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The legacy of Charles Oliver Ingamells (1916–1994)

Francis F. Pitard

Charles Oliver Ingamells passed away in April 1994 at age 77. Ingamells received his BA at the University of Western Ontario and his MS at the University of Minnesota. During his later years in his retirement home in Florida he was a faithful representative of a group of well-known world experts in Sampling Theory, such as Pierre M. Gy, Francis F. Pitard, Jan Visman, Paul Switzer at Stanford University and J.C. Engels at the US Geological Survey and the Linus Pauling Institute in Menlo Park, California. His association with Francis F. Pitard during several years at Amax Extractive Research & Development in Colorado has added to a unique combination of different experiences in the field of geochemical analysis. His pioneering work in the field of geological sampling led to collaboration with the above experts.

Charles Oliver Ingamells, CIE, BASc, MS, MM, ILI, RPCV

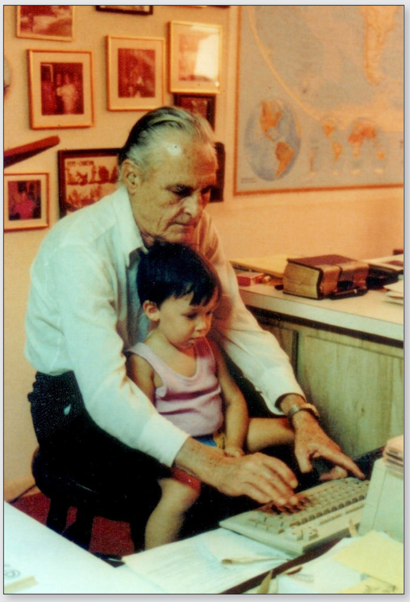
Passing away much too young from brain cancer, Oliver Ingamells was one of the most brilliant intellectuals I ever met. He would have loved the concept of the WCSB and would have been, with no possible doubt, an amazing addition to the TOS community. As early as 1967, he was an admirer of Dr Pierre M. Gy's work.

During his life, Oliver was never short of straight-to-the-point remarks when he would reach a point where patience was running short. As his daughter, Margaret I. Resnick said it so well, "My father was an Einstein; and it is a shame that he was not more recognised. His genteel, selfless and aggressive desire to learn what's out there made him a valuable asset to the scientists who want to further mankind's sense of awareness." For many personal reasons, I fully agree with these words. But, as a man of great vision, he had no patience for people who are prisoners of short-sighted paradigms. Another point I fully agree with Margaret Resnick is when she said: "My father was scientifically superior but diplomatically inferior!" It was easy to feel the accuracy of that statement when working every day with Oliver.

The legacy of Ingamells for TOS

Ingamells's knowledge on sampling[1–8] has its roots with J. Visman, who he personally knew very well. It would be futile to compare Ingamells's work with Gy's achievements. Rather, it is important to emphasise the work that may be beneficial and provide relevant, harmonious additions in some areas of TOS, and indeed there are many possibilities. Such additions may enhance our capabilities to predict sampling difficulties by using a stronger strategy and to design better sampling experiments that would allow us to further understand the heterogeneity of minor and trace constituents.

Amounts of minor and trace constituents are the key issues in many industries where their accurate determination is of paramount importance. The Theory of Sampling would be incomplete without an understanding of what we can do when *Poisson processes* are almost inevitable, or when people are unaware of such possibilities, or when people are in denial that they are indeed a possible event. There are numerous examples, such as quantifying trace amounts of constituents in pharmaceutical products, in high purity materials, in the environment, in genetically modified organisms, in precious metals exploration etc. This is where the work of Ingamells is priceless; his entire work is based on Visman's work and Poisson statistics. It is of paramount importance to make the emphasis very clear: *without a good understanding of Poisson processes there is no possible in-depth understanding of the TOS* because too many subtleties become elusive, and this has escaped the attention of most sampling practitioners around the world and it needs to be corrected.



Oliver Ingamells showing the subtleties of a 1993 PC world to his grandson Sender.

