



A miner extracts the tantalum ore coltan in the Democratic Republic of the Congo.

MINERALOGY

Painful extractions

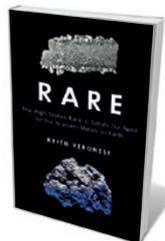
Andrew Bloodworth weighs up a study revealing the high cost of our technology-driven lust for rare metals.

Since the late 1990s, more than 5 million people have died in a civil war raging sporadically in the Democratic Republic of the Congo. This little-known, under-reported horror has been largely fuelled by conflict over minerals including coltan, an ore of tantalum — a rare metal that is a small but crucial component of almost all mobile digital devices. In 2010, a long-running dispute between China and Japan over ownership of the Senkaku Islands flared up, and China threatened to embargo shipments of rare-earth metals such as neodymium to Japan. Given China's then near-monopoly on global supply, prices of rare-earth metals spiked, and some Western governments became seriously worried about the threat to their high-tech manufacturing industries.

These events demonstrate the geopolitical consequences of our need for an ever-widening range of elements in ever larger quantities. Competition and conflict over natural resources is nothing new, but in *Rare*, Keith Veronese gives this old story a modern twist. In an engaging, eclectic but sometimes rambling journey around this complex topic,

he takes a 'cradle to grave' approach — from the stellar origins of these elements at the dawn of the Universe to their eventual fate in toxic landfills and backyard recycling sites in Africa and Asia.

Until the mid-twentieth century, only about 15 metallic elements in the periodic table had any practical use. Since then, humankind has broadened the palette of useful metals enormously, to take in 'critical', 'exotic' or 'technology' materials, including rare-earth elements, platinum-group elements, and others from antimony to zirconium. Handheld digital devices, and their almost magical appeal to billions of consumers, are driving this expansion: a smartphone can contain up to 60 elements. Other drivers include growth in



Rare: The High-Stakes Race to Satisfy Our Need for the Scarcest Metals on Earth
KEITH VERONESE
Prometheus: 2015.

renewable-energy generation (wind turbines and solar photovoltaics) and low-carbon transport (electric and hybrid cars). As *Rare* makes plain, the nuclear and defence industries also have particular requirements for exotic and scarce raw materials such as beryllium and polonium, used to initiate reactions in nuclear fuel rods.

More sinister uses of rare metals are covered in a chapter ominously entitled 'Pale Horses' (named after a 1961 Agatha Christie novel featuring thallium poisoning). The physiological effects of some metal poisons are described in gruesomely compulsive detail. Thallium sulphate, for instance — used by the infamous 'Aunt Thally', Caroline Grills, to murder four relatives in 1940s and 1950s Australia — generally triggers kidney failure. Radioactive polonium, which fatally damages the lymphatic and immune systems, was allegedly used to kill Russian dissident Alexander Litvinenko in London in 2006.

Veronese's background as a chemist comes to the fore in his fascinating description of a tortuous process — the separation and identification of many rare-earth elements by Scandinavian scientists in the eighteenth and nineteenth centuries. A peculiar consequence of this Nordic endeavour is that the small village of Ytterby in Sweden gives its name to four elements: ytterbium, yttrium, terbium and erbium. Veronese is also authoritative when describing the link between elements' fundamental chemistry and their functional use. For example, he clearly sets out the elegant subatomic relationships behind the much-sought-after magnetic properties of rare-earth metals such as neodymium. Alloyed with iron and boron, this element forms permanent magnets with very high field strengths, key to the manufacture of hard disks and wind turbines.

However, Veronese is less comfortable in unpicking the complicated mineralogy of these elements, and how they become concentrated as ore deposits. His rather jumbled explanation may leave many readers confused about the geology of rare metals. Another weakness is an incorrect use of terminology: the term 'rare-earth metals' applies not to the metals tantalum, beryllium, rhodium or niobium, but to the 15 elements from lanthanum to lutetium (atomic numbers 57 to 71), plus scandium and yttrium.

Although sporadically distributed in *Rare*, Veronese's analyses of the various factors affecting supply of these metals adds up to a good overview. He recognizes the market's role in dictating how and where they are produced, and how geopolitics can potentially interfere with supply, particularly when it is concentrated in one country (in 2012, for example, 68% of global cobalt production came from the Democratic Republic of the Congo). He describes how China's current domination of rare-earth-element production

is mainly down to its large-scale, low-cost producers undercutting smaller operations elsewhere. Perceptively, he recognizes the significant amounts of time, money, technological know-how and risk-taking required to find an economically viable geological deposit and set up a mine and extraction plant. He also notes the technical, environmental and economic limitations of obtaining the metals through recycling.

“Until the mid-twentieth century, only about 15 metallic elements in the periodic table had any practical use.”

