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Case Studies and Guidelines for Drainage-Chemistry Prediction

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Why Worry About Good Predictions of Drainage Chemistry and ML/ARD?

- We all want to do good, competent work for our clients.

- What happens when we are drastically wrong?
  - We are embarrassed. Hopefully, we learn from our and others' mistakes, so something good comes from it. However, many people believe mistakes should be covered up and not discussed.

  - The client spends extra millions to tens of millions of dollars that could have otherwise been saved.

  - We would like to blame others, like the B.C. ML/ARD Manual and upcoming MEND Manual (i.e., Bill Price).

  - We cannot purchase ML/ARD liability insurance. When I recently asked a friend about insurance for B.C. Professional Geoscientists working in ML/ARD, she said, "The only PGeo I've found with insurance since we talked are all in the geotech field and work mainly with engineers so are paying a high premium."

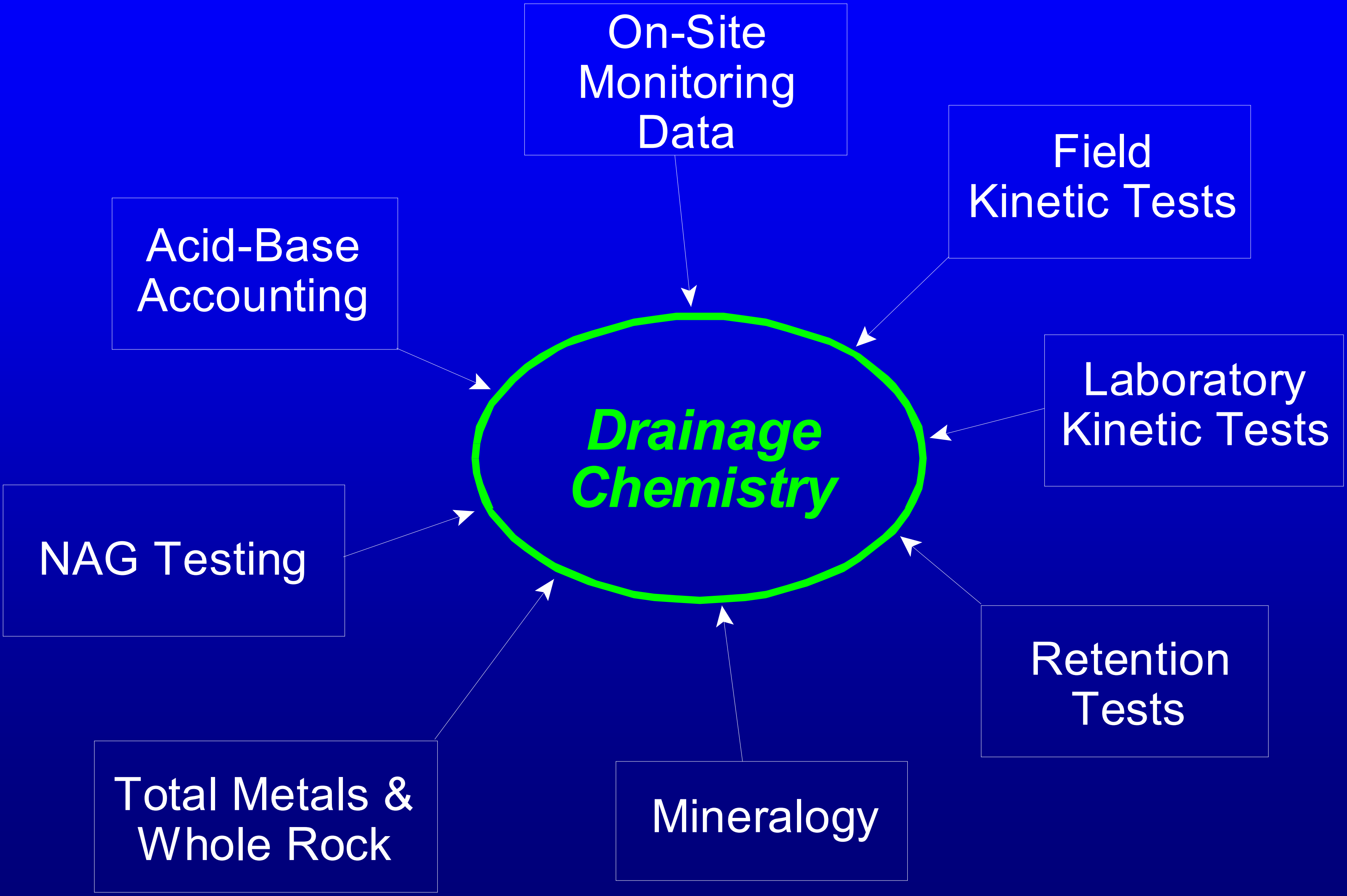
B.C. Provincial Guidelines on ML/ARD

- “In most scientific work, practitioners would be satisfied with a 90 to 95 percent success rate. However, in ML/ARD prediction and prevention, any failure that results in significant environmental impact is unacceptable .”

Why Worry About Good Predictions of Drainage Chemistry and ML/ARD?

- Most of the time, ML/ARD predictions turn out to be reasonable. A great deal of good work is being done today.
- Instead of patting everyone on the back for the great work being done, we want to focus on the small percentage of problems, inaccuracies, and errors that can be encountered. We want that small percentage of problems to be reduced further.
- Therefore, we challenge you to improve your ML/ARD work, by watching out for the following pitfalls.

The "Wheel" Approach for Drainage Chemistry



On-Site Monitoring Data

Field Kinetic Tests

Acid-Base Accounting

Drainage Chemistry

Laboratory Kinetic Tests

NAG Testing

Retention Tests

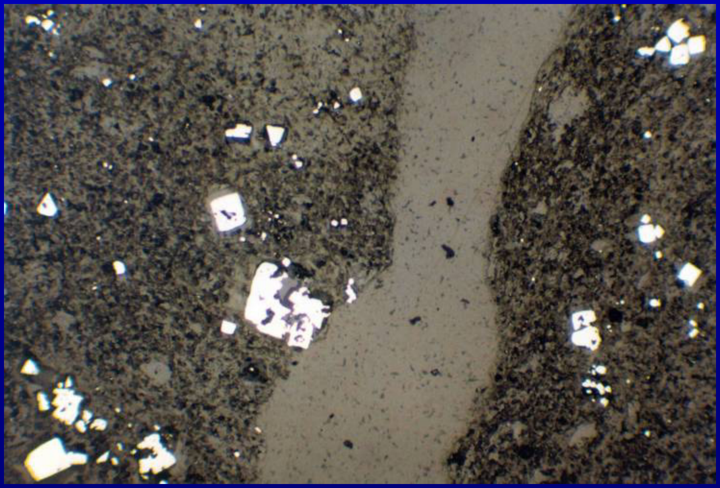
Total Metals & Whole Rock

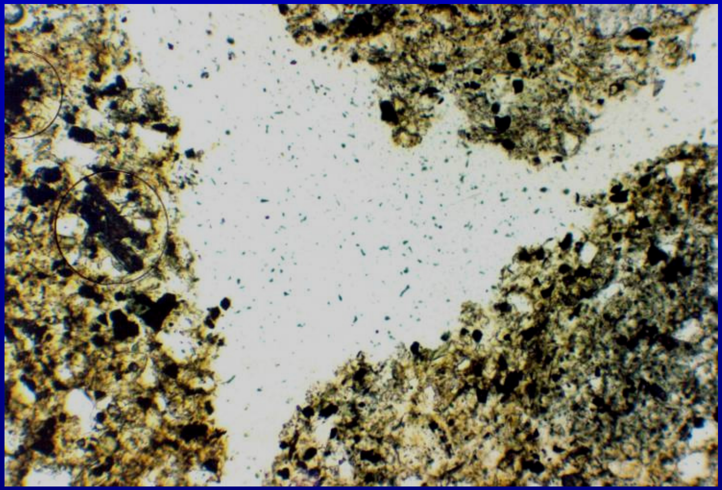
Mineralogy

Mineralogy

The “Holy Grail” of Mineralogy

- The Premise: Minerals create drainage chemistry. So, if we know mineralogy accurately, we can predict aqueous concentrations accurately.
- Question: Can we delineate mineralogy of a sample accurately using “everyday” techniques?

