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PREFACE

75 years of Mineral Exploration and Future Challenges in India

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Azadi ka Amrit Mahotsav is an initiative of Government of India to celebrate 75 years of India's independence and the glorious history of her culture and achievement. Inspired by the theme, *Atomic Minerals Directorate for Exploration and Research (AMD)* has taken up various programmes during the period as per directions from the Department of Atomic Energy (DAE). The National Seminar on "**75 years of Mineral Exploration and Future Challenges in India – MEFCI–2022**" organized in association with the Geological Society of India is one such programme. The exploration efforts of AMD, having a glorious history starting in the pre-independence era, have helped India to attain self-sufficiency in atomic minerals, particularly in the last 75 years. The joint efforts of AMD and the Geological Society of India resulted in this well attended national seminar. The Geological Society of India, since the past 64 years, has been tirelessly engaged in dissemination of geoscientific and mineral exploration research through critically reviewed journal publications.

The Atomic Minerals Directorate for Exploration and Research (AMD), the oldest unit of the Department of Atomic Energy (DAE) in India, was created on 29th July, 1949 by the visionary nuclear scientist Dr. Homi J. Bhabha for exploring and establishing resources of strategic minerals of interest to the nuclear energy programme of India. AMD originated as the erstwhile Rare Minerals Survey Unit (RMSU) created during the Second World War (1939-1945) under the Geological Survey of India (GSI) for augmenting beryl resources from the mica mines. RMSU was renamed as 'Raw Materials Division' and then as 'Atomic Minerals Division' in 1958. Later in 1998, during its Golden Jubilee Year, the then 'Atomic Minerals Division' was rechristened as 'Atomic Minerals Directorate for Exploration and Research (AMD)'. AMD has matured into a geoscientific organization of excellence comprising nearly 2,400 personnel, with the primary mandate of establishing the resources of uranium, thorium, niobium, tantalum, zirconium, beryllium, lithium and REE in tandem with a strong research base.

The exploration efforts over the years by AMD utilizing an integrated, multi-disciplinary exploration strategy have yielded rich dividends in the form of atomic minerals resources including ~3,76,000 tonnes (t) uranium oxide, ~1,200 million tonnes (mt) BSM and ~7mt REE. The unique statabound uranium deposit in Tummalapalle, Andhra Pradesh with nearly 2,00,000t uranium oxide is one of its kind in the world and has attained a special status as 'Carbonate hosted deposit – Tummalapalle type' in the classification scheme of Uranium deposits by IAEA in 2015. AMD has a pan India presence with Regional Centers/Sectional Offices spread across the country with highly professional manpower and state-of-the-art laboratories supporting the exploration programme. The motto of AMD – 'Those who search – Find' aptly sums up its dedicated commitment to the nation i.e. achieving '*Atmanirbharta*' in atomic mineral-resources for the three-stage nuclear power programme of India.

It is heartening to note that the two-day seminar, MEFCI-2022, organized in Dr. Homi J. Bhabha auditorium, AMD Complex, Hyderabad during 5-6 April, 2022 has attracted wider participation from the academia and mineral industry in the country, with nearly 150 delegates including student-faculty participation. The entire proceedings of the seminar were webcast in the virtual platform (*JGSI*, June 2022, pp.859-862). In addition, a large number of participants including nonagenarian Shri T.M. Mahadevan, former Director, AMD (1985 to 1987) joined the proceedings through virtual mode.

The theme based National seminar comprised six (06) sessions, were chaired by eminent personalities from AMD, BARC, GSI, IBM and IIT-Roorkee. Each session had oral and poster presentations. A total of 75 presentations, corresponding to AMD's celebration of 75 years of India's independence, included six (06) keynotes and 69 research articles. The six (06) themes were related to various aspects of mineral exploration. One of the significant highlights of the seminar was the interactive poster session, which was conducted in both virtual and physical modes. The seminar provided an opportunity for documenting the history of mineral exploration in India especially for atomic minerals.