The logical evolution of Ingamells's ways of thinking

The best way to follow the evolution of Ingamell's ways of thinking for sampling issues is to read the first chapter of *Applied Geochemical Analysis*, a textbook written by Ingamells and Pitard in 1986.[9] This article presents an overview of some of the most important of Ingamells' work, which can be summarised as follows:

"If you wish to sample the ocean for its salt content, several cups of seawater taken in several of the world's seas would probably yield a useful distribution of *assay values* and a useful average value. But, if you wish to sample the ocean for its herring content, a million cups would very likely yield a false distribution of assay values and thus an erroneous average. No one would blame the person who counts the number of herrings in the nets for potentially poor estimate of the herring content of the ocean; yet geologists have sometimes been led into the habit of collecting minuscule samples of *mountains* (literally) containing large chunks (nuggets) of ore sparsely distributed analytes and attributing anomalous assay values to deficiencies in the analytical techniques."

All his life, Oliver Ingamells was concerned on how a 1-g analytical subsample can fairly represent "an entire mountain" (this caricature is intended quite deliberately). In his own words:

"Traditionally, the geochemical analyst receives a *small* sample in a bag or bottle, further removes, again, a small portion hereof (sometimes as little as a few milligrams), and compares this with a small portion of another material of *known* composition, using an instrument of some sort, such as a burette, a set of weights and a balance, a spectrometer, a colorimeter etc. He then uses a measured ratio to obtain one or more numbers, which he reports. The submitter of the original sample uses the data so obtained to make important geological, geochemical decisions or other judgements.

For this process to be successful, several essential requirements **must** be met:

1) The sample submitted to the analyst must have the same composition, within acceptable limits, as the material from which it was taken.
2) The small analytical subsample must have the same composition, within acceptable limits, as the submitted sample.
3) The material used as a *reference* (the balance weights, the salt to prepare a standard solution etc.) must be *known* with acceptable certainty.
4) Small analytical subsamples of the *known* must have the same composition, within acceptable limits, as the bulk reference material. This requirement is important when analysed *standards* are used to calibrate an instrumental method (e.g., X-ray fluorescence spectrometry).
5) The process of comparison and ratioing is essentially unaffected by differences in composition between *known* and *unknown*.
6) Interfering factors are insignificant or under adequate control.
7) The measurement precision is adequate.
8) The sampling weight baseline is preserved throughout.

In each analytical exercise, these essential requirements assume different degrees of consequence, but they should all be kept in mind. Failure to meet any one of them will lead to the generation of poor or meaningless data."

A summary of C.O. Ingamells and F.F. Pitard: *Applied Geochemical Analysis* (1986)

This unique textbook about primary analytical methods used to prepare geostandards starts with a long chapter on *sampling* presenting Ingamells' views on sampling issues.

Ingamells' perception of Gy's Sampling Theory

Oliver had a hard time with the concept of the Liberation Factor. I recall the many times we discussed that subject. To him, the size of particles of the constituent of interest was the only relevant factor, and it did not make any difference if the constituent of interest was liberated or not. What was missing in his ways of thinking is the fact that no matter what, the sample must represent all size fractions, gangue (side rock) and constituent of interest, since it is very likely the grade of the constituent of interest would change between coarse and fine size fractions. Ultimately, he fully agreed with that concept.

Elaboration of Ingamells' and Switzer's constant K

The constant K is a way to measure the sample ability of a well-mixed granular material defined as the weight w necessary to achieve a 1 % uncertainty.

A summary of Visman's Sampling Theory

This part is an introduction to the concept of the Fundamental Sampling Error (FSE), or its Visman equivalent, and to small scale segregation.

Relationships among the Sampling Theories

Ingamells makes an attempt to show similarities between Gy's and Visman's theories, a concept I vastly expand in my Doctoral Thesis and in the third edition of the textbook *Theory of Sampling and Sampling Practice* published in 2019.

Comments on Geostatistics

Ingamells emphasises the fact that the geostatistician must assume that irrelevant variance due to subsampling and analytical errors are low. If not, calculations are likely to show a false nugget effect that generate incorrect assessments.

The laboratory sample

Emphasis is also made that a stringent guideline must be provided to the laboratory to prevent unfortunate difficulties during the subsampling process when starting with the field sample that may weigh 5–10 kg and end up with a representative 0.5-g analytical subsample.