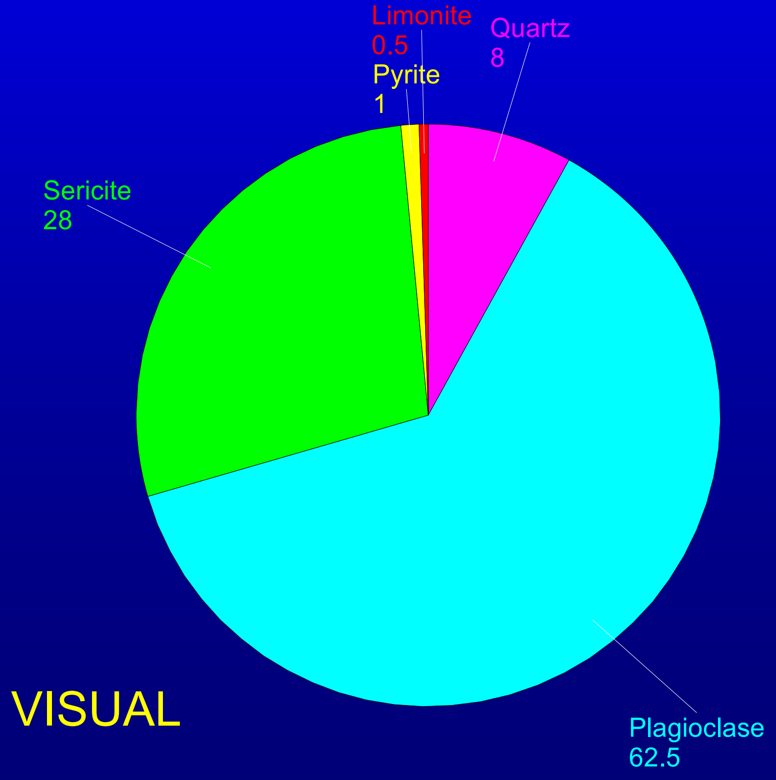




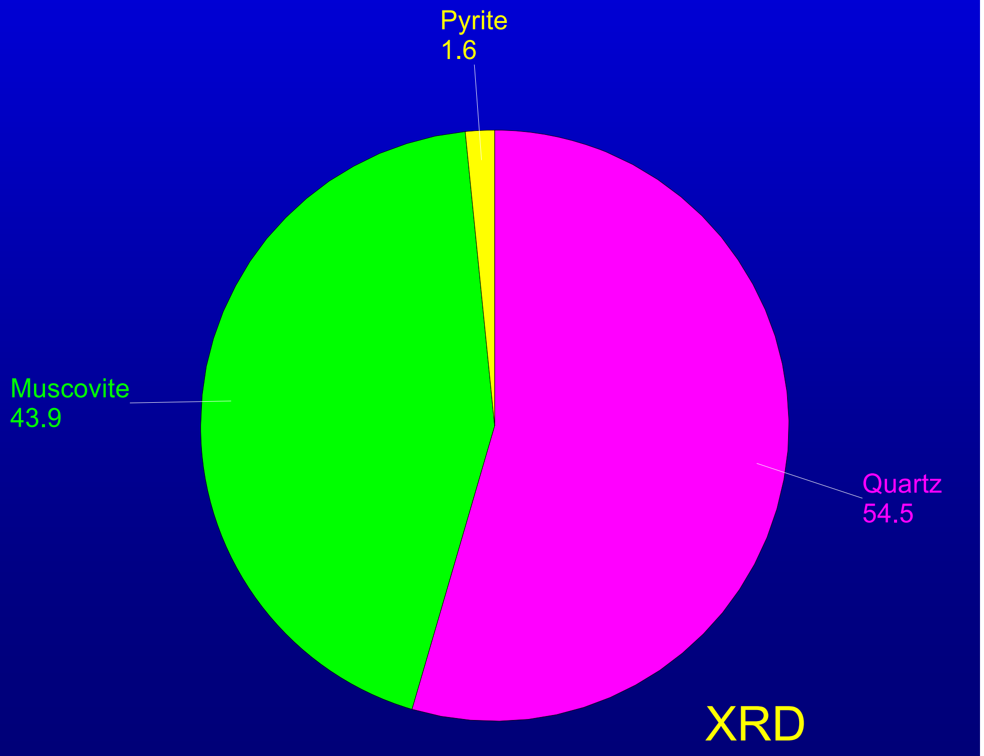
In this volcanic sample, visual observations indicated over half the sample was feldspar, whereas Rietveld XRD indicated more than half was quartz with no feldspar.

Both petrographic measurements of pyrite as visual volume-% (1 and 1.6%) were within a factor of 2 of the ABA value of 0.82 wt-%S. However, 0.82 wt-%S is equivalent to 3.1 wt-% FeS_2 which is more than 3 vol-% in this sample.

Volcanic Dacite - Petrographics (ABA Sulphide = 0.82%S)



