Established mines also become less productive over time as mining plans initially target the ore that is easiest to access and promises the best returns. Over time, average grades decline, ore haulage distances grow and the rock becomes harder to crush and treat. This impacts production and increases mining costs.

Second, environmental standards are rising in most countries, with a particular focus on water efficiencies and use, the safety of tailings storage facilities and community relations. These trends are necessary to ensure sustainable development but lead to longer environmental approval processes and increased costs.

Third, exploration budgets are a fraction of what they were a decade ago. Nor has spending on exploration during that period led to a notable increase in discoveries. The copper resource base grew by an average 0.33% a year in the first two decades of this century compared to 1.2% from 1961 to 2000. This is due to both a decline in the number of discoveries (two in the decade to 2019 compared to 94 in the previous one) and the smaller average size of the discoveries.

The relative scarcity of copper puts pressure on supply, a position that has become more challenging over time.

Converting copper ores into metal

Copper ores are transformed into metal by concentration or leaching technologies but a paradigm shift to treat primary sulphides may be on the horizon.

It can easily take a decade, and often much longer, for a discovery to become an operating mine. There are many stages in the assessment of a deposit, during which greater certainty is developed about its composition and scale. Mining and metallurgical treatment plans have to be evaluated and tested and a detailed assessment of environmental, social, infrastructure and political factors completed before a decision can be made to develop the deposit into an operating mine. Most discoveries never make it beyond the early stages of this process.

The optimal processing method for extracting copper depends on the deposit type. Porphyry copper deposits, which account for some 60% of global copper production and are commonly found in Chile, are typically divided into three main ore types: copper oxides, secondary sulphides and primary sulphides. Oxides are nearest the surface and are formed over millions of years from primary sulphides weathered by the elements. Secondary sulphides, often called supergene deposits, are enriched with higher concentrations of minerals leached from the oxide ore body above. The primary sulphides (hypogene) at the bottom are unaltered and usually have lower grades of copper than the secondary sulphides.

Once a project is permitted and approved, it usually takes at least two years for a mine to be built and start operation and permitting can take years to complete.

Copper production

Copper is extracted from the ore and converted into pure metal, through two processing routes: concentration and leaching. Concentration is the main route to process both primary and secondary sulphides and accounts for 80% of total refined copper production. Leaching, which is less capital intensive, came into wide commercial use in the 1980s and, until recently, has only been viable in treating oxides and sometimes secondary sulphides. By-products such as gold, molybdenum and silver can be extracted using the concentrator route, but not with leaching.

Concentration involves crushing and grinding mined ore into a fine powder and then separating the copper from the unwanted waste material in a froth flotation process in a concentrator plant. The resulting concentrate contains 25-35% of copper and is sent, often by sea, to smelters for further processing and then to refineries for refining into pure copper. If by-products such as gold and silver are present, they can be extracted from the copper concentrate, but molybdenum is processed into a separate concentrate. Concentration is capital intensive and benefits from economies of scale; it is often used for lower-grade large sulphide deposits.

In the case of leaching, also known as hydrometallurgy, crushed ore is usually piled up and leached with sulphuric acid to create a copper sulphate solution called a pregnant leach solution (PLS). The copper is then extracted in a solvent-extraction and electro winning (SX-EW) plant to produce copper cathodes. However, as oxide deposits are near-surface and being depleted, production from this process route accounts for a lower and lower percentage of total copper production.

Since SX-EW technology was developed in the 1960s there have not been any new commercially-proven copper processing innovations. But this may change. New technology appears to be able to leach copper economically from previously unresponsive primary sulphides and recover it using a variant of the SX-EW process route. A promising example is our Cuprochlor-T® process which is currently in the industrial-scale testing stage at Centinela (see page 68 for more information).

Confirmation of this technology would be a milestone in the treatment of primary sulphides, which account for an estimated 70% of the world's copper production. It would allow for less capital-intensive processing, maybe even using disused oxide SX-EW plants. This would represent a paradigm shift for the copper mining industry.