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VIEWS III

# Is Mineral Depletion a Threat to Sustainable Mining?[1]

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## SYNOPSIS

For many people, the term "sustainable mining" is an oxymoron. After all, mining entails the exploitation of nonrenewable resources. Eventually, these resources will be gone and mining will have to cease. As a result, many concerned individuals urge society to conserve nonrenewable resources and, where possible, to use renewable resources instead.

Drawing on what we have learned from the debate over the long-run availability of mineral commodities over the past several decades, this paper describes two very different models of mineral depletion. The first, known as the fixed-stock paradigm, relies on physical measures of availability, and does indeed suggest that mining in the long run is inherently nonsustainable. Fortunately for economic geologists and the mining industry in general, and even more importantly for humanity as a whole, the fixed-stock paradigm suffers from several serious shortcomings.

As a result, the second way of viewing depletion, known as the opportunity-cost paradigm, is more useful and appropriate. It assesses resource availability by what society has to give up to produce another unit of a mineral commodity, for example, another a barrel of oil or ton of copper. While over time depletion tends to drive up the opportunity cost of mineral production, new knowledge and technologies produced by economic geologists and others can offset this upward pressure. Indeed, for many mineral commodities this has actually been the case over the past century, indicating that sustainable mining is possible.

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## INTRODUCTION

Sustainable mining means different things to different people. To some, it means mining carried out in a manner consistent with sustainable development. In particular, it is mining in a way that preserves the environment, protects indigenous cultures, and promotes the welfare of local communities. To others, sustainable mining implies the extraction of mineral resources from the earth in a manner that permits this activity—that is, extracting minerals resources from the earth—to continue indefinitely.

Here we focus on this second definition and address the question: Is mineral depletion a threat to sustainable mining? For many, the answer is obvious. Indeed, they see the term "sustainable mining," when defined in this manner, as an oxymoron. Since mining depends on nonrenewable, depleting mineral resources, by its very nature it is unsustainable. Eventually, the resources from which we produce copper, tin, nickel, and other mineral commodities will be exhausted.

Some may contend that this is not a pressing issue—that known stocks coupled with what we are likely to discover are sufficient for the foreseeable future. Still, fears about depletion, even if misplaced, can alter the way society behaves today for good or for bad. For example, concerns over the long-run availability of copper resources led Gordon et al. (2006) to suggest that society will need to do more recycling, and where possible, substitute more available resources for copper over the current century.[1]

Another example concerns lithium batteries, which many believe will be widely used over the coming decades to power hybrid and all electric automobiles. Fears that the needed lithium may simply not be available have led some (Tahil, 2007, 2008; Bradbury, 2008) to recommend that society avoid developing better lithium batteries and instead invest in new battery technologies that rely on more abundant metals.[2]

So the question—is mineral depletion a threat to sustainable mining?—has implications and consequences not just for the distant future but for today and tomorrow as well. To address this question, this analysis draws on the ongoing debate over the long-run availability of mineral commodities.[3] In particular, it focuses on two very different ways or models of looking at depletion—the first is known as the fixed-stock paradigm and the second as the opportunity-cost paradigm—and it highlights their very different implications for sustainable mining.

## THE FIXED-STOCK PARADIGM

The most common model used to assess the threat of mineral depletion is the fixed-stock paradigm. It starts with the observation that the earth is finite. As a result, the supply of copper, oil, or any other mineral commodity must also be finite and hence, a fixed stock. Demand, however, continues year after year, and so is a flow variable. This means that demand eventually must exhaust the available supply. When demand is growing exponentially, as has been the case for many mineral commodities in the past, the end will arrive sooner

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[1] This note is based on my presentation at the International Conference on sustainable mining on April 17, 2009 in Santiago de Compostela, Spain. It draws heavily from Tilton (2003, 2006), which provide more information for the interested reader.

[2] The International Copper Association, concerned that these conclusions might discourage copper consumption, sponsored a study by Tilton and Lagos (2007) to review and assess the research of Gordon and his colleagues. See Gordon et al. (2007) for their reply.

[3] For a different perspective on the long-run availability of lithium, see Yaksic and Tilton (2009).