Volcanic Dacite - Rietveld XRD

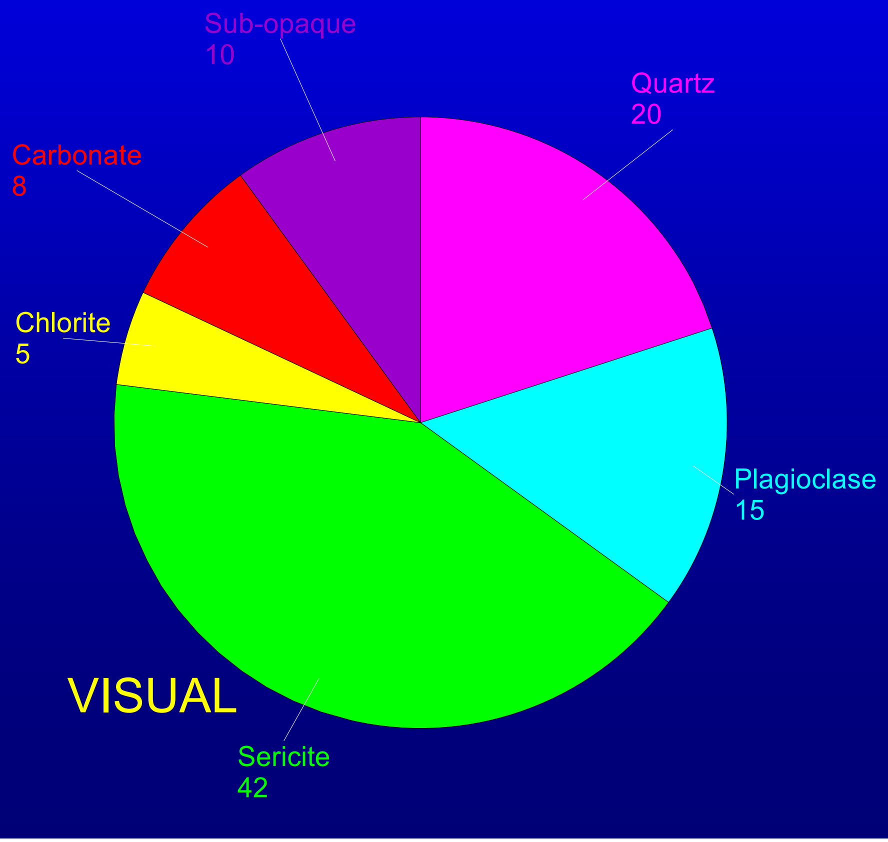


In this sedimentary sample, visual observations indicated 15% plagioclase, whereas Rietveld XRD reported no feldspar.

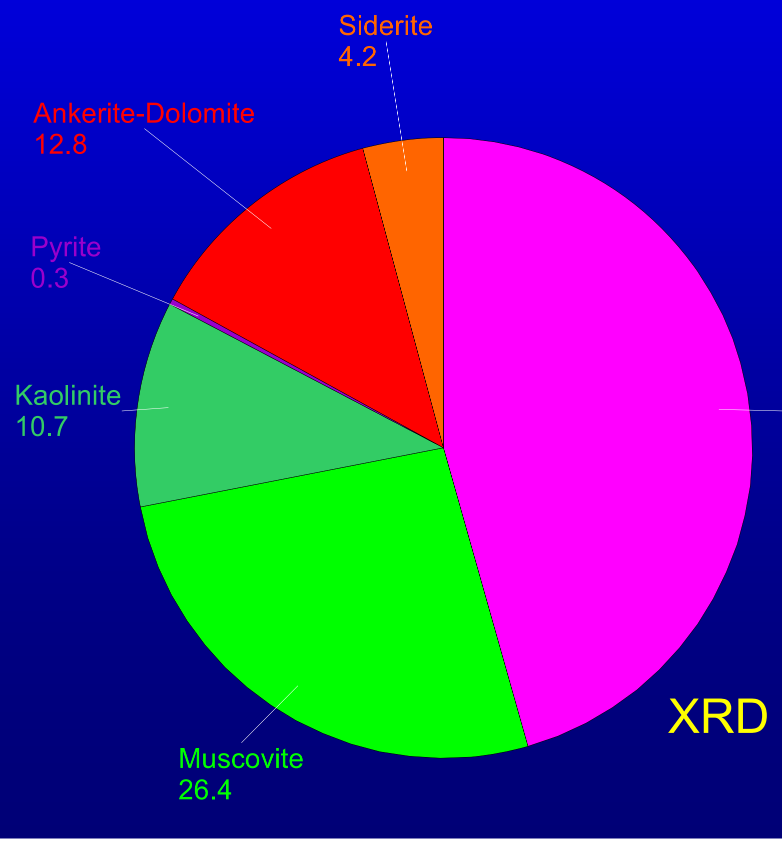
Rietveld detected the pyrite at a low level, whereas visually it was not reported.

The NP of 10.8 wt-% was similar to the visual 8 vol-% and the Rietveld sum of 17.0 vol-%, but the type of carbonate was not characterized visually.

Mudstone/Siltstone - Petrographics (ABA Sulphide = 0.25%S, NP = 108 kg/t)



Mudstone/Siltstone - Rietveld XRD



The “Holy Grail” of Mineralogy

- Our objective is to predict concentrations in mg/L, such as for antimony and zinc, under sites-specific conditions. Can we predict this drainage chemistry from mineralogy?

- No. For example:
  - There can be significant mineralogical variations on small to medium scales, even within sample splits.
  - Current techniques have significant errors bars and do not necessarily agree with each other.
  - XRD cannot detect amorphous phases, which can be significant in some samples.
  - Small impurities and solid solutions can affect the solubilities and leaching rates of minerals, and affect the elements released by dissolution of a mineral.

- Mineralogy is just one part of the integrated “wheel” approach for drainage-chemistry prediction.

QA/QC Range Check on Neutralization Potential (NP) Measurements

NP (kg $CaCO_3$/t) OA-VOL08	Fizz Rating Unity OA-VOL08	Fizz Rating NP Range	Comparison of Fizz Rating & NP
127	3	100 - 500	In Range
355	3	100 - 500	In Range
4	1	0 - 50	In Range
51	2	50 - 100	In Range
47	2	50 - 100	Below Range
110	3	100 - 500	In Range
108	3	100 - 500	In Range
106	2	50 - 100	Above Range
3	1	0 - 50	In Range
137	3	100 - 500	In Range
121	3	100 - 500	In Range
68	2	50 - 100	In Range
174	3	100 - 500	In Range
123	3	100 - 500	In Range
2	1	0 - 50	In Range
121	2	50 - 100	Above Range
31	2	50 - 100	Below Range
4	1	0 - 50	In Range
62	2	50 - 100	In Range
42	2	50 - 100	Below Range
57	2	50 - 100	In Range
13	1	0 - 50	In Range
308	3	100 - 500	In Range
4	1	0 - 50	In Range
3	1	0 - 50	In Range
2	1	0 - 50	In Range
2	1	0 - 50	In Range
5	1	0 - 50	In Range
6	1	0 - 50	In Range
5	1	0 - 50	In Range

For the standard Sobek NP, each fizz rating corresponds to a certain range in NP.

If the final NP is below this appropriate range, too much acid was entered and NP may be overestimated.

If the final NP is above this range, insufficient acid was added and there may be additional NP. However, this might be attributable to analytical error or artifacts, because the added acid cannot theoretically dissolve more than its maximum limit.

QA/QC Check on Analyses of Humidity-Cell Cycles

Each humidity-cell cycle should be checked for its charge-balance error. Theoretically, the charge balance should be 0%, but tolerances of ±10% to ±20% are often accepted as routine analytical error. The laboratory can be asked to check out-of-balance analyses, but usually do not resolve them.

Therefore, occasional out-of-balance weeks are expected. However, a continuous series of out-of-balance weeks, like the first four cycles (right-side table) suggest a non-standard geochemical effect.

