BISMUTH
a potential life-saver

by Peter Ion MSc MBA

Classified as poor metals or minor metals, the p-block elements exhibit lower melting points and boiling points than neighboring transition elements within the periodic table. They also possess a higher electronegativity (the tendency of an atom to attract electrons towards itself and the inverse of its ability to donate electrons). Sharing this distinction with aluminum, tin and lead, is bismuth. Classically considered one of the heaviest naturally-occurring, stable elements, with only mercury having a lower thermal conductivity, bismuth is notable for its ability to generate an opposing magnetic field to its immediate environment. It rarely merits the focus of attention within the exploration agendas of mining companies , but with its only primordial isotope (Bi-209) having a half-life of over a billion times that of the estimated life of the universe, it has a certain longevity to its name.

Bismuth's status as a poor metal is lost when it is deposited as a thin layer on a substrate, becoming a semi-conductor. For this reason it has found application in electro technical areas. Its ability to expand when it solidifies, a property for which its liquid phase is denser than its solid phase (as with water), gives elemental bismuth an additional value in high technology applications in integrated circuitry. Bismuth is a brittle metal with many iridescent refractive hues when oxidized, setting it aside from its dull, periodic table neighbour lead. It is this pearlescent quality that renders it suitable for use in cosmetics. Further, its lower comparative toxicity is the underlying reason that bismuth is gaining some momentum as a lead substitute in high technology and other manufacturing processes where relatively recent RoHS (Restriction of Hazardous Substances) compliance criteria are gaining importance. Bismuth's pink hue and anti-bacterial proportions are readily recognizable in over-the-counter remedies for gastro-intestinal complaints including Pepto-Bismol.

Whilst there are several low-tech sectors where bismuth serves as a substitute for lead (fishing line sinkers), the main commercial scale substitution is in the manufacturing of electrical components. In its 100% pure form it is used as a non-superconducting solder in low-temperature physics. As an alloy with tin (58% Bi 42% Sn) it is used in mainframe computer assembly and, when fused with lead, zinc or indium, it has been used as a proprietary patented alloy by manufacturers such as Matsushita. Alloys with a composition of at least 47% bismuth will expand upon cooling to offset the stresses of thermal expansion. In soldering it can significantly lower the melting point and improve wettability (the ability of the liquid to spread out over a surface).

The use of bismuth is not without risk. The European Copper Institute has stated that in concentrations of over 20 ppm, its use has been known to promote grain boundary embrittlement, leading to pre-

LEFT: Bismuth ingots produced by MCP Group, now 5N Plus – Fortune's NICO deposit is the world's largest deposit of bismuth with 15% of global reserves.

RIGHT: Fortune Minerals' pilot plant extraction of bismuth solution from concentrates produced at its NICO project in the Northwest Territories. Photos courtesy of Fortune Minerals Ltd.

mature failure, particularly during hot forming. Large gains are promoted during solidification, and once initiated, cracks are difficult to stop.

Despite the overuse of bismuth salts in the 1970s causing cases of neurotoxicity, the identification of the *Heliobacter pylori* bacterium in the early 1980s renewed interest in the treatment of digestive tract infections. The compound, bismuth subsalicylate, serves as the active ingredient in such products as Kaopectate which is marketed by Chattem Inc.

Although not a key target element of RoHS compliance (as is lead in a range of non-exempt manufacturing processes) bismuth is classed as toxic and its compounds have been voluntarily included in the materials declaration of many Silicon Valley semiconductor makers. Hewlett-Packard has included it in their list of substances for further evaluation 'for possible future restriction or elimination' alongside more familiar compounds such as arsenic, mercury and beryllium. Bismuth is available in RoHS-compliant grades within the European Union – lead is not.