Calibration standards

Rapid instrumental methods require calibration; calibration is most satisfactory if a few of the actual samples analysed by primary methods are used to develop working calibration curves.

Samples and subsamples

A warning is stated about the economic consequences of introducing unacceptable subsampling errors at the laboratory.

Weight proportions and volume proportions

In a mixture of two minerals, or an ore mineral and a gangue, the weight proportions of the two components are the same as their volume proportions *only* if the densities of all minerals in the mixture are the same. Most often, analytical or assay values are reported in terms of weight proportions (e.g., percent, part per million, ounces per ton and so on). Sampling characteristics of the mixture are, however, more dependent on volume proportions: it is, therefore, necessary to relate these two ways of measuring concentrations.

Size and number of particles in a mixture

Introduction is made of a uniform hypothetical mineral mixture making a simulation of a real mixture of the same minerals.

Contribution of a single grain

This section is an introduction to create a Poisson model that would be accurate enough to give early warning to the fact that sometimes the subsample mass that has been selected is totally inappropriate. Approximations made in this model are good enough to make such an assessment of paramount importance.

Histograms

Histograms should be constructed using a rational interval. Use of a completely arbitrary interval may lead to a false impression of a distribution.

Standard deviation and estimated standard deviation

The standard deviation is an index used to measure the dispersion of a number of measurements about their arithmetic mean. In dealing with analytical or assay values, there are almost always too few of them to permit an exact measure of their dispersion, and only an estimate can be made. The standard deviation, σ, is a theoretical quantity; the estimated standard deviation, s, is an experimental approximation of σ. Nevertheless, the estimate s is often referred to as *the* standard deviation, without mention of the fact that it is an estimate only with all its inherent limitations.

Gaussian, or Normal, distribution

At one time in history, scientists became convinced that the Gaussian distribution was universally applicable, and an overwhelming majority of applications of statistical theory are based on this distribution. In this context, a common error has been to reject *outliers* that cannot be made to fit the Gaussian model or some modification hereof, e.g. the popular log-normal model. Failure to recognise that the real distribution of the grade *may not* be Gaussian is one of the biggest mistakes made in sampling practice.

Poisson statistics

A sample is too often only a miniature amount of material and within such small scale an observed feature, such as why this particle is there rather than here, or why is it bigger than the other one, is a property of statistical independence; and yes, in practice this assumption of independence is satisfied only approximately. The Poisson model is only the simplest and most random possible model to describe a phenomenon where the collected sample is obviously one or several orders of magnitude *too small* to contain a sufficient, statistically significant number of particles of the constituent of interest, the analyte. If the drill-core sample shown in the Figure 2 weighs, say, 10,000 g, and contains only a limited number of gold particles that cannot comminute, we may well wonder what will happen for the analytical subsample weighing only, say, 30 g?

Relative deviation

The subtle distinction between the terms *relative deviation* and *coefficient of variation* is addressed; the former is a theoretical quantity while the latter is an estimate obtained by empirical investigation, an experiment.

Homogeneity

An effort is made to demonstrate that completely homogeneous materials are so rare that they may be considered non-existent.

Reduction of samples to laboratory subsamples

Given an original sample of weight W that must be reduced to weight w, to find the subsample weight demanded by an analytical method for determining the constituent of interest X with a certain reliability, one may follow a number of procedures. Such procedures must be rationally designed.

Gy's sampling slide rule

At one time Ingamells was very proud to show Pierre Gy that he was using his slide rule to optimise subsampling protocols. Then, Pierre Gy's remark was "I use it myself to draw lines!"

Determination of Visman constants A and B

Ingamells describes the logic behind Visman's *Homogeneity Constant* A and the *Segregation Constant* B.

Determination of gangue (side rock) concentration *L*

The low background content L that is easy to sample can be a parameter of great interest. It is a variable of its own in a mineral deposit, or in a high purity product, or in the environment. Such variability should be the object of more research as it can have significant geometallurgical and economic implications. For example, if a deposit is difficult to sample for its gold content, it would be critically important to find out *what proportion* of the gold is difficult to sample.

