RESERVE JUDGEMENT: FOCUS EFFORT ON DECARBONISATION NOT DEPLETION

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Geologists and others working in the field of mineral exploration and mining use precise terminology to describe and classify mineral deposits, based on increasing levels of geological knowledge and confidence, and the feasibility of economic recovery. Although the terms mineral resources and reserves are sometimes used by other scientists and the media, they are frequently confused and/or used incorrectly. This can lead to misconceptions and flawed predictions that we may soon ‘run out’ of certain minerals and metals. While it is true that the Earth is a finite system, there is no prospect of physical exhaustion of minerals and metals in the foreseeable future. Questioning how much we have left in the Earth’s crust is a serious diversion from the immediate challenge of rapidly approaching environmental limits associated with current methods used in the extraction and refining of minerals and metals.

Depleted thinking about mineral exhaustion

The availability of natural resources to support the global population and maintain economic growth has been a widespread concern for more than 200 years. The eighteenth-century political economist Thomas Malthus made dismal predictions that population growth would exceed the capacity of the Earth to provide resources. In the 1970s the ‘Club of Rome’ analysed the relationship between both economic and population growth and finite resources. Their publication, ‘The Limits to Growth’ (Meadows et al., 1972) predicted that copper and aluminium would be exhausted within four decades. However, these predictions were seriously erroneous: despite a continual increase in production, the estimated amounts (e.g. United States Geological Survey, 2019) of these metals remaining in identified mineral deposits, which could be economically extracted are much larger than in the 1970s.

The annual use of metals worldwide is projected to double between now and 2060 (OECD, 2018). This forecast, coupled with the increasingly wide range of raw materials needed to deliver a low carbon economy (Vidal et al. 2013), has led to a
revival of concern about the capacity of the Earth to meet future demand for minerals and metals (e.g. Cohen 2007; Bardi and Pagani 2007; Ragnarsdóttir, 2008; Laherrère, 2010; BBC, 2012; Sverdrup and Ragnarsdóttir, 2014; Ragnarsdóttir and Sverdrup, 2015; Royal Society of Chemistry, 2019). Some of these authors suggest that certain minerals and metals have reached ‘peak’ production and that scarcity, and ultimately exhaustion, may occur over relatively short timescales of a few decades or even years. Some go as far as specifying the number of ‘years left’ for certain elements. The use of emotive and misleading language e.g. ‘Elements in danger’, ‘stock check’, ‘getting rarer’, and ‘reserves are dwindling’ only serves to compound the myth that we are going to deplete the Earth’s crust of minerals and metals.

Definitions and clarity are vital

Although the total amount of metal in the Earth can be estimated, based on the average crustal abundance of elements, it is irrelevant to discussion about future supply. This is because the majority of the metal occurs in common rock-forming minerals and the amount of energy required to recover it and the associated environmental impacts will prevent its use. In the broadest sense, mineral resources are Earth’s total endowment of valued materials derived from geological processes that may be accessible to humanity. The terms mineral ‘resources’ and ‘reserves’ are widely used in discussions about future mineral supply. Geologists attach strict definitions to these terms, related to increasing levels of geological knowledge and confidence, and the feasibility of economic recovery.

An identified mineral resource is a natural concentration of minerals or a body of rock that is, or may become, of potential economic interest as a basis for the extraction of a commodity. Measurement of the size and shape of a mineral resource is the first step in delimiting a mineral reserve. A mineral reserve is that part of a mineral resource that has been fully geologically evaluated and is commercially and legally mineable.

However, mineral resources and reserves are not fixed quantities because they are, by definition, linked to their economic viability at a particular time. Furthermore, mineral reserves are a small subset of identified mineral resources, which, in turn, are small relative to undiscovered mineral resources that may be found in the future. In addition to identified mineral resources, there are undiscovered mineral resources (United States Geological Survey, 2019; Graedel et al. 2014), also referred to as ‘geopotential’ (Wellmer et al. 2019) that may be found in the future. These resources are postulated to exist, either in favourable geological environments for known types of mineralisation, or in concentrations of minerals and metals as yet unrecongised for their economic potential (United States Geological Survey, 2019) (Figure 1).

The reporting of mineral resources and reserves by companies listed on stock markets are subject to strict rules and precise definitions. Various international standards
of reporting have been established and are widely used to ensure rigorous legal compliance e.g. the Pan-European Reserve and Resources Reporting Standard.

**Figure 1**  Schematic representation of the relationship between mineral reserves, identified mineral resources, undiscovered mineral resources and the entire Earth. Not to scale, as the relative proportions are unknown and liable to change. Mineral reserves generally represent only a small portion of identified mineral resources, which represent a tiny fraction of Earth’s total endowment of minerals and metals, which occur in undiscovered or unidentified mineral deposits that may be found in the future. Adapted from Graedel et al. (2014) and image of the Earth is © iStock.com/leonello. © UKRI.

**Data uncertainty, timescales and relevance**

Many articles discussing mineral supply and future availability use data from the United States Geological Survey (USGS), which publishes the most widely available estimates of national and world mineral ‘reserves’. However, this data requires careful use because it may be incomplete and of variable quality. It is compiled by USGS experts from disparate sources, including national government bodies and commercial companies. There is no guarantee that the reporting practices and dates are consistent across these sources. Inclusion of company data raises a further issue. Company data serves the primary purpose of allowing a company’s underlying assets to be valued and sound commercial decisions to be made (Figure 2). There is little to no incentive for companies to report on mineralisation that is currently uneconomic to exploit, or to carry out the additional, expensive work required to
convert identified, but currently unrequired mineral resources into reserves — the companies, markets and investors are rarely interested in the life of a mineral deposit beyond two to three decades. Whilst this data provides an indication of what is likely to be available for mining in the short-term, long-term public planning and policy development to improve the security of supply of raw materials needs to consider much longer timescales.