Considering the significance of the proceedings of the sessions and their relevance to the historical aspects and future outlook of mineral exploration in the country, the Geological Society of India resolved to publish a special issue on the 75th anniversary of India's independence comprising 21 selected peer reviewed scientific articles resulting from the proceedings of the seminar.

The first contribution in this issue is authored by *D.K. Sinha* describing the evolution of exploration strategy for atomic minerals

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in the country entitled *Reappraisal of 75 years of exploration for atomic minerals in India and the way forward*. The article highlights the significant landmarks achieved by AMD since independence for *Atmanirbharta* in atomic minerals. The paper concludes about the way forward for augmentation of atomic minerals in India.

Akhila et al. have reported the occurrence of allanite in Singhbhum Shear Zone (SSZ) and its implications on the genesis of REE mineralization. The micro-structural, textural and compositional characteristics of multiple generations of allanite and the nature of hydrothermal fluids responsible for the allanite mineralisation have been described in detail.

Sinha et al. report event of thorium metallogeny for the first time in U-Cu-REE bearing Singhbhum Shear Zone in Eastern India in the form of thorite bearing zones intercepted in course of sub-surface exploration for uranium. Multiple modes of occurrences of thorite, presence of secondary thorium phases and associated mineralogy suggest the mobility of thorium under a hydrothermal regime. The hitherto unknown thorium related hydrothermal mineralisation in SSZ is the highlight of exploration activities carried out during the last five years in SSZ.

Goyal et al. have identified additional signatures of a complex metallogenic history in Umra, Udaipur district, Rajasthan wherein multiple generations of uranium mineralization, deformation, metamorphism and hydrothermal alteration are well known. Compositional characteristics and mode of occurrence of uraninite deduced from EPMA analysis suggest dominantly epigenetic hydrothermal mineralization events coeval with deformations in the Aravalli Supergroup.

Mishra et al. present mineralogical studies of metasomatized host rocks of Jahaz uranium prospect in NDFB, Rajasthan. Based on detailed petrographic and electron microprobe studies of borehole samples, the authors have accounted for the metamorphic mineral assemblage, fluid induced alteration products and its deformational attributes.

Saxena et al. discuss the genetic aspects of magmatic albitite related hydrothermal uranium mineralisation in Geratiyon-ki-Dhani, Sikar district, Rajasthan. The authors have concluded that magmatic albitite provided single flux mineralising fluids for precipitation of davidite/brannerite in albitite/albitised metasediments and progressive cooling of high temperature-high saline aqueous-$NaCl \pm MgCl_2$ fluids is the controlling factor for uranium mineralization. This is the first report of hydrothermal type uranium mineralisation related to magmatic albitite resulted from the exploration activities over last five years in North Delhi Fold Belt (NDFB).

Pandey et al. have reported the age of uranium mineralisation from NDFB in Rajasthan based on U-Pb, Pb-Pb and Sm-Nd systematics. Multi-method geochronological study has established the age of uranium mineralization as 830Ma. Isotopic data suggests that the source of uranium is from older crustal rocks viz. Paleoproterozoic Delhi/Aravalli Supergroup (c. 2200 Ma) or Basement Granite Gneisses (BGC).

Saxena et al. have made a comparison of metasomatic and pegmatite type of uranium mineralization in and around Rohil uranium deposit at Sikar district, Rajasthan, based on field relations, petrography and mineral chemistry. The paper reports a new type of uranium mineralization, interpreted as of pegmatitic origin established in Rohil West, at ~500m west of main Rohil uranium deposit.

Somani et al. presented a 3D representation of geo-exploration data pertaining to Brahmagiri Mineral Sand Deposit, Odisha, in which the prime depositional environments of heavy minerals are represented by using GIS applications. The study focusses on the Brahmagiri deposit, which is a part of barrier bar system having different sub-depositional environments, which has controlled the heavy mineral concentration at various depths.

The paper contributed by *Satyanarayana*, provides an insight into the past and present status of exploration and mining of diamonds in India. The paper gives an account of the primary (kimberlites & lamproites of Mesoproterozoic age) and secondary (Neoproterozoic diamondiferous placer conglomerate & gravel) sources