Are Scientific Honesty and “Best Practices” in Conflict?

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Abstract

Honesty is the most frequently cited ethical principle for scientists. The growing use of “best practices” frequently conflicts with the honesty by failing to recognize when the “best” practice is inappropriate due to changed conditions or technology. These changes require the use of professional judgment. But professional judgment is harder for non-professionals to assess, hence the appeal of recipe-type “best” practice standards. Recipes assume standardized input ingredients; something geology fails to provide. Honesty demands this recognition, even if it eliminates the easy answer. These difficulties must be recognized if the use of “best” practices is to be scientifically honest.

Honesty: the fundamental scientific ethical principle

“The only ethical principle which has made science possible is that the truth shall be told all the time. If we do no penalize the false statements made in error, we open up the way, don’t you see, for false statements by intention. And of course a false statement of fact, made deliberately, is the most serious crime a scientist can commit.” C.P. Snow, *The Search (1959)*

Snow’s statement, which serves as the epigraph for this paper, concisely summarises the importance of honesty in science. *The Search* is a novel in which the protagonist, a young physicist publishes results that are based on an assistant’s work that was not checked. When others attempt to repeat the results, errors in the original work are discovered. The young physicist’s previously promising career is ended because he has violated the honesty rule as quoted above.

Further support for the contention that honesty is the fundamental scientific ethical principle can be found in professional ethics codes and statements. For example, the European Federation of Geologists Code of Professional Conduct includes the following statements:

- “5. The rules of … honesty should control the actions of the geologist …
- “6. The geologist must not put his name to anything that is untrue, …
- “9. The geologist must not alter, or deny the existence of, facts or accepted technical or scientific truths which could thereby favour a client or mislead the public.”

And the Geological Society of London’s Code of Conduct states:

- 1. … In pursuing and applying the science, the practice of geology requires the highest standards of integrity, responsibility and professional knowledge. This Code of Conduct applies to all Fellows of the Geological Society and is consistent with the code of professional conduct of the European Federation of Geologists.
- 3. A Fellow shall treat his colleagues with honesty and integrity…
- 7. A Fellow shall avoid any form of negligence in the practice of geology and shall at all times take all reasonable precaution to avoid any act or omission which might either (i) endanger life or adversely affect the health and safety of any person or (it) needlessly endanger or damage property or the environment.
- 8. A Fellow must express opinions on the basis of knowledge and honest conviction and must not alter or deny the existence of technical or scientific truths in order to enhance his arguments. He should never yield to pressure to make knowingly false statements and must always inform a client or employer of the true limitations of practical results.

The opposite of honesty is deception. Deception covers more than lying, *i.e.* saying something you know to be untrue. Avoiding deception requires communicating the whole of the relevant truth. Misleading statements are a form of deception. They are statements that while true fail to state the whole truth with the result that those hearing or reading the misleading statement is led to believe something that is not true. For example, if a geologist is asked whether a property located in the general vicinity of a gold mine contains gold, a truthful but misleading answer would be "yes." It is probable that detectable gold exists on the property. But the real question being asked is not whether there is detectable gold on the property but is there economically recoverable gold on the property.

Misleading statements are often supported or accompanied by material omissions, which are the failure to include statements needed in order to make the whole truth clear. Material omissions are frequently at the heart of deception and fraud. For example, a purported valuation for a quarry contained the following statements about the potential value of the tiles that might be produced.

- The property contains 13 million cubic feet of in-situ marble measured vertically from the property boundary.[1]
- Approximately 50% of the in-situ marble can be used for producing tiles.
- Thus there are approximately 6.5 million cubic feet of recoverable marble that can be cut into tiles.
- If the tiles are 12″ × 12″ × ½″ in dimensions, there are 12″ ÷ ½″ = 24 tiles per cubic foot; thus there are approximately 156 million saleable tiles.
- If the 156 million tiles can be sold at retail for $13 per tile, the gross value of the tiles that can be produced from the property is over $2 billion.

The owner of the property who requested the report containing the foregoing statements attempted to use the report to obtain loans using the $2 billion value of the tiles as collateral.