Sampling diagrams

Ingamells' sampling diagrams are very different from Pierre Gy's nomographs which we are accustomed to. They are more complex and contain far more information. Figure 3 illustrates the concepts of Low Background Content L (i.e., portion of the constituent of interest easy to sample) and the Most Probable Result (i.e., the *mode* of a Poisson process) as a function of sample mass shown by the dashed line.

Figure 4 illustrates the evolution of the standard deviation of the Fundamental Sampling Error (Visman's homogeneity concept).

Sampling diagrams for segregated mixtures

With segregated mixtures (i.e., mixtures in which all particles are *not* randomly distributed), it is necessary to estimate not only a *homogeneity constant*, A, but also a *segregation constant*, B. It must be understood that B is a constant only at certain sampling stage, since segregation is a transient phenomenon that can change rapidly. Nevertheless, we need to have an idea

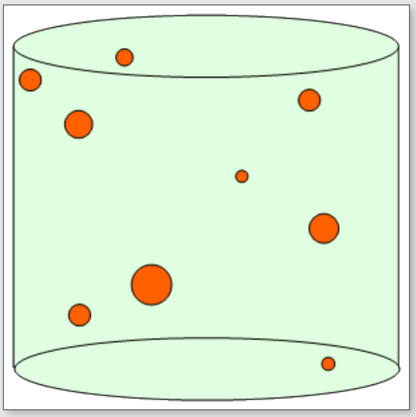


Figure 2. Illustration of a possible Poisson process for gold assaying.

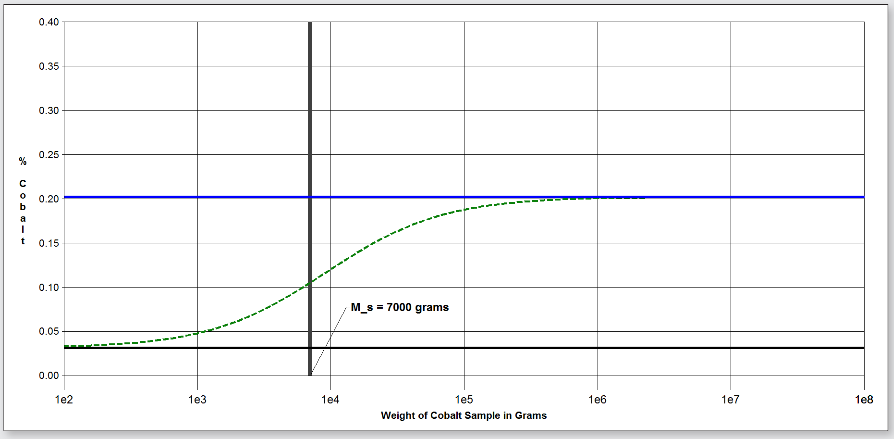


Figure 3. True content (Blue line), Low background content (horizontal black line), and most probable assay value (green dashed line) as a function of sample mass.

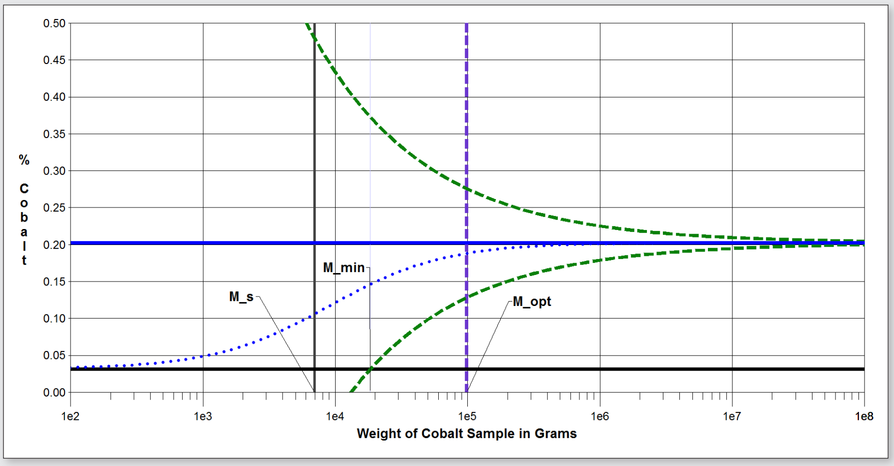


Figure 4. Adding the standard deviation of the Fundamental Sampling Error as a function of sample mass (green dashed line).