Week No.	Date	Dissolved Sum of Cations	Dissolved Sum of Anions	Dissolved Charge Balance Error (%)
0	14-Jul-04	3.59	-3.18	6.01
1	20-Jul-04	4.72	-4.36	4.01
2	28-Jul-04	3.59	-3.52	0.95
3	04-Aug-04	2.66	-2.60	1.08
4	11-Aug-04	2.26	-1.78	11.87
5	18-Aug-04	2.02	-1.99	0.79
6	25-Aug-04	1.74	-1.79	-1.23
7	01-Sep-04	1.65	-1.73	-2.31
8	08-Sep-04	1.64	-1.62	0.65
9	15-Sep-04	1.48	-1.49	-0.36
10	22-Sep-04	1.58	-1.72	-4.11
11	29-Sep-04	1.62	-1.68	-1.95
12	06-Oct-04	1.61	-1.61	0.10
13	13-Oct-04	1.65	-1.69	-1.02
14	20-Oct-04	1.61	-1.58	0.92
15	27-Oct-04	1.09	-1.03	2.73
16	03-Nov-04	1.59	-1.60	-0.42
17	10-Nov-04	1.67	-1.61	1.76
18	17-Nov-04	1.51	-1.46	1.38
19	24-Nov-04	1.45	-1.45	0.02
20	01-Dec-04	1.45	-1.40	1.73
21	08-Dec-04	1.48	-1.43	1.98
22	15-Dec-04	1.55	-1.53	0.65

Week No.	Date	Dissolved Sum of Cations	Dissolved Sum of Anions	Dissolved Charge Balance Error (%)
0	14-Jul-04	2.22	-1.43	21.48
1	20-Jul-04	2.37	-1.77	14.45
2	28-Jul-04	1.93	-1.49	12.81
3	04-Aug-04	1.74	-1.34	13.12
4	11-Aug-04	1.44	-1.27	6.50
5	18-Aug-04	1.36	-1.12	9.48
6	25-Aug-04	1.32	-1.19	5.27
7	01-Sep-04	1.06	-1.05	0.37
8	08-Sep-04	1.11	-1.02	4.41
9	15-Sep-04	1.08	-1.06	0.79
10	22-Sep-04	1.16	-1.08	3.66
11	29-Sep-04	1.19	-1.08	4.88
12	06-Oct-04	1.08	-1.06	0.88
13	13-Oct-04	1.15	-1.10	2.33
14	20-Oct-04	1.21	-1.09	5.31
15	27-Oct-04	1.23	-1.13	3.98
16	03-Nov-04	1.20	-1.16	1.88
17	10-Nov-04	1.24	-1.12	5.04
18	17-Nov-04	1.00	-0.93	3.81
19	24-Nov-04	1.10	-1.02	3.54
20	01-Dec-04	1.23	-1.14	3.70
21	08-Dec-04	1.08	-0.99	4.08
22	15-Dec-04	1.05	-1.03	1.29

Week No.	Date	Dissolved Sum of Cations	Dissolved Sum of Anions	Dissolved Charge Balance Error (%)
0	14-Jul-04	4.02	-1.79	38.29
1	20-Jul-04	3.58	-1.87	31.40
2	28-Jul-04	2.36	-1.08	37.00
3	04-Aug-04	2.59	-0.77	53.90
4	11-Aug-04	1.35	-0.73	29.71
5	18-Aug-04	1.68	-0.46	56.75
6	25-Aug-04	0.82	-0.36	38.21
7	01-Sep-04	1.03	-0.36	48.13
8	08-Sep-04	1.62	-0.51	52.31
9	15-Sep-04	1.15	-0.36	52.52
10	22-Sep-04	0.94	-0.32	49.42
11	29-Sep-04	0.73	-0.22	53.56
12	06-Oct-04	0.75	-0.20	58.41
13	13-Oct-04	0.79	-0.25	51.53
14	20-Oct-04	0.68	-0.24	47.28
15	27-Oct-04	0.72	-0.20	55.85
16	03-Nov-04	3.08	-0.17	89.75
17	10-Nov-04	1.42	-0.61	40.31
18	17-Nov-04	1.63	-0.45	56.91
19	24-Nov-04	1.72	-0.36	65.22
20	01-Dec-04	1.01	-0.30	54.40
21	08-Dec-04	0.88	-0.28	51.37
22	15-Dec-04	1.64	-0.28	70.84

Interesting results arise when one cell out of several (as seen to the left) repeatedly and consistently is out of balance.

In this example, pH averaged 7.4, while aqueous dissolved aluminum concentrations averaged 3.6 mg/L. This amount of dissolved aluminum was not normal at this pH. Most of the imbalance was attributable to aluminum and sodium.

This sample was composed of 75% sericite/chlorite according to mineralogy. The laboratory stated that effluent from this cell was always turbid and required several filters to obtain a sufficient amount of effluent. Thus, this sample was probably releasing aluminum-oxide-based colloids, which can carry important implications for water chemistry.

Unavailable Neutralization Potential

Unavailable Neutralization Potential (UNP)

- The draft ML/ARD Prediction Manual already discusses and illustrates the fact that not all measured NP from the Sobek and Modified Procedures actually neutralizes internal acidity. The most common value for Unavailable NP is around 10 kg/t, but site-specific values from 0 to 60 kg/t have been reported. UNP should be subtracted from all measured NP values to obtain an Effective NP for net-balance calculations.
- The ABCC procedure associated with NAG testing also evaluates Unavailable NP.
- In the past, there were rules of thumb, like only 1/3 of measured NP should be used in ARD predictions.
- Also, in the old days of NNP, the common criterion of +20 kg/t implicitly recognized up to 20 kg/t of NP would be unavailable.

Unavailable Neutralization Potential (UNP)

- While NNP highlighted Unavailable NP, NPR does not because of mathematical artifacts. For example, if NP = 10.5 kg/t and AP = 1 kg/t, then
  - NNP would be a net-acid-generating +9.5 kg/t,
  - NPR would be a net-acid-neutralizing 10.5, and
  - adjusted NPR [(NP-10)/AP] would be a net-acid-generating 0.5.
- We have seen ML/ARD reports not subtracting Unavailable NP (UNP), but using 100% of the measured NP. With low-NP samples, this can lead to ARD errors, and such errors have occurred.
- Therefore, there is no due diligence defense in cases where UNP was not considered.

Acronyms, Terminology, and Ambiguities

Acronyms

- “To ensure results are not misused or misinterpreted, practitioners should use accurate and precise terminology…” B.C. ML/ARD Guidelines, p.12
- Acronyms represent a balance between (1) brevity and (2) clarity.
- This should be considered from the viewpoints of:
  - the writer/interpreter and
  - various audiences, such as mining companies, regulators, media, first nations, and general public.

Acronyms

- NAG = net acid generating

OR

- NAG = non acid generating

- Non acid generating = no acid-generating minerals (non-PAG and NAF?)

OR

- Non acid generating = minerals actually generate acidity, but the acidity is neutralized by other minerals (non-PAG and NAF?)

Acronyms

- PAG = “potentially acid generating” or “potentially ARD generating”

- PAG = may be net acid generating, but we are not sure yet

OR

- PAG = definitely is net acid generating when exposed to air and moisture

An ML/ARD Episode of Law & Order

- Lawyer cross-examining an ML/ARD Expert Witness

  - Lawyer: You predicted this sample was NAG – non acid generating.
  - Expert: Yes.
  - Lawyer: Does it contain pyrite?
  - Expert: Yes.
  - Lawyer: Was the sample exposed to air and moisture during mining?
  - Expert: Yes.
  - Lawyer: Did the sulphide oxidize and generate acidity?
  - Expert: Yes.
  - Lawyer: So you were wrong to say the sample was non acid generating?
  - Expert: What I meant was the sample would generate acidity, but was non acid generating because…

Better Wording with No Acronyms

- Net acid generating = will generate net acidity at some point when exposed to air and moisture; may have a long lag time; but what is this rock called if not exposed to air and moisture?
- Net acid neutralizing = may or may not generate acidity, but contains excess NP to neutralize all self-generated acidity plus some additional acidity.
- Inert for ARD = capacities to generate and neutralize acidity are minimal (below detection, not below 0.3%S or below 0.1%S); could still be a good metal leacher.
- No acronyms yet for leaching of metals, other elements, and nutrients; wide open for fanatical acronym creators.

