Mineral Supply and Consumption—
Searching for a Twenty-First Century Balance

presentation for the

Government-University-Industry Research Roundtable

The National Academies

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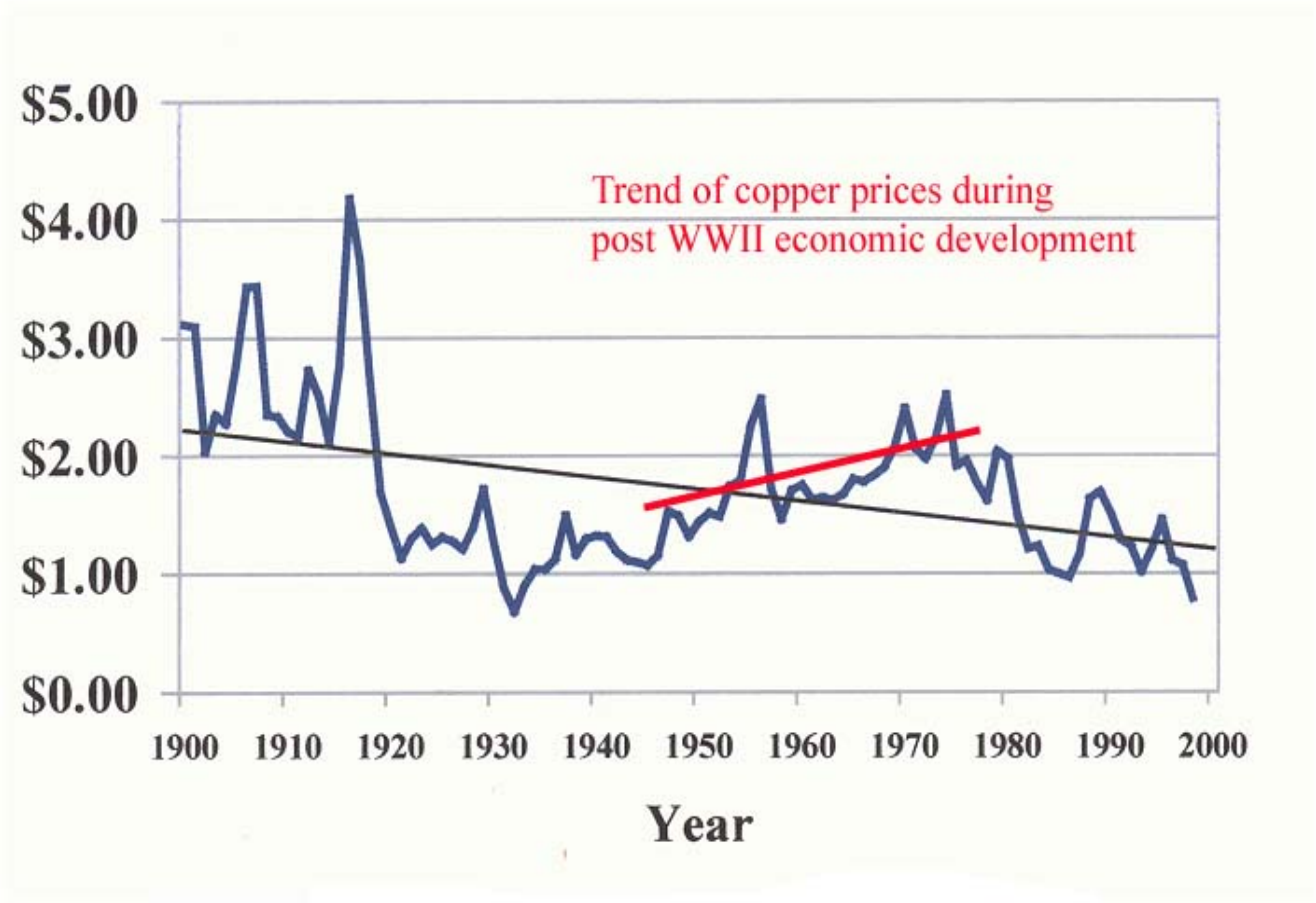
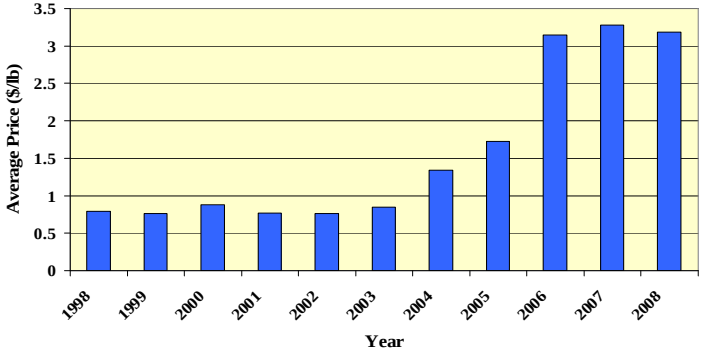
For Much of the 20th Century, Prices of Many Minerals Declined in Real Terms.

