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VIEWS

VIEWS I

The World is Changing

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(SEG 1985 F)

There is plenty of evidence that economic geologists should be optimistic about opportunities in our profession. The fundamental reasons for this are an increasing global population and an increasing standard of living for many people throughout the world. Many commodities could illustrate the point, but iron, the metal most used by modern society (on the basis of weight), is an excellent example. In the past 100 years, the world's population has increased four-fold and iron ore production has increased twenty-fold. Thus, average per capita consumption (defined here as production divided by population) has increased five-fold (Fig. 1). This all bodes well for exploration as well as for needs to improve metallurgical recovery, reexamine low-grade resources, evaluate opportunities for recycling metals from municipal and industrial landfills, and design products with efficiency of use, as well as future recycling, in mind.

A close examination of Figure 1 points to what appears to be a significant change in the world. The rapid rise in iron ore production in the last eight years is unprecedented. What has changed is China. As it invests in major infrastructure and building projects, and as its citizens become more affluent, the world's most populous country has dramatically increased its consumption of essentially every commodity. China's annual iron ore production increased by 316 percent from 2001 to 2009 (Fig. 2). China also imports iron ore for its steel industry; much of the rise in iron ore production from Brazil and Australia from 2001 to 2009 met Chinese demand. China produced 50 percent of the world's steel in 2009. India also has been increasing its average standard of living, as is illustrated by its 233 percent rise in iron ore production during this same period, but India's overall production is well below that of China. Largely because of Chinese demand, global iron ore production reached an all-time high of 2.3 billion tonnes in 2009. That equals approximately 0.4 km^3 of magnetite or hematite, an impressive amount to be mined (and, in the long run, discovered) each year.

China is now the leading

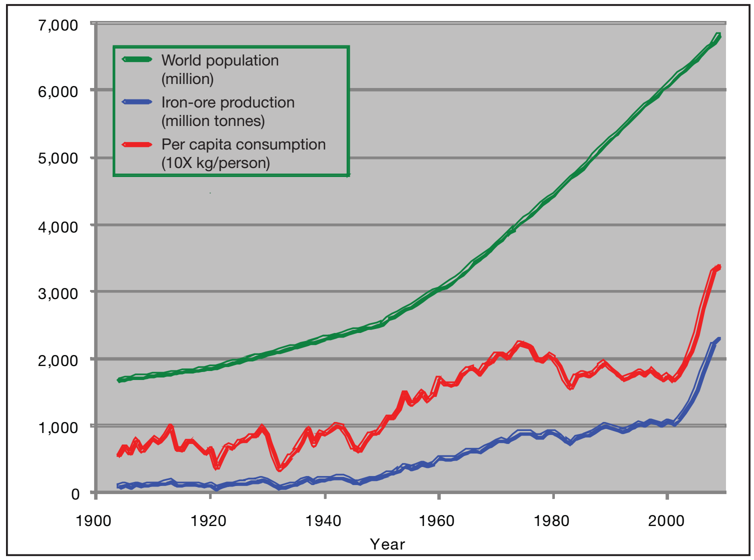

FIGURE 1. Global population, iron ore production, and per capita consumption of iron ore, 1904 to 2009. Production data from the U.S. Geological Survey (January 30, 2010, http://minerals.usgs.gov/minerals/) and U.S. Bureau of Mines; population data from the United Nations (December 24, 2009; United Nations, 2009; http://www.un.org/esa/population/).

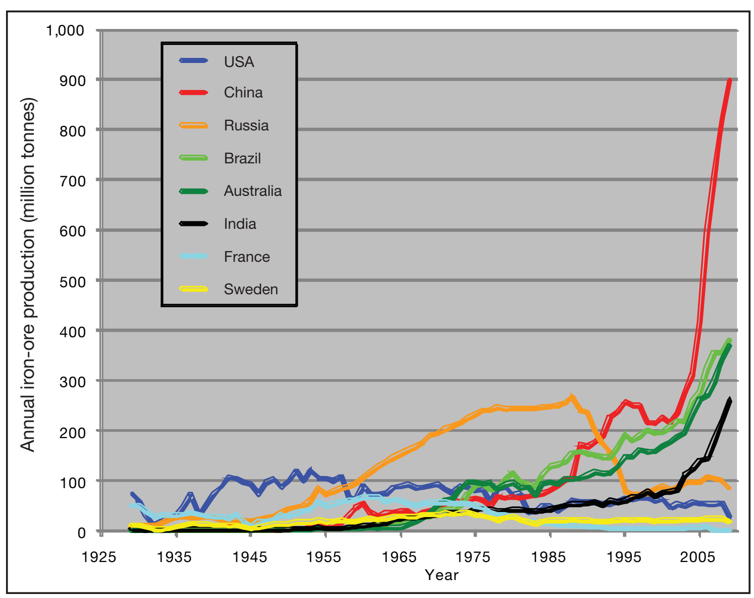

FIGURE 2. Global iron ore production by leading producers, 1929 to 2009. Production data from the U.S. Geological Survey (January 30, 2010; http://minerals.usgs.gov/minerals/) and U.S. Bureau of Mines.