Errors in ARD Prediction

Errors in ARD Prediction – Equity Silver

- “Drill core samples of ore were tested by B.C. Research to study the rock’s acid producing potential. These tests indicate that under acidic conditions the rock has the potential of producing acid water. Because the rock will not be artificially acidified and the climate is not hot and humid, acid production from the dumps is not anticipated.” (Equity Mining Capital Limited, 1976)

Initial Phase of ARD Prediction at Ekati (1995)

- Studies for the Ekati Diamond Minesite in the Northwest Territories included geochemical static and kinetic tests of the diamond-hosting kimberlite as well as several units of waste "country" rock like granite, diorite, schist, and recent sediments.

- Some initial conclusions were:
  - Rock contained up to 1.3 wt-%S, typically as pyrite in the framboidal form.
  - Portions of several rock units including granite, kimberlite, till, and lake sediments were potentially net acid generating.
  - Neutralization Potential (NP) was not derived from carbonate minerals, but from various aluminum- and silica-bearing minerals like such as olivine and plagioclase.

Initial Phase of ARD Prediction at Ekati (1995)

- Additional initial conclusions were:
  - Initial sulphide-based NPR criteria [SNPR = NP / (%S-sulphide * 31.25)] for kimberlite were set at <4.0 for net acid generating and between 4.0 and 6.0 for “uncertain”, based on initial estimates of unavailable NP. This is unusual in that the criteria are often around 1.0 to 2.0 for many minesites. Further mineralogical work was recommended to clarify this.
  - Kinetic tests demonstrated that some waste rock was capable of generating acidic drainage within a few months of exposure.
  - “There may be small zones of kimberlite capable of generating net acidity. However, this could not be confirmed with available information. . . . When dealing with a large volume of rock, nearly $1x10^9$ t for this project, [the current number of samples] cannot provide a comprehensive characterization of this rock . . . additional static and kinetic tests should be done.”

Subsequent Phase of ARD Prediction at Ekati (Waste Rock, 1996 - 1998)

- Some conclusions for Panda waste rock were:
  - “Acid potential (AP) was very low, averaging < 1 kg $CaCO_3$/tonne.” “Due to the very low sulphur concentration [~0.05%S] and low NP, this rock type has negligible potential to influence drainage chemistry.”
  - Important observation: *For every 100,000,000 t of rock, there is up to 100,000 t of potential acidity if the sulphide is exposed to air and moisture. Also, at the very low measured kinetic rates like 1 mg/kg/wk, each 100,000,000 t of rock would generate 10^{11} mg (100 t) of sulphate and acidity each week. This could adversely affect up to one billion liters of water a week. The effects of scale can be critical to ML/ARD predictions.*

Subsequent Phase of ARD Prediction at Ekati (Waste Rock, 1996 - 1998)

- Panda waste rock continued:
  - “Geochemically, the majority material to be stored in this waste rock dump is benign.”
  - “Neutralization potential (NP) for the granite was also low, reporting an average of 6 kg $CaCO_3$/tonne. . . . ”
  - Important observation: *At several minesites with sulphide-bearing rock, an NP < 10 kg/t provides no neutralization under field conditions and is called “Unavailable NP”.*
  - “pH was not predicted but is expected to be between 7.5 and 8.5 (this range was used in the model).”

Subsequent Phase of ARD Prediction at Ekati (Kimberlite Rock, 1996 - 1998)

- Some conclusions for Panda kimberlite were:
  - “Acid potential (AP) ranged from 6 to 33 kg $CaCO_3$/tonne and averaged 13 kg $CaCO_3$/tonne.”
  - Important observation: *For every 100,000,000 t of kimberlite, there will be an average of 1,300,000 t of potential acidity if the sulphide is exposed to air and moisture.*

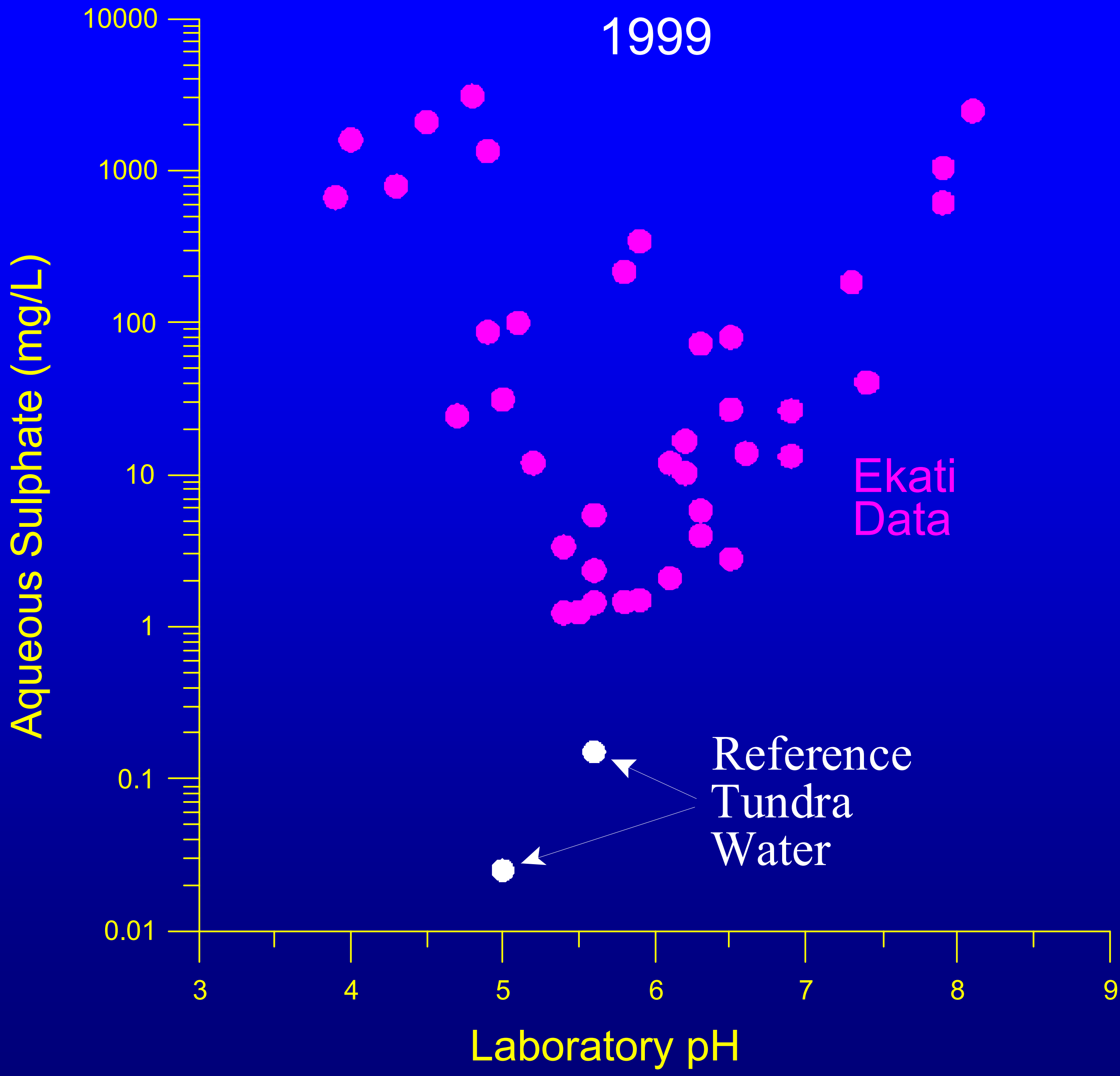
  - “As a result of the high NP values, NP/AP ratios had a relatively high mean value of 18 . . . , indicating no potential for acid generation.”
  - Important observation: *At other minesites, averaged values of ABA parameters predicted no ARD, yet ARD appeared within a year or two. Two NPR values of 0.3 and 10 have an average of 5.2, but this does not mean ARD is impossible*.

