FROM EMPIRE TO ENTERPRISE: 100 YEARS OF HISTORY THROUGH MINERAL EXTRACTION STATISTICS

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Abstract

In 1913, the average annual wage in the UK was £72, the British Empire was approaching its peak in size and 162 million tonnes of iron ore was produced worldwide. The latter figure appears to be a huge quantity but 100 years later, in 2012, this had increased to nearly 3000 million tonnes, a 1700 per cent increase. However, the rate of production increase during the century has not been smooth, with output nearly trebling since 2001 alone.

Perhaps it is not surprising that consumption and production of most minerals have increased over the last 100 years, but which ones have experienced the most dramatic changes? Is it the so called 'critical' or 'technology' metals used in an array of modern devices such as mobile phones and photovoltaic cells, or the more common, bulk minerals such as coal or iron ore? Furthermore, how have the principal producing countries changed over time?

The British Geological Survey (BGS) is one of only two organisations globally that has the data to address these questions. A team at the BGS collects, analyses and publishes mineral production data by country for more than 70 commodities. The BGS dataset contains continuous annual data from 1913 and in 2014 the BGS published its 100th year of data.

This paper examines the variations in the production of minerals between 1913 and 2012, as reflected in the BGS data. Human development, innovation and enterprise have evolved dramatically over the last century and are clearly reflected in global mineral production statistics. Particular sectors such as aerospace, the automotive industry and technological developments are used to illuminate trends and highlight significant changes that have occurred over the past 100 years.

Brown, T.J. 2015. From empire to enterprise: 100 years of history through mineral extraction statistics.
Pp 125-131 in Hunger, E. and Brown, T.J. (Eds)
Proceedings of the 18th Extractive Industry Geology Conference 2014 and technical meeting 2015,
EIG Conferences Ltd, 250pp.
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Introduction

The British Geological Survey (BGS) World Mineral Statistics (WMS) dataset contains global mineral production data for more than 70 economically important mineral commodities. The annual data are listed by country and are continuous from 1913. The dataset also contains mineral trade statistics for most of the last century. It is maintained and continues to be compiled by staff from the BGS; one of two organisations globally that has compiled these statistics for this length of time. In 2014 the BGS published 'World Mineral Production 2008–2012 Centenary Edition' thereby completing the 100th year of this dataset (Brown et al., 2014).

Brief History

It is not a coincidence that the centenary of the WMS dataset coincides with the centenary commemorations for the First World War (1914–1918). Demand for numerous mineral commodities escalates during times of conflict as manufacturing demand increases and new technologies are developed. Often concurrent with this is a restriction in supply, either because minerals were previously sourced from war zones or because transport infrastructure is disrupted. Although the need for comprehensive statistics on mineral supply was identified before the war, it was the interruption of key supplies of commodities such as manganese, tungsten, phosphates and petroleum that heightened concerns and lead the 'Imperial War Conference' of 1917 to conclude that a Bureau should be established to address this issue.

Thus the Imperial Mineral Resources Bureau was established by Royal Charter in 1919 for the express purpose to '… collect, co-ordinate, and disseminate information in regard to the resources, production, treatment, consumption, and requirements of every mineral and metal of economic value …' (Imperial War Conference, 1918). In 1921, this Bureau published the first in the series of mineral statistical publications, entitled 'The Mineral Industry of the British Empire and Foreign Countries, Statistical Summary (Production, Imports and Exports)' and covering the years 1913–1920. This edition notes that the starting year of 1913 was chosen to enable the reader to directly compare the years of conflict with the final pre-war year (IMRB, 1921).

Since that first publication there has been many changes, not least the elimination of references to the 'British Empire' and the somewhat derogatory sounding 'Foreign Countries', in the 1950s. The first statistical publication included 39 commodities, whereas the Centenary Edition of 'World Mineral Production' contained 73. The units used to report figures were first standardised, in order to allow comparisons to be made between countries, and subsequently were converted to metric in the early 1970s. The methods used to collect, store and disseminate the data have become digital. One of the many interesting features of the old publications is the frequent change in country names that reflect the evolving political history of the world during the last century (some examples are provided in Table 1).

