

Views columns are the opinions of the authors and do not necessarily reflect the opinions of SEG.

VIEWS II

The Practical Limits of Technology: The Imperative for Geoscience Collaboration

Ken Witherly†
(SEG 2008 M)

INTRODUCTION

The first era of modern minerals exploration is defined as beginning shortly after World War II and lasting for the next 50 years (1950–2000). This period was inaugurated by the conjoining of global economic, technological, and societal factors that produced a perfect storm of opportunity, capability, and outcomes, resulting in what might be considered as an effective discovery machine. In the formative first two decades of this period (1950–1960s), an important sub-story arose that dealt with exploration geophysics. In suitable settings, technology never before seen gained an almost omnipotent reputation for its ability to detect and, in some cases, define economic ore deposits. The momentum generated in this period was so great, with the rapid discovery of deposits such as Heath Steele, Thompson, Matagami and Kidd Creek, that an entirely new professional group within the exploration discipline arose, based on the development and use of geophysical technology. For exploration this was the Age of Discovery and for exploration geophysics this period could be considered the Golden Age of Technology.

Advancing to the present, over a half-century later, we see the exploration industry now struggling to reinvent itself in the face of declining performance and a number of daunting challenges, many beyond its control.

__Ken Witherly__ has been involved in mineral exploration for over 35 years and has contributed directly to the discovery of a number of economic deposits. In 1999, Ken helped form a technology-focused service company that specializes in the application of innovative processing and data analysis to help drive discovery success.

The *SEG Newsletter* and various SEG lecturers have spread this message over the last several years. A number of industry pundits see a critical part of the way forward into a second era of discovery as requiring an industry-wide commitment to extending exploration to areas with significant cover. This challenge was surmounted by the oil industry almost a century ago and relied heavily on the development of robust geological models and the effective use of geophysical technology. Probably most importantly, geologists and geophysicists realized that collaboration in the discovery process was essential and no one discipline alone was responsible for discovery success.

The challenge for the minerals exploration industry is different from what the oil industry faced 90 years ago, in that the minerals exploration industry has enjoyed a hugely successful period for much of the last 60 years, using largely geologically driven approaches with only a modest input overall from geophysical technology.[1] The challenge now is for the exploration industry and its associated professional disciplines to work together to define new approaches in order to carry out exploration. Geoscience collaboration will be a critical facet of this new paradigm and should be the glue that will hold the whole exploration process together. The oil industry discovered this in the last century and now the minerals exploration business will need to embrace this if a new era of minerals discovery is to come to fruition.

THE GOLDEN AGE OF TECHNOLOGY

The legacy in the first era of discovery of what geophysics provided, and why, is important to understand as we are poised to enter into the hoped-for second era of discovery. In the first 50 years of modern exploration, the case for the efficacy of geophysical technology is solid and demonstrable. Soon after World War II, the underlying physics of geophysics was defined by groups such as Arthur Brant's team at Newmont. This resulted in an outpouring of geophysical technology and geophysically driven discoveries. Following an initial decade of rapid development and discovery, there was a steady advance of new approaches in the fields of data acquisition, signal processing, and visualization of data. This work was carried out by a mixture of groups in the private sector, government, and academia. Large mining companies were sometimes the generators of new developments; however, entrepreneurs and inventors such as the McPhar group, Tony Barringer, Harry Seigel, and Duncan Crone were also key agents in the process, either providing the primary developments themselves (often with help from mining concerns) or acting as incubators to commercial ideas initially developed inside mining companies or universities. The flow of this technology and the resulting applications were well documented in two sources that are still operating: the Geological Survey of Canada (GSC) initiated an annual Geophysical Technology Review in 1963 (www.KEGS.org), and decennial review meetings were started by the GSC in 1967 (www.dmec.ca).