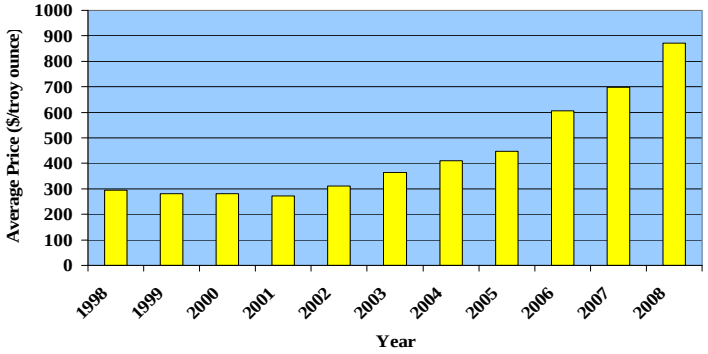


Beginning around 2001, prices of many mineral commodities increased substantially; many prices increased until the second half of 2008.

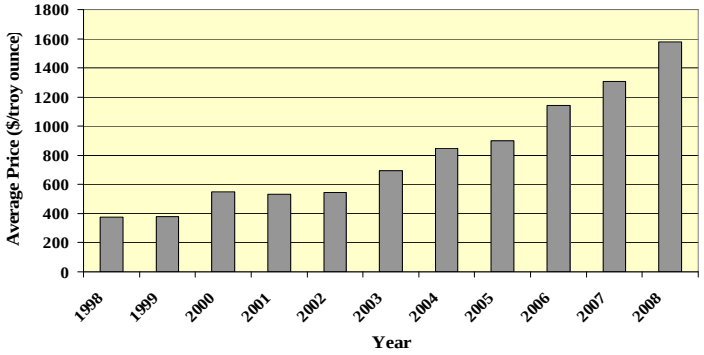
Copper



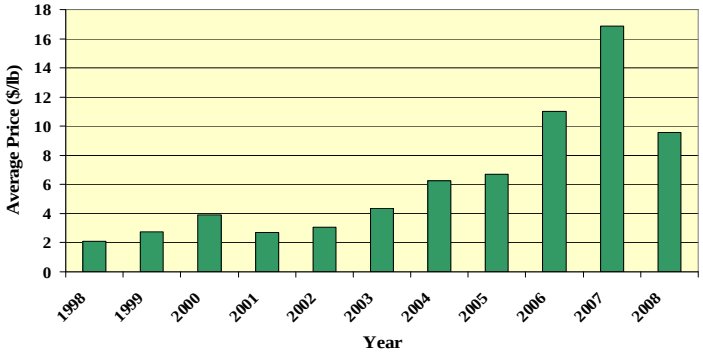
Gold



Platinum



Nickel



- The rise in mineral prices has largely been attributed to the economic growth in China and other rapidly developing countries.
- Over the last 20 years, increased consumption in China and other developing countries has accounted for more than 60% of the increase in consumption of many mineral commodities.
- This has lead to renewed concerns about the longer term balance between mineral supplies and mineral consumption.

Searching for a Balance

- Of course, by definition, a balance will occur but we would like to know something about what the balance will look like and how it will be achieved.
- Several factors make this a difficult task—
  - the multitude of mineral commodities
  - hidden dependence (embodied consumption)
  - technological change
  - crisis mentality.

Physical Factors that Affect Mineral Supply

- Chemistry and mineralogy of mineral deposits
- Geology of mineral deposits
- Reserve and resource measurement

Chemistry and mineralogy of mineral deposits

- Most metallic mineral commodities (and a number of industrial minerals) are derived by separating the cations from minerals.
- The difficulty of obtaining the useful cations is a function of the anionic composition of the mineral. Most metals are derived from sulfide, oxide, or carbonate minerals. However, silicates, which require very high levels of energy to separate, are the most common minerals.

Chemistry and mineralogy of mineral deposits

- Skinner (1976) postulated that the distribution of metals in different minerals (silicate versus nonsilicate) could result in a bimodal distribution of cations that could have major implications for mineral supply.