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[1] This example uses US measurement units. Because the calculations work out evenly using these units, I have retained them rather than converting them to metric units. As no one is expected to re-measure the property used in the example, the choice of units makes little difference other than convenience.

However, the foregoing statements contain several material omissions; they are:

- ♦ The calculated 24 tiles per cubic foot allow no space for cutting and polishing each tile. A yield of 12 or 13 tiles per cubic foot is more realistic.
- ♦ The retail price per tile is more than the value of a tile at the quarry due to shipping costs and retailer's costs and profit margin. Further, the value of a tile at the quarry assumes it is cut, polished, and ready to ship, which is greater than in-situ value of the marble to the property owner.
- ♦ No operating set-back is allowed for the quarry. This is not a reasonable extraction plan from either technical or regulatory perspectives and would not receive the required operating permits if proposed.

The foregoing was an example of intentional deception. Much more difficult to avoid are the unrecognized biases and resulting deceptions that we humans inherently have. As De Freitas (2000) pointed out, "scientists frequently do not property acknowledge the limits of what they really know and uncertainties involved." Richard Feynman (1974, 1999) forcefully makes the point in his famous "Cargo cult Science" lecture at Cal Tech. Feynman urges us to avoid our biases, stating, "…you should report everything that you think might make it invalid—not only what you think is right about it: other causes that could possibly explain your results; and things you thought of that you've eliminated by some other experiment, and how they worked—to make sure the other fellow can tell they have been eliminated."

Best Practices and Standards: Their Appeal and Their Problems

The appeal of best practices and standard is that they provide a measuring tool, a meter stick against which a professional's practice can be measured. Those professionals failing to follow the specified best practice or standard can be judged incompetent for their failure. Failure to follow the best practices and standards expose the professional legal actions based on incompetent practice regardless of the applicability of the best practice or standard to the problem under consideration. The problem with the growing use of best practices and standards is that they fail to recognize the inapplicability of the best practice or standard to a particular case due to changed conditions or changed technology (Abbott, 2003). If best practices and standards are to comply with the honesty requirements of our professional codes of ethics and conduct, they must recognize their limitations and permit the use of professional judgment in their application. The following examples illustrate problems encountered with best practices and standards.

Accounting principles and standards. Generally accepted accounting principles (GAAP) and generally accepted auditing standards (GAAS) are the *sine qua non* example of standardized practice. Their goal is to ensure that every entity using these principles and standards will generate comparable results. The *Wall Street Journal* (2004) reported an interesting example of the application of accounting practice comparing the results for the first quarter of 2004 for Google and Yahoo, the two biggest internet search engines. Yahoo was a public company and Google had announced its intention to become a public company. Given the similarities of their business, one would assume that their financial results would be similar. This wasn’t the case as illustrated in Figure 1. Using the accounting methods employed by Google, Google’s sales costs were $53 million for the quarter, but if Yahoo’s accounting methods were employed, Google’s sales costs would be $316 million. Yahoo’s first quarter sales costs would be $74 million using Google’s accounting methods, but Yahoo reported them to by $282 million. The differences in results are dramatic. Reportedly, both Google and Yahoo were using accepted accounting methods; nothing suggested that either was engaged in improper or incompetent accounting. The reported reason for the differences was revealed deep in the footnotes to the financial statements. Google reported only the net revenue from hits received by those advertise on Google while Yahoo reported the gross revenue from such hits. Because the costs associated from using Yahoo’s accounting method must be shown somewhere, the result is the higher sales cost figures. Nevertheless, the results of the differing accounting methods exceeded an order of magnitude. In accounting, a change of greater than 10% is considered material. Those lacking accounting expertise would have difficulty detecting and understanding the differences when comparing the summarised results.

