Synergy between computational and empirical methods in the mining and metallurgy

The importance of the mining and metallurgical disciplines to the collective future of humanity cannot be overemphasized. These fields are the fulcrum for engineering, information technology, and biotechnology. The efficacious interplay between these areas will drive a green future, a circular economy, and technologies of the future. This future must enable innovation for prosperity and reduction of carbon footprints for human survival.

The mining, geology, and metallurgical industries have undergone four major paradigm shifts. The first shift is based on empiricism sparking the curiosity of humans through a hands-on approach; experiments are carried out to allow interaction with the environment in ways that link theory to practice. The second focused on model-based theoretical science, where the laws of thermodynamics became apparent in the 1950s. The third paradigm shift is deeply embedded in computational modelling and simulations. This is underpinned by design and systems, thinking which was popularized in the early 2000s. In this era of overwhelming complexities, tremendous competition, and accelerated change, the fourth paradigm shift is mainly concerned with Big Data. This involves the application of statistical and probability theory for predictive analytics, relationship mining, and materials informatics. The characteristics of Big Data revolved around the 'six Vs': volume, value, variety, velocity, veracity, and variability. The mining and metallurgical industries will in the future thrive on the synergies between artificial intelligence and empirical research.

Geological materials are heterogenous. The concept of geometallurgy is critical for the optimization of mining and exploration operations. Advanced computation and simulation are tools for predicting operational scenarios and performance. These approaches are essential to metallurgical and mineral recovery in addressing circularity for a green economy and innovation for all. Computational approaches provide the opportunities to test a great many assumptions and then finally optimize the parameters required to execute a few experiments in a cost-effective and timeous manner. Irrespective of advanced techniques and high throughput, simulation and computation methods are available and more are being constantly developed. Experimentation is the final arbiter where theory aligns with practice.

In this edition of the *Journal*, the main themes of the papers focused on empiricism and Big Data-driven approaches for mineral resource optimization. These multidisciplinary and transdisciplinary approaches are expected to contribute to and deepen our understanding of current research hotspots in mining and metallurgy.

In summary, rational approaches to exploratory, basic, and applied research are essential in this knowledge economy. Hence, computation and experimentation, with their complementary approaches, are the right tools for a resource-constrained world and the future. This is essential for the metallurgy and mining industries. We hope readers will glean insights from these papers in ways that contribute to further intellectual discourse.

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