While the outcomes during this era were significant, much of what can be attributed as geophysical discoveries were relatively shallow deposits, typically in the upper 50 m. This was the result of several factors: geophysics worked best where there was sufficient exposed geology for explorers to believe an area was prospective but also where there was enough cover to make direct detection by prospecting difficult. Thus,

†Condor Consulting, Inc., Lakewood CO; e-mail, ken@condorconsult.com

[1] Geophysical successes were limited to certain classes of deposits that were petrophysically amiable to detection with geophysical techniques; VMS-style Cu-Zn-Ag, IOCG, magmatic nickel and kimberlites likely comprised about 80% of the attributable discoveries achieved with geophysics. This excludes the use of magnetic surveys for the discovery of iron ore deposits, a poorly documented but important use of geophysics that occurred primarily in the 1950-1960s.

geophysical methods were then able to quickly highlight the responses of previously undetected but only thinly covered deposits. As a result of this early and often very successful approach, "geophysical saturation prospecting" (Bragg, 1959) was the term used to define the application of geophysics (this was in later years somewhat disparagingly termed bump finding). Consequently, much of the emphasis during this era was on new geophysical developments that could produce an enhanced bump. This was driven in part by the need for greater technical efficacy, but also for a better story for the service company to win more work, or the mining concern that controlled the technology to attract more investors or collaborators.

One important observation that emerged in this era was that large deposits could be expected to have significant signatures (aka Big Bumps) and as a result were typically found first. As knowledge about the style of deposits and the technology to make discoveries improved, more deposits would be found but these were often of smaller size or grade. Over time this observation appears to have held up and has also been found to be scale independent, i.e., it can be seen at the camp, district, terrain, and global scales. While the industry has been able to compensate for some aspects of this discovery maturity by developing means to extract lower grade ores more efficiently, such as has happened with the gold business in the last two decades, at some point diminishing returns are reached.

By the late 1990s, more and more explorers appeared to recognize that discovery of most of the shallow, easy to find deposits had occurred to a large extent around the world.

THE IN-BETWEEN DECADE

With the current decade now closing (2000–2010), we have seen a period that should neither be considered part of the first era nor the beginning of a new period of discovery, but a transition time characterized by great turmoil, a degree of self-reflection and the possible signs of reorganization within the industry.

Funding for junior exploration began to dry up in the latter part of the 1990s, driven in part by the Bre-X incident and the Asian fiscal crisis of 1997, and stagnated until ~2004, when a huge surge basically carried exploration expenditures to record levels three years later. One consequence was that severe shortages in both qualified professional and technical people across the board became the norm. At the top end of the people chain, we also began to see the erosion of influence of the baby boomers that grew up and reached their prime in the declining stages of the Age of Discovery; these people have basically run much of the exploration and mining industry over the last 20 to 30 years but are now inextricably moving off the stage with the passage of time. At the other end, after years of neglect in developing the next generation of professionals to replace the baby boomers, a certain degree of panic has set in as the industry starts to recognize that it is too late to correct many of the issues, and new approaches (many as yet undefined) will be required. Adding to the churn is the consolidation of the production side of the business, and the revamping of its strategic focus. This has resulted in a retreat from primary greenfields exploration by many producers, the effects of which are now seen as part of the future discovery challenge.

Starting over a decade ago,[2] a number of pundits in the industry recognized that an approximately 50-year run of the Age of Discovery was coming to an end. However, the great infusion of money into exploration during the past decade, with only modest discovery outcomes, led to the larger community finally recognizing that the situation is now fundamentally different, and that continuing to do the same as before will most likely result in a further erosion of outcomes.

THE MESSAGE

From within the SEG, two of the people who have addressed this issue, Williams (2008) and Hronsky (2009), both noted what overall is the same issue: where should the industry go and what should we be doing to reverse the decline in quality discoveries?

Williams (2008) argued that the process must change: "The explorer of tomorrow will regularly use exploration models in which the mineralogy of target deposits and host rocks is expressed in geophysical terms, with integrated inversion modelling of potential field data used to produce quantitative 3-D subsurface rock-property maps and to identify targets."

Hronsky (2009) highlighted the need to identify new regions in order to reverse the decline in significant discoveries: "Greenfields (also sometimes referred to as grassroots) exploration is the way that all major mining districts begin and is the foundation of our industry. Greenfields exploration seeks to discover mineral deposits in new areas, away from the immediate vicinity of producing mines."

THE PARADOX AND THE NEW PARADIGM

The paradox is that geophysical technology is both part of the current milieu of declining performance but is also seen as an important element of the solution.