Name(s) used in one or more editions prior to 1939	Name(s) used in Centenary Edition in 2014
Bechuanaland	Botswana
British India	India, Pakistan, Bangladesh, Burma
Ceylon	Sri Lanka
Dutch East Indies	Indonesia
Dutch Guiana	Suriname
Formosa	Taiwan
French Indo-China	Vietnam, Cambodia, Laos
Gold Coast	Ghana
Persia	Iran
Portuguese East Africa	Mozambique
Siam	Thailand
South West Africa	Namibia
Tanganyika, Zanzibar	Tanzania

Table 1. *Examples of changes in country names between the early editions of the World Mineral Statistics series and the Centenary Edition published in 2014.*

Despite the changes, the purpose of the statistical compilation has remained identical throughout the decades; namely to provide an objective, comprehensive, reliable and continuous set of data for the benefit of governments, industry and academia. As noted in the preface to the 1977 edition, the factual data on the worldwide minerals industry represents 'the end-product of geology and a measure of the unceasing contribution of the geological sciences to man's material welfare and progress' (Institute of Geological Sciences, 1977).

Statistical Trends

With such a vast dataset it is impossible to include exhaustive details of its content and value in a paper of this length and consequently selected examples of interesting observations that can be made from 100 years of data are provided in this section. A later section provides some key underlying explanations for the long-term trends that are described and which are common to all minerals.

Iron ore

In 1913 worldwide production of iron ore was 162 million tonnes; a figure that seems quite large until it is compared to the global production in 2012, which was nearly 3000 million tonnes. This represents an increase of 1700 per cent in total or an annualised increase of 17 per cent. However, the majority of this increase has occurred since 2001 (Figure 1). A significant component of this increase is demonstrated by the second line on Figure 1, representing the rapid increase in the production of iron ore in China. While the global increase between 2003

