The Complex Futility of the Liberation Factor

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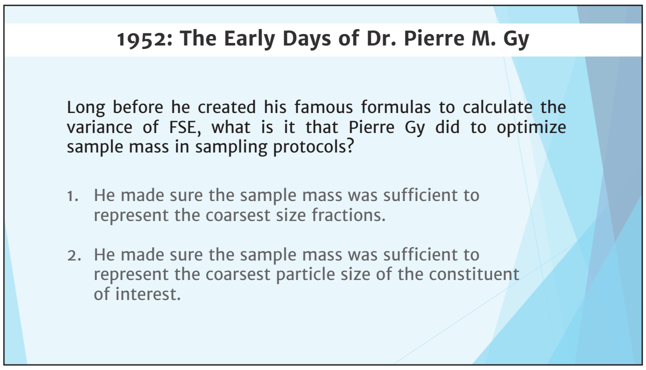

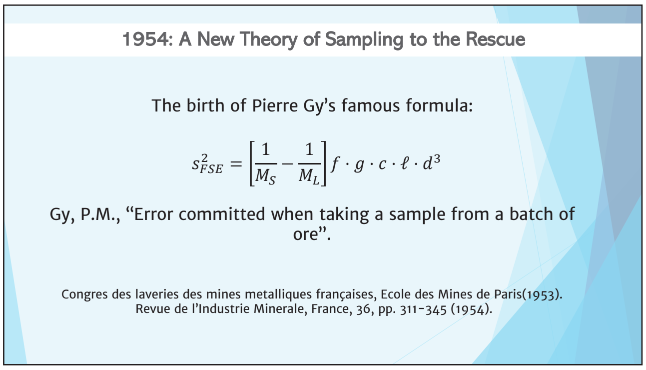

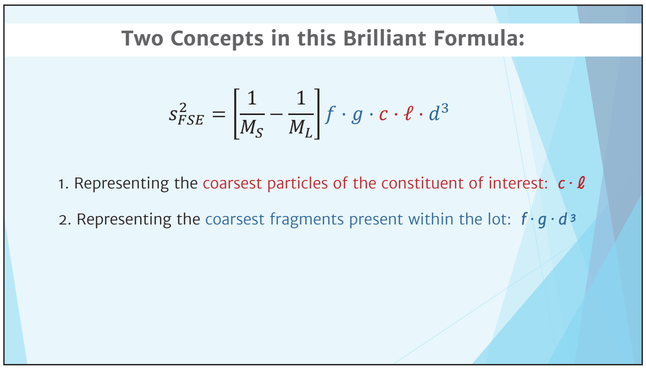

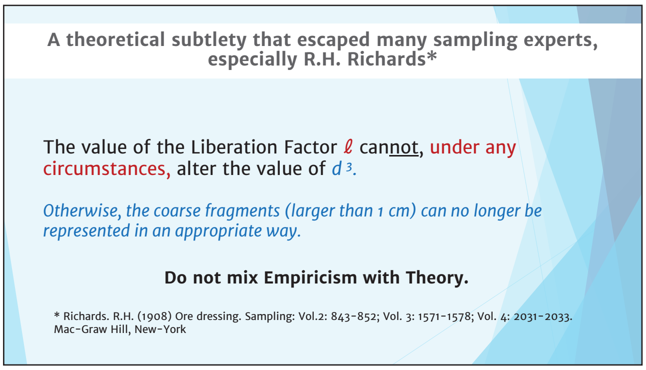

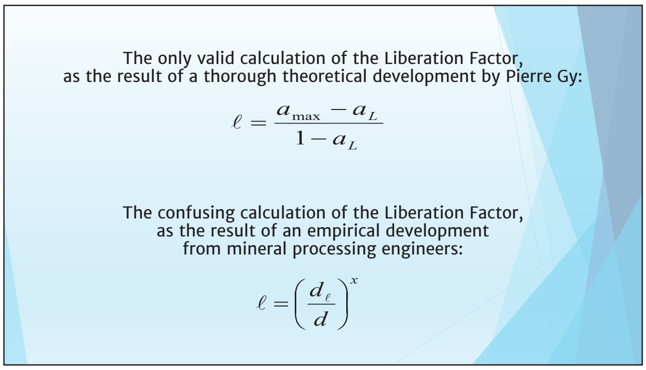

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The damage was done, leading to:

Massive confusion,
Unjustified arguments,
Misleading modifications in TOS,
Unnecessarily complex theoretical developments,
Sampling practitioners struggling to find the best approach,
A state of TOS unattractive for International Standards,
Weak testing programs,
Showing obvious lack of maturity.

