au	Pt	Pd	Cu	Ni	Fe
Loaded carbon	16	118	732	0.15	<0.05	0.20
Eluted carbon	0.6	1.8	7	0.002	<0.05	0.20
Elution efficiency %	96	98	99	99		~0

Other Concentrates

(NaCl = 20 g/L, Time = 2 h, Temp = 220°C, Initial acid = 50 g/L, O_2 overpressure = 100 psi)

Feed	Sample	Au g/t	Pt g/t	Pd g/t	Rh g/t	Cu %	Ni %	Co %
A	Feed	2.5	6.0	14.4	1.8	4.4	9.9	0.6
	Residue	0.22	2.1	0.44	0.11	<0.01	<0.01	0.02
	Recovery%	93	72	97	95	~100	~100	~100
B	Feed	3.6	24.6	38.9	4.1	2.6	4.7	
	Residue	0.76	6.1	3.2	1.15	0.06	0.08	
	Recovery%	83	80	93	77	98	99	
C	Feed	4.0	81.1	59.8	14.2	3.2	5.7	
	Residue	0.16	22.1	3.93	1.44	0.01	0.03	
	Recovery%	96	76	94	92	~100	~100	
D	Feed	12.4	12.3	143.0		5.8	4.1	
	Residue	0.22	0.85	8.9		0.03	0.04	
	Recovery %	99	95	94		~100	99	


Ore
Concentration
Nickel Recycle
Pressure Leach
CIP
Carbon Elution
Sol
Liq
Residue
PGM Prec. or EW
NaHS Precipitation
Au/PGM Product
for Sale or Upgrade
Sol
Liq
Partial Neutral.
Partial Neutral.
Residue
Sol
Liq
Sol
Liq
Gypsum
Copper SX/EW
Cu Cathodes
Bleed
Fe and Imp. Rem.
Iron/Impurity
Precipitate
Ni/Co Recovery
Ni, Co Products
Solution to Waste

Continuous Integrated Pilot Plant Results at Lakefield (Canada)

(Polymet Mining Company News Release – August 22, 2000)

	Pt	Pd	Au	Co	Cu	Ni
Extract. (%)	96.0	94.6	89.4	96.0	99.6	98.9

CONCLUSIONS

- A new pressure leaching process has been developed for the simultaneous dissolution of gold, the PGM’s and base metals in the autoclave.

- The process is particularly well suited to the treatment of lower grade copper and/or nickel sulphide concentrates that contain PGM’s, but which are not well suited to smelting for one reason or another.

- The process involves the addition of chloride ion to the autoclave feed.

- At high temperature and oxygen over pressure gold and the PGM’s are oxidized and stabilized in solution as chloride complexes.

- The process has been shown to be quite versatile. A number of custom feeds have shown good response.

- Gold and PGM’s may be recovered by carbon adsorption or sulfide precipitation.

- The base metals (Cu, Ni, Co) may be recovered by conventional processing.

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