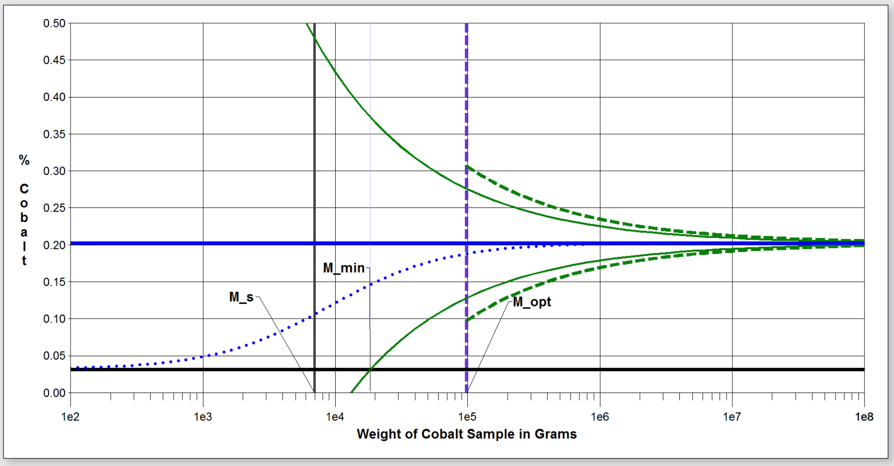


Figure 5. Adding the concept of optimum sample weight = A/B.

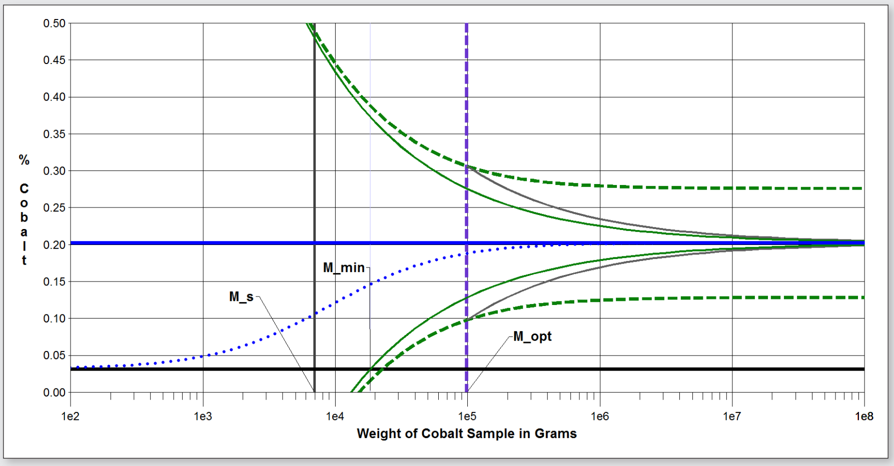


Figure 6. Illustration of the complete sampling diagram.

about its order of magnitude and its likely occurrence. Figure 5 illustrates the additional curve (dashed green line) showing the combination of FSE and the contribution of possible segregation *if* a sample were of an optimum sample weight defined as the ratio of Visman's sampling constants A and B (i.e., A/B). By following the convergence of that line toward the true content one may easily calculate how many samples of optimum weight should be collected over the field of observation to reach a certain preselected overall precision.

Construction of sampling and subsampling diagrams

Ingamells shows that to construct a valid sampling diagram, it is desirable to calculate the Visman sampling Constants A and B by the method of repetitive determination using two series of samples of different individual weight or by another avenue.

Figure 6 illustrates (dashed green line) what would be the overall uncertainty if only one sample was collected over the lot. You may notice that regardless of sample mass, the error due to segregation cannot be minimised as it, to a large extent, is a non-random variable.

Usefulness of sampling and subsampling diagrams

Once a sampling diagram has been prepared, one can tell at a glance how large a sample or subsample should be to achieve the desired sampling precision. For segregated materials, the total weight of a sample does not establish sampling precision; the number of samples taken is equally important. All samples may be assayed, or only considered as increments to prepare a representative large composite sample.

