

## INVITED CONFERENCE: "ANALYSIS? WHICH ANALYSIS, OF WHAT AND WHY?"

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### INTRODUCTION

A long time ago -in July 1999- on another planet called Australia, in another galaxy, a seminar was held, entitled "Good Project -Wrong Assays". It was subtitled "Getting Sampling and Assaying Right!"

This topic certainly warrants the rapt attention of all geochemists.

In the convenor's forward to the published papers of that symposium, R.D.(Ron) Butler stated, inter alia:

"It was clear that one major cause of the concerns was a lack of understanding and communication between the geologist or metallurgist who needed to know the composition of a sample and the chemist in the laboratory who was asked to analyse it. The seminar is intended to be a first step towards strengthening the relationship between the mineral industry and the assay laboratories." (My emphasis, CCB)

Kindly note the use of the word "first"!!! This is a clear recognition of a failing.

A logical next step would be to review some of the history of development of various analytical techniques commonly in use in our fields, and to review the ways in which samples are taken and subsamples prepared for analysis. That could be rounded out with a few examples of tricks and traps of the trade, some old, some new. The revelation of each was quite surprising to the perpetrators.

Perhaps it is also worth noting that in the convenor's foreword another relevant paragraph reads:

"Whilst the validity of sample assay results is dependent on both (BOTH, CCB emphasis) sample preparation and sample analysis, the papers contained in the volume focus predominantly on the problems arising in laboratory analysis".

From a geologist's point of view it is even more important that the samples taken are relevant, from which analytical answers may be obtained that can be interpreted in context.

This implies that appropriate sample preparation (if needed) is carried out and that appropriate analysis follows, leading to the obtaining of a set of results that can be interpreted.

These points will be taken in order

## GEOLOGY

The 1999 Edition of the Australasian Code for Reporting of Mineral Resources and Ore Reserves (The JORC Code) prepared by the Joint Ore Reserves Committee of The Australasian Institute of Mining and Metallurgy, Australian Institute of Geoscientists and Minerals Council of Australia, which took effect in September 1999, contains the following paragraphs in its Foreword:

8. A Public Report concerning a company's Mineral Resources and/or Ore Reserves is the responsibility of the company acting through its Board of Directors. Any such report must be based on, and fairly reflect, the Mineral Resource and/or Ore Reserve estimates and supporting documentation prepared by a Competent Person or Persons.

In compiling Mineral Resource and/or Ore Reserve information in a Public Report, a company may need to edit the documentation prepared by the Competent Persons. Where such editing takes place, the Competent Persons must give their consent in writing to the company to the inclusion in the Public Report of the matters based on their information in the form and context in which it appears in the Public Report.

9. Documentation detailing Mineral Resource and Ore Reserve estimates from which a Public Report on Mineral Resources and Ore Reserves is prepared, must be prepared by or under the direction of, and signed by, a Competent Person or Persons.

10. A 'Competent Person' is a person who is a Member or Fellow of The Australasian Institute of Mining and Metallurgy and/or the Australian Institute of Geoscientists with a minimum of five years experience which is relevant to the style of mineralisation and type of deposit under consideration and to the activity which that person is undertaking. If the Competent Person is estimating, or supervising the estimation of Mineral Resources, the relevant experience must be in the estimation, assessment and evaluation of Mineral Resources. If the Competent Person is estimating, or supervising the estimation of Ore Reserves, the relevant experience must be in the estimation, assessment, evaluation and economic extraction of Ore Reserves."

The concept of Competent Person was first aired in 1971, when reports came to hand signed by Consulting Geologist Dr. "X" whose Ph.D. was in botany and

whose formal training included very little geology, mining engineering and primary metallurgy. The concept became an integral part of Australia's first Code, and of all subsequent editions. Its necessity is highlighted in King et al, 1982 on p. 13 where they state in their section "Geology in Ore Estimation":

"In the course of the study it is the geological factor that has impressed itself on us more and more as being the key deficiency where serious weaknesses in ore reserve estimation have appeared, especially in grade. In case this conclusion should look like someone pushing his own (former) barrow, it may be mentioned that one of the authors is not a geologist and that the others reached that conclusion only in the course of this study, having for most of their professional life been concerned with the large-scale rather than small-scale features of ore occurrence."