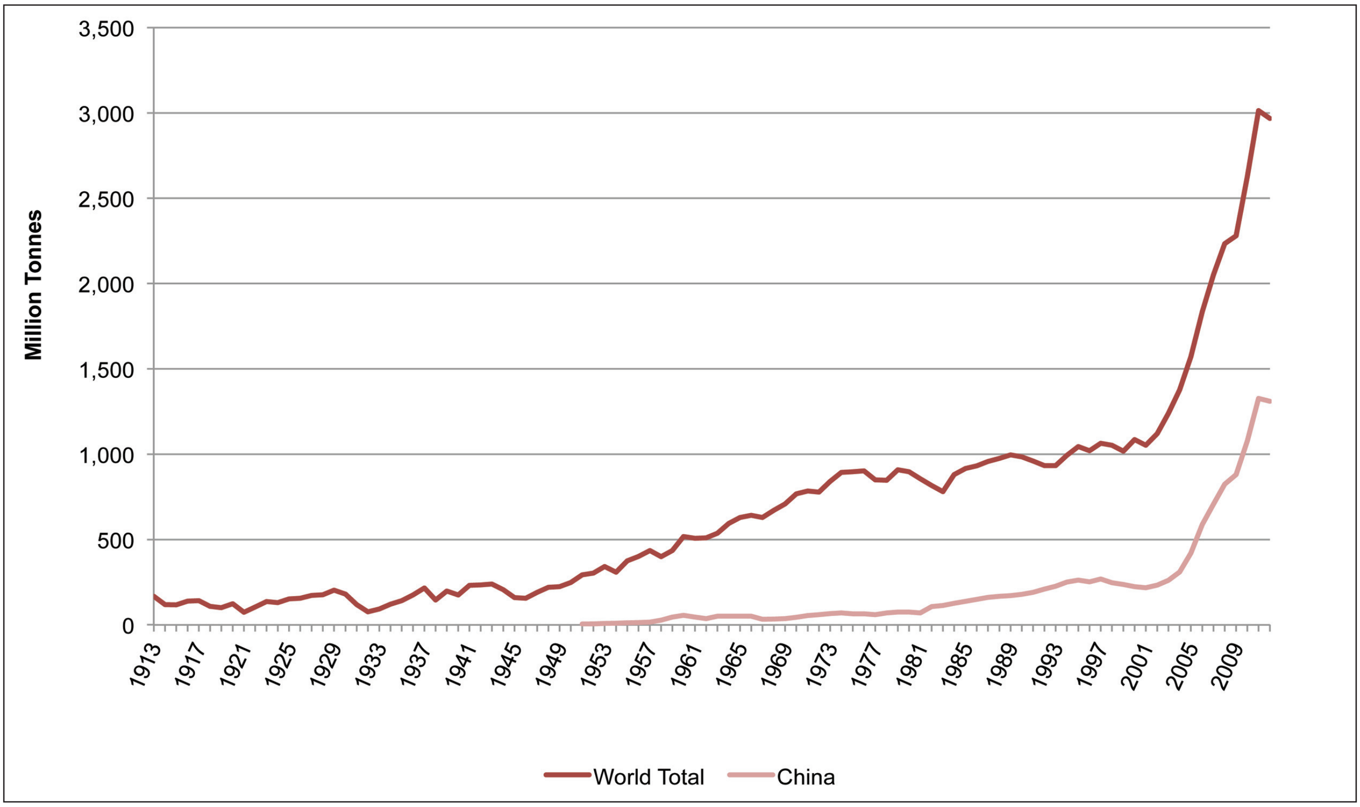

Figure 1. *Total worldwide and Chinese production of iron ore by year from 1913–2012.*

and 2012 was 139 per cent, the increase in China during this period was 402 per cent. The recent history of economic growth in China is clearly reflected in these data.

As would be expected from these differing growth rates, there has also been a significant change in the share of global production from individual countries. In 1962 China accounted for seven per cent of the world's total production of iron ore, by 2012 this had increased to 44 per cent.

Coal, crude petroleum, natural gas

Coal is considered to have been the primary energy source for most countries for the majority of the last century and global output has risen significantly from 1342 million tonnes in 1913. However, global production of crude petroleum increased more rapidly than coal output during the 1950s and was almost equivalent to the quantity of coal produced in 1973 (Figure 2). Since then coal has again become more dominant with production increasing by 83 per cent between 2000 and 2012, reaching 7924 million tonnes in 2012. In comparison production of crude oil has increased by just 12 per cent over the same period to 4008 million tonnes in 2012. Undoubtedly the trends since 1973 can partially be attributed to global politics, with the output of oil affected by the so-called 'oil crises' of the 1970s and subsequent efforts to support prices by limiting supply. However, as with iron ore the production of coal in China has risen significantly between 2000 and 2012 (by 266 per cent) and this has contributed to the widening of the gap between these two commodities in the global totals.

A complicating factor in the examination of production trends for coal and oil is the emergence of natural gas as an alternative energy source. Global production of natural gas was comparatively small until the 1960s but has increased steadily since and was more than 3000 million tonnes of oil equivalent for the first time in 2011. With an increase of 39 per cent between 2000 and 2012, the data reveal that global output of natural gas is increasing at a faster rate than for oil in recent years.

Cobalt (mine production)

The change in the production of cobalt is even more dramatic than for iron ore and coal, with an increase of 510 per cent during the period 1994–2011 (Figure 3). Cobalt is one of several commodities where there has been a significant shift in its end uses. In the early part of the century cobalt was mainly used as a pigment for colouring glass and paints, but in recent years it has been used in rechargeable batteries, super alloys, hard metals and as a chemical catalyst. As its range of uses has expanded so its production has soared. However, it is also a commodity that is associated with conflicts in central Africa, notably the Democratic Republic of Congo (DRC), which remains the largest producing country with 68 per cent of the world's total output in 2012.

Lithium

Lithium is a very topical commodity as a result of the development of lithium-ion batteries. However, what is surprising is that the publication of statistics for lithium was included in the book series from 1925. Worldwide production jumped in the late 1950s before remaining