Planning a sampling campaign for exploration

Procedures for sampling and analysis of unknown masses of material such as ore bodies, shipments, mountains, rock piles, slag dumps and so on, should of course be designed to minimise costs, using available sampling theory to avoid misdirected effort and applying analytical techniques in the most efficient manner. Any evaluation of the unknown mass must take place in several iterative stages or steps:

1) Design a pattern for sample collection
2) Sample collection
3) Reduce samples to analytical subsamples
4) Assay for the elements of interest

5) Analyse and interpret data
6) Loop back to 1
7) Continue until information is as adequate as cost permits.

This chain of steps is no stronger than its weakest link.

Effect of variable sample or subsample weight: weighted average

Ingamells warns that it often happens that available data are derived from samples or subsamples that are not all of the same weight. Such data make the estimation of sampling constants difficult, especially when there is appreciable segregation.

Minimising exploration costs

Any system of data evaluation assumes *a priori* that the data points are sufficiently accurate to warrant evaluation. It is assumed that the assay value developed from a field sample reflects to a reasonable degree the composition of the ore surrounding the place from which the field sample was taken. It is also assumed that the assay value is, within acceptable limits, representative of the composition of the field sample itself. Ingamells shows that for these assumptions to be true, the field sample must be:

1) Large enough to represent the surrounding ore, and
2) Reduced to an analytical subsample in such a way that the 1-g, or so, weighed out for assaying has the same composition as the whole field sample.

There must be a cost-effective balance between field sample mass and the number of field samples collected to minimise risk and reach the point of diminishing returns.

Evaluation of preliminary data

Ingamells raises a red flag when the standard deviation of preliminary data is *larger* than the mean. This may occur for one or two or more reasons:

1) The ore body may be badly segregated on a large scale, then geostatistics takes over.
2) The field sample may be too small. Or
3) Errors in reduction or assaying may have been committed.

It is of paramount importance to be able to make a difference between three cases.

Manipulation of skewed data

Exploration data are often highly skewed. It is important to discover the underlying causes of skewness in any particular case. If it is due to segregation on a large scale, field samples should be *small* and *numerous*, and Matheron's geostatistics should be employed in data evaluation that are often log-normally distributed. If on the other hand, the skewness is due to coarse-grained ore, or randomly distributed pockets of ore, larger field samples should be taken because a Poisson process has taken place, and the use of geostatistics is counter-indicated, at least until the Poisson process has been reasonably minimised. Ingamells suggests an interesting data manipulation to eliminate the skewness if it is proven that the field sample mass was indeed too small.

Data from segregated ore bodies

Ingamells invites caution in applying his suggested manipulation if the variance due to large scale segregation is misinterpreted.

Double Poisson distribution

When samples taken from a geological formation of interest (Ingamells' proverbial "mountain"), or other accumulations of material that contain the constituent of interest in discrete grains, are subsampled in such a way that the subsamples also contain discrete grains of reduced size, a double Poisson distribution of the assay values is likely. This is a worse-case scenario during sampling in connection with exploration, grade control, environmental assessments, high purity materials and pharmaceutical products and their trace constituents content assessments. The general analysis of such cases by Ingamells is profound and extremely useful.

Fitting statistical models

Ingamells emphasises that in data sets derived from ore bodies and in trace elements data, the Gaussian approximation is seldom valid; its uninformed application is likely to lead to erroneous conclusions.

Purposes of sampling

Ingamells shows that sampling may have other purposes than the determination of the gross composition of materials. In geochronology, for example, whole-rock rubidium-strontium or potassium-argon ages depend more on the character of the portions taken for analysis than they do on the sample being chemically representative of the whole-rock mass. On the other hand, age determination on specific minerals depends more on the rejection of altered material and on clean mineral separation from geological masses and rocks, than they do on gross sampling procedure.

Field sampling methods

Geologists and mining engineers are often unaware of the difference between a rapid and a primary analysis and must be informed when they ask for one but need the other.