Examples of the impact of geology on ore reserve estimations readily available in the published literature include four given in King et al. 1985.

Perhaps it is worth remembering that geostatistics can only give answers in relation to the numbers (assays and dimensions) available, not to a deposit. This is highlighted by the observation that Bougainville's ore reserve understated the grade, "where at least two identifiable factors resulted in upgrading in the first few years; "These were given as: "Loss of sulphides in early diamond drilling and failure of the vertical drilling pattern to intersect some small high grade vertical breccia pipes." (King et al. 1982 p. 7). They also stated (p.10):

"It follows that a 'quick look' at an ore reserve estimate is almost worthless".

The major point is that the drilling was pattern drilling - not designed to resolve the critical geological problem.

These points must be kept in the forefront of the minds of people involved in mining exploration, as the aim of such exploration is to identify deposits warranting the calculation of ore reserves.

It is abundantly clear that sampling in exploration needs the supervision of serious competent professional people if the subsequent steps from sample preparation through analysis to interpretation of those results are to be reliable and meaningful.

## **SAMPLE PREPARATION**

"Preparation is a sequence of non-selective operations such as transfer, crushing, grinding, pulverizing, drying, mixing, etc., carried out on a batch of matter in order to bring it under a convenient form for the next processing stage, which can be another sampling stage or the ultimate analysis. Preparation shall not be confused with sampling, which is the selection process itself." Pitard, 1989, Vol. I p. 16.

In the 1950's, when the lower limits of detection for most of the elements sought as tracers, ore minerals or byproducts were, by 1999 standards, very high, the effects of most gross errors in sample preparation could be found, but smaller errors, particularly systematic errors, were much more difficult to identify and quantify.

Slowly we came to realize that certain sample preparation practices, themselves, introduced significant errors, but even today we find very large errors passing un-noticed resulting in quite misleading assays or analyses being reported.

## **WHY?**

Commonly, the answer again is a lack of communication between laboratory and field personnel. This is because neither has sufficient appreciation of the work of the other, in many instances, but in others we find that no-one in the field-to-results chain has sufficient knowledge of the niceties of relevant sample preparation. The initial errors - often large - are made in the field in the first stages of preparation, which is carried out with quite inadequate supervision.

While much has been written on the theory of heterogeneity, sampling, sampling correctness and practice, (an excellent example is Pitard, 1989) until the late 1980's, much of this was only in mining engineering text books and journals and not drawn to the attention of geologists, much less geological field assistants, while much of the remainder was in chemistry and metallurgical books & journals.

A useful reference for the exploration geologist or research worker is Lenahan and Murray-Smith, 1986, which is a mine text book, not an exploration one !

Exploration field samples, as discussed above, are often not representative, or even intended to be, but if they are intended to be representative, for the analytical results to be useful, sample preparation must be appropriate and not introduce significant departures from total analysis of a complete sample.

Experience has confirmed that sample preparation of exploration samples continues to be a major source of error.

Commonly, the first stage of cutting a so-called representative sample from a percussion drill's chips or subsampling (usually by nominally halving) diamond drill core introduces errors. So much so that in some projects accepted practice is to photograph all core, retain only skeleton core and submit the rest for crushing, grinding or pulverizing and subsampling for assay.

Errors of the order of 30% to 40% of the "true" value of gold, uranium, copper and platinum, to name a few, are readily introduced by such practices as unfaithful halving of core, incorrect feeding of sample crushers, incorrect feeding of splitters,

such as Jones riffle splitters - or even using incorrectly designed equipment. Soft, high value minerals such as native gold, electrum and molybdenite readily contaminate sample preparation equipment, while dense minerals, such as gold, electrum, uraninite and the platinum group metals gravity separate from comminuted host rocks having of the order of a quarter to an eighth of the specific gravity of even composite particles.

Contamination from the sample reduction equipment itself is still a problem in places, in the 1990's.

