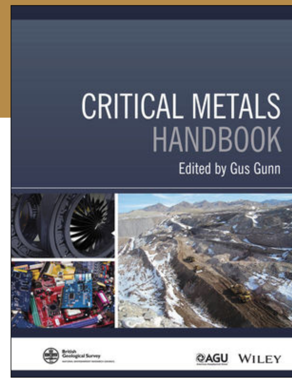
CRITICAL METALS HANDBOOK*



Recent years have seen growing concern for the potential imbalance between the supply and demand of metals that are vital to the production of high-tech materials, components and devices. These products are generally taken for granted by lay people in our technological society, with little regard for the origins of the raw materials used to make them or the potential issues that could arise were their supply to be disrupted. Many of the rare metals that are critical to these applications are derived only as by-products of base metal production. Changes in the way that base metals are produced, both now and in the future, can and will have a profound effect on the availability of those by-products.

A significant number of these so-called 'critical' materials are the topic of the *Critical Metals Handbook*, published by the American Geophysical Union and Wiley, in collaboration with the British Geological Survey, and edited by Gus Gunn. The book includes introductory chapters on what 'criticality' actually means, how metals are derived from their host minerals, and how such metals can be recycled at the end of the useful lives of the components and alloys in which they are used. These chapters are particularly strong and review recent thinking and findings on the topic. As noted in the opening chapter, the criticality of any given metal or material is not a binary proposition but is instead a matter of degree. What factors might increase or decrease the criticality of a given metal? Is criticality a universal characteristic of the individual metals considered, or is the definition somewhat more arbitrary? A good discussion on just how the mining industry and its ongoing development affect critical metals is also included, as well as a pragmatic review of the state of the recycling industry for critical metals. Political as well as technical and logistical considerations are featured.

The remainder of the book consists of chapters focused on specific metals and groups of metals, some of which have become the 'poster children' for the issue of metals criticality (such as the rare earth elements) while others appear that are not often thought of as being critical (such as magnesium and tungsten). Each chapter adopts a similar format, reviewing the properties of the subject metal or metals, their occurrence in the Earth's crust, the associated mineralogy, the deposit types and the methods of extraction. Each chapter also tackles issues of recycling and substitution, the latter being of increasing interest particularly in the face of significant price volatility for some of these metals. The various authors also tackle the more difficult topics of pricing of these metals and the outlook for their respective markets.

The metals covered in the book include antimony, beryllium, cobalt, gallium, germanium, indium, lithium, magnesium, the platinum-group metals (PGMs), the rare earth elements (REEs), rhenium, tantalum, niobium and tungsten. The narrative in each chapter is generally well supported with appropriate figures, tables and useful data. Any analysis of these rare metals is hampered by a dearth of good-quality data, and the book usefully collates such information into a single reference.

I had some minor issues with the introductory comments in a couple of the chapters, but nothing that detracts from the value of the subsequent content. Most chapters have a good range of references from which the data are drawn; a concern in recent years is the over-reliance on data from 'official' sources, such as the U.S. Geological Survey, which are not always as up to date or as detailed as they might once have been.

There is an understandable tendency to group the REEs and PGMs together when talking about the criticality of materials, since they are often found together and mined and processed together. I would have liked to see more detail on the characteristics and end uses of the individual metals within these groups, since they are not monolithic. I would also have liked to see chapters on tellurium and natural graphite, both of which have a part to play in the growing needs of the renewable- and sustainable-energy sectors.

These are, however, but minor quibbles. The *Critical Metals Handbook* is an excellent reference on some of the most critical metals on which our society is dependent and will be of value to the layperson and the technical specialist alike.

