

VIEWS

Innovation in Mineral Exploration: Successes and Challenges

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The pressure is on. The world needs more metals, more energy, and more industrial minerals. At the peak, 20 years ago, a U.S. citizen consumed about 10 kg of copper per year, and more than 50% of that was derived from new ore material. Although there has been a significant decrease in the last 20 years in terms of the relative saturation of the needs for basic infrastructures, Americans continue to consume three times the world average for copper, six times for aluminum, etc. To put it in perspective, in order to satisfy the demand of China at the same level, we would need to increase the production of copper by 3 Mt Cu per year. This is a tough challenge!

The way to increase metal discovery and production is to increase funding for exploration, improve exploration effectiveness, and bring discoveries to production. The recent boost in exploration funding by the stock market may help answer the former, but as noted in previous Views columns, this has not resulted in a significant increase in discovery—at least, not yet. Also, more funding might also decrease the overall productivity of the minerals industry by supporting thousands of competing junior explorers instead of supporting a more efficient structure.

Therefore, effectiveness is the key concern for enhancing exploration. There are three major fields of innovation in exploration: (1) the target model itself, including the terrane and the type of deposit, (2) the method, or the technology to discover and define the deposits; and (3) the organization of the exploration process, including the people involved.

A quick historical review of the ways that exploration companies have worked for the last 50 years shows signs of change and signs of permanence. The types of the deposits that we are searching for have changed; we have increased the size and decreased the grades of our targets, we have opened new regions that had never been explored, we use many geophysical and geochemical methods, and we have a better understanding of ore deposits. Changes are also reflected by the level of our professional people, which has improved through the certification process since Bre-X. However, the exploration industry shows signs of permanence, also, because the industry remains slow in adopting new technologies (Bartos, 2008). A recent South Australian report (Bridge8, 2009) notes the conservative attitude of the mining industry, although it acknowledges that some changes have occurred. Driven by the Schumpeter concepts of entrepreneurship and by stronger competition, innovation is a word that has begun to be more and more employed in the community.

A survey evaluates the innovations that have changed the way exploration has been carried out in the last 10 years in Quebec (Jébrak, 2010). The targets have not changed very much, but new metallogenic models, both descriptive and genetic, are recognized as having a major input to exploration. The most cited innovations are technical; for instance, the increased use of GPS in the field and the use of ICP-MS analyses in the laboratory has increased the quality and the speed of data acquisition. Other cited innovations in exploration technology are developments in lithogeochemistry, the use of portable geochemical sensors, the development of mineralogical tools in exploration, and the improvement of EM techniques and airborne gravimetry. Data management and the use of 2-D and 3-D integration have also considerably changed the lives of explorationists. The e-staking developed by the Quebec government is also cited as a huge and positive change in the exploration process that has allowed significant changes in the organization of exploration programs. This list would certainly be different in other geological environments, especially in tropical terranes, but it is probable that GPS and ICP-MS will remain among the top innovations.

Another interesting point this survey makes is that the key innovations came from disciplines outside the exploration community, from surveying to chemistry. This is a reminder that exploration is team work, and that our geologic concepts, although essential, cannot be applied without the help of other specialists. Major innovations are disruptive and world changing and require all participants to realign with the new paradigm.

A Radical Change in Our Core Business

Radical innovations have been at the root of several booms of the mining industry. Revolutionary approaches to ore treatments have allowed new styles of deposits to be explored and mined, from iron carbonates to aluminous bauxite and invisible gold (Bartos, 2008). After World War II, airborne geophysics was also a revolutionary innovation that created a surge of discoveries, especially in Canada in the 1960s. Major styles of deposit, such as copper porphyries, became economic due to the combination of several major innovations, from geological understanding, to exploitation methods (showels inherited from Lake Superior BIF mines), to treatment methods, with flotation adapted from Broken Hill. Geo-positioning and huge capabilities of data processing are probably the latest big change in the mining exploration industry, creating new product categories, both at the surface and underground. However, this has not radically changed the geological methods that we use, and the mineral industry has been able to adapt without the many failures that characterize revolutionary changes (Dismukes et al., 2005).

What will be the source of the next radical innovation? On the one hand, some innovations may come from metallogenic studies, but most of them remain in the normal science model of Kuhn; we need to challenge ourselves toward greater expectations. On the other hand, if we look over our shoulder to see how the exploration for metals has evolved in the last century, one of the key elements has been the transfer of methodologies from one domain to another. For example, drilling was transferred from the petroleum industry to the mining industry at the end of the 19th century, and that allowed deeper

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discoveries in the Witwatersrand goldfield. The recent use of GPS is thanks to a military development.