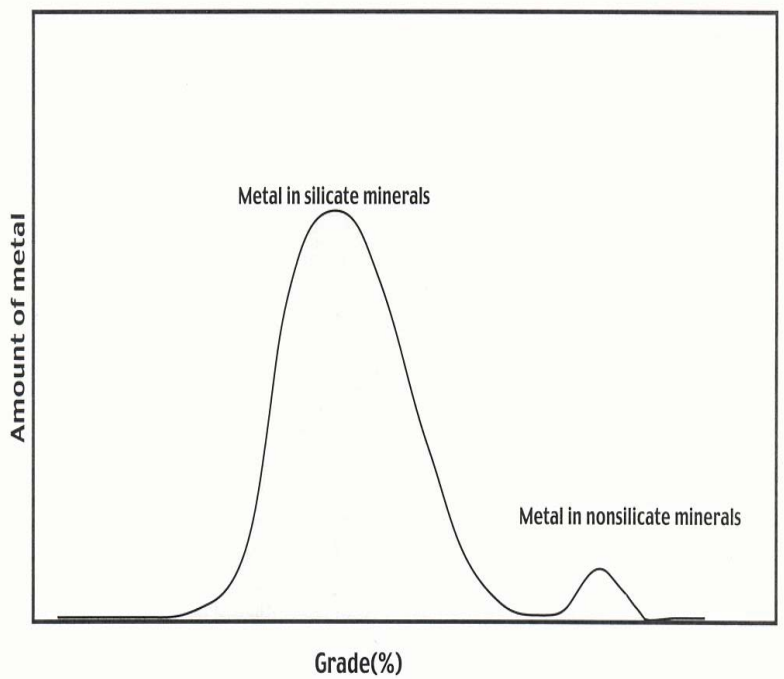


Figure 1. Probable distribution of geochemically scarce metals in the earth's crust (After Skinner, 1976).

Chemistry and mineralogy of mineral deposits

- In addition, some cations only occur as limited substitutions or trace components in commonly used minerals.
- Thus mineral commodities may occur as major products, co-products, or by-products depending upon the mineralogy of the major ores of the mineral commodity.