Outmoded practices such as the use of contra-rotating disc pulverizers for reducing gold ore samples and mat rolling to mix ground samples are still in use despite obvious loss by smearing in the first and gravity segregation followed by incomplete subsampling in the second.

Introduction of the Siebteknik swing mill in the 60's (eg. large bowl pulverisers), its derivatives and variations, have certainly reduced many of the errors but in some laboratories there is insufficient use of barren so-called "wash dirt" between samples to clean the crushing and/or grinding surfaces - resulting in cross-contamination which, in precious metal exploration remains a serious concern.

During the 1980's several sets of sample comminution equipment, made of materials that could contaminate the samples being reduced, were found. Another trap for the unwary.

Incorrectly cleaned sieves and even sieves of contaminating material have been noted in use in the last decade.

Incredibly, in the 1980's and 1990's subsamples for assay are often still scooped from the top of a mound of pulp in the pulverizer (or, worse, from a mat-rolled mound). As Hellman says (1999, p6) the former practice, on the Bendigo field, Victoria, Australia, resulted in an average of 30% less than gold assays by cyanidation of the whole pulp or by screen fire assaying of a large sample. The dominant cause was the presence of coarse free gold.

As far back as the 1960's Dr. Rudy Obial of the Philippines showed during post graduate study in England that mat rolling gold ore pulps then sampling the tops left almost all of the free gold and dominantly gold rich composite particles in a thin layer, unsampled, on the top surface of the mat, i.e. at the bottom of the pile, yet the practice was in use in several operating gold mines in the last 10-15 years - resulting in grossly understated head grades, overstated mill recoveries and conflicts between geologists and mining engineers re reserve ore grades, head grades, grade control etc. The exploration staffs of such mines may well have missed ore targets if their samples were assayed in the mine plant!

Bloom & Titaro gave a very concise paper in 1997 illustrating this point!

## ANALYSIS

When we speak about analysis in mining exploration today, few people realize that almost all of the techniques commonly used have evolved within the last 50 years, and that older ones have been so modified by “add-ons”, instrumentation and computer technology that most are almost unrecognizable to those familiar with the originals.

As geochemical and, to a lesser extent, mineralogical tracer work, rely on these techniques, and as the division between chemistry and physics has become blurred in this field, perhaps, at a conference such as this, a brief historical overview of relevant analytical techniques and their application and misapplication is warranted.

In the early 1950's “wet chemical” techniques, such as the short iodide method for copper, D.C. arc spectrography for trace elements and fire assay with a gravimetric finish for gold, silver and the platinum group elements were the norm. As late as 1955 Walsh published his seminal paper “The Application of Atomic Absorption Spectra to Chemical Analysis”, heralding the development of the first AAS units in the late 1950's. He presaged the use of emission spectra, too, but recognized how much more difficult that would be to develop to the commercial application level.

X-ray diffraction and X-ray fluorescence technologies were well developed by the mid-1950's after publication forty years earlier of the basic physical principles (earning a Nobel prize for the Braggs -father and son- for their work in Adelaide -resulting in  $\lambda = 2 d \sin \theta$ !).

After WWII work on radiation rapidly evolved workable neutron activation analysis for many elements. This became commercially available in the 1970's (Kruger, 1971) both in the classical form (Hoffman, 1992, for example) and in the remote form for which a sample, e.g. Pd-bearing, is castled with a radioactive source rather than exposed in a reactor to a neutron flux.

At about the same time we saw the shift of neutron activation analysis from an expensive laboratory tool of moderate precision into a good tool, albeit at high cost and then during the sixties and seventies into a very good tool at reasonable cost.

Meantime the old gravimetric fire assay technique evolved, with the use of AA finish, (with or without heavy liquid extraction of the FA prill) to a quite common, cheap, relatively sensitive, relatively accurate analytical method.

Harking back to Ron Butler's Foreword, we now see where some of the problems arise.

“Analysis” to many young geologists is something done by chemists and/or physicists using magic black box machines connected to computers linked to printers which spit out “correct” answers on request.

Consideration of just a few of the problems encountered in analysis - not just historically, but as recently as 1999 - should encourage the mining exploration people to pay a lot more attention to strengthening the relationship between the mineral industry and the assay laboratories.