So what is required now that has not been happening before? Hasn't geophysics always delivered in the crunch? Bigger and better anomalies? More channels? Brighter colors in the images? Fancy 3-D models? All of these changes and improvements are, in a real sense, true, but much of this has been akin to the marketing of breakfast cereals; the touted changes and improvements are really as defined by the vendor of the goods and are extolled in order to try and sell more of their product on what is often a crowded shelf in the grocery store. When these self-proclaimed improvements by the exploration industry are examined in any sort of systematic fashion over time, the real benefits, especially as they relate to improving the discovery record, fall short.

The ever-widening gap in discovery performance, however, is not regarded as a limitation imposed by the technology per se, but rather in the implementation at the strategic level. After a half century-long reliance on geophysics as the commensurate bump finder, a new paradigm

to next page •

[2] This issue is still controversial within the industry and the argument is made that the issue of performance is variable based both in terms of geography and commodity (PDAC Special Panel: "Exploration expenditures are increasing, but discoveries are not. Why?"; Prospectors and Developers of Association of Canada Annual meeting, March 7, 2010, Toronto, Canada).

of technology, guided by collaborative decision-making, needs to be put in place.

THE FUTURE

Our abilities

Among the outcomes from the Golden Age of Technology are a global endowment of significant capability in terms of geophysical services and people. While there is no official census of mining geophysicists, estimates are in the range of 1,000 to 1,200 actively employed in the industry around the world, with a breakdown of approximately 65% working for service and manufacturing companies, 25% as consultants and 10% with mining companies. Of the service companies, the airborne contractors are the largest employers, commensurate with the cost and complexity of the technology employed. Consultants are defined as those not generally involved directly with data acquisition but rather in the planning, supervision, processing, and interpretation of geophysical surveys for clients. The consultants are a mixture of those who are between jobs for either service companies or mining concerns (estimated 30% of total), and the remainder who are in the consulting business for the long term.

The major mining companies historically employed a larger percentage of the geophysicists (and geophysical technical staff) but have downsized in the past decade due a combination of strategic re-alignments focused more on advanced projects, mergers between companies (along with the mandatory downsizing of staff) and a greater degree of outsourcing. Mid-tier producers might have one geophysicist on staff, usually fulfilling an internal consulting role, supervising consultants and tendering contracts to service companies. Few exploration-only companies (aka juniors) employ staff geophysicists, which is consistent with their overall management of exploration that involves few if any full-time employees.

Impediments

The oil industry, although viewed at times as if it were a technology-driven discovery juggernaut, has experienced significant challenges over the last 50 years in maintaining the quality and quantity of new discoveries. The peak of large-field discoveries occurred in the 1980s, and overall discoveries in the 1990s were actually less than the 1960s.

This issue was examined in detail by the petroleum consultant Pete Rose (Rose and Citron, 2000); his assessment was that the industry had developed an over-reliance on the abilities of individuals who were thought were able to beat the odds. Rose described this behavior by the oil companies as a belief in the Prospector Myth. While acknowledging that there was a time when exceptional people could appear to work magic, Rose observed that, owing to a variety of geological and business factors, combined with severely declining discovery rates, companies would no longer invest large sums into the intuitive hunches of few driven explorers, however persuasive they might be. This required putting into place risk-management practices and applying what Rose describes as portfolio management practice to exploration, which allowed better geoscience to be applied to assessments; biases that were inherent when there was an over-reliance on the enthusiasm and intuition of a few people were thus removed. Using the collaborative inputs of geoscientists, engineers and financial experts to assess and manage risks became a key part of this new process. This was also a tacit acknowledgment that even with all the sophisticated technology available to the oil industry to guide discoveries, multidisciplinary teams operating with a well-defined set of procedures are required to properly manage the overall risk and ensure acceptable returns from exploration.

The minerals industry appears to have followed a similar track to the oil industry, only delayed by a few decades; what happened to the oil explorers in the 1970s to 1980s occurred in the mineral industry during the period 1990s to 2000s. There is now the recognition, albeit not necessarily unanimous, that a period of peak discovery in minerals has occurred; with it there has been a corresponding decline in return on exploration investment.