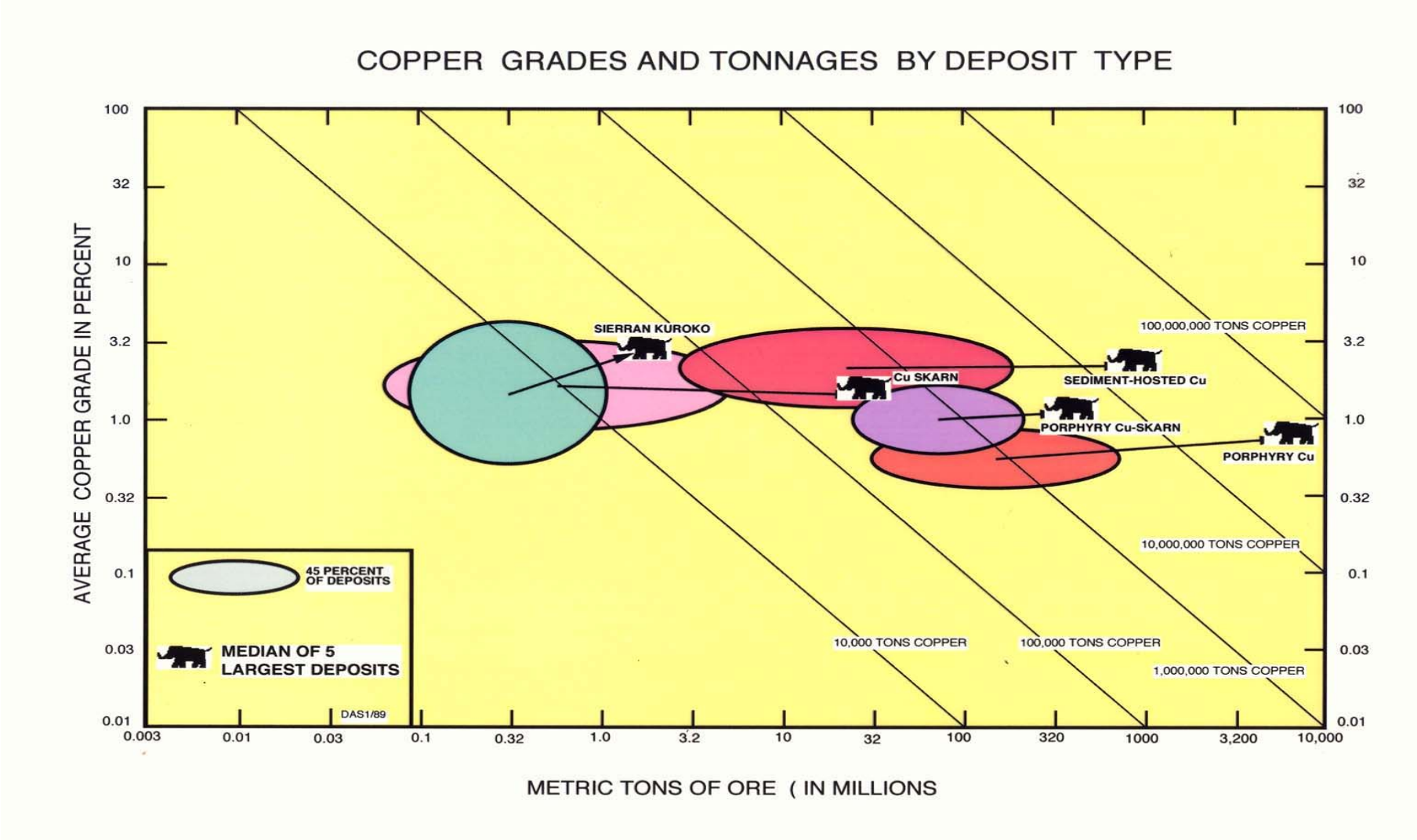
Geology of mineral deposits

- Geologic processes control the formation and distribution of minerals within the earth's crust and, most importantly, result in those concentrations of a mineral of sufficient size and grade that they might, under the most favorable of circumstances, be considered to have economic potential (mineral deposits).

Geology of mineral deposits

- Mineral deposits can generally be classified into groups, or types, that reflect the geologic processes that form them.
- These deposit types are usually characterized by similar geology, mineralogy, and size (tonnage) and richness (grade) of the mineral commodities they contain.

Geology of mineral deposits



Geology of mineral deposits

- Usually a few mineral deposit types account for the majority a mineral commodity, and a few deposits of a particular type contain most of the mineral commodities in the deposit type.

- This is owing to the distribution of grades and tonnages of deposits of each type.