As late as 1961 "spectrographic methods" could "... not approach the required accuracy or reproducibility required for low contrast anomalies". Analytical reproducibility and accuracy required in Zambia (then Northern Rhodesia) were defined as statistical mean accuracy to not exceed 20% in the range 10 to 150 ppm for copper, lead, zinc and nickel with detection limits of about 10 ppm. (Cornwall in Mendelsohn, 1961, p. 197).

Colorimetric methods were then still in vogue for trace analysis for geochemical prospecting purposes.

Cornwall's table 16 (pp. 198-199 in Mendelsohn, op. cit.) details nine of the techniques then in use with relevant remarks. Analytical mean accuracies were expected to be better than 20% and if they exceeded 25% on the statistical controls the intervening routine analyses were rejected and repeated (Cornwall op. cit. p. 200).

How many of today's' highly accurate analyses would withstand this check in the 10-25 ppm range for soils?

By the mid-1960's, however, AAS technology had evolved to the stage where it was routinely supplanting DC arc spectrography and colourimetric techniques in mineral exploration. Here, however, there were other problems.

Lead values in the mid sixties to early seventies constantly proved to be poorly reproducible in the tens to a hundred ppm range. Only with the advent of double beam digital AAS units with helium lamp background correction could this (and several other similar problems) be solved.

The cause of the lead "errors" was an absorption line of calcium that was so close to the line normally used for lead that we, in exploration, were paying for lead assays and receiving (lead + calcium) results, or even, occasionally, only calcium ones ! Oops! Back to the drawing board.

Problems with AAS finish on fire assay gold continued into the mid-1970's. There, however, another, more serious problem arose to confirm that those who will not read history are often doomed to repeat historical errors.

At the turn of the last century fire assaying for gold was a well developed art. Naturally, gravimetric finishing was used. Values down to as low as one or two parts per million were read, using beam balances with platinum wire riders, that some of us still remember fondly. A major, well-known problem that received a lot of publicity in the twenty year period from 1895-1915 was that of deleterious elements such as selenium and tellurium "wetting" the surface, i.e. destroying

the surface tension, of the cupelled prill, causing as much as 40% of the gold to be absorbed into the top of the cupel. Assayers very quickly learned to recognize distinctive rings of colour on the cupel surface and to scorify out the surface and retreat the products. During these times fire assaying for gold was a skilled trade and a real art. Each operator learned to mix his appropriate flux for fusion, and to determine the proportions needed, as well as detect those oddities. In the 1980's a drill core sample -5m of 27g/t Au- was reported as having no detectable gold, a result accepted by the senior geologist of a major international company until a consultant mineralogist found free gold in the remaining half core, pushed for re-analysis, refused to accept the confirmatory "zero" and eventually caused the cupel to be scorified. 500 ppm Te caused total "loss" of 27 ppm Au !!

As Lenahan and Murray-Smith put it so neatly on page 41 of their 1986 text book:

"The determination of the optimum flux composition requires some knowledge of the ore type and an understanding of the elementary principles of pyrochemistry. An ore with an acid gangue will require a basic flux, whereas an ore with a basic gangue will require an acid flux. The slag should consist mainly of borosilicates, existing as a mixture of metasilicates and metaborates." They go on to discuss self-fluxing ores and the difference between those and pyritic ores and give details of various constituents of various flux reagents.

Unfortunately, as Sawyer so neatly expressed it, "... in the years immediately prior to the 1970's and in the twenty years or so since then ... we lost a whole generation, or perhaps two generations of fire assayers; " (Sawyer, 1992 p. 38) as a direct result of that, and of "competitive" pricing, as he says (p. 39). "One sample is going to be treated exactly the same as the next sample even though the character of the two samples may be quite different. Anyone who thinks that a \$15 precious metal assay on a complex ore is going to be accurate on any but an accidental basis is not living in the real world." And yet, today, we see so-called reputable laboratory groups using "standard fluxes" and operators with no training in recognizing Se or Te coloration of cupels.