Sampling for potassium-argon dating

Ingamells did considerable work of great importance for K-Ar dating of low-potassium minerals when these minerals are cogenetic with high-potassium minerals that have suffered diffusional or other loss of either potassium or of radiogenic argon.

Mixing and blending

Most of the attempts towards a complete sampling theory as outlined by many authors is based on the *assumption* that during reduction the material being sampled is *well mixed*. That is **all** mineral grains are randomly distributed among themselves. However, it is not easy, in practice, to maintain thorough mixing throughout the reduction process. Ingamells stresses that various widely employed mixing devices should be regarded with *suspicion*; some of them actually segregate minerals of different particle shape and density, and the V-blender is a good example of such a problem.

Contamination

It is **impossible** to collect, reduce, grind, screen and mix rock or mineral samples without introducing some (significant, but typically low level) contamination from the equipment and the environment. The best that can be done is to make sure that critical contaminants are excluded. Which contaminants can be tolerated and which cannot depends on the purpose at hand. Ingamells provides a list of common problems.

Preparation of the laboratory sample for analysis

When a mass of material has been efficiently sampled, mineral separations have been completed, unavoidable contamination have been measured and the analyst has received a small vial containing the results of all these efforts, he or she must decide on the preliminary steps to be taken prior to analysis for the constituents of interest.

The first step should usually be a microscopic examination. This will often give much useful information in a very short time. Under a binocular microscope, the presence of a relatively few grains of a minor mineral rich in the constituent of interest will effectively warn of subsampling difficulties. A judgement of the need for further grinding, screening or purification can be made.

Basically, the amount of information and extremely pertinent questions is massive, even today on the eve of WCSB10.

The unique contribution of Ingamells about Poisson processes in sampling

To this day, nobody has analysed Poisson processes in sampling as far in depth as Ingamells and this valuable work is on display in the list of references provided in this tribute. This is the reason why the author included Part V, Chapters 14–16, in the third edition of his sampling book *Theory of Sampling and Sampling Practice*—to make sure this valuable knowledge does not get lost. The lengthy summary of major issues above is a call for action!

Outliers—which are not outliers

A common error clearly pointed out by Ingamells concerns the ease and willingness to reject data points as *outliers* if they cannot be made to fit the universal Gaussian model. This inclination, used by some geostatisticians, is tantamount to *make the data fit a preconceived model instead of searching for a model that fits the data*.

Table 1 shows a case where an entire NQ-diameter core sample was assayed for gold to extinction, in other words until no material was left. What should be food for thought to the reader is the undeniable fact that the few bolded assays shown in red **are not outliers, but they illustrate a Poisson process where all values are real values and none of them should be tampered with!** This example illustrates where Ingamells was a maestro.

Today, it is now apparent that *outliers* are often the *most important data points* in a given data set, and a good understanding of Poisson processes is not only a convenient tool to use, but a mandatory one! Is this a universal understanding in 2020, however? Sadly **not**, there is still much work to do.

Other scientific breakthroughs from C.O. Ingamells

The classic rock or mineral analysis

This subject matter is where C.O. Ingamells also was a historic master. The term *classical analysis* has become something of a misnomer. In Ingamells' work it is used to signify not the way things were done in ancient times, but the hard core of well-tried methods of maximum accuracy. Those who talk of the *superiority* of new methods are missing the point. Whenever a primary method is developed and is proven more accurate than the old, it is incorporated in the *classical* scheme. Thus, by definition, the classical analysis is more accurate than any other. The fact is that the classical procedures often require more skill and more knowledge and ability than those that involve little more than putting the sample in a machine and reading a signal.

A common error is to confuse accuracy, which cannot be objectively measured, with precision, which can. There are numerous examples of highly precise methods from which systematic error can be eliminated only by means too tedious to warrant the effort. Those who promote such methods on the basis of their precision alone anarchise the art and science of geochemical analysis.

Besides drawing the distinction between *precision* and *accuracy*, it is necessary to observe the differences between *analysis* and *determinations*. Analysis is the opposite of synthesis; it is the separation, partial or complete, of a material into its constituents. How these constituents are determined, after their separation, is an entirely different matter.