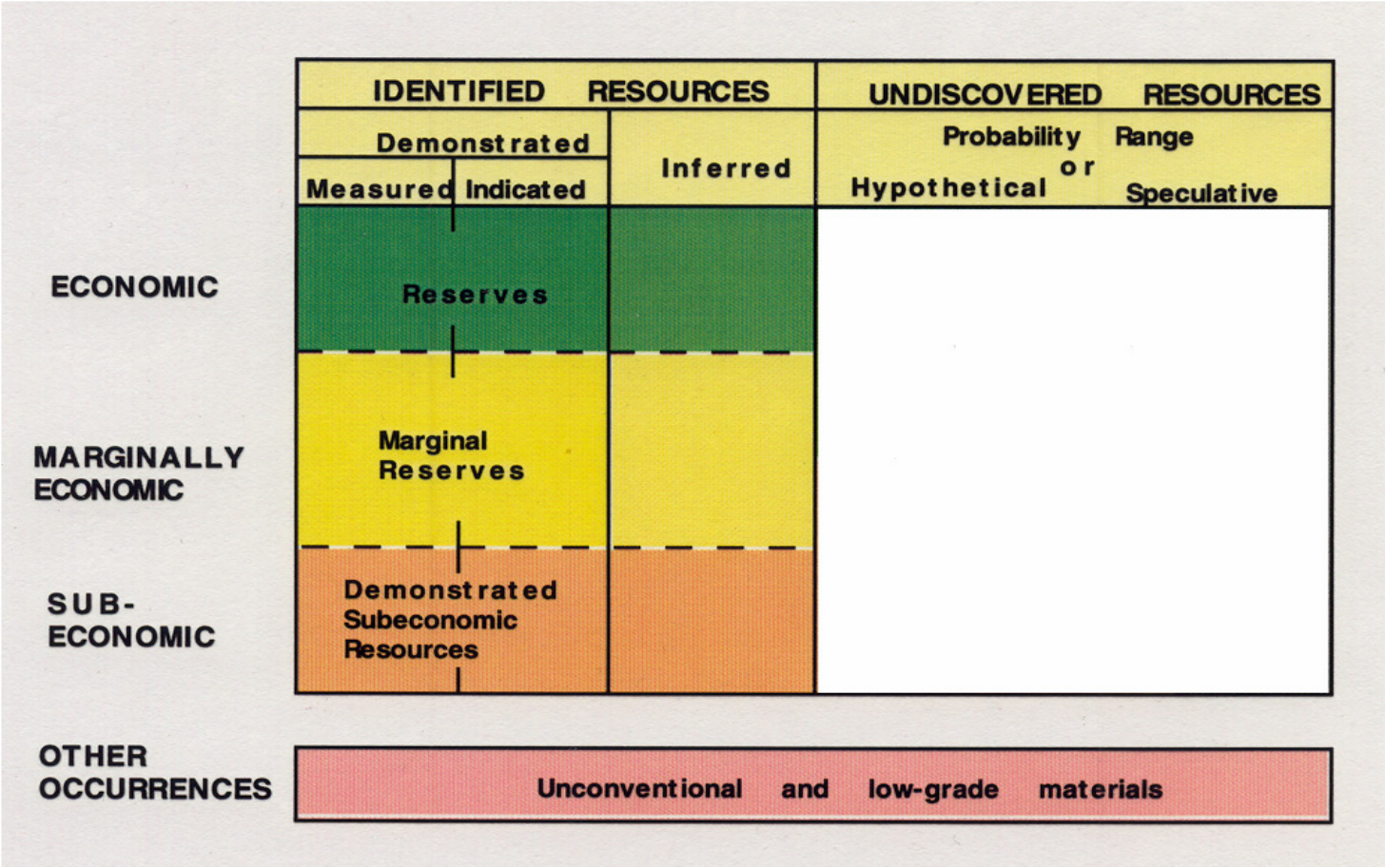
Reserve and resource measurement

- Concentrations of minerals are commonly classified according to how well they have been characterized, or measured, and whether they can be produced at a profit.
- In terms of measurement, resources may be divided into identified resources, which include demonstrated and indicated resources undiscovered, and undiscovered resources.

Reserve and resource measurement

- In terms of economic viability, resources are characterized as economic, marginally economic, and subeconomic.
- It is important to understand that measurement is in terms of classes, not as continuous variables, and that the classification is dynamic. Materials may move about within the “box” based upon changes in prices, technologies, discovery from exploration, and geologic understanding.

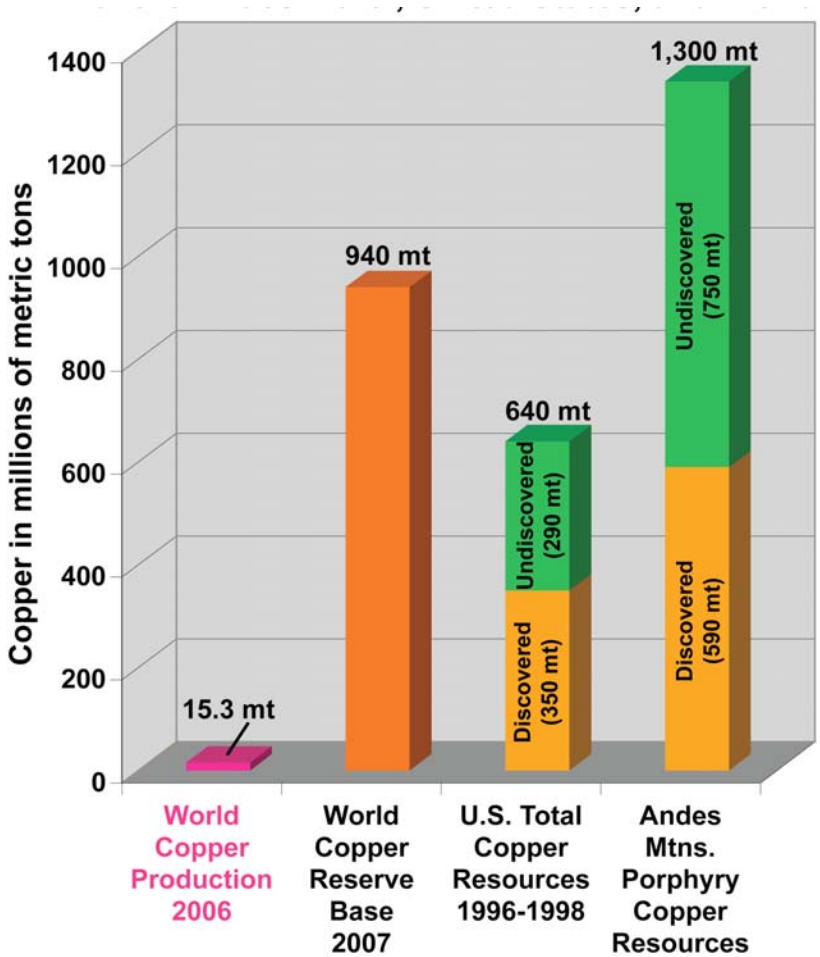
Reserve and resource measurement



Reserve and resource measurement

- Resources of different categories have significantly different associated uncertainties that depend upon whether they have been measured or estimated (undiscovered resources are not amenable to measurement) and their status as major products, co-products, or by-products.