Coming back to the basics, one element that has not changed in the mining and exploration industry is drilling, where we have witnessed few changes in the last 50 years. We drill more rapidly, we get core, and we log most of the time with our naked eyes. This is a very long process, especially for the increasingly large deposits that the world needs. Inexperienced geologists are commonly under pressure to routinely log kilometers of core without sufficient opportunity to learn about the local rock units and alteration.

Future orebodies will increasingly tend to be lower grade, high-tonnage deposits, frequently under cover, openpittable or underground (Wood, 2010); the need for drilling will increase tremendously, both for exploration but particularly to delineate reserves. This will inevitably lead to rising costs and challenges for consistent logging. Large deposits may present a large variability of mineralized facies. One of the premier deposits of this style was Olympic Dam in South Australia, where it has always been a challenge to achieve consistent classification and mapping of puzzling multistage breccias. In such a situation, the easiest solution is to reduce the number of geological units that are distinguished, but this potentially weakens our understanding and diminishes our ability to answer geological questions.

The same problem arose in the sister industries of oil and uranium some decades ago. Answers came from the progressive replacement of core by a variety of geophysical well logs; although the information seems poorer, it can be more readily processed with consistency, based on well calibrated drill core. This method has clearly demonstrated its efficiency, reducing both time and cost, especially for sandstonehosted uranium deposits. Radioactivity measured and corrected with several parameters allows the derivation of credible U values, and other tools reflect the geology and some elements of rock mechanics. Moreover, this has changed the way reserves are calculated for a certain segment of the uranium industry. The metal exploration business is ripe for such a revolution, in order to improve the exploration for and assessment of large deposits. Some people will feel a sense of loss, and will claim that nothing could replace a nice core of ore. But this will move the exploration toward faster, cheaper and better methods, with fully digital logging; the few remaining drill cores will have to be thoroughly studied and understood.

Paths to Innovation

How do we facilitate this revolution in the metal sector? It will require several technical developments, such as getting smaller and smarter log instruments for mineralogy, geochemistry, and structure, and it will also require some processes to change so that we can adapt the methodology to complex basement geology. But the first and biggest challenge is to get a leader to drive the change. Few participants can lead this evolution; neither the junior companies nor the academics have the resources to undertake these bigger, industry-wide issues. Until the 1970s, such research could have been carried out by the laboratories of the larger mining companies. However, most of these laboratory groups no longer exist. More importantly, with the electronic age followed by the information age, the amount of knowledge necessary to develop innovations has increased so much that even the largest companies have recognized that they must share knowledge with others and develop common public laboratories, connected to or within universities or government-funded research institutions. At the same time, there is a natural tendency of academics to focus on fundamental studies; in the Western world, it has been a challenge to sustain schools of exploration geology and mining that have a practical focus.

In the exploration and mining industry, we were able to develop very functional structures quite early, such as the consortia that were mainly developed in Australia and Canada, but also in Europe and South Africa. These types of organizations can develop useful innovations for explorers; one example is AMIRA in Australia, and the numerous successful projects, largely university based, that are supported by consortia of client companies along with the input of government funds. The rise of the Canadian Mining Innovation Council is the latest embodiment of this concept. The system works especially well to develop concepts in mineral exploration, a rather cheap, non-technology intensive activity, that can be used by the senior management of mining companies.

Unfortunately, these consortia do not foster development of radical innovation because their research programs result from a consensus among different partners. A radical change will produce winners and losers, and that is certainly not a good prospect for any large and diverse group of professionals! Moreover, radical innovation takes time, several years or even decades to develop, and many consortia operate only annual or 3- to 5-year programs. Finally, radical innovation requires commercializing agents; service companies are an indispensible links for the development of products. When the Cornwall tin mines purchased their first steam pumps, they called the Boulton & Watts Company, not the Glasgow University where James Watts had been a technician.

What can the SEG community do to jump into this new arena? There are numerous technical aspects that we can improve, such as the acquisition of more petrophysical data from the rocks that host mineral deposits, discovering clever ways to transform quantitative data into geologically meaningful information, using downhole imaging for structural evaluation, etc. The use of digital core benches may provide a nice transition toward fully digital in situ measurements. Furthermore, we can facilitate better rotation of people between domains, from uranium to oil to mineral exploration, which is certainly the best way to enhance technology transfer between our silos.

No great strides in science and technology have come without great challenges. And to slightly adapt a Steve Jobs comment, we will choose innovation because we have a burning passion for exploration and mining.

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