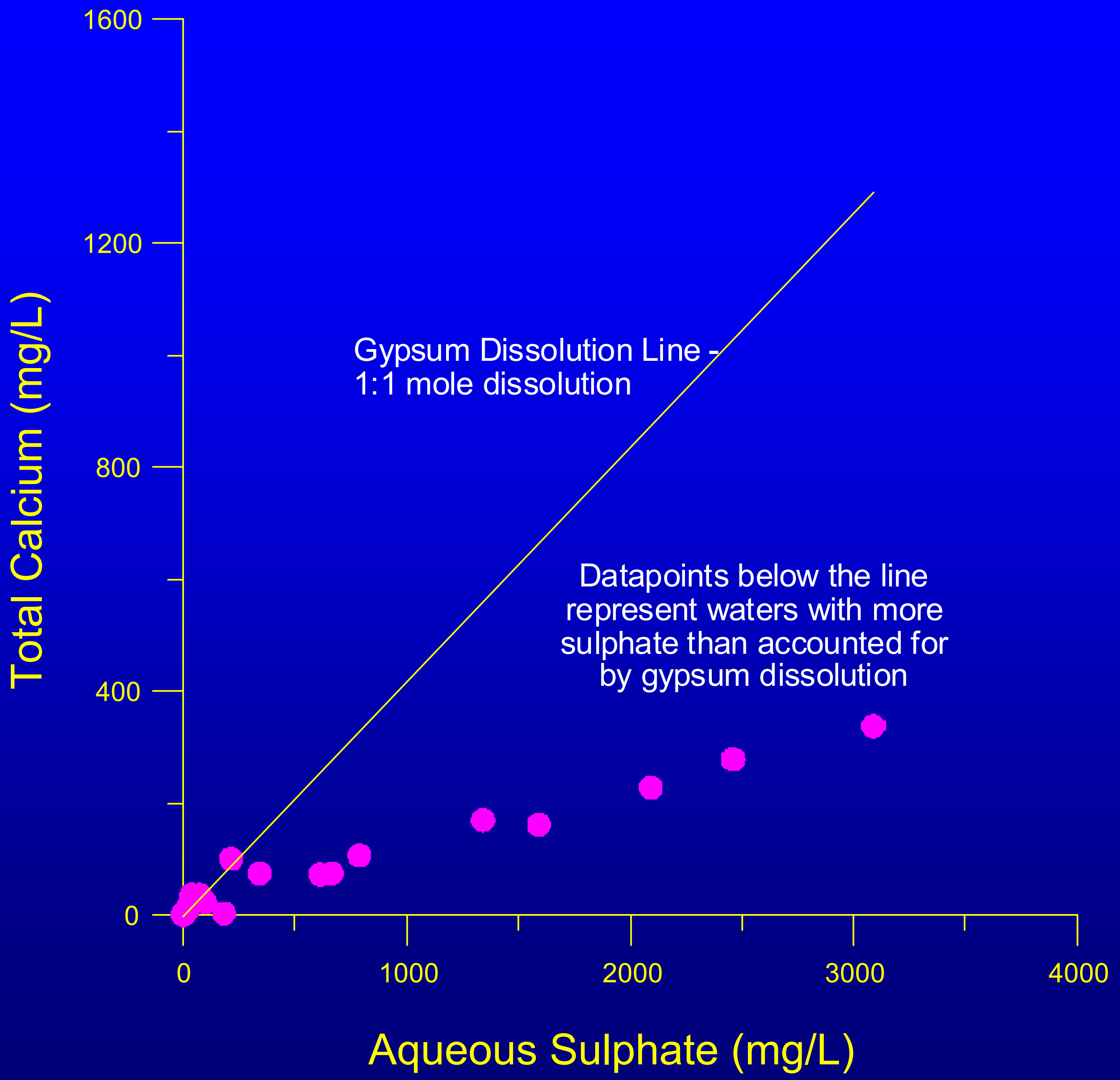
Subsequent Phase of ARD Prediction at Ekati (Kimberlite Rock, 1996 - 1998)

- Panda kimberlite continued:
  - Based on humidity-cell post-test analyses, "Neutralization potential (NP) decreased significantly from 175-300 kg $CaCO_3$/tonne to approximately 75 kg $CaCO_3$/tonne in the kimberlite samples . . . reflect[ing] the leaching of readily soluble neutralizing minerals . . . [and] suggest[ing] that there is a second, less soluble mineral present. . . ."
  - Important observation: *This indicates that the NP was depleted from kimberlite at a faster rate than the acid-generating sulphide, and that all remaining NP may not fully neutralize pH to above 6-7.*
  - *Also, a 2006 ICARD abstract (Rayne and Connell, 2006) says, "High carbonate weathering rates for exposed kimberlites suggest long-term ARD risks, possibly leading to the unusual scenario of a waste rock unit changing from alkaline to acidic drainage following mine closure."*

1999 – The Onset of ARD

- "It has been BHP's view that that [sic] pH levels in the range measured at SEEP-002 may be reflective of natural characteristics of the local tundra environment and snow melt conditions. Other potential causes for low pH, like the onset of acid rock drainage (ARD) have also been suggested, but are not likely, based on the predictive geochemistry work that was completed on the Panda granite, prior to the commencement of mining operations."

