The Declining Discovery Trend: People, Science or Scarcity?

(These columns are the opinion of the author and do not necessarily reflect the view of the SEG)

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I have had the good fortune to have worked in more than 50 countries during my career while chasing many metals—silver, gold, platinum group metals, copper, nickel, lithium, uranium, lead, and zinc—to name a few. I have been involved in a few discoveries and many more exploration disappointments and failures. Where I have had success as an exploration geologist and mining entrepreneur has mostly been due to a focus on acquisition of known deposits which had exploration upside, rather than grassroots discovery. I simply took other geologists' discoveries from previous periods and made them bigger and more commercial. But for the last 39 years I have been a professional observer, watching hundreds of other individual and corporate efforts at discovery, most of which have ended in failure. What a great profession: geologists are paid even when they fail! Nobody is bothered too much if exploration results in failure, but if the unlikely happens and a deposit is found, people are euphoric and great wealth is made!

Exploration is getting tougher. Despite increasing global exploration budgets year after year, it seems that fewer and fewer new discoveries are being made. Why is this? Is it due to a lower quality of mineral explorationists working globally, a dearth of new scientific methods being applied to discovery, or the increasing scarcity of mineral deposits? It is most unlikely that there is a lower level of intellectual capital or science being applied to exploration. My vote is therefore for scarcity—at least, scarcity at current metals prices (this qualifier neatly avoids the complicating factor that mineral scarcity is closely linked to mineral prices; Tilton, 2006). Whereas a greater focus on exploration might work for awhile, one certain solution to this problem is on the demand side: less consumption and better recycling.

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In 1972, the seminal book *Limits to Growth* was published by the Club of Rome (Meadows et al., 1972), a global think tank which espoused (among other things) the seemingly self-evident thesis that ever-increasing consumption of non-renewable resources would lead to scarcity and dramatic negative consequences for the world's population. Yet 38 years later we find ourselves living in a world with nearly twice the population of the early 1970s, consuming massively greater amounts of virtually all non-renewable commodities, yet seeing much lower global poverty and a vastly better standard of living for many of the people on our small planet. In 2004, a revision and update was published to the 1972 *Limits to Growth* book (Meadows et al., 2004). Its main conclusion is that the original thesis remains absolutely valid. Can this be wrong? Can our present consumption rates be sustained through exploration? Is world growth sustainable based on ever-increasing rates of metals consumption (and therefore ever-increasing rates of mineral discovery)? I believe exploration trends are telling us the answer to these questions is "no." Global economies cannot rely on ever-increasing metals supply—sustainable consumption and metals reuse will be increasingly required in future years.

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In "Fifty-Year Trends in Minerals Discovery—Commodity and Ore-Type Targets" (Blain, 2000), Chris Blain reviewed discovery rates and metal consumption trends for a variety of metal commodities over a 50-year period, from about 1947 to 1997. The clear record for this period is that mineral discovery rates have fallen despite progressively increasing exploration budgets. The principal reasons adduced by Blain for this record are as follows: (1) deteriorating economics as increasing real costs and decreasing real prices continue to raise the economic hurdles for exploration targets, and (2) increasing exploration maturity in many search terrains, particularly those in the traditional regions of North America and Australasia.

Consumption growth has in recent decades been fed by larger, more mechanized mining operations at the world's great orebodies—those discovered, in most cases, many years ago. Application of technology and economies of scale are enabling more productive mining, overcoming the failure of exploration to sustain the resources mined. But this is temporary and it is unsustainable. I believe these great orebodies are being discovered less frequently because they are getting scarcer. Furthermore, there are increasing conflicts between mining and growing global populations. And there are barriers to what technology can achieve, especially in a world where environmental issues are limiting unrestricted application of technology and economies of scale.

Many field geologists (natural optimists) may disagree with the following comments but I believe them to be true. Much of the earth has been pounded by prospectors and geologists. The entire world is readily accessible today by remote sensing and most of it by physical means. Much of the world has been surveyed by satellite imaging, airborne magnetometry and radiometry; surface geochemical surveys and regional-scale geological mapping have been carried out over large portions of the earth. Many areas have seen very intensive exploration. Until the early 1990s, the diminishing returns of exploration efforts relative to funds expended was largely confined to the most heavily explored regions of the world—southern Africa, North America, and Australia—although most of the world's greatest orebodies had been discovered decades earlier, no matter where they were located. Beginning in about 1993, exploration became a truly global effort as the Soviet Union collapsed and opened up to new exploration, as Africa and Latin America became much more easily accessible, and as global sources of exploration capital became available to thousands of junior exploration companies that spread their mineral search all over the world. This global search temporarily increased the success rate of global exploration efforts as new lands opened up in the 1990s, but in recent years exploration seems to have become increasingly unsuccessful again. Specifically, the massive increase in exploration budgets during the commodities boom from 2003 to 2008 was not mirrored by a massive increase in metals discovery during this period. Quite the opposite.

Indeed, discovery trends for most metals display a kind of "Hubbert's Curve," that is, a preponderance of discoveries has been made in a relatively short period in past decades. The notion of "Peak Oil" is generally accepted today, and, by the same token, discovery rates seem to me to have peaked for different metals at various times in the past and have declined ever since. Key reasons for the discovery peaks have been breakthroughs at various periods of geological understanding of genetic models for mineral deposits and new technologies for discovery. But I believe most of these are behind us now and are unlikely to be repeated to any significant degree.