Two more of the many traps of fire assaying that need wider publication among geologists and metallurgists are those of copper sulphides collecting gold during fusion, and acceptance of lead collection (in fusion) for analysis of the P.G.M.s, or some of them.

How many geologists are aware that the gold content of porphyry copper ores can be reported at well below true value if fire assay techniques are used to determine their levels ? In a 1992 paper, on p. 302 Hoffman stated inter alia: "Fire assay followed by AA or ICP-AES finish were also shown to be low for certain samples (low by 26% in the case of porphyry Cu drill core)."

Even worse, Mary Doherty, of B.H.P., Denver, published in 1999 results of some cross-checking of standard PGE analyses at four commercial laboratories



in Canada and Australia. Lead Collection Fire assay PGE results and gold blanks came out rather poorly. She concluded that NiS collection fire assay INAA determination with 3 months turn around and a cost of US\$ 125/sample "provided reasonably accurate results ... with few exceptions." - an echo of Sawyer's comments.

This leads us to consideration of INAA, a technique which has been described as cheap and convenient if one has an appropriate nuclear reactor to hand.

As with most techniques this, at first, was a scientific curiosity in the 1930's, but with the advent of "modern" low powered, well controlled reactors in the 1960's it rapidly developed into a useful tool.

Initially, early gamma ray detection devices could not resolve many of the complex gamma ray spectra emitted from irradiated samples, the levels of emission were quite low due to low intensity neutron sources being used to irradiate the samples, recording devices were rather primitive by today's standards, as were data presentation systems.

All of this had changed by the mid 1970's and by the early 1990's as Hoffman wrote in 1992 (op. cit.) "Over the last decade significant advances in the manufacture of high purity Ge detectors with very good resolution and also able to process high incident count rates have provided the necessary detection equipment for high quality, high volume INAA." (p.299). As he says on p. 302 "Modern detectors can easily resolve even the 411.1 ke V Eu interference on the 411.8 ke V Au peak."

Various elements, for technical reasons, may require different irradiation times, leading to long turn around times, e.g. for Pd of three months (Doherty, 1999, p.15) while for uranium, the  $U_{235}$  isotope emission is counted within tens of seconds of very short irradiation time. Indeed, Gregory and Knight in 1977, writing of an Australian facility, could advise: "The samples are inserted into the MOATA reactor, withdrawn, the activity counted and recorded on tape, all in less than two minutes." (p.7)

Hoffman gave a useful table of relative sensitivities for rock matrices by INAA on p. 304 of his 1992 op. cit., and describes limitations of the technique.

Another technique, I.C.P. has opened another Pandora's Box of problems, both in control of temperatures and reporting of values from samples with matrix interference, incomplete uptake in the original dissolution, Fe interference etc. and commonly quoting in results sheets elements for which the technique is not suited.

As with every analytical technique it has its advantages and its limitations, and it was grossly oversold in the 1980's.

Several other analytical techniques are available, but the same caveats apply.

## EXAMPLES OF PROBLEMS

### EXAMPLE 1

One of the major unadvertised deficiencies in analysis today is the practice of laboratories reporting partial analyses without any mention of that in their reports.

A typical example is the reporting of K by ICP when the digestion applied to the original sample would have taken up less than half of the K in the sample.

To illustrate this in an extreme form, sediment chromium assays reported in a UNDP report in 1968 (Pisarski, 1967) were given as ppt, of the order of 20 to 200, and the note made that "ppt" were thousands of ppm ! not parts per trillion.

>From the same area CRA, using Craestar, reported approximately 20 to 200 ppm.

To resolve the problem in the 1970s, the same areas were re-sampled, and the sediments submitted to microscopic examination - revealing lots of chromite and to electron probe micro-analysis which yielded 49%-57% Cr<sub>2</sub>O<sub>3</sub> on three points. Re-analysis by a reputable laboratory yielded CRA - level results.

When the laboratory was advised of the microscopic and micro-probe examinations, the samples were attacked with hot concentrated KOH and NaOH, yielding 10% to 20% Cr - i.e. UNDP was right.

The message, after talking with CRA, was that CRA's method was inappropriate for Cr, and that the results should therefore not have been reported to the then B.S.I.P. government without any disclaimer.