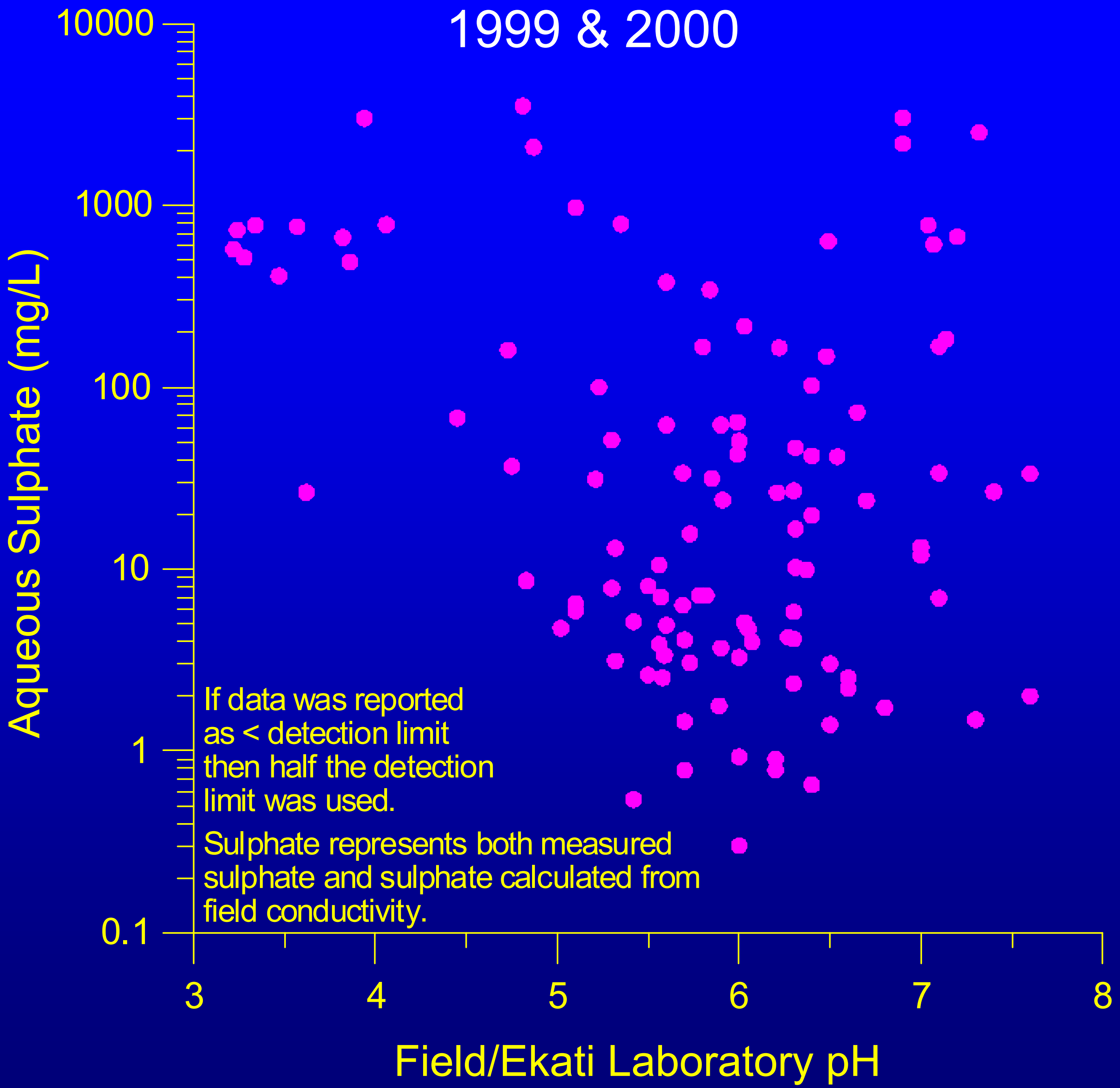

1999
Aqueous Sulphate (mg/L)
10000
1000
100
10
1
0.1
0.01
Laboratory pH
3
4
5
6
7
8
9
Ekati Data
Reference Tundra Water



Gypsum Dissolution Line -
1:1 mole dissolution

Datapoints below the line
represent waters with more
sulphate than accounted for
by gypsum dissolution

1999 & 2000



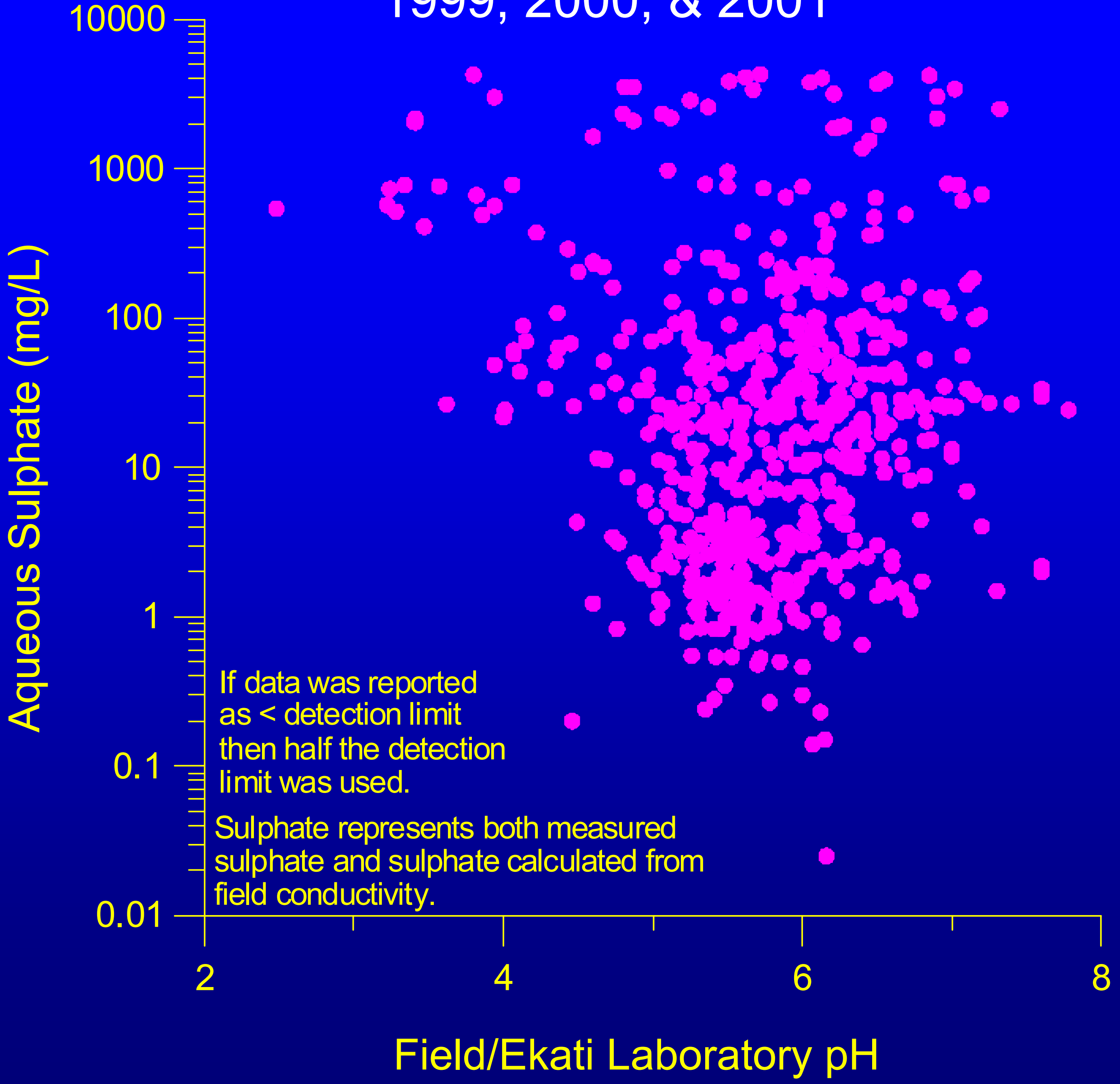
If data was reported
as < detection limit
then half the detection
limit was used.

Sulphate represents both measured
sulphate and sulphate calculated from
field conductivity.

2000 – More ARD

- “The key results . . . in the 2000 Seepage and Waste Rock Survey Report submitted to you in February 2001 were as follows:
    - - Low pH observed from seepage monitoring stations in the Beartooth-Bearclaw Drainage were primarily the result of natural rain water and the decomposition of naturally occurring organic tundra material. . . .
    - - The Panda granite is not a likely source of acidity in seepage waters due to its uniformly low sulphide content.
    - - One seepage monitoring location (SEEP-022) had a low pH that was thought to originate from the complex interactions between tundra water and small quantities of kimberlite that became entrained with the Panda waste granite. . . . A soil perimeter [toe] berm has been constructed at this location to test the perimeter berm concept [the seepage area was buried under meters of waste rock].”