Fire assays for placer deposits. Fire assays are the *sine qua non* method of accurately determining the quantities of precious metals in geologic samples. This has been true since ancient times; the Old Testament contains a number of references to trying by fire or purifying by fire. From time to time alternative methods of quantitative analysis of precious metals are put forward but none have proven more accurate than fire assaying.[2] Most have proven to be either fraudulent or lacking fire assaying’s precision. Why then does a heading in a well-known book on placer examination read, “Fire Assay of Placer Samples—Misleading Results” (Wells, 1973, p. 91). The short answer to the question is that fire assays, because of their procedures, report the total precious metal content in the sample assayed. The reported quantity frequently is materially higher than the quantity of precious metal that can be recovered using the gravity concentration techniques employed in placer mining. This is an example of the misleading statement I discussed earlier. The value of a precious metal deposit does not depend on the total quantity of precious metal within a specified volume of rock but rather on the quantity of precious metal that can be recovered and sold. Placer examination values report the amount of precious metal recovered by particular concentration techniques. In hard rock mines where fire assaying is the accepted methodology, the average assay values must be reduced by various mining and processing losses to determine the recoverable quantity of precious metal.

High-grade sampling. Deliberately taking high-grade samples is not a normally accepted practice. Normally, sampling programs are designed to obtain representative samples of the material in question. However, when I was examining cases of fraudulently hyped precious and base metal mining properties for the US Securities and Exchange Commission, I deliberately sampled the areas identified by the promoters as containing the highest grade material, including sampling only the high-grade part of a vein or similar concentration. I did this because I had neither the budget nor time to conduct a thorough sampling program. Invariably, the analyses of these high-graded samples reported undetectable or only trace amounts of precious and base metals. I could then argue that if the highest grade material on the property as identified by the promoter had no economically recoverable values, the lower grade portions of the property

[2] I’m ignoring various technologic improvements to fire assaying’s precision such as Induction Coupled Plasma finishing analyses. These improvements do not change the basic argument.

would not either. Given the purpose for which I was collecting the samples, high-grade sampling was the quickest and cheapest method for determining the fraudulent character of the claims being made by the promoters even though high-grade sampling is a non-standard and generally unacceptable practice.

Improper application of a standard practice due to changed conditions.

Swelling soils (bentonites) present foundation problems in many parts of the Denver, Colorado metropolitan area. Most of the Denver metro area is built over essentially flat-lying Upper Cretaceous and Tertiary rocks and the standard method of testing for swelling soils is illustrated in Figure 2. A number of drill holes are bored to depths below the level at which swelling soils might present a problem and any swelling soils found are tested to determine appropriate mitigation of the problem.

However, on the west side of the Denver metro area on the flanks of the Rocky Mountain front, the bedrock is steeply dipping rather than flat-lying and the standard method of drilling vertical holes to test for swelling soils problems is unlikely to intersect the swelling soils that are present as illustrated in Figure 3. Even though geologists have known about the change in dip for years, something that is clearly evident in the hogbacks flanking the mountains and problem areas, soil testing firms continued to use the standard practice despite the changed conditions (Noe, 1997, Noe and Dodson, 1997).

The two photos in Figure 4 illustrate the consequences for two of the many homes affected by the failure of the standard practice to properly test for swelling soils in areas where the bedrock and contained bentonite layers are steeply dipping. The “bat wings,” which are particularly noticeable in Figure 4a, result from the upward heaving of the garage and driveway concrete slabs, which are poured directly on the underlying soils. Both houses in Figure 4 display non-parallel lines, one drawn along the line of the garage and one drawn along the line of a porch. These non-parallel lines, which are parallel in unaffected homes, result from the shifting foundations for these homes and indicate the potential amounts of resulting structural damage to the homes.

Honesty: avoiding misuse of models

Computer modelling has become a commonly used tool for the evaluation of a variety of geologic processes. However, as pointed out by both Rahn (2000) and Oreskes (2000), the limitations of computer models are frequently insufficiently discussed in the presentation of modelling results. Among the major reasons limiting computer modelling are the following points:

- Geology is heterogeneous and non-linear—if the mathematics conflict with geology, suspect the math.
- Models can never be validated; they can only be invalidated by comparison with actual data (Rahn, 2000).

- Models can be tweaked to fit the actual data—does the tweaking hide a bad model or improve a good model? (Oreskes, 2000).
- 3D models are interpretations, not necessarily the "truth."