### EXAMPLE 2

A porphyry copper deposit was put into production with less than half of the minimum diamond drill hole meterage most of us would consider necessary for calculation of resources and reserves.

What was worse, most of it was pattern drilling on the assumption that the detailed grade controls within the body need not be resolved at that stage !!

As far as knowledge of the relevant specific details of mineral exploration and economic geology were concerned, the senior executive driving the program reached management in a field of endeavour remote from mining.

His chief geological adviser seems to have had very few years in the commercial world and no hands-on experience of the ore type, resource or reserve calculations nor relevant grade control techniques. A recipe for the subsequent financial débacle, and a significant reduction in published reserves after very few years of operation.

Neither person was trained nor had the experience to recognize the traps they led their management (and hence shareholders and joint venture partners) into.

Neither met the requirements of a Competent Person in this field, nor, to my knowledge, did they rely on anyone who did!

The sampling was inadequate because the geology was inadequate and pattern drilling was used in a situation calling for resolution of the geological controls on grade. To view such controls the reader is referred to Clark's 1990 paper on Bougainville.

### EXAMPLE 3

Nabarlek, the high grade uranium deposit now mined out, some 140 km east of Darwin, N.T., Australia, caused a major stock market upset when its announced resource of 55,000 tonnes contained U<sub>3</sub>O<sub>8</sub> was abruptly downgraded to 10,000 tonnes before any mining started.

A thorough investigation revealed a series of startling facts.

The head office supervisor of the exercise, who calculated the initial resource, was a senior experienced geologist, with a good Ph.D., in his fifties, who had most of his professional career in the oil game and in photogeological work. He could not be deemed a Competent Person to calculate a high grade vein uranium resource.

None of the other geologists associated with the project during the investigation could have, either.

The geology had not been mapped properly, and when the chief geologist, from eastern Asia, insisted on his 2 1 C mapping an S-3 or S4 surface as bedding, that European quit.

The core halving was done badly; the crushing of half core on site was poorly carried out; the unsupervised field assistants on site had completely unwittingly used a Jones riffle splitter as a gravity separator; the subsamples sent 3,000 km to a laboratory were then not ground finely enough to permit the subsequent subsampling ( phase two, in the laboratory ) to be accurate.

The results were shown by re-comminuting and re-subsampling the remaining ] of crushed half core of 20 high grade samples to be consistently too high - by a minimum of 15% of value and a maximum of 28% of value.

The results used in calculations were unweighted for S.G. despite the high grades generally being 10% to 20% U<sub>3</sub>O<sub>8</sub> as uraninite and subsequent checks showing S.G.'s of ore in the range of 6.0 to 10.0.

There were many other errors which need not concern us here. The message re competence was crystal clear.

#### **EXAMPLE 4**

In the same vein - a senior staff man in a capital city insisted on porphyry copper drill core being halved, crushed to minus a quarter of an inch and then split in a Jones splitter, despite the protests of his senior project geologist (Acting Project Manager). Some 20,000 metres of core had to be re-assayed, and the Vice President of Exploration of the parent company chose this point as justification for firing his Australia-and-South-Asia Manager, as standard company operating procedure clearly forbade putting half core through a splitter at coarser than minus ten mesh.

#### **EXAMPLE 5**

A copper/lead/zinc deposit in N.S.W., Australia, had about 40 diamond drill holes through its lensoid ore bodies. Calculations indicated that at least 40 more holes would be needed to reduce the grade uncertainty from  $\pm 10\%$  to  $\pm 5\%$  of that estimated, but the experienced mathematical statistician, (M.E. Joseph), who died shortly thereafter, insisted that there was not enough known about the geology to carry out the calculations.

The company chief geologist proposed to sink an exploratory shaft to 500m, drive on and pattern drill at 10m centres both known bodies, then sill them out to determine the best answer as to drilling density needed for reserve calculation and mine planning.