Real and perceived threats to supply security of these metals have led to speculation and hype about resources in more exotic locations. Veronese explores new frontiers for mining, from Antarctica to the deep ocean and even the asteroid belt. This entertaining discussion is realistic about the prospects and the huge financial, technical and environmental risks associated with attempts to recover rare metals from wilder shores. However, although many of these elements are relatively rare and geologically often unevenly distributed, it is unlikely that we will run out of any of them in the near future. As Veronese points out, it is more likely that geopolitics will trigger short-term supply disruption.

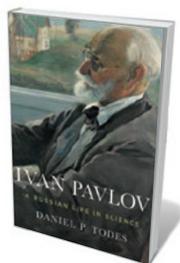


Coltan contains metals key to digital devices.

Although prone to digression and hyperbole, *Rare* makes powerful points about the consequences of conspicuous consumption. The influence of the ‘haves’ over the ‘have-nots’, the willingness of rich countries to export their environmental obligations to poor ones, and the fragility of global supply chains in a resource-constrained world are uncomfortable truths. Yet they must be told. ■

Andrew Bloodworth is science director for minerals and waste at the British Geological Survey in Nottingham, UK.
e-mail: ajbl@bgs.ac.uk

Books in brief



Ivan Pavlov: A Russian Life in Science

Daniel P. Todes OXFORD UNIVERSITY PRESS (2014)

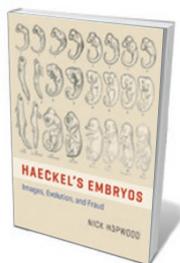
Profoundly researched, densely detailed and likely to be definitive, Daniel Todes’ biography of physiologist Ivan Pavlov was 20 years in the making. The tome is a corrective, not least to the idea that Pavlov was a behaviourist: this obdurate Russian survivor of war, revolutions and Stalinization was in fact focused on “consciousness and its torments”. His immense labours in his factory-like lab produced a mixed legacy. Conditional-reflex methodology, for instance, is a staple of addiction studies, yet Pavlov’s scrutiny of canine saliva for a solution to the ‘hard problem’ of neuroscience came to nothing.



Trees, Woods and Forests: A Social and Cultural History

Charles Watkins REAKTION (2015)

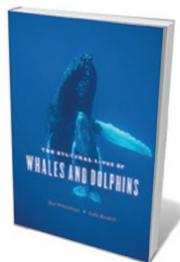
Charcoal, warships, fruit, houses, shade and sheer beauty — the manifold uses of trees have bound them inextricably to human culture. Geographer Charles Watkins’ interdisciplinary exploration of that long, convoluted relationship is a fact-packed dazzler. With Watkins we walk a Neolithic ‘road’ of ash planks, delight in Pliny’s description of German forests as “untouched by the ages and coeval with the world”, celebrate the rise of scientific forestry and ponder the diseases and creeping urbanization now threatening the future of these stupendous organisms. Sumptuously illustrated.



Haeckel's Embryos: Images, Evolution, and Fraud

Nick Hopwood UNIVERSITY OF CHICAGO PRESS (2015)

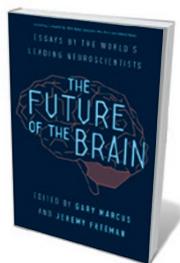
Rarely have images proved so incendiary as the embryo drawings of nineteenth-century experimental zoologist Ernst Haeckel. In this lavishly illustrated volume, Nick Hopwood traces the chequered history of the sketches, which showed similarities between embryos of higher and lower vertebrates, including humans, at particular points in their development. Haeckel intended the images as support for Charles Darwin’s evolutionary theory, but under attack revealed that they were schematics. Hopwood meticulously charts how, despite the controversy, the drawings took on a life of their own.



The Cultural Lives of Whales and Dolphins

Hal Whitehead and Luke Rendell UNIVERSITY OF CHICAGO PRESS (2014)

This research round-up on cetacean culture opens with a description of one of nature’s great arias: the “high sweeping squeals, low swoops, barking, and ratchets” of the humpback whale. That song, argue cetacean biologists Hal Whitehead and Luke Rendell, is the best evidence of culture in this intriguing family, because it is an indicator of social learning in action — communal singing evolves over time and changes radically over individuals’ lifetimes. Fascinating findings litter this sober treatise, from sperm whales snacking off fishing longlines to the “Star Wars vocalisation” of dwarf minke.



The Future of the Brain: Essays by the World's Leading Neuroscientists

Edited by Gary Marcus and Jeremy Freeman PRINCETON UNIVERSITY PRESS (2014)

How to unify data from initiatives such as US President Barack Obama’s BRAIN? In this essay compilation, editors Gary Marcus and Jeremy Freeman argue that a “confluence of new technologies” will kick-start astonishing advances in mapping, computation and simulation related to the brain. Geneticist George Church’s “Rosetta Brain” sample, for instance, assembled by methods such as ‘barcoding’ cells, could prove key in brain comparison. **Barbara Kiser**