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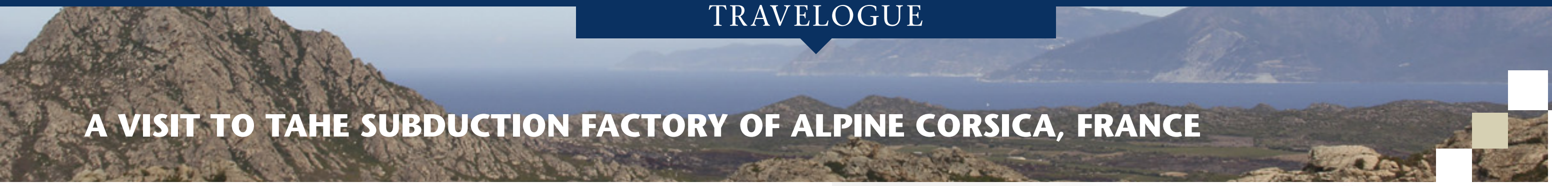

A VISIT TO TAHE SUBDUCTION FACTORY OF ALPINE CORSICA, FRANCE

Corsica, the native land of Napoleon, is a French island separating the Tyrrhenian Sea from the Gulf of Lyon in the western Mediterranean. Corsica has had a long and complex history, as ownership has been disputed several times by France and the Republic of Genova – now Italy – and the island has even been independent for a short while (1755–1769). The result is a mixing of different cultures – the "Corsican" language is actually quite similar to Italian – and a distinct identity.

The Roman San Michele church in Murato built by the Pisans in the 12th century exhibit remarkable naive motifs. Image courtesy of Doug Rumble, Carnegie Institution

The Nonza serpentinite beach (bottom right) and the Canari asbestos mine beyond. The beach is recent and is composed of mining debris thrown into the sea and returned naturally to the coast during the 20th century. The mine was exploited for asbestos between 1948 and 1965.

The Santa Reparata chapel (Morosaglia, Alpine Corsica), initially built by the Pisans in the 11th century, is composed of various schists from Alpine Corsica. The granites of Hercynian Corsica are in the background.

Corsica is home to natural wonders in its mountains and along its coast, and it also boasts fantastic geology. The geological map of Corsica depicts two main ensembles: to the west and south is Hercynian Corsica, composed mainly of Precambrian to Permian continental basement, and to the northeast is Alpine Corsica, which is equivalent to the Tethyan western Alps and Apennines.

Alpine Corsica is one of the world's best-preserved and best-exposed examples of subduction geology. Closely associated ophiolites and continental basement rocks are exposed in a relatively narrow and accessible mountain belt, and they span the complete range of metamorphic conditions of shallow to deep subduction. For centuries, the belt has been a source of a variety of natural resources. For instance, serpentinites are widespread in Alpine Corsica and have been exploited for various applications from very ancient times. The spectacular setting and still huge environmental impact of the Canari mine in Cape Corsica remind us that it was among the biggest asbestos producers in Europe in the mid-20th century (more than 30,000 tonnes in 1961). Waste material from the mine was dumped into the sea, and then it returned to the coast where it produced the dark and immense serpentinite beach at Nonza. In the mountains of Cape Corsica and in the Castagniccia region ("chestnut region"), one can find the remains of small mines formerly exploited mainly for iron and copper. Some of them go back to very ancient times as mining in neighbouring Elba Island started with the Romans. Mining is now over, but it was often brutally ceased with little consideration for environmental impacts.

The wide lithological variability of Alpine Corsica has inspired a multitude of different architectural styles over time. The San Michele church in Murato (12th century) is a wonderful example of Pisano Romanic style, with alternating greenstone and marble derived from the surrounding ophiolites. The cathedral of Nebbio (Romanic, 12th and 13th centuries) is entirely made of calcarenite from the nearby Miocene Saint Florent basin. Throughout Cape Corsica and the Castagniccia region, churches and bell towers dominate the traditional villages, which are built of local marble, calcschist, serpentinite and eclogite.

Alpine Corsica is home to fantastic subduction petrology and mineralogy. The geological "beauties" of Alpine Corsica make this a unique high-pressure mountain belt. A drive through the metamorphic terrane of Alpine Corsica provides a natural cross-section through the blueschist–eclogite transition of a subducting slab. The high-pressure mineral assemblages typical of subduction zone metamorphism are extremely well preserved. These include carpholite, aragonite, glaucophane, omphacite and lawsonite. Although these minerals are also characteristic of the metamorphic history of other well-known mountain belts, such as the western Alps and the Cyclades, their preservation during exhumation is indeed quite rare owing to severe overprinting during decompression. Delicate minerals such as lawsonite, carpholite and aragonite are widely preserved in the blueschist and eclogite facies rocks of Corsica, where only weak overprinting occurred during exhumation to the surface.

Cont'd on page 476