A couple of examples will help illustrate these points.

Contouring programs. Drawing contour or isoline maps of topography, structural layers, sediment thickness (isopach), and many other quantities is widely applied geoscience practice. Formerly done manually, contouring now is most frequently done by computer using gridded data. The problem is that different contouring algorithms generate different results and personal preference tends to be the basis for choosing between algorithms. Figures 5 and 6 illustrate this point. Both contour diagrams in Figures 5 and 6 were generated from the same gridded data set using the Surfer™ program but Figure 5 used a triangulation algorithm while Figure 6 used an inverse distance to the 4^{th} power algorithm. Both diagrams show the major isoline features, the trough running from the top centre slanting down to the left and a high along the bottom just to the right of the centre. However, if these isolines are to be used to derive data for various points across their extent, then their differences rapidly become apparent as each method yields differing results for the same point.

Mathematical proof of exponential decline. When the production of hydrocarbons from a well is plotted on semi log paper over time, the production trend, particularly after about 6 months, frequently falls along a straight line. Straight-line plots on semi log paper reflect the applicability of the exponential function or change by a constant percentage amount per unit of time.

I once attended an oil reserve estimation short course during which a petroleum engineer mathematically proved that exponential decline should occur if one assumed that the reservoir was (1) isotropic, (2) homogeneous, (3) had a uniform thickness, and (4) had infinite horizontal dimensions. The problem is that these assumptions are never valid.

Figure 7 illustrates the reality of fluid flow in an oil reservoir rock. The rock is a Lower Cretaceous Dakota Group sand, which is a common reservoir rock in the Denver Basin. This outcrop, in a road cut southwest of Denver, is saturated with a fossil oil deposit. During the erosion and uplift of this unit, uranium and other metal-bearing waters entered and flowed down gradient. When the oxidizing, uranium and other metal-bearing water encountered the reducing environment of the fossil oil reservoir, a roll front uranium deposit formed along with related trace element features, one of which is the ilsemannite (a blue molybdenum oxide) tongue outlined in Figure 6. The ilsemannite tongue represents 2-dimensional cut through a geochemical cell resulting from ground water flow into and through the sandstone. The irregular shape of the tongue illustrates the reality of fluid flow, which is very difficult, if not impossible, to accurately and precisely model.

Professional judgment is required

Geologic conclusions are, in the final analysis, expressions of judgement predicated upon knowledge and experience. A geologic conclusion, however, purports to be more than an arbitrary determination—it is reached as a consequence of method. No specific method is required, but the method used must be an orthodox method, in accordance with orthodox definition of terms, and the one best adapted to the dealing with the questions asked about the property in question. This is only basis for judging the validity of geologic work. Although different professionals will arrive at different conclusions, they should be able to honestly determine whether another professional arrived at his differing conclusions in a scientifically sound matter.

Ultimately, we must recognize that achieving the degree of honesty required of us as geoscientists is difficult to achieve but must be pursued with diligence. It is not enough to avoid conscious lies or deception; we must strive to avoid the subtle deceptions. We must describe what we don't know as much as what we know. We must ensure that the limitations of "best practices" and "standards" are understood by all!

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Figure Captions

Figure 1. The first quarter 2004 results for Google and Yahoo using their respective accounting methods.

Figure 2. The standard method of testing for swelling soils by drilling vertical holes to intersect subhorizontal beds.

Figure 3. The failure of the standard method of testing for swelling soils when the beds are steeply dipping. The probability of intersecting a bentonite bed with vertical holes is very low.

Figure 4. Two homes affected by swelling soils. The non-parallel, dotted white lines illustrate the shifting between the garages and the homes while the “bat wings” illustrate heaving of the garage and driveway slabs.

Figure 5. Gridded data contoured using a triangulation algorithm.

Figure 6. Gridded data contoured using an inverse distance to the 4^{th} power algorithm.

Figure 7. A tongue of ilsemannite (“moly blue”) associated with a roll-front uranium deposit precipitated by a “fossil” oil pool in Dakota Group sandstone. This tongue illustrates how fluids really move through rock.