1999, 2000, & 2001



If data was reported as < detection limit then half the detection limit was used.

Sulphate represents both measured sulphate and sulphate calculated from field conductivity.

2001 – ARD Confirmed

- “We consider approximately one quarter (25%) of existing seep analyses [those fitting into the incomplete classification scheme] to represent ARD” and “These results show that the waste rock is making ARD . . . [which] contradicts the laboratory tests that show granite and kimberlite waste rock could not generate ARD” (SRK, 2001).

2001-2002 – Other Causes of Acidic Drainage

- Proposed causes included:
  - acidification by precipitation,
  - acidification by organic decomposition,
  - aluminum buffering,
  - oxidation of ammonia,
  - ferrous-iron oxidation at the toe of rock piles,
  - sulphate dissolution resurrected as an explanation for elevated sulphate concentrations,
  - net-acid-generating kimberlite (originally predicted to be net acid neutralizing with hundreds of kg/t of NP) incorporated into waste rock, and
  - tundra water resurrected to consume NP in rock.

- While data support all causes to some extent, data apparently do not confirm or eliminate any causes.

Even today consultants are pulling an "Equity Silver", by interpreting data so that they can tell their client "don't worry, be happy".

The client may be happy for a few years. But, when the water treatment starts and it is too late to minimize the costs, is the client still happy about paying . . .

Some Unexpected Water-Treatment Costs for ML/ARD

- Strong, world-class ARD at a Canadian minesite:
  - pH = 2.6
  - Flow = 830,000 m^3/yr
  - Annual treatment cost ~ $1.5 million/yr for ~200 years

- Near-neutral drainage at a Canadian minesite that is not toxic to aquatic life, but is a threat to humans because of molybdenum:
  - pH = 7.9
  - Flow = 3,000,000 m^3/yr
  - Annual treatment cost ~ $1.5 million/yr for ~50-200 years

- Near-neutral drainage at a Canadian minesite that is toxic to aquatic life because of metals like cobalt as well as elevated nitrate and ammonia:
  - pH = 7.9
  - Flow = 350,000 m^3/yr
  - Annual treatment cost ~ $2.5 million/yr for an unestimated period

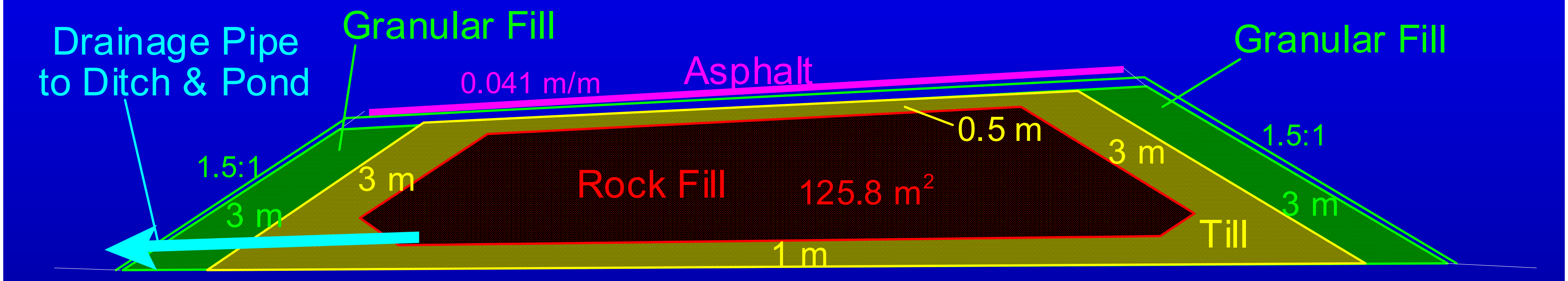
ML/ARD on the Road –

British Columbia
Ministry of Transportation and its Public-Private Partnerships (P3Ps)

Control of ARD on the Inland Island Portion of the Vancouver Island Highway Project (VIHP)

- Multi-phase ML/ARD predictions were made for the VIHP section near the Tsolum River in 1999-2000, below the Mt. Washington Minesite.
- Initial steps in ML/ARD control involved realignment of the highway right-of-way and fine adjustments to its elevation along the Tsolum River portion.
- This minimized the amount of net-acid-generating rock that had to be exposed and moved.

Control of ARD



The blasted rock fill was encapsulated in the bed of the highway, by surrounding it with up to 3 m of till and granular fill, and covering it with asphalt. At low points, pipes allowed any internally accumulating water to drain into nearby monitoring ponds for contingency collection and treatment.

Blasted rock being placed on the till base and eventually encapsulated.

For rock cuts, (1) water above was diverted away, (2) drainage ditches included some limestone, and (3) all ditches drained to control ponds like the encapsulated fills.

The completed ARD-controlled highway.

Pennask Environmental Prosecution 2005 – Regina vs. B.C. Ministry of Transportation

- In 2005, the Ministry of Transportation faced 10 criminal Counts of violating the Fisheries Act, because of uncontrolled ML/ARD entering “Unnamed Tributary” (aka “Highway Creek”) flowing into Pennask Creek.
- Pennask Creek is crossed by the Coquihalla Connector (Highway 97C), which connects Merritt and Peachland. Unnamed Tributary is located several km west of Brenda Mines and in a different watershed.
- The ML/ARD from the highway was a legacy problem, not a recent problem. It was caused by a rock cut excavated in the late 1980’s.

Pennask Environmental Prosecution 2005 – Regina vs. B.C. Ministry of Transportation

- While there were technical flaws in the Crown’s evidence, the judge and lawyers agreed that a prolonged trial at taxpayers’ expense was not justified.
- MoT pleaded guilty to Counts 9 and 10 only. The fine was $500 for each count, plus $45,000 paid to the Environmental Damages Fund for use in Pennask Creek.
- MoT has probably spent a few million dollars to date controlling ML/ARD at Unnamed Tributary, and will incur ongoing annual treatment costs.

The B.C. Ministry of Transportation is very diligent in predicting and controlling ML/ARD. MoT and its P3P Partners are conducting ML/ARD assessments for all major projects. This includes the $700-million improvement of the Trans Canada Highway in the Kicking Horse Canyon, between Golden and Yoho National Park. It also includes the $600-million improvement of the Sea to Sky Highway between Vancouver and Whistler. There are websites with lots of technical information on these projects.

Specified ML/ARD Control on the Sea-to-Sky Highway Improvement

(www.seatoskyimprovements.ca)

- Rock must be divided into four ARD categories:
  - NAG: not acid generating, NPR > 4
  - NGAP: not potentially acid generating, 2 > NPR > 4
  - PAG: potentially acid generating, 1 > NPR > 2
  - AG: acid generating, NPR < 1 and/or paste pH < 5
- “If the [suspected AG/PAG] zone is larger than 1 m^3 or if the suspect zone occurs as a continuous feature, such as a shear zone or joint plane, the material will be segregated and temporarily stockpiled under conditions of full containment pending test results to determine its classification and the appropriate disposal method.”

THE END