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producer of more mineral commodities than any other country, by far. Among 28 elements featured in Table 1, China is among the top three producers of 18 elements and the leading producer of 14. Neither Chile (the leader in three) nor South Africa (the leader in two) comes close to China's dominance in mineral resource production. China's leadership is not restricted to metals. It also ranks first in the production of barite, cement, coal, gypsum, and phosphate rock.

The global mineral statistics compiled by the U.S. Geological Survey (http://minerals.usgs.gov/minerals/) give us some clues about the commodities to focus on exploring. Some metals (including Al, Pt, and Au) tend to have high prices relative to the overall trend of decreasing price with increasing abundance or decreasing rarity (Fig. 3). Others (including Te, Se, Cd, and As, all of which are used in certain types of solar cells) appear to be underpriced, probably because they are easily extracted as by-products (of Cu for Te and Se, of Zn for Cd, and of Cu, Au, and Pb for As). Some elements appear to have high prices relative to their abundances (e.g., Tl, Ge, and Ga), but their global annual production (Table 1) tends to be small, because production today is largely for niche markets. More could be learned during exploration about the concentrations of these elements in specific deposits and in concentrates of ore minerals (Tl as well as In in Zn ores; Ga in Al and Zn ores; Ge in Zn, Pb-Zn-Cu, and coal deposits). Among the mid-range elements in terms of price relative to crustal abundance (Fig. 3), Cu, Cr, Ni, and Co are attractive because of large demands (Table 1). For example, global Cu production in 2009 (an all-time high of 15.8 Mt) nearly equaled the total production over 100 years from the Bingham Canyon porphyry Cu deposit in Utah (about 16.4 Mt). That is, to keep up with global demand, exploration geologists now need to find the equivalent of one world-class Cu deposit each year. Similarly, to keep up with global annual Au production (2,350 tonnes in 2009), we need to find the equivalent of one Carlin trend (Nevada's major production area, with cumulative production of 2,300 t through 2009) every year.

Interestingly, the economic recession, which went into full swing late in 2008, is not reflected in many of the statistics on global mineral production, although it is evident in some domestic production numbers, particularly in the USA's iron ore (Fig. 2) and construction-related commodities such as sand and gravel, crushed stone, cement, and gypsum (U.S. Geological Survey, 2010). The Great Depression, felt strongly in the global and United States iron ore production in the 1930s (Figs. 1, 2) was not a long-lasting dip in the overall trends of increasing production and increasing per capita consumption over time. The dominance of China in the global supply and demand for mineral resources

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TABLE 1. Global Production and Leading Producers of Selected Elements (with percentage of world production in 2009)[1]

Element	Global production (tonnes)	Leading Producer	2nd Producer	3rd Producer
Aluminum[2]	201,000,000	Australia (31%)	**China (18%)**	Brazil (14%)
Arsenic[3]	53,500	**China (47%)**	Chile (21%)	Morocco (13%)
Cadmium[4]	18,800	**China (23%)**	Korea (12%)	Kazakhstan (11%)
Chromium	23,000,000	South Africa (42%)	India (17%)	Kazakhstan (16%)
Cobalt	62,000	Congo (40%)	Austalia (10%)	**China (10%)**
Copper	15,800,000	Chile (34%)	Peru (8%)	USA (8%)
Gallium[5]	78	**China**	Germany	Kazakhstan
Germanium[6]	140	**China (71%)**	Russia (4%)	USA (3%)
Gold	2,350	**China (13%)**	Australia (9%)	USA (9%)
Helium[7]	22,900	USA (63%)	Algeria (19%)	Qatar (12%)
Indium[8]	600	**China (50%)**	Korea (14%)	Japan (10%)
Iron[9]	2,300,000,000	**China (39%)**	Brazil (17%)	Australia (16%)
Lead	3,900,000	**China (43%)**	Australia (13%)	USA (10%)
Lithium[10]	18,000	Chile (41%)	Australia (24%)	**China (13%)**
Manganese	9,600,000	**China (25%)**	Australia (17%)	South Africa (14%)
Molybdenum	200,000	**China (39%)**	USA (25%)	Chile (16%)
Nickel	1,430,000	Russia (19%)	Indonesia (13%)	Canada (13%)
Niobium	62,000	Brazil (92%)	Canada (7%)	
Palladium	195	Russia (41%)	South Africa (41%)	USA (6%)
Platinum	178	South Africa (79%)	Russia (11%)	Zimbabwe (3%)
Rare earths[11]	124,000	**China (97%)**	India (2%)	Brazil (1%)
Selenium[12]	1,500	Japan (50%)	Belgium (13%)	Canada (10%)
Silver	21,400	Peru (18%)	**China (14%)**	Mexico (12%)
Tellurium[13]	>200	Chile	USA	Peru
Thallium[14]	10			
Tin	307,000	**China (37%)**	Indonesia (33%)	Peru (12%)
Uranium	43,800	Canada (21%)	Kazakhstan (19%)	Australia (19%)
Vanadium	54,000	**China (37%)**	South Africa (35%)	Russia (26%)
Zinc	11,100,000	**China (25%)**	Peru (13%)	Australia (12%)

