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NEWS AND NOTES

Geological Insights for Sustainable Mineral Exploration Program: A Metallogenetic Approach

Janmejaya Sahoo
Geological Survey of India, State Unit: Telangana, Southern Region, Hyderabad - 500 068, India
E-mail: *jsjanmejaya@gmail.com*

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Minerals are the key raw materials for several industries and play a significant role in the economic status of a country. With the development of science and technology, the dependability of modern civilization on mineral resources has been increasing exponentially. However, minerals are non-renewable natural resources and are being exhausted through overutilization. Hence, the emerging challenges to meet the demand for mineral resources and their management reorient the exploration techniques to explore new mineral resources and the sustainable development of both existing and newly discovered mineral resources. Metallogenesis refers to the geological processes and conditions that lead to the genesis of metallic mineral deposits in the earth's crust. It involves a complex interaction between the geosphere, biosphere, atmosphere and hydrosphere to concentrate valuable metals like Platinum, Gold, Silver, Copper, Iron and many more. The science of metallogeny of ore minerals has been evolving with innovations in state-of-the-art instrumentation facilities to generate high-precision geological, geophysical, geochemical, aero-geophysical and remote sensing data, etc. Interpretations of these huge datasets using Artificial Intelligence (AI)-driven algorithms for predictive modelling, target identification, mineral characterization, data analysis and integration, etc. help to build an effective metallogenetic model for a desired economically viable mineral deposit within a short time span. Sustainable mineral development, on the other hand, emphasises ethical and sensible methods of mineral extraction and their use. It strives to ensure that mineral resource development satisfies current generational demands without compromising the needs of upcoming generations. In order to achieve a harmonious balance, sustainable mineral development takes into account of economic, social, and environmental factors.

Each mineral deposit has formed at a particular geological time (metallogenic epochs) and in a specific geological space (metallogenic provenances). For example, iron ore usually occurs in the Archaean basins (old age basins). Hence, searching for iron ore in the Gondwana basin (a relatively young basin) will not yield fruitful results. Similarly, chromite originates from magma at a higher temperature, greater depth and is associated with ultramafic rock. Searching for chromite in any felsic volcanic terrain is often futile. Apart from that, the degree and intensity of the alteration pattern of a hydrothermal mineral deposit also act as a guiding tool to understand the spatial distribution of the ore bodies. Pathfinder elements and float ores are also extremely important indicators leading to the discovery of new mineral prospects. Thus, thorough knowledge and proper understanding of the metallogenesis of each mineral commodity is crucial prior to their exploration. Again, preliminary knowledge on the formation of landmasses and the geological activities responsible for the present earth forms is essential. The apparent geographic scenario of the landmass on the earth was much different from a few million years ago. According to continental drift theory, there was a single landmass called Pangaea floating over a large ocean called Panthalassa. Later on, it was broken into Gondwana land and Laurasia. With the passage of time, the breakdown and drifting of the continents continued to form the present spatial distribution of the continental landmass. According to Plate tectonics theory, the earth's outer shell is divided into a number of solid rock slabs, called plates (which comprise the crust and upper part of the upper mantle) that move on top of the molten material (upper mantle) called the asthenosphere. Interactions between these plates result in different geological formations, such as the Himalayan mountain ranges in Asia, the East African Rift and the San Andreas Fault in California, the United States, etc. The movement or gliding of these plates also produces weak zones, which serve as conduits for ore-bearing fluids to migrate upward and form giant mineral deposits. Since the plates move from one part of the globe to the other, the possibilities of simultaneous occurrences of mineral deposits on any two continents or countries with similar geological setups cannot be ignored. Thus, we can expect similar types of mineral deposits in similar geological environments and ages.

Research on the metallogeny of newly discovered mineral deposits involves a thorough understanding of the mineral system of the deposits. These include proper knowledge of the geological processes that are responsible for ore formation as well as their preservation. Economically developed countries with advanced science and technology have better opportunities to understand the mineral system and explore more mineral deposits by utilizing their scientific, technological knowledge and experiences. The know-how includes a thorough understanding of the genesis, mode of occurrence of ore and host rocks; associated minerals with the ore deposit; mining; mineral beneficiation through the extraction; of by-products and/or co-products; management of overburden; restoration of biodiversity and so on. So it is always important to understand the metallogeny of any mineral deposit at the very beginning by generating adequate datasets. This not only helps to vector new deposits in the nearby area but also helps in global correlations with well-established mineral deposits. The acceleration of research leads to the accumulation of huge datasets with respect to individual deposits. The availability of plenty of datasets can be used for data mining prior to conventional mining to prepare a geodynamic model of any new deposit. This will create a platform to exchange scientific and technological know-how between any two deposits around the globe to articulate sustainable development of existing as well as newly discovered mineral deposits.