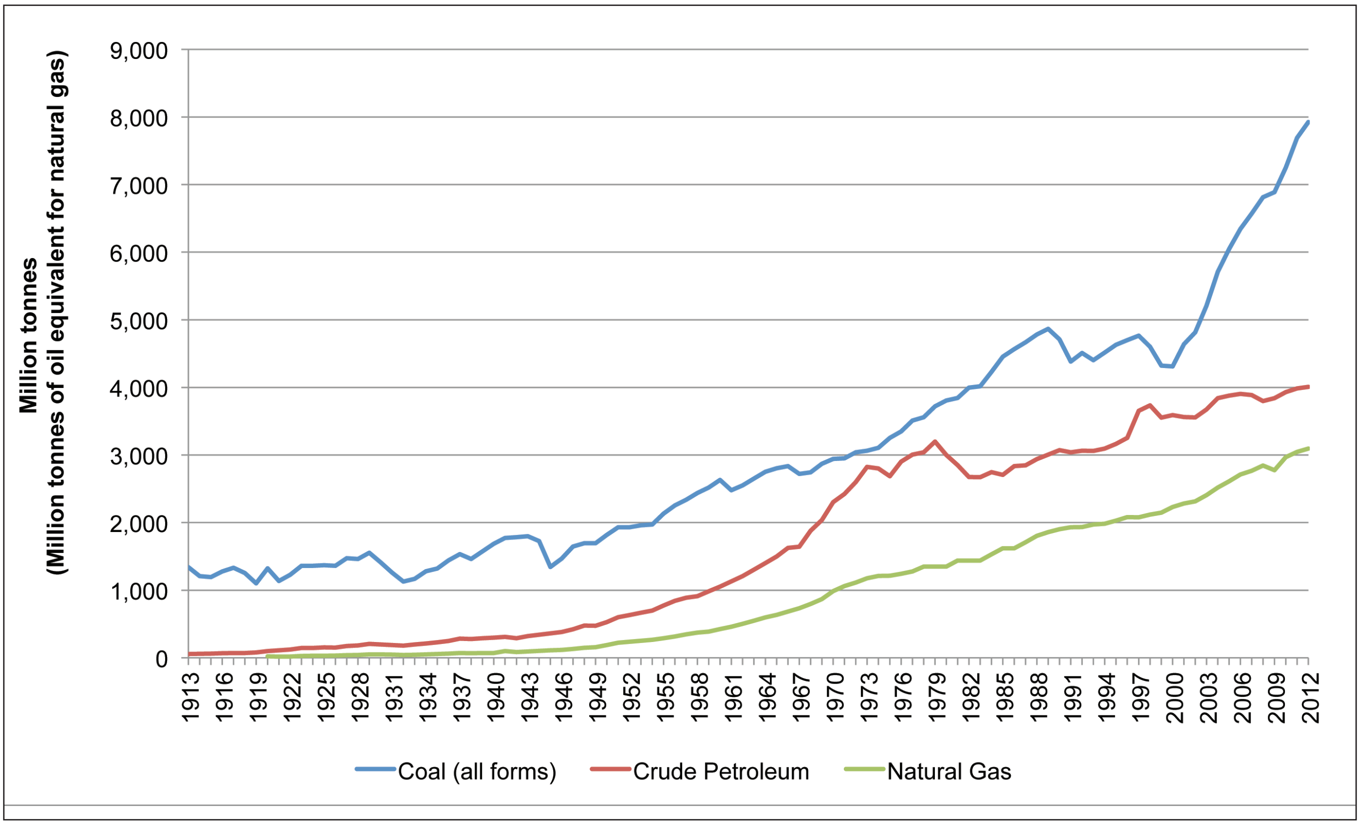

Figure 2. *Total worldwide production of coal, crude petroleum and natural gas, by year 1913–2012.*

