Sustainable development is a term that all too often has been hijacked within our society by politicians and business promoters eager to endorse their “green” credentials. Yet human society requires sustainable growth in order to continue. However, in the context of much of society’s mineral resources what does sustainability actually mean?

In the interest of complete disclosure, I have been a miner from the age of 16 and still own my own mining operations, so I am unapologetically pro-mining. However, I also appreciate the planet we live on. The context and concept of mineral development being sustainable is one that intrigues me. By its very nature, mineral deposits are rarely “sustainable”. The activity of mining consumes a resource as the development progresses. At some point, a given mineral deposit will be physically or, more commonly, economically exhausted. Other than marine evaporates, guano phosphate and some soda ash deposits, mineral deposits are not renewed on a human timescale of true sustainability (Fig. 1).

This is nothing new. Georgius Agricola in his mid-16th century book *De Re Metallica [On the Nature of Metals (Minerals)]* commented on the waste of resources in many of the mines around Freiberg, St Andreasberg and the Harz Mountains (Germany) and how they would cause problems for future generations. Yet, despite the consumption of resources, many mines continue for many generations. For example, the base metal–sulfide deposits of the Iberian Peninsula have been continuously mined for 5,000 years; the mines of Laviron in Greece were mined over a period of 3,000 years; and Bingham Canyon in Utah (USA), although just over a hundred years old, has seen the extraction of over 19 million tonnes of copper ore and continues to produce approximately 300,000 tons of copper, 500,000 ounces of gold, 4 million ounces of silver, 30 million pounds of molybdenum and 1 million tons of sulfuric acid every year! So, although not sustainable, certainly long lived (Fig. 2).

Despite often long and active periods of mining, most mines do not close as a result of the exhaustion of all ore. Mines close because the ore that is left costs more to extract at prevailing metal prices than will be realized in revenue. As many ore bodies reach this maturity or are abandoned, potential negative environmental impacts can and do occur.

It is conceivable that the mining legacies of previous generations can, through new technology, be considered as providing an alternative ore source, possibly in perpetuity: truly “sustainable mining”. A recent publication by Nordstrom et al. (2017) addressed the potential methods that could be applied to offset environmental impact mitigation and produce critically required metals from contaminated water discharged from mine sites. But is there really value in such an exercise?

An evaluation on mine waters discharged from Iron Mountain (California, USA) (Fig. 3) indicates “ore grade” concentrations up to 650 mg/L copper and 2,600 mg/L zinc in water with a pH less than 1.5 at a flow rate up to 50 L/s (Alpers et al. 2003). The calculated value of the water in terms of metals (primarily as copper and zinc) could be in excess of US$12,000 a day, making it a mid-size base-metal producer. This water also has a wide range of other potentially valuable trace...
components as well (such as Ag, Pb, Cd, Li, Be, Ga, Ge, Sn, Te, Ti, and rare-earth elements). However, the reality is that the total metal value can be very different from the economic value because it does not account for the cost of metal extraction, refining or transport. These costs can be on the order of 60% or more of total metal value. So, despite the attractive costs, if it costs $8,000 to $10,000 per day to recover these metals then the operation is less attractive as a commercial concern but could be driven by other factors, such as environmental clean-up.

Metal recovery from mine waters, such as at Iron Mountain, represents a potential source of revenue to offset water treatment costs and, in some places, may even represent an economic project in its own right. A caveat exists, however: even if the “ore potential” can be proven and the technology can recover economic amounts of metal, there may still be little incentive to “re-mine” many old mining districts.

Companies that attempt such re-mining ventures may be held responsible for all past mining legacy, as well as any new disturbance. Furthermore, the mere mention of metal value from these old districts could result in legal action from property owners or bankruptcy trustees who will lay claim to any recovered value. It is quite conceivable that potentially “sustainable” developments could become unattainable simply due to legal quagmires. So, despite the potential for extractable minerals, in some cases they could become “legally off-limits”.

Nevertheless, in the current environment of high-metal demand and exhaustion of historically important metal sources, different sources of metals or technologies to extract metals will have to be found. This could be from mining deeper primary mineral resources, using new types of ore (such as bauxites) providing rare-earth elements or returning to recover extractable minerals from abandoned mines. These challenges will require a good understanding of the mineralogy and geochemistry of the target metals and minerals in order to identify such “sustainable” opportunities. The geological community must be suitably trained and equipped to characterize such “sustainable” opportunities.

REFERENCES