[1] Data mostly from U.S. Geological Survey (2010); uranium data from World Nuclear Association (December 24, 2009; World Nuclear Association, 2009; http://www.world-nuclear.org/info/uprod.html)
[2] Bauxite and alumina production, not aluminum metal
[3] Production figures in tonnes of arsenic trioxide; produced from arsenopyrite and as a by-product of Cu, Au, and Pb
[4] Production (as a by-product of Zn) figures are for refinery production, not where the metal was mined
[5] By-product primarily of Al, some as a by-product of Zn
[6] By-product of some Zn and Pb-Zn-Cu ores; resources also in coal; leading producers assumed to be same as for Zn
[7] By-product of some natural gas deposits; production from China not available
[8] By-product primarily of Zn and Cu; resources in Sn and W deposits; figures are for refinery production, not where the metal was mined
[9] Mine production of iron ore
[10] U.S. production withheld and not included in the global total; the USA may be the third largest producer, based on the latest published figures (Driesner and Coyner, 2007)
[11] REE (lanthanides) include La, Ce, Pr, Nd, Pm, Sm, Eu, Gd, Tb, Dy, Ho, Er, Tm, Yb, and Lu; production figures are in tonnes of rare earth oxide
[12] By-product of Cu production; figures are for refinery production, not where the element was mined
[13] By-product of Cu production; leading producers assumed to be same as for Cu
[14] By-product of Zn, Cu, and Pb production

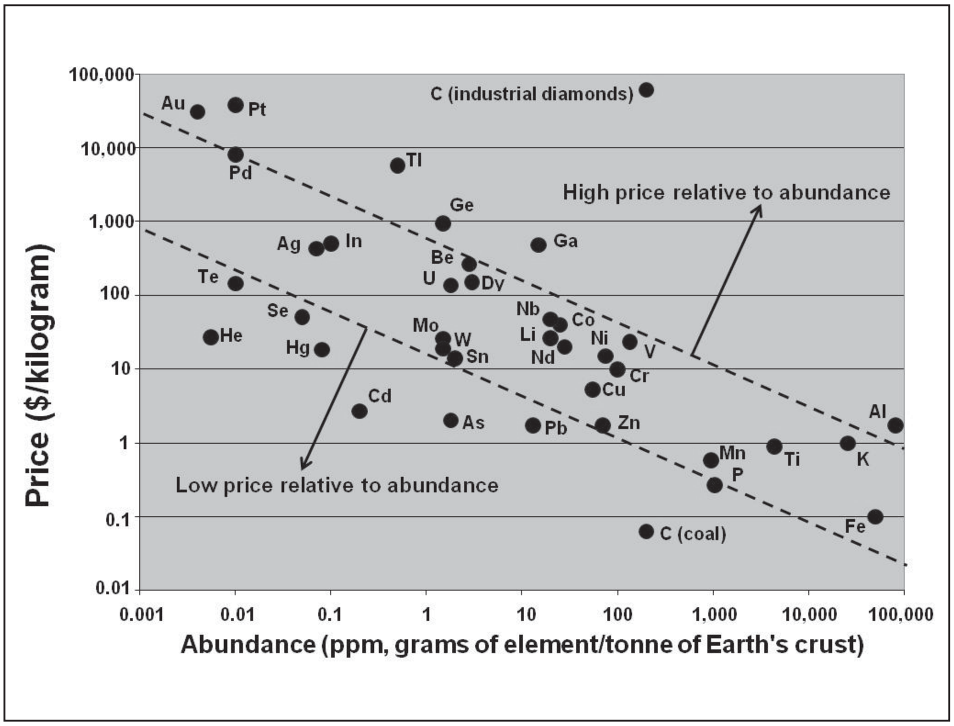

FIGURE 3. Price versus abundance for selected elements. Prices are mostly averages for the year 2009 from U.S. Geological Survey (2010); uranium price from Cameco (December 24, 2009; http://www.cameco.com); lithium price from Davis (2009); neodymium and dysprosium prices from Metal Pages (December 24, 2009 and April 22, 2010, respectively; http://www.metal-pages.com/); niobium price from MetalPrices.com (December 24, 2009; http://metalprices.com/), using the December 31, 2007 quote; crustal abundances mostly from Mason (1966); helium abundance from Web Elements (December 24, 2009; http://www.webelements.com/helium/).

suggests to me that economic geologists can be optimistic about the future demand for their services. I would expect that the global demand will be strongest for those mineral commodities for which China does not produce enough to meet its domestic demand (such as Au, Cu, Co, PGE, Ni, Cr, diamonds, and potash) and for those commodities for which China may largely control the market (such as REE, W, In, and barite).

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