CONCLUSION:

It would be wise to return to the old strategy making the calculations of the appropriate sample mass twice, to find out what is the most stringent requirement.

CARDINAL RULE #1:

The selected sample mass must be such that all size fractions are represented in line with appropriate Data Quality Objective (DQO).

A sample that is too small to represent the coarsest fragments in the lot cannot, and will not, be representative of anything.

Pierre Gy provided a wonderful formula to satisfy Cardinal Rule #1:

$$s^2_{FSE} = \left[\frac{1}{M_S} - \frac{1}{M_L}\right] f \cdot \rho \left[\left(\frac{1}{a_{Lc}} - 2\right) d^3_{FLc} + \sum_x d^3_{FLx} \cdot a_{Lx}\right]$$

$$s^2_{FSE} = \frac{f \cdot \rho}{M_S}\left[\frac{1}{a_{Lc}} - 2\right] d^3_{FLc}$$

A wise habit to prevent the misuse of Gy's formulas in domains where they do not apply.

- The wrong strategy:

$$s^2_{FSE} = \frac{f \cdot \rho}{M_S}\left[\frac{1}{a_{Lc}} - 2\right] d^3_{FLc}$$

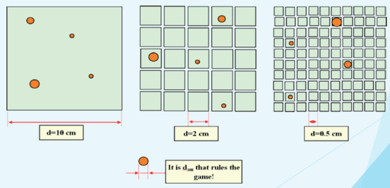
- The right strategy for a preselected DQO:

$$M_S = \frac{f \cdot \rho}{s^2_{FSE}}\left[\frac{1}{a_{Lc}} - 2\right] d^3_{FLc}$$

CARDINAL RULE #2:

The selected sample mass must be such that the maximum size d_M of the grains of the constituent of interest, liberated or not, be fairly represented in the collected sample, in line with appropriate DQO.

A sample that is too small to represent the coarsest particles of the constituent of interest in the lot cannot, and will not, be representative of anything else.



FUNDAMENTAL SAMPLING ERROR (FSE) Gy's Many Applications

$$s^2_{FSE} = \left[\frac{1}{M_S} - \frac{1}{M_L}\right] f \cdot g \cdot c \cdot \ell \cdot d^3 \quad \Rightarrow \quad \ell = \frac{a_{max} - a_L}{1 - a_L}$$

$$s^2_{FSE} = \left[\frac{1}{M_S} - \frac{1}{M_L}\right] \frac{f_{INT} \cdot g_{INT} \cdot \rho_{INT} \cdot d^3_{INT}}{a_L} \quad \Rightarrow \quad \ell = 1$$

$$s^2_{FSE} = \left[\frac{1}{M_S} - \frac{1}{M_L}\right] f \cdot \rho \left[\left(\frac{1}{a_{Lc}} - 2\right) d^3_{FLc} + \sum_x d^3_{FLx} \cdot a_{Lx}\right]$$

$$s^2_{FSE} = \left[\frac{1}{M_S} - \frac{1}{M_L}\right] K d^{3-x} \quad \Rightarrow \quad \ell = \left(\frac{d_\ell}{d}\right)^x$$

EMPIRICISM vs THEORY

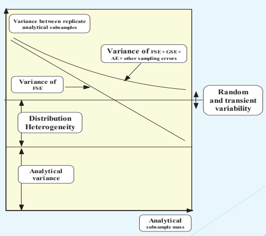
Do not confuse
Prediction & Comprehension.

Prediction from experiments are valuable, however causes of effects are multiple and the final analysis is not easy.

If observation from experiments can lead to prediction, only comprehension allows access to laws expressed in TOS.

Replicate samples variance and its components

This is where R.H. Richards in 1908 was totally confused.



From the rigorous TOS (economically impractical) to necessary approximations (economically practical)

Approximations diminish the precision of predictions; however,

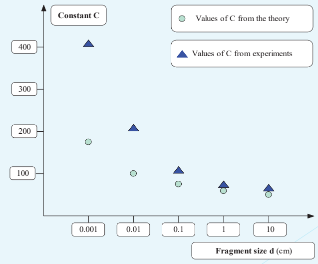
when **well understood**, should not alter the comprehensive rigor of TOS.

The reconciliation of theoretical prediction with empirical observation

Example:

More often than not, the theoretical estimate of the **variance of FSE < the variance observed in reality** from experiments using replicate samples.