With lead as its most immediate economic comparator, the eco-audit data return very similar (typically less than 5% difference) numbers for energy consumed in casting, rough rolling, extrusion, wire-drawing, metal powder formation, vapourization, coarse and fine machining and grinding processes. The 'CO_2 footprint' of processing the materials is consequently very similar. Over a range of processes for converting lead into a metal powder greater energy is consumed than for the equivalent process for bismuth. Conversely, vapourization processes are consistently more energy-intensive (and CO_2-emitting) for bismuth than lead. The significant differences between lead and bismuth arise in terms of extraction, the 'embodied energy' of primary production for lead being between 25 and 29 MJoules/kg. The equivalent data for bismuth are between 139 and 154 MJoules/kg. On a gram per gram basis, the extraction of bismuth generates a three to four-fold increase in NO_x and SO_x emissions compared to lead. Water usage in the extraction of bismuth is an order of magnitude greater than that for lead.

Bismuth compares equally unfavourably with lead on post-use criteria. Its energetic cost of recycling is almost four times that of lead and has a recycle fraction in the current supply averaging out at between 9 and 10% (that for lead is 68-76%). The economic non-viability of recovering the element from increasingly small electronic components makes the bismuth increasingly a one-shot application.

Located 160 km north of Yellowknife, **Fortune Minerals Ltd.** [FT-TSX] is developing the NICO gold-copper-cobalt-bismuth open pit and underground mine – Canada's largest known source of bismuth. With planned annual production of 4.2 million pounds, they lay claim to being the largest future producer of the element globally. The NICO mine site contains proven and probable mineral reserves of 77 million pounds of bismuth. As part of the development, Fortune has acquired the buildings and equipment from an Ontario minesite for relocation to NICO and is further developing a proposed hydrometallurgical refinery near Saskatoon. The company projects that ore will be processed at the rate of 4,650 tonnes per day at an onsite concentrator over an 18-year mine-life. The mill will produce approximately 180 tonnes of bulk concentrate per day for transport to Saskatchewan, with the pre-requisite Environmental Assessment work already 'progressed to the analytical phase' as of early 2012.

Diamonds North Resources Ltd. [DDN-TSXV] recently undertook geophysical surveys at their Hepburn Copper-Silver Iron-Oxide Copper Gold (IOCG) targets approximately 470 km north of Yellowknife. Anomalies in the data and grab and chip samples from the zones suggest a strong correlation, with returned assay data including 0.17% bismuth. Elsewhere in Canada, bismuth is produced as a by-product of **Teck Resources**' specialty metals division at Trail, BC.

Terranova Minerals NL recently announced a comprehensive evaluation of its Crawford copper-bismuth project some 190 km east of Carnarvon, Western Australia. **Auzex Resources** of NSW Australia recently undertook drilling of a quartz pipe at their Kingsgate property that revealed an average grade of 0.64% bismuth,

a figure they admit to being 'unexpected' and with occurrences on a larger scale than had been modeled. As the global recession peaked they were undertaking trial mining whilst seeking equity finance for a projected annual rate of bismuth processing of 260 tonnes per year as a high purity metal for the pharmaceutical and cosmetic industry.

On a broader global scale, China accounts for in excess of two-thirds of supply and reserves, typically produced as a by-product of tungsten and of the lead ores that occur in large enough volumes to justify co-extraction of bismuth. One Chinese mine and one in Bolivia are the only locations producing directly from a bismuth ore. Chinese production and exports, a major determinant of world price (currently standing at around $10.50 per pound for 99.99% ingot), has been influenced by transport delays caused by river levels falling as a result of drought conditions in major producing provinces such as Yunnan.

You are likely to find it in your medicine cabinet next time you are hit with indigestion and you will never see it embedded into your computer's circuitry. But scale can mean everything in some applications arenas. At the nano-scale, bismuth's relatively large nucleus has been found to interact strongly with X-rays, delivering high-contrast to computed tomography (CT) scans – invaluable in targeting cancerous tissue. As an element it may be relatively unreported but bismuth could yet prove itself a life-saver to some. ■