Great eras of discovery occurred when these genetic models of mineral deposits became accepted and widely known. Some examples, to name a few, include the great burst of roll-front uranium deposit discoveries during the 1950s, porphyry copper deposits during the 1960s, unconformity uranium deposits and SEDEX lead-zinc deposits in the 1970s, Carlin-type gold deposits during the 1980s, and IOCG deposits in the 1990s. Geologists who became acquainted with these models took their exploration programs to areas in the world showing potential for such deposits and a burst of discovery resulted because the science was correct, even though in many cases the discoveries were not brought to production for many years. Hence, today we are bringing to production copper deposits discovered in the 1960s, lead-zinc deposits discovered in the 1970s, and so on.

Anomalous periods of mineral deposit "discovery" have also occurred when new technologies enabled mining of low-grade deposits. For example, advances in SX-EW copper mining allowed large, low-grade copper deposits to become economic; heap-leach gold mining using cyanide leaching allowed large, low-grade gold deposits to become economic; and large-tonnage saprolitic and limonitic nickel deposits became economic when various new pyrometallurgical and hydrometallurgical processes were developed. Many of these processes, however, involve surface orebodies that are easy to discover and, by now, most such deposits have been identified and many already mined out. Many of these deposits also require low-cost energy for their extraction, something that is probably a thing of the past.

It is certain that new technologies will continue to be discovered in the future, which will allow new deposits to be found and known deposits to be mined commercially, but my guess is that discovery rates will continue to trend lower relative to funds expended on exploration. Consider the scale of the problem: today, world copper demand consumes each year nearly 20 million tonnes (Mt) of copper, requiring discovery of four new world-class copper orebodies annually, each containing 500 Mt grading 1 percent copper. World silver demand consumes 900 Moz annually, whereas world-class silver deposits are rarely found in excess of 100 Moz. Global gold demand consumed 3660 t in 2008, yet how many plus-150 t gold deposits are found annually? Very few. It is no wonder that gold discovery rates are falling and that global gold-mine supply seems to have peaked.

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Yet many mineral explorationists will argue, "But only the surface skin of the earth has been explored, and only in those places where the geology is exposed," and "Only a tiny percentage of the world's surface has been intensely explored." They will remind us that some of the greatest discoveries in recent years have occurred in some of the world's most intensely explored exploration terrain: Resolution in Arizona, Spence in Chile, and Valdecanas in Mexico. Some will argue that new exploration techniques for penetrating the enormous covered areas of the earth will enable new discoveries, and new techniques for exploring deeper in the crust will open up massive unexplored regions for future discovery. I disagree—not with the potential for actual discovery but with the potential for economic extraction in these frontier exploration regions.

The problems with exploring in deeper and deeper areas of the earth's crust are those of geology and economics. In terms of geology, many of today's orebodies are located in oxidized or otherwise near-surface materials that, once gone, can never be found in deeper zones. In terms of economics, exploration is more expensive as search depth increases, and mining is clearly more costly as it goes deeper, requiring higher grades and less ability to use bulk-mining methods. The result is that fewer and fewer mineral deposit discoveries will be economically recoverable, at least until metals scarcity forces up prices. Just look at the three largest grassroots copper discoveries made in the last 15 years: the Resolution deposit in Arizona, the Pebble deposit in Alaska, and the Oyu Tolgoi deposit in Mongolia. Each of these world-class deposits is a deep discovery and will likely be mined by underground block caving. But despite enormous size and high grade, each has enormous technical challenges to exploitation, not to mention massive political, social, and environmental challenges. Discovery of these deposits was a triumph of exploration perseverance and skill (and luck), but exploitation is by no means certain, and without the likelihood of economic return, why would anyone finance such high-risk exploration? So, yes, there is plenty of potential for discovery in deeper areas of the crust, but not so plentiful potential for economic discovery—and what is a discovery anyway if it is not economically recoverable? Just so much waste rock.

Exploration will go on, of course. But I suspect that diminishing returns will continue to prevail in our industry, due to scarcity of deposits, and this will ultimately lead to scarcity of metal supply at today's metals prices. The economic returns from successful exploration will, of course, always entice the exploration gamble, especially when metal scarcity prompts higher prices in future years. Deeper areas of the crust will be pursued and techniques developed to better explore, delineate, and extract minerals in these

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regions. It should be no surprise to anyone, though, that current declining mineral discovery trends will likely continue, that ever-growing mineral commodity consumption will become harder to sustain, and that mineral and metal prices will increase.

Over the long term, the central thesis of *Limits to Growth* seems unassailable to me: today's pattern of a continuing increase in the rate of metal consumption is simply unsustainable (along with many other trends of food, water, and energy consumption). Without a deliberate and sharp reduction in resource consumption to supportable levels, or a significant reduction in world population, the likelihood is high that we will experience during the 21st century tremendous dislocations in our global economy. One solution lies in a massively greater focus on exploration technology and exploration efforts. However, a much more successful strategy seems to me to lie with reduced mineral consumption and better metal recycling, efficiencies that will allow us to do more with less. A combination of continued smart exploration and sharply reduced metal consumption will sustain global populations for eons. The trick is to get there without the stress of uncontrolled global collapse.

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