Reserve and resource measurement



This graph shows recent global production of copper, estimates of global identified resources, U.S. identified and undiscovered resources, and identified and undiscovered resources in porphyry copper deposits in the Andes of South America.

note: in figure mt = million tons

Reserve and resource measurement

- Note undiscovered resources are as large or larger than discovered copper resources. Many geologists believe this is the case for many mineral commodities; however exploration companies report that mineral deposits are increasingly difficult to discover. This may be due to the fact that the estimated resources occur beneath significant thicknesses of covering materials.

Reserve and resource measurement

- As a result these resources will be significantly more expensive to discover and to mine.
- Therefore, while it seems unlikely that mineral supplies will be constrained from the lack of existence of materials, the location of materials may place constraints upon the availability of mineral commodities.

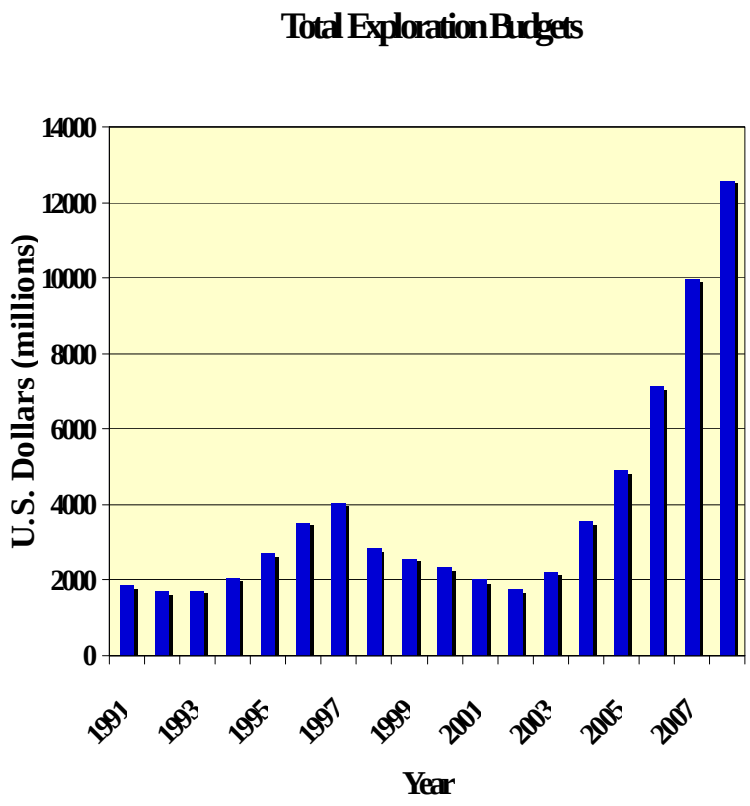
Effect of institutional structure, technology, and social factors on mineral supply

- Beyond the occurrence of mineral resources, other institutional, technological, and social factors may affect the availability of mineral commodities.

Effect of institutional structure, technology, and social factors on mineral supply

- Large mining companies have outsourced mineral exploration to smaller junior mining companies and have turned to replenishing their reserves by either entering joint ventures with junior companies once exploration has advanced beyond an initial phase, or purchasing other companies with reserves.

Effect of institutional structure, technology, and social factors on mineral supply



Although this graph would seem to indicate that exploration budgets have increased significantly since 2002, data on the amount of drilling per year suggest that the increase in exploration activity is much less impressive than the budgets indicate and may only be at about 1997 levels (Crowson, 2009).

Effect of institutional structure, technology, and social factors on mineral supply

- New technologies have significantly decreased exploration, mining, and mineral processing costs. However, reduced public and private support for research in mineral exploration, mining, and mineral processing may slow the rate of development of new technologies.