Figure 2  The open pit of the Lege Dembi gold mine in southern Ethiopia. Quantification of mineral resources and reserves in hard rock mineral deposits involves drilling boreholes into the mineralisation to obtain representative sample material. Visual and geochemical analysis of the sample material provides data on the concentration and distribution of minerals and metals in the rock volume. Drill holes have to be close enough together to be statistically representative of the mineral deposit. The geological data gathered are assessed to help determine whether the amount of a mineral or metal present is mineable at current commodity prices, enabling companies to make sound commercial decisions over timescales typically in the range of 10–30 years. The mineral resource and reserve data for a mineral deposit represent a snapshot in time and are, therefore, an unreliable indicator of long-term mineral availability. © UKRI

Resources and reserves are poor indicators of the future availability of minerals and metals

The USGS ‘reserve’ dataset comes with the explicit guidance that “Reserves data are dynamic” and “may be reduced as ore is mined and (or) the feasibility of extraction diminishes, or more commonly, they may continue to increase as
additional deposits (known or recently discovered) are developed, or currently exploited deposits are more thoroughly explored and (or) new technology or economic variables improve their economic feasibility.” (United States Geological Survey, 2019). Failure by some authors to appreciate the dynamic nature of mineral reserves leads to this data being used for forecasts based on ‘static life times’, which are derived by dividing quoted mineral reserves by current or projected future mineral consumption.

Resources and reserves are economic entities that are best considered as working inventories at a particular point in time. They vary in response to the rate of extraction of raw materials, to new discoveries and to numerous political, social, technical and environmental factors, which effect economic viability (Lusty and Gunn, 2014; United States Geological Survey, 2019). As they are neither well known nor fixed, current resource and reserve estimates should not be regarded as reliable indicators of the future availability of minerals and metals. In fact, we would go so far as to say that published resource and reserve estimates are largely irrelevant to long-term foresight analysis (Figure 3).

Figure 3  World mine production (British Geological Survey, 2020) and ‘reserves’ (United States Geological Survey Mineral Commodity Summaries 1996–2018) of copper since 1995. In 1995 the USGS estimated global copper ‘reserves’ to be 310 million tonnes of contained metal (United States Geological Survey, 1996). Over the next two decades, cumulative global copper production amounted to nearly 350 million tonnes but global copper ‘reserves’ increased annually and were estimated to be 790 million tonnes in 2017 (United States Geological Survey, 2018). Therefore, mineral reserves are not static; they are continually updated to reflect new data and changing economic conditions. © UKRI
Earth’s total endowment of minerals and metals is much greater than current mineral resource and reserve estimates indicate. Future supplies of mineral raw materials will come from many sources, including identified mineral resources, further exploration and development of currently exploited mineral deposits, undiscovered or unidentified deposits that will be found in the future as we explore more of the Earth, and secondary raw materials in the anthropogenic environment (Figure 4). As a result, there is consensus among economic geologists that geological scarcity of minerals and metals is simply a myth (Williams, 2008; European Commission, 2010; Crowson, 2011; Graedel et al. 2014; Meinert et al. 2016; Arndt et al. 2017; Wellmer et al. 2019). However, geologists have a vital role to play in communicating this important message to the broad scientific community, the media and the public.

Figure 4  British Geological Survey rare metal pegmatite research in eastern Africa. As we explore more of the Earth, and geoscience data and understanding improves then we will identify new mineral resources, which may be converted into mineral reserves under appropriate economic conditions. © UKRI

Facing up to the real issue: environmental limits on resource use

So, if physical exhaustion of minerals and metals is not a problem, why should humanity be concerned about our use of Earth’s mineral resources? Instead of worrying about the physical limits of our mineral resource use, a far more immediate
Concern should be the pressure this utilisation is placing on the environmental limits of our planet. The OECD recently warned that “Growth in materials use, coupled with the environmental consequences of material extraction, processing and waste, is likely to increase the pressure on the resource bases of our economies and jeopardise future gains in well-being.” (OECD, 2018). Primary metals production is estimated to account for about 20 per cent of all industrial energy use globally, and 7–8 per cent of the total global energy use (UNEP, 2013). Unless interventions are made, this situation is likely to deteriorate, as primary metal production increases, as increasingly lower grade mineral deposits from greater depths in the subsurface are exploited, and desalination is increasingly used to supply fresh water to mines for mineral processing operations (Mudd, 2005; Calvo et al. 2016; Koppelaar and Koppelaar, 2016; AME Research, 2017; AME Research, 2018; OECD, 2018). Whilst there has been much research over the last decade into the so-called ‘critical metals’ (e.g. European Commission, 2010; Naden, 2012), the largest reductions in carbon emissions can be achieved by improving the efficiency of mining, use, reuse and recycling of the major industrial metals (such as iron and steel, aluminium and copper). Because we use these metals in such large amounts, even relatively small efficiency gains have the potential to reduce the environmental impacts, especially of greenhouse gas emissions, associated with their primary extraction and processing (Bloodworth et al. 2019). For example, it is estimated that improving energy efficiency (e.g. smart blasting, improved sorting and waste removal, process optimisation, heat recycling etc.) in copper mining would result in a 0.5 per cent reduction in projected total global energy demand in 2050 (Elshkaki et al. 2016).

References