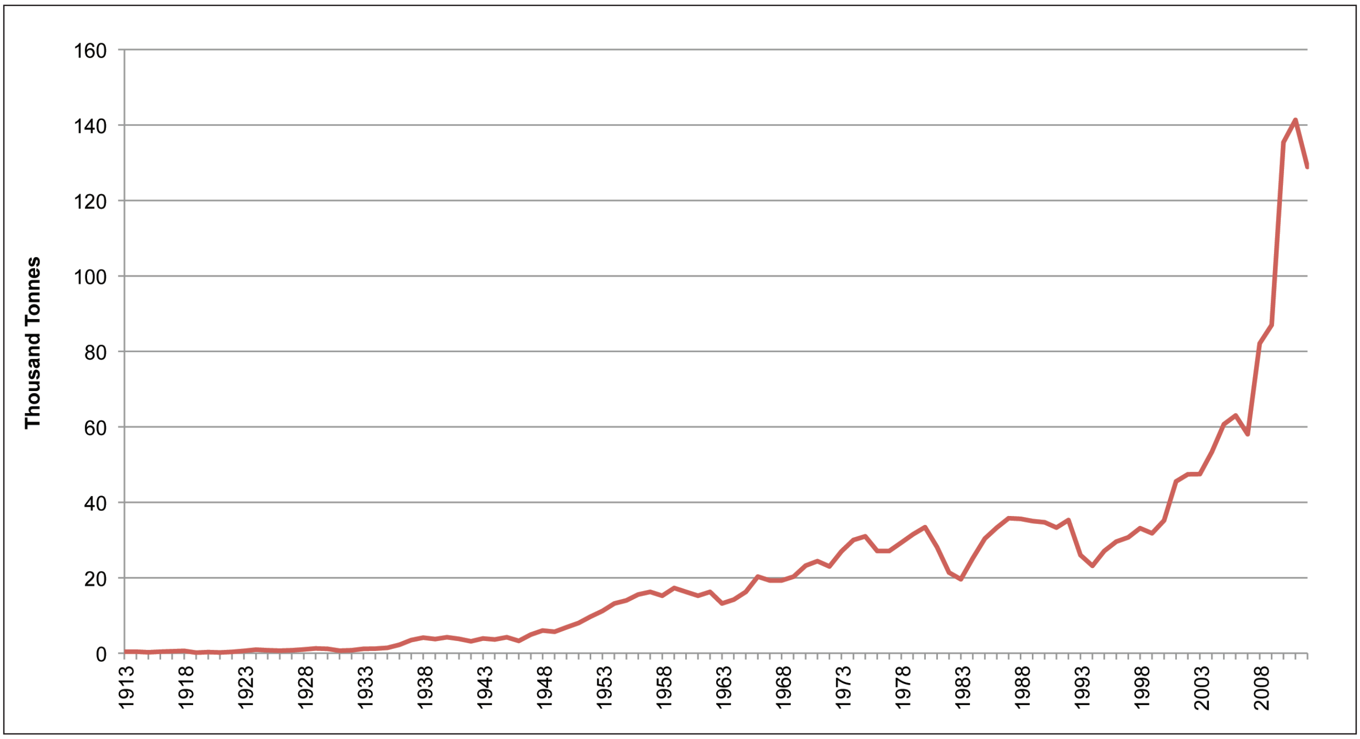

Figure 3. *Total worldwide mine production of cobalt, by year from 1913–2012.*

relatively constant until the mid 1980s when it started to increase. Although not as dramatic as for cobalt, and despite a significant decrease during the recession of 2009, global production of lithium has increased by 580 per cent between 1982 and 2012 (Figure 4).

In addition to the development of new uses for lithium, with the quantity used in batteries recently overtaking that consumed in ceramics and glass, there have also been significant developments in the extraction technology used to recover it. Until 1966 all lithium was extracted from ores such as spodumene, petalite and lepidolite using conventional mining and processing techniques and due to the relatively low grade of these ores production was comparatively expensive. In 1966 a new source of lithium became available, initially from California, USA, in the form of brine waters beneath salt pans, or salars. Output from brines significantly increased from the early 1980s with the commencement of production from the Andes of Chile and Argentina. Production from brines has lowered the costs associated with lithium production and it is notable that the increase in global output of lithium correlates with the expansion of this new type of source.