However, what has not happened yet in the mineral industry is for there to be a broad appreciation of the problem, coupled with accepted concepts on how to manage the greater risk that exploration now carries. The majors appeared to have pulled back from exploration (especially greenfields), and large amounts of often poorly constrained funds have flowed into exploration via the junior sector. It appeared in the 1990s that some majors thought that the expenditures by juniors would replace the need for the majors to fund higher risk exploration (i.e., non-brownfields). While this assumption appears no longer to be the case, it likely postponed the internal re-assessment by the majors as to how they managed the full spectrum of exploration, including the higher risk-higher reward greenfields component. Some awakening as to what the oil industry had gone though, and what the mineral industry could learn from this, started to appear early in this decade (Gouveia et al., 2003), but these concepts do not appear to have been broadly accepted.

A scenario

A convincing case can be made that the shallow, easy to find deposits have by and large been found. While the discovery of another Voisey's Bay (basically a major outcropping deposit found by boots-on-the-ground prospecting) remains a possibility, such discoveries need to be treated as singular events (albeit auspicious ones); however, they will not change the well-defined decline in overall discovery trends. In some instances, geophysics made major contributions to the historic discovery record, as it continues to do in near-mine or brownfields settings. But technology alone will not solve the complex problems associated with future greenfields exploration, which largely involve working under cover at consider depths, commonly in remote areas.

Geological modeling of the upper several kilometers from an economic geological perspective is critical but appears to be still in its infancy (Begg et al., 2009). To help achieve this, geophysical techniques will be required at two stages: first, to assist in characterizing the overall search interval from a modeling perspective and then to assist with the direct mapping of potential targets.

While defining an economic depth for mining requires a number of factors to be considered at the early stages of exploration, an interval of investigation from surface to 3 km deep is deemed critical to understand with regards to ore-forming processes. However, direct detection of actual targets from the surface is limited to ~1 km depth and there is little expectation that this will change in the next 20 years. While potential field techniques (gravity and magnetic studies) can image the geology much deeper than 1 km, the ability to reliably resolve discrete targets the size of ore deposits is problematic.

Direct sampling of the geological column via drilling is critical in order to provide unambiguous information about subsurface geology, as well as to provide a platform for deep geophysical measurements and material for geochemical analysis. Seismic and MT (deep-seeing EM) transects that connect deep drill holes will be vital to help stitch the search area together into a coherent 3-D model prior to target selection. All of these processes will require input and assessment from a broad range of geoscience disciplines.

The cost to conduct such programs will be significant and some of the work will most likely have to be borne by governments as part of their continued development of pre-competitive science infrastructure in their jurisdictions. Who undertakes the actual exploration work, given the time, cost, and diverse expertise required is not clear; the model used by the oil industry may point the way whereby large service companies such as Halliburton and Schlumberger perform much of the actual exploration work for their clients. While major mining concerns might be able to support such deep-search teams, juniors will be required to team up with several others to be able to share the cost. Where should the geoscience team reside in such a process? Within the service group? Or within the contracting group, either the major mining concern or a group of juniors? Whatever model is adopted, I predict that the situation soon will look quite different from how the industry has operated for the last 60 years.

REFERENCES

Begg, G., Hronsky, J., O'Reilley, S. and Hayward N., 2009, Plumes, cratons and nickel sulphide deposits, 2009 SEG International Exchange Lecturer, Colorado School of Mines, Golden Colorado, November 3, 2009.

Bragg, J.G., 1959, Saturation geophysical exploration: CIM Bulletin, v. 52, p. 49–55.

Gouveia, J., Rose, P. and Gingerich J., 2003, The Prospector Myth - coming to terms with risk management in mineral exploration: presented at Prospectors and Developers Association of Canada (PDAC), March 9–12, 2003.

Hronsky, J., 2009, The case for a greenfields renaissance; SEG Distinguished Lecture Series: Colorado School of Mines, Golden, Colorado, October 14, 2009.

Rose, P. and Citron, G., 2000, The "Prospector Myth" vs. systematic management of exploration portfolios: Dealing with the dilemma: Houston Geological Society Bulletin, October, p. 15.

Williams, N., 2008, The exploration crisis—an industry perspective, SEG Newsletter, April, no. 73, p. 7.