Many instrumental methods reduce the amount to analyse almost to zero prior to determination of one or another constituent; probably this is a cause of the common failure to distinguish the two concepts.

The classical analysis, skillfully performed, provides high accuracy, but without consideration of time and cost. Instrumentation is used to the extent that it can provide greater accuracy. There is no dependence on samples analysed by someone else. The work of paramount importance of Ingamells in this domain is well documented in *Applied Geochemical Analysis*.[9] Unfortunately, this knowledge is slowly getting lost today in the name of efficiency and cost effectiveness.

Table 1. Replicate 30-g fire assays from a single 1-m NQ core sample. Results expressed as $\mathrm{g\,t^{-1}}$ gold. Red values are not outliers, but they illustrate a Poisson process where all values are real values. What is shown here is but an example of extreme material heterogeneity.

0.524	1.722	0.436	0.664	0.611	0.546	0.490	**53.826**
0.574	0.528	0.557	0.557	0.527	0.529	0.490	0.519
9.739	1.052	**6.852**	0.668	1.052	0.677	0.468	0.831
0.948	0.742	0.588	0.555	0.744	0.188	1.600	0.725
1.591	0.800	1.400	0.677	0.670	0.749	1.817	0.846
1.200	0.640	0.587	1.078	0.769	**22.000**	0.983	2.383
2.609	1.235	2.017	0.857	1.765	0.833	0.913	3.583
0.703	0.664	0.688	1.417	1.591	0.715	**7.235**	0.734
0.505	0.492	1.278	0.698	0.669	1.261	0.527	0.794
3.017	0.685	0.674	0.655	1.296	2.765	0.983	0.785
1.374	1.191	1.27	0.549	0.672	0.587	2.122	1.374
0.693	0.570	0.896	1.052	0.609	1.339	0.592	0.541
0.668	0.568	0.584	2.852	0.681	0.652	0.360	0.948
1.339	0.597	0.670	0.589	0.703	0.597	0.530	0.590
0.538	0.503	1.278	**16.696**	0.522	2.417	0.704	0.666
0.739	0.636	0.638	0.641	1.113	**63.043**	1.722	2.174

X-ray matrix corrections

Energy-dispersive X-ray analysers have poor resolution. Ingamells suggested a method for deconvoluting two, three or more overlapping peaks that is entirely based on Poisson statistics. The method is unique and unparalleled by anyone else.

A better system of dimensions and units for nuclear physics

Ingamells showed, beyond any possible doubt, that our current system of dimensions and units, metric or not, is not an appropriate tool for advanced nuclear physics; it is unnecessarily complex with foundations that are more emotional than scientific, probably due to the fact that some areas of physics were established by people who were reluctant to communicate with other branches of physics. The system is acceptable for our day-to-day lives, when we cook for the family or work for the mining industry as we both did, but totally unacceptable when we explore the nature of the Universe. Ingamells suggests a simpler system that makes it easier to penetrate the subtle environment of which we are all part.

He proved that time, mass, permeability and permittivity do not need units of their own. In the suggested new system, all values for the "fundamental" physical constants are absolute, with the exception of the so-called "time-thickness constant". This alone eliminates unnecessary ambiguity and greatly simplifies our search for the ultimate truth.

The amazing achievement of his essay is proving beyond any possible doubt that the electric charge of electrons, protons etc… **are a surface area**, which is by itself a scientific achievement of paramount importance, and still unrecognised and never addressed by the "Establishment" today.

The theory of vacuoles

The direct by-product of this new, far more powerful system of dimensions and units, and greatly enforced by the fact that the electric charge of electrons, protons etc… is a surface area, is the new possibility that our existing model of particles is *flawed*, or at the very least very *naïve*. Based on this, following many years of investigation, Ingamells suggested the *vacuole hypothesis*, which was a completely new view of the Bohr atom. The long-term implications of this work are still unclear, but most certainly carry profound possibilities.[10]

Conclusions

Overall, and this is what is most fascinating, for every subject where Charles Oliver Ingamells found some interest to make a participation, he left his footprint as a challenge for many people and many years to come. It definitely takes a superior mind to be able to do this and this is the deep reason for his due place also within TOS.

Ingamells' work related to sampling

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