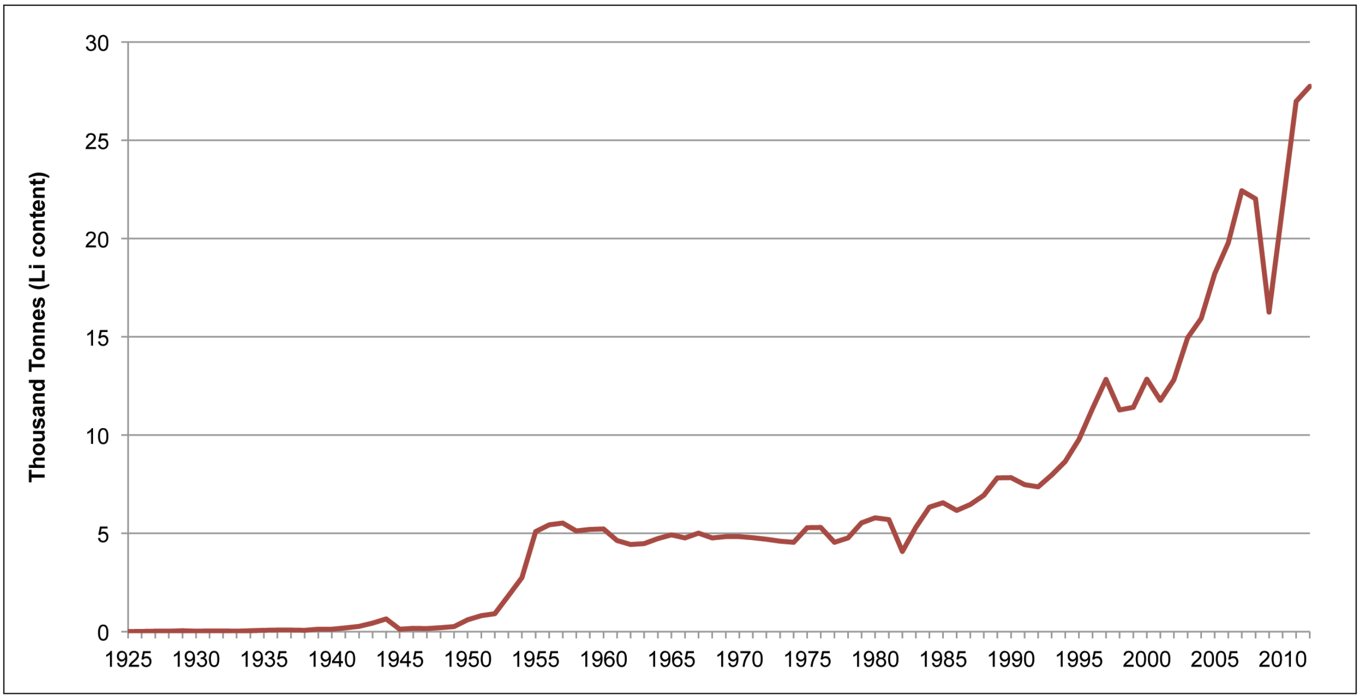

Figure 4. *Total worldwide production of lithium, by year from 1925–2012 (expressed as lithium content).*

Key Drivers Behind The Trends

Population growth

In 1913 there were approximately 1.7 billion people on the Earth but during 2011 this number exceeded 7 billion for the first time. The rate of increase is also rising significantly. It took 123 years for worldwide population to increase from 1 billion to 2 billion (1804 to 1927), but only 12 years for global population to rise from 6 billion to 7 billion (1999 to 2011) (Dunlevy, 2011).

Clearly this provides a significant reason for the increase in the demand for minerals of all kinds and it is demand that drives mineral production. All people need to consume a certain minimum level of materials in order to survive. But it does not explain all of the increase.

Global development by country

In 1913 terms such as 'most', 'less' and 'least' developed were not in common use, but even when these types of terms first appear the number of countries in the first category was relatively small. However, this situation is changing as more and more countries improve their standards of living, ultimately aspiring to those in the 'most developed' category such as the USA or the majority of countries in Europe.

In the most recent edition of the United Nations' Human Development Index, 25 countries are categorised as having a 'very high human development', a further 27 countries are listed as 'high', 21 as 'medium' and 22 as 'low' (United Nations, 2014). Numerous programmes have been established in an attempt to improve the development status of poorer countries, with consequent improvements in health and quality of life.

As living standards improve, people acquire and use a range of new products: for example, more robust construction materials leading to improved buildings, enhancements in the provision of clean water and sanitation systems and the increased availability of domestic electrical products and technology requiring energy infrastructure. All these products use minerals both directly in their construction and indirectly in the provision of services to them. A general principle holds true: if a raw material is not plant-based then it is a mineral, consequently as standards of living improve greater quantities of minerals are consumed, driving higher levels of production.

Types of materials consumed

Innovation and development of many products, including new technologies, has significantly affected the pattern of mineral consumption over the last century. Developments in a number of industrial sectors serve to illustrate this.

In the aerospace industry progress following the success of the Wright Brothers in 1903 was rapid. By 1913 planes were being built in many countries using wooden frames, covered with linen, which would be stiffened, tightened and made waterproof using a plasticised lacquer. The only metals in these early planes were used in the engines because even the propellers were constructed from wood.