 

rather than later, given the well-known tyranny of exponential growth.

This, for example, is the view of depletion found in *Limits to Growth* (Meadows et al., 1972). Mineral scarcity due to depletion occurs suddenly and without warning. It is like a car that that runs out of gas—one minute speeding down the highway, the next stalled on the berm.

Despite its logic and intuitive appeal, the fixed-stock paradigm suffers from four critical shortcomings. First, many mineral commodities, especially the metals, are not destroyed when they are consumed. As a result, recycling and reuse are possible. Of course, recycling in some cases (such as the lead once used as an additive in gasoline) is prohibitively expensive, but this is a question of costs, not of physical availability.

Second, for other mineral commodities, including oil and other energy minerals, substitution can mitigate the threat of mineral depletion. Coal, natural gas, petroleum, nuclear, hydropower, geothermal, wind, and solar energy can all be used to generate electric power. The mix of these resources in use at any particularl time reflects their costs. If depletion drives up the costs of some, their consumption will decline as society relies more on alternative energy sources.

Third, the fixed stock of many mineral commodities is huge. At current rates of consumption, for example, the copper and iron present in the earth's crust would last 120 million years and 2.5 billion years, respectively. These are very long periods of time. For comparison, the Big Bang occurred about 13 billion years ago, our solar system is about 5 billion years old and already halfway through its expected life, and Homo sapiens evolved as a species only several hundred thousand years ago.

Fourth, and most important, long before the last barrel of oil or the last ton of zinc has been hoisted from the earth's crust, costs will rise dramatically. This would first curtail and then eventually eliminate demand. In short, the threat is not physical depletion, by which we literally run out of mineral resources, but economic depletion, when the costs of producing and using mineral commodities rise to the point where they are no longer affordable.

## THE OPPORTUNITY-COST PARADIGM

For these four reasons, a more useful model for assessing the threat of depletion is the opportunity-cost paradigm. This focuses on what society has to sacrifice or give up in order to produce another ton of coal or pound of nickel. Several measures are available for this purpose, including production costs and the value of mineral reserves in the ground. However, the most readily available and reliable measure is price. When the real price for a mineral commodity rises over the long run, it is growing less available or more scarce.

The opportunity-cost paradigm completely changes our perception of depletion. First, even in the absence of physical depletion, economic depletion may occur in the sense that mineral commodities become too expensive to use.

Second, if depletion does occur, it will occur gradually over time as the real prices of mineral commodities rise persistently, slowly eliminating the demand for them in one end use after another. Depletion will not be a surprise. We will not wake up one day and find the cupboard bare or the car out of gas.

Third, and particularly important for the future of humans, mineral scarcity due to depletion is not inevitable, as the fixed-stock paradigm implies. While the need to exploit lower grade, more remote, and more difficult-to-process deposits tends to drive up the costs and prices of mineral commodities over time, new technology can offset this upward pressure. In short, the long-run availability of mineral commodities is now determined by a race between the cost-increasing effects of depletion and the cost-decreasing effects of new technology.

Over the past century, this race has largely been won by new technology, as the long-run trends in real prices for most mineral commodities have either declined or remained the same.[4] Of course, the past is not necessarily a good guide to the future, and we have no guarantee that such benevolent trends will continue indefinitely.

Fourth, population growth no longer necessarily reduces the long-run availability of mineral commodities. Every new baby is born with a brain as well as a mouth. While population growth tends to accelerate the consumption of mineral resources, which pushes up costs and prices, it also increases the human resources needed to generate the new technologies that reduce costs and prices. As a result, population growth can conceivably increase the long-run availability of mineral commodities, a possibility that a few scholars suggest is actually the case.[5] It also raises the likelihood that poverty and discrimination (which prevent millions of people from developing their potential and contributing to society) may pose a greater challenge than population growth per se. In some countries, of course, population growth may impede development and contribute to poverty.

Fifth, the United States and other developed countries consume a disproportionately large share of the world's resources compared to their populations. To many this seems unfair to the rest of the world, where billions of poor people struggle just to survive. Under the opportunity-cost paradigm, however, the high levels of mineral consumption in the developed world need not necessarily increase resource scarcity. While this consumption tends to accelerate mineral depletion, the wealth that it creates in the developed world supports the technological efforts that push down the cost and prices of mineral commodities over time. It is not an accident that most of the new technologies increasing the availability of many mineral commodities over the past century have come from the developed countries. This raises the possibility that the poor may actually benefit from the apparent profligate use of mineral resources in the developed world, in the sense that today they have access to cheaper mineral commodities compared to the developed countries at comparable stages of development.

## CONCLUSIONS

The way one thinks about depletion matters. With the fixed-stock paradigm, physical depletion is inevitable and mining is unsustainable. The end will come suddenly, and likely take us by surprise. Mineral consumption accelerates the day of reckoning. Both population growth and the widespread use of mineral commodities in the developed world

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[4] For more on this debate, see Tilton (2003).
[5] See, for example, Barnett and Morse (1963), Krautkraemer (1998), Howie (2002), and Svedberg and Tilton (2006).
[6] See Simon (1981).

undermine the long-run availability of mineral commodities.

With the opportunity-cost paradigm, if society can continue in the future, as it has in the past, to create new technologies that offset the cost-increasing effects of depletion, mining can be sustainable indefinitely. In this case, the primary production of steel, aluminum, copper, and other mineral commodities from extracted mineral ores will remain competitive, with recycled materials and with substitute materials produced from renewable resources. In addition, the costs and prices of these products will not rise persistently over time, and consumers will not be forced to curtail their demand.

This favorable future, however, is not assured. It requires that economic geologists, along with mining engineers, metallurgists, and others in the mining sector constantly develop new, lower cost methods for finding and extracting mineral commodities to offset the relentless upward pressure of depletion on costs. The success of economic geologists and others in this endeavor will determine the future of mining, and in turn shape the future for economic geologists.

## REFERENCES


Barnett, H.J., and Morse, C., 1963, Scarcity and growth: Baltimore, Johns Hopkins for Resources for the Future.

Bradbury, D., 2008, What is going to power our cars?: The Guardian, July 31, www.guardian.co.uk/technology/2008/jul/31/motoring.energy (accessed on August 10, 2008).

Gordon, R.B., Bertram, M., and Graedel, T.E., 2006, Metal stocks and sustainability: Proceedings of the National Academy of Sciences, v. 103, p. 1209–1214.

——2007, On the sustainability of metal supplies: A response to Tilton and Lagos: Resources Policy, v. 32, p. 24–28.

Howie, P.A., 2002, A study of mineral prices: analyzing long-term behaviors and testing for noncompetitive markets: Unpub. PhD dissertation, Golden, Colorado School of Mines.

Krautkraemer, J.A., 1998, Nonrenewable resource scarcity: Journal of Economic Literature, v. 36, p. 2065–2107.

Meadows, D.H., Meadows, D.L., Randers, J., and Behrens, W.W., 1972, The limits to growth: New York, Universe Books.

Simon, J.L., 1981, The ultimate resource: Princeton, Princeton University Press.

Svedberg, P., and Tilton, J.E., 2006, The real, real price of nonrenewable resources: Copper 1870–2000: World Development, v. 34, p. 501–519.

Tahil, W., 2007, The trouble with lithium: Implications of the future PHEV production for lithium demand: Martainville, France, Meridian International Research, http://www.meridian-int-res.com/Projects/Lithium_Problem_2.pdf.

Tahil, W., 2008, The trouble with lithium 2: Under the microscope: Martainville, France, Meridian International Research, http://www.meridian-int-res.com/Projects/Lithium_Microscope.pdf.

Tilton, J.E., 2003, On borrowed time? Assessing the threat of mineral depletion: Washington, DC: Resources for the Future.

——2006, Depletion and the long-run availability of mineral commodities: Society of Economic Geologists Special Publication 12, p. 61–70.

Tilton, J.E., and Lagos, G., 2007, Assessing the long-run availability of copper: Resources Policy, v. 32, p. 19–23.

Yaksic Beckdorf, A., and Tilton, J.E., 2009, Using the cumulative availability curve to assess the threat of mineral depletion: The case of lithium: Resources Policy, v. 34, p. 185–194.