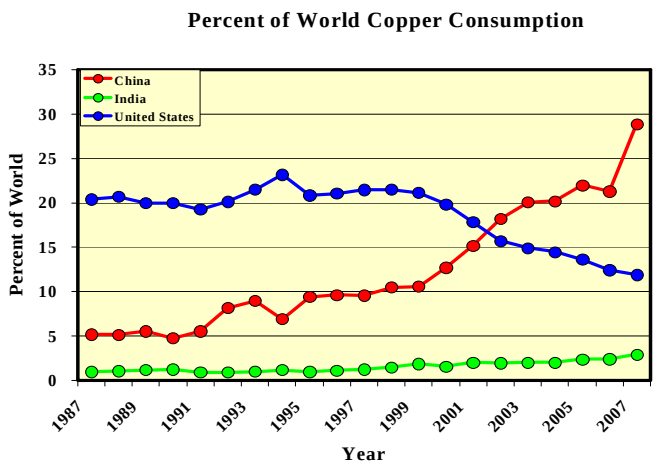
Effect of institutional structure, technology, and social factors on mineral supply

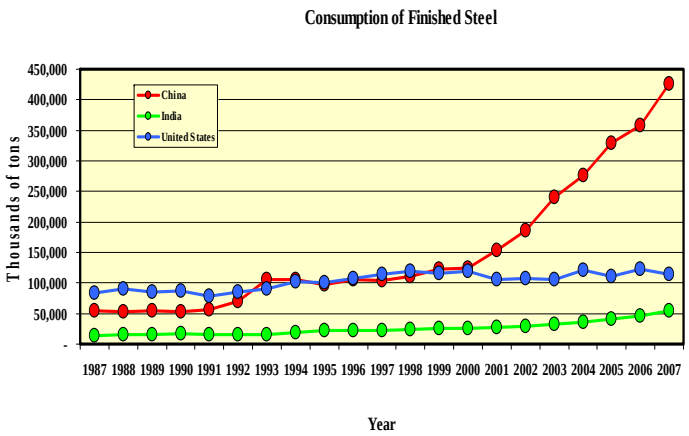
- Changing societal attitudes toward resource extraction and processing have decreased the amount of land available for mineral exploration and development as society has increased its concern about the environmental effects of mineral production. Producing minerals in a more environmentally sensitive manner could add significantly to the cost of mineral production

Economic growth and mineral consumption

- Although, the physical availability of minerals and a supportive institutional, technological, and social framework are important inputs to mineral supply, the balance of supply and consumption will also significantly depend upon the level of consumption.
- Economic development in Asia is increasing rapidly and will have a major effect on the balance.

Economic growth and mineral consumption

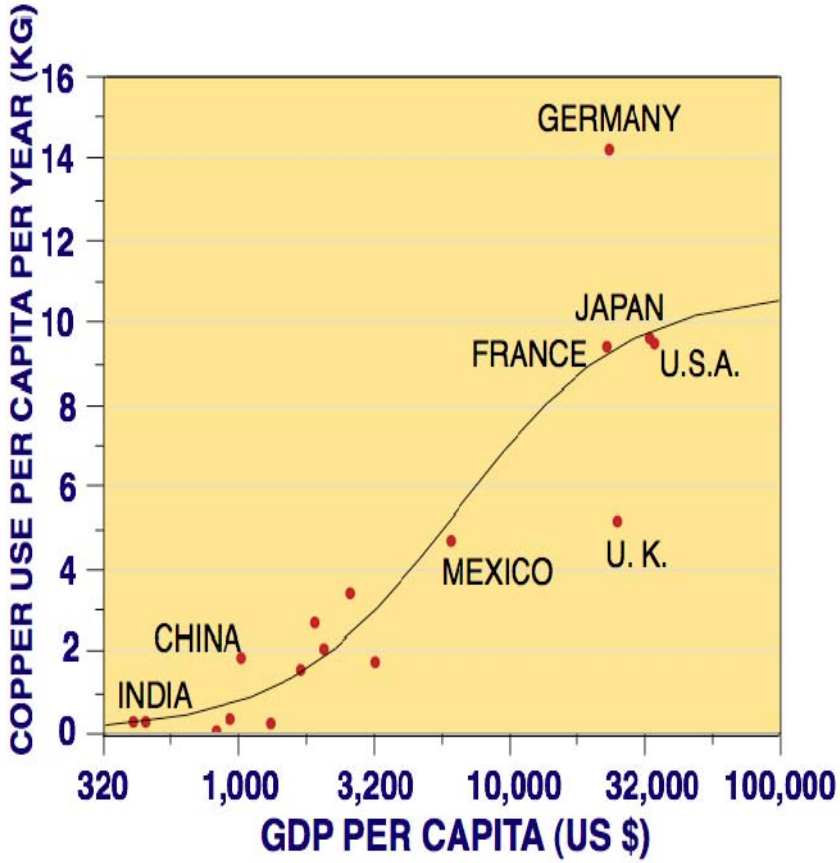




- China's consumption of minerals has increased significantly since 1990 and dramatically since 2000.
- India's consumption of minerals is at about the level of China just before 1990.