Over a 30-year period technology rapidly advanced and many of the planes used in the Second World War were constructed of aluminium alloys over a steel frame, including the iconic Supermarine Spitfire. By the 1960s the air passenger industry had expanded dramatically and in 1968 the Boeing 747 or 'Jumbo Jet' entered service. This wide-bodied airliner, powered by four jet engines, is constructed predominantly of aluminium with less than 20 per cent of the materials used being steel, titanium and other constituents.

More recent developments have included the increasing use of 'composite' materials, such as carbon-fibre reinforced plastic. The Boeing 787 Dreamliner, for example, is built from 50 per cent advanced composites, 20 per cent aluminium and 15 per cent titanium with only ten per cent steel and five per cent other materials (Boeing Commercial Airplanes, 2006). As a consequence these aeroplanes are significantly lighter and therefore more fuel-efficient than their predecessors. The uptake of these new planes is still in its early stages but it will be interesting to observe what impact these new materials will have on the future consumption of those metals traditionally used by this sector. However, it is important to note that the composite materials themselves are ultimately derived from minerals.

While the rate of development in the aerospace industry has been dramatic over the last century, other industries have also significantly advanced during this period. In 1913 cars such as the Ford Model T were typical, whereas in 2012 many electrically powered cars are manufactured, including the Tesla Model S, which was released in that year. The number of electric cars (of all varieties) is increasing and if this trend continues, or if it accelerates, then the demand for batteries containing lithium is likely to rise significantly. This will not only increase the requirement for higher levels of lithium production, but also of other minerals such as graphite.

In 1913 the world's railways were the domains of steam locomotives with common usage remaining until the 1960s. Since then diesel and then electrically powered trains have taken over. In the 2010s the world's fastest train is the Shanghai Maglev Train, which is lifted and propelled along a 'guideway' by electromagnets at over 400 kilometres per hour. The use of minerals in these different forms of propulsion have evolved from the direct use of coal in steam trains or diesel produced from crude oil, to the indirect use of fossil fuels to create electricity or the wider range of minerals required for electromagnets. Materials that can be magnetised include iron, nickel, cobalt and alloys of the rare earth elements.

The telephone was invented in the 1870s and was already widespread by 1913. Although typical models in 1913 were more compact than earlier versions, they were still fixed in one location. The first hand-held cellular telephone call took place in 1973 and 'mobile phones' became increasingly popular throughout the 1980s and 1990s. The first 'smart phones' were released in 1999 and the first touch screen in 2007. The mass adoption of mobile phones and then smart phones has been dramatic, with the number of smart phones in use surpassing 1 billion in 2012 (Reisinger, 2012).

Today's smart phones need in the order of 50 to 60 different chemical elements, almost half of the entire periodic table, all of which are produced from minerals.

For example, the touch screen on a smart phone requires indium-tin oxide, the battery requires lithium and the electrical capacitor requires tantalum. Although each phone may only have miniscule amounts of these compounds and metals, the scale of worldwide production of these and similar products is a significant driving force behind the increases in consumption and production of these commodities.

Changes In Supply Patterns

The WMS dataset, in addition to describing global trends, also illustrates the changes that have occurred in the countries that produce the minerals needed by society. In 1913 the world's largest iron ore producers were the USA, Germany, France and UK whereas by 2012 China, Australia, Brazil and India were the largest producers. A similar picture exists for coal with the largest producers recorded in 1913 being the USA, UK, Germany and Austria. By 2012 this had changed to China, USA, India and Australia.

For both these bulk commodities the emergence of China as a major producer is obvious, but so is the growing importance of other countries such as Australia, India and Brazil. Alongside this is the significant reduction in output, relative to the global total, of European countries such as the UK, Germany and France.

For cobalt only two countries are listed as producers in 1913: New Caledonia and Canada. The emerging importance of the country today known as the DRC can be seen from the middle of the century and it remains the largest producer in 2012. China, Zambia and Australia follow DRC as the world's largest producers in 2012.

Production statistics for lithium begin in 1925 with Germany and Portugal listed as the only producers. By the middle of the century the largest producing countries where Rhodesia (now Zimbabwe), Canada, Argentina and South West Africa (now Namibia). In 2012 this has changed to Chile, Australia, Argentina and the USA.

