



Breakthrough technologies and innovations along the mineral raw materials supply chain — towards a sustainable and secure supply

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Friedrich-Wilhelm (Fred) Wellmer, 80 years June 2020

Without any doubt, our societies live at a turning point in history. The future of geopolitical and geo-economic relations is changing. These developments are catalyzed by (i) sweeping new climate political concepts and legislations around the globe, (ii) a growing demand for fossil-free energy technologies, (iii) an increasing share in demand by emerging economies for infrastructure and goods together with rising political tension between autocratic and democratic worlds, and (iv) the questioning of international conventions on peace, trade, and investment. The financial crisis of 2008/2009, followed by the EU debt crisis and the USA-China trade war, or lately the blockage of the Suez Canal and the COVID-19 pandemic have demonstrated how interconnected and vulnerable societies and supply chains have become. The current Russian war against Ukraine has destabilized the trust in well-functioning trade flows between strategically important economies. Altogether, the taken path towards a more sustainable society and way of living is at risk to slow down as global conflicts remain unsolved.

This special issue of *Mineral Economics* comes at a time, when global transition proceeds in rapid steps and new conflicts arise on the horizon. Current challenges such as poverty reduction, the energy transition, new mobility concepts, and digitalization cannot be managed without reliable, predictable, and sustainable access to mineral raw materials and smooth supply chains. Mineral raw materials are indispensable to our daily lives. They are a cornerstone for industrial supply chains and strategic to the functioning and integrity of a wide range of industrial and social ecosystems.

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All industrialized, emerging, and developing countries have one thing in common: They are import dependent on at least some mineral raw materials, either primary ores and concentrates, intermediate, or semi-finished products. Many of these minerals and intermediates are potentially critical, because global supply and trade are highly concentrated in certain, partly geologically favorable, regions or in a few suppliers. Under these circumstances, increasing demand in the mineral raw materials sector and widening geopolitical and geo-economic tension may lead to new international trade conflicts.

Recurring problems in raw material supply chains over the past decade — including environmental mismanagement and human rights abuses — have resulted in government action around the world. The EU commission for example has initiated mitigation strategies through the EU Raw Materials Initiative and its Critical Raw Materials Action Plan, including massive investment in R&D and project funding. The governments of Germany, the USA, Japan, South Korea, and the PR China, to name a few, have initiated new political initiatives and governmental strategies to minimize the risks and tensions in the raw material markets. They provide various financial instruments to the industry and invest heavily in R&D.

In many ways, R&D could be key to developing mitigation strategies along supply chains. This is the approach to this special issue. R&D needs to cover the whole value chain, from exploration, mining, processing, metallurgy, recycling to circular economy, environmental advances, substitution, and risk analysis of demand, supply, and trade patterns. In the next decades, a wide range of critical raw materials will be in high demand. Wind and solar photovoltaic power generation is predicted to have the largest growth rates among renewable energy systems, including new and decentralized stationary energy storage systems such as vanadium redox flow and lithium-ion battery systems. The required expansion of the electric power infrastructure will demand more iron, copper, aluminum, zinc, steel, ferroalloy metals, and other construction materials and platinum group elements for the production of hydrogen. Besides that, renewable energy technologies will significantly increase the demand for rare earth elements such as neodymium, dysprosium, praseodymium, and terbium. These elements are an integral part of permanent magnets of wind turbines and generators for e-mobility. Lithium, cobalt, nickel, and graphite are contained in batteries in electric vehicles, and silicon, indium, gallium, tellurium, and other base and minor metals are part of solar photovoltaic cells and electronic components. Forecasts about the growth in demand for critical raw materials often fail to address the need for a fundamental rethink about consumption models. Large amount of research, in the past

and in future, has been and will be directed to optimize a circular economy, including design for circularity and raising recovery rates especially from electronic waste.

This special issue contains review-like articles, technical papers, and brief comments or reports about current game changing innovations along the entire supply chain. The aim is to provide a holistic overview and vision about the future of the raw materials sector, and the articles give examples from a much more complex research environment. The special issue should not only be of particular interest to the scientific community but also to politicians and practitioners in the industry from mining and smelting companies to the manufacturing industry using mineral raw materials. For these two groups, it is particularly important to get an overview of current trends in the raw material sector and information about future demand and supply based on latest research and innovations.

The first articles of this special issue cover geologic-metallogenic models of ore forming processes and deposit types as well as new exploration technologies to detect these mineral deposits. There are for example rapid developments in high resolution hyperspectral satellite imagery to explore ore deposits from space, or new geophysical methods such as SQUID, which will direct us to new ore bodies at below 500 to 1000 m depth. The huge resource potential in planet earth, yet to detected, leaves no doubt that societies will not run out of mineral raw materials in the future. Access to these resources may however be a strong limiting factor whether because of political, environmental reasons or from competing land usage. New autonomous mining technologies, remote control, and new processing technologies ranging from high velocity impact crushing to new metallurgical approaches will increase future supply and supply efficiency. At the same time, the rising environmental and social problems caused by increased production will have to be closely monitored and effectively mitigated. These challenges will necessitate a fresh approach to bring the performance improvement of the industry to align with present social values. Sustainable supply can also be achieved through well-managed extraction and recycling. It is obvious that a better understanding of growth in demand and supply will be necessary to possibly avoid excessive market and price imbalances. New big data and artificial intelligence systems could be used to track supply disruptions and market volatility much faster than what was possible only a few years back.

With this special issue, we also want to honour Professor Friedrich-Wilhelm (Fred) Wellmer who celebrated his 80th birthday in June 2020. He was the head of exploration at Metallgesellschaft of Australia (Pty) Ltd. and later president of the Federal Institute of Geosciences and Natural

Resources (BGR, the German Geological Survey) and Professor of Mineral Economics and Raw Material Politics at the Technische Universität Berlin in Germany — among many other positions. Fred is an economic geologist with heart and soul and has an in-depth knowledge and generalist thinking about the functioning of raw material markets. Fred still meticulously follows recent developments in mineral economics and we hope to bring him joy when reading this special issue. In particular as he was a member of the Editorial Advisory Board of the journal between 1995 and 2008. Former directors of leading geological surveys and life-long

friends have written personal notes to Fred, which may also be of interest to young geoscientists and students of mineral economics and policy. His own contribution “What we have learned from the past and how we should look forward” covers his life time experience and is a milestone towards a better understanding of mineral economics.

We hope all readers will enjoy this Mineral Economics special issue in all its depth and width.

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