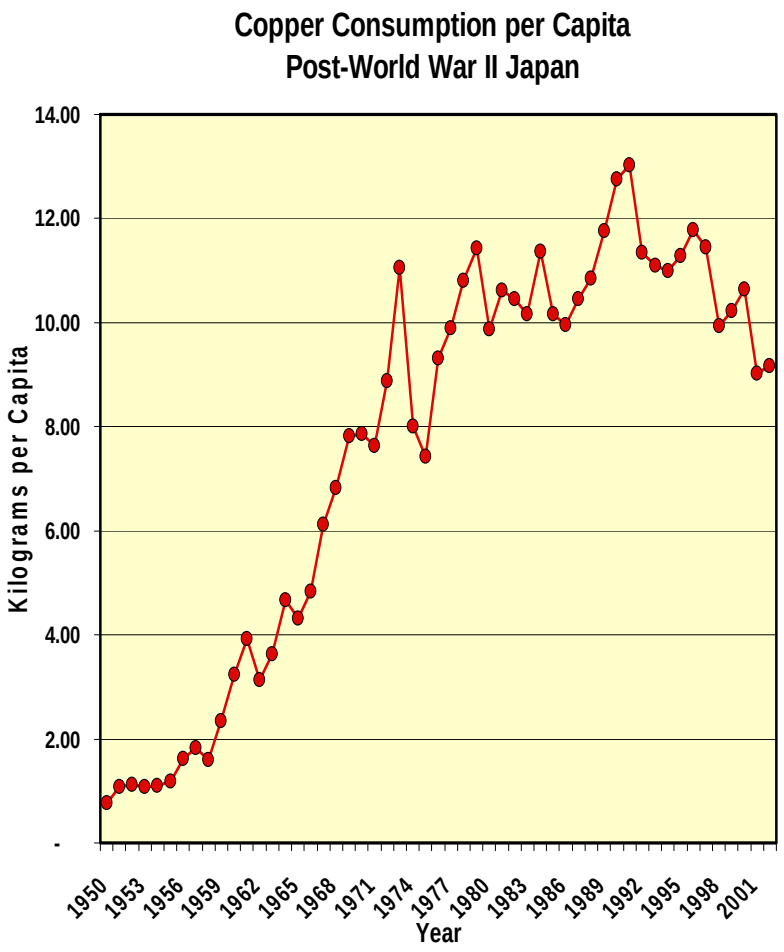
Economic growth and mineral consumption

- Recent studies have suggested that mineral consumption per capita can be estimated as a logistic function of income (GDP/capita).
- Mineral consumption increases rapidly from a low level to higher levels as countries undergo economic development.



Economic growth and mineral consumption

- Examination of copper consumption across the period of economic development in Japan and the Republic of Korea show a pattern of initial low levels of consumption followed by a rapid increase in consumption, and finally stabilization at a level of consumption similar to that of other developed countries.



Economic growth and mineral consumption

- The logistic model was used with estimates of future population and 10 year economic growth rates to estimate copper consumption to 2020 for the 20 most populous countries.
- The model predicted that global consumption of copper would grow to 24 million tons (Mt) by 2020, and that China's consumption will consume 5.6 Mt of copper and India will consume 1.6 Mt of copper in 2020.

Economic growth and mineral consumption

- Increases in the consumption of particular mineral commodities appear to occur in phase with the development of particular sectors of the economy:
  (1) Infrastructure (cement and construction materials)
  (2) Light manufacturing (copper)
  (3) Heavy manufacturing (steel and aluminum)
  (4) Consumer goods (aluminum, energy minerals, specialty steels, and industrial minerals)
  (5) Services (static rates of consumption except for energy minerals?)

Implications

- Increased consumption of minerals and minerals information (world copper consumption could reach 24Mt by 2020 with China using about 5.6Mt, in 200; world production in 2003 was estimated to be about 13.9 Mt)
- Higher prices and possibly more volatility
- Increased competition for minerals
- Continued trade disputes
- Pressure on manufacturers in developed countries and need for new material strategies
- Increased environmental residuals

Environment

- Economic growth will dramatically increase consumption of minerals
- This will create large environmental residuals
- And will require new strategies to increase recycling, remanufacturing, and reuse

Strategic and Political

- China is actively seeking minerals in Africa and Latin America and is purchasing mineral producers and increasing foreign investment in these regions
- Increased competition for mineral supplies
- Possible increase in trade disputes

Global Markets

- High mineral prices could return as the economic crisis ends
- Greatly increased investment will be required for minerals development
- China’s imports of minerals are rising and her exports of minerals are declining (rare-earth elements, tin, and tungsten)