The Importance Of Data

This discussion relating to trends and supply patterns is only possible because the BGS (and the United States Geological Survey) annually collect and publish mineral production statistics for every country. But why do these two organisations continue to perform this task?

An increasing global population, seeking improved living standards and constantly evolving technology over the last century has resulted in significant increases in demand for most products and the minerals they are manufactured from. However, the main consuming nations are not necessarily the main producers and competition for mineral resources is growing. These and other factors increasingly result in a supply risk for some minerals.

Identification of this potential risk has stimulated governments and researchers to assess many aspects of raw material supply and the future availability of minerals. Comprehensive, accurate and objective statistical data relating to mineral production by country are essential for analytical and foresight studies on mineral resource security.

Conclusion

The 100 continuous years of the World Mineral Statistics dataset, held by the British Geological Survey, provides valuable statistical data, which are useful for a wide range of analyses and research studies. This paper highlights the long-term trends and changes in the leading mineral producing countries using iron, coal, cobalt and lithium as examples, but the dataset covers more than 70 mineral commodities.

The last century has experienced considerable increases in production for most mineral commodities, particularly in recent decades, and this is attributed to rising global population, improvements in living standards particularly in emerging economies and the new applications for minerals as technology advances. It is likely that all three of these drivers will persist into the foreseeable future.

The preface to the 1995 edition of World Mineral Statistics noted that '… it appears that the second half of the decade may see real growth in world economic activity and hence in the demand for raw materials. Resources of most minerals are sufficient to meet demand for the foreseeable future but the uncertainties that surround geographic patterns of production and trade make the availability of reliable statistics an essential tool …' (Taylor et al., 1995). This quotation seems equally pertinent to the situation twenty years later.

Acknowledgements

The author publishes with permission of the Executive Director of the British Geological Survey (Natural Environment Research Council). The author would like to acknowledge the considerable input and dedication of the BGS staff that compile the World Mineral Statistics dataset each year and their predecessors throughout the last century. She would also like to thank her colleague Paul Lusty for providing extensive comments on the early drafts of this paper, together with the EIG reviewer and editor.

References

Boeing Commercial Airplanes. 2006. Boeing 787 From the Ground Up, in Aero Magazine, Qtr_04, 2006. http://www.boeing.com/commercial/aeromagazine/articles/qtr_4_06/AERO_Q406_article4.pdf

Brown, T.J., Idoine, N.E., Raycraft, E.R., Shaw, R.A., Deady, E.A., Rippingale, J., Bide, T., Wrighton, C.E. and Rodley, J. 2014. World Mineral Production 2008-2012 Centenary Edition. British Geological Survey, Keyworth, Nottingham, UK.

Dunlevy, S. 2011. Shift of young population to cities may leave elderly without support they need: UN report. The Australian http://www.theaustralian.com.au/news/world/shift-of-young-population-to-cities-may-leave-elderly-without-support-they-need-un-report/story-e6frg6so-1226177302868 (includes a graph with data sourced from the Population Division of the United Nations Department of Economic and Social Affairs)

IMRB (Imperial Mineral Resources Bureau). 1921. The mineral industry of the British Empire and foreign countries. Statistical summary (production, imports and exports) 1913-1920. https://www.bgs.ac.uk/mineralsuk/statistics/worldArchive.html

Imperial War Conference. 1918. Imperial Mineral Resources Bureau. Revised memorandum by the Minister of Reconstruction. Extracts from the minutes of proceedings and papers laid before the conference, pp236-238. HM Stationery Office, London.

Institute of Geological Sciences. 1977. World Mineral Statistics 1970-74: production, exports, imports. HM Stationery Office, London https://www.bgs.ac.uk/mineralsuk/statistics/worldArchive.html

Reisinger, D. 2012. Worldwide smartphone user base hits 1 billion. CNET. http://www.cnet.com/news/worldwide-smartphone-user-base-hits-1-billion/

Taylor, L.E., Lofty, G.J., Hillier, J.A., Fellow, M.E., Bate, D.G., Linley, K.A., Mills, A.J. and White, R. 1995. World Mineral Statistics 1990-94. British Geological Survey, Keyworth, Nottingham. https://www.bgs.ac.uk/mineralsuk/statistics/worldArchive.html

United Nations. 2014. Human Development Report. United Nations Development Programme, New York, USA. http://hdr.undp.org/en