Theoretical prediction vs empirical observation



Comparing oranges and apples

$$s^2_{FSE} = \left[\frac{1}{M_S} - \frac{1}{M_L}\right] K \cdot d^{3-x}$$

smaller than

$$s^2_{QFE1+AE+X} = \left[\frac{1}{M_S} - \frac{1}{M_L}\right] K \cdot d^{3-x}$$

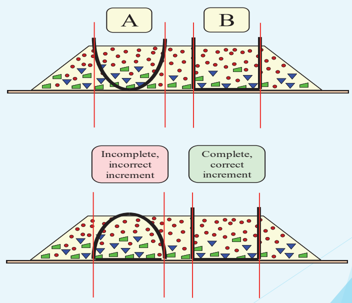
x ?

The many hurdles of empirical experiments

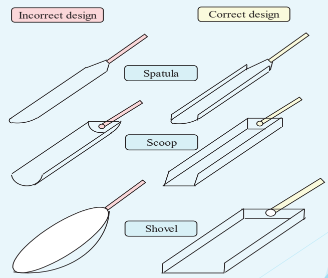
- Fragments not collected one by one at random
- Unrecognized delayed comminution of minerals of interest
- GSE
- AE
- Correctness:
  - IDE
  - IEE
  - IPE
  - IWE

Basically, empirical experiments do not have access to FSE.

IDE and IEE



Correctness is in the details



Only the Theory of Sampling has access to FSE

Which leaves us with:

$$s^2_{FSE} = \left[\frac{1}{M_S} - \frac{1}{M_L}\right] f \cdot g \cdot c \cdot \ell \cdot d^3 \Rightarrow \ell = \frac{a_{\max} - aL}{1 - a_L}$$

$$s^2_{FSE} = \left[\frac{1}{M_S} - \frac{1}{M_L}\right] \frac{f_{INT} \cdot g_{INT} \cdot \rho_{INT} \cdot d^3_{INT}}{a_L} \Rightarrow \ell = 1$$

$$s^2_{FSE} = \left[\frac{1}{M_S} - \frac{1}{M_L}\right] f \cdot \rho \left[\left(\frac{1}{a_{Lc}} - 2\right) d^3_{FLc} + \sum_x d^3_{FLx} \cdot a_{Lx}\right]$$

With all their **well-known and well-addressed limitations** of course.

Step 1. A simple and pragmatic strategy to address FSE

Allow a **Total Allotted Uncertainty** considered as an upper maximum limit.

DQO or SQC?

Examples:

Exploration for gold:	± 32%
Exploration for copper:	± 20%
Material Balance for gold:	± 10%
Material Balance for copper:	± 5%
Sales of concentrates for gold:	±3%
Sales of concentrates for copper:	±1%
Environmental assessments:	± 32%

DQO: Data Quality Objectives / **SQC:** Sample Quality Criteria

An important step to address the validity of simplifying assumptions

If the desired precision for FSE is ±16% or ±10%, approximations for IH may be acceptable.

However, if a precision of ±1% is required for FSE, then a careful size/density analysis may be required.

Further Reading: See WCSB10 presentation by Stephane Brochot et al.

Step 2. A good understanding of Geology and Mineralogy is important

Information from logging diamond core samples is extremely valuable to obtain information to get started with FSE, such as:

a_{max}

d_M

Mineral associations

Beware: the potential for delayed comminution
Beware: the potential for Poisson Processes

Step 3. Create a reliable model for the liberation factor

The following model must be based on reliable geological and mineral information:

$$\ell = \left(\frac{d_\ell}{d}\right)^x$$

This gives access to **D. François-Bongarçon's** favorite approach:

$$s^2_{FSE} = \left[\frac{1}{M_S} - \frac{1}{M_L}\right] K.d^{3-x}$$

The necessary reconciliation & the myth

$$f.g.c.\ell.d^3 = \frac{K}{d^x} d^3$$

Both sides **must be the same, although in a different language.**
However:

$$s^2_{FSE} = \left[\frac{1}{M_S} - \frac{1}{M_L}\right] K.d^{3-x}$$

and

$$s^2_{QFE1+AE+X} = \left[\frac{1}{M_S} - \frac{1}{M_L}\right] K.d^{3-x}$$

are incompatible!

CONCLUSIONS

Empirical experiments are useful to detect problems:
They are whistleblowers.

However, they cannot provide solutions.

Only TOS can provide solutions through a thorough understanding of all sampling errors.

RECOMMENDATIONS

If TOS, as presently structured, seems incapable to provide solutions, it is because we don't understand TOS well enough.

All necessary approximations made in the daily applications of TOS have been well addressed a long time ago by Pierre Gy.

Reinventing the wheel does not help and most of the time leads to confusion, chaos and unnecessary expensive tests.

Anyone who wants to improve TOS first *needs to be familiar* with the subtleties of Pierre Gy's work.