The shaft was halfway down when a mining engineer was given control of the company. He had no experience in this kind of ore. He insisted on going straight into early production with a two shaft system. History showed the mineable grade to be 2.2% Cu, not the 2.7% Cu calculated, as the geology was much more complicated than that of the models derived from the drilling to that date, and the exercise was quite a financial disaster, despite much more higher grade ore being found later at depth.

#### **EXAMPLE 6**

Mathematical assessment of a large amount of drilling on a complex uranium ore body showed no serial correlation down-hole or crosshole.

A reserve calculated by bulking every assay, good or bad, within the open pit mineable envelope came very close to the mined tonnes and grade, while most other techniques were somewhat astray from this result.

Sometimes it is best to admit that we cannot resolve the geology adequately enough to allow lithological control of grade to be applied in calculating a mineable reserve.

## COMMENT

Stream sediment sampling is just one more of the areas warranting careful supervision. The following three examples have been chosen to illustrate this.

### EXAMPLE 7

In 1965 the late H.E.(Herb) Hawkes came to Australia for the first time and went straight to the Koonenberry Range, N.E. of Broken Hill, N.S.W.

His thought was that the minus 200 mesh stream sediment mud flakes would be best for a base metal search sediment analysis program, but his advice was to carry out a good orientation program, using all available geological knowledge.

The minus 200 mesh proved to be almost totally composed of wind blown material and the minus 20 plus 40 mesh fraction gave both the largest detectable train down stream from known mineralization and the highest contrast, too.

### EXAMPLE 8

In the high rainfall area of Obano, west of Danau Paniai, in the West Irian highlands an orientation survey again showed the coarser fractions to give better contrast and longer train than the finer fractions. The mechanical degradation obviously was beating the adherence of cations onto clays.

### EXAMPLE 9

In an auriferous area in the south of the South American continent a major company carried out a stream sediment sampling program with poor results in one area, which was later targetted by a second company and shown to have several small outcropping gold veins.

A third company checked the sampling of sediments with similar results to the first, but then detailed mapping showed that the area had been recently glaciated and then quickly covered by several major volcanic ash falls.

## ENOUGH SAID? ORIENTATION? GEOLOGY?

## CONCLUDING REMARKS

In summary, if the professional people guiding mining exploration are in the least bit cavalier in their supervision of sampling, sample preparation and/or analysis the results will surely impugn their probity and probably make a serious attack on some people's financial standing.

The tasks can be done well, but must be executed under expert supervision to achieve their avowed aims. This mandates excellent communication at all management

and contractor levels, which, fortunately is tending to be more the rule than the exception in mineral exploration.

We joke that if one compares apples with oranges, the result is usually bananas. We prefer our results to be fruitful.

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The Las Palmas gold district is located at the flanks of the Las Palmas creek, 100 km northwest of Santiago city at an elevation of 260 m above sea level, in the Coastal Range of Central Chile. Mined intermittently since Inca times, the district was famous for its placer gold ores. The source of coarse-grained gold in recent sediments at Las Palmas district is of considerable economic and geologic significance but remain poorly understood. The study about the characteristics and origin of gold grains was carried out in connection with a project dealing with precious metal exploration in the district, which conducted to the discovery of lode-type mesothermal gold mineralization. Economic potential of the orebodies remains under exploration. However, preliminar estimations indicate resources of about 1 million ounces of gold. The topography of the zone is dominated by deep weathering profiles (30-70 m), in which outcrops of rocks are very scarce, and conventional exploration geochemical methods were unsuccessful. The relief is almost flat and mature, and differences of elevation at the district do not exceed 200 m. Small creeks, active only in winter, deposit discrete pediments, consisting of middle to fine-grained sands. The morphology of gold grains evolves during transport, as a function of the distance from the source (e.g. DiLabio, 1990; Herail et al., 1989; Eyles, 1995). Considering the existence of a single relationship between the hydrothermal ore deposit, erosion, and gold-grain concentrations in recent sediments, an excellent opportunity for the quantification of morphologic evolution of gold particles versus distance from the source is represented.

## GEOLOGY OF THE DISTRICT

The oldest rocks consist of a metapelitic sequence of the upper Paleozoic, which exhibit amphibolitic metamorphic assemblage. This sequence is intruded

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