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Mineral Resources - Supply, Demand, and the Future

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The adequacy of mineral resources in light of population growth and rising standards of living has been a concern since at least the time of Malthus (1798) [1]. Many studies [2,3] erroneously forecast impending peak production or exhaustion because they confuse reserves with "all there is". Reserves are formally defined with proscribed standards for drilling and sampling necessary to prove out an ore body, and thus reserves constitute only a subset of known resources. Even the total of all known resources is only a small subset of "all there is", due to new discoveries and changes in price and technology. Peak production or exhaustion cannot be modeled accurately from reserves. Identified resources are more than adequate to meet projected needs through the 21st century; thus, forecasts of imminent peak production in the next 20–30 years due to resource exhaustion are not valid [4].

However, a very real problem is the disconnect between short-term price swings and the long time frames of exploration, discovery, and getting mines into production. This may cause supply disruptions, not due to resource exhaustion, but rather due to the inability of market forces to supply resources when and where needed, and at a price competitive for use. This problem may be exacerbated by supply-chain disruptions due to natural disasters (earthquakes, tsunamis, hurricanes) or political complications (wars, tariffs, or trade embargos). All of these problems are made more urgent and more serious by the increasing quantities of raw materials being consumed as world population and standards of living increase. For example, China has used more cement in the past three years than the United States did in the previous century [5]. Thus, a supply disruption that might have been only a local problem half a century ago may precipitate a world-wide economic meltdown a half century in the future, due to the greatly increased utilization of raw materials.

Needed to resolve these problems are better education and exploration technology development, access to prospective terrain, better recycling, and better accounting of externalities associated with production (pollution, loss of ecosystem services, and water and energy use). As much as recycling [6] and substitution [7] will be part of the solution, they cannot by themselves solve the problem. Population growth and rising standards of living, combined with the sequestration of elements, like copper in buildings, cars, cell phones, *etc.*, for periods of years to decades and, in some cases, centuries, will require new primary supplies of mineral resources. The lead time from discovery to mine development can be 10–30 years. Extensive mineral exploration will be required to meet this future resource demand, because many of the undiscovered deposits will be harder to find and more costly to mine than near-surface deposits located in more accessible areas. At a global level, it is not clear that society is making the investments in education, research and development to ensure that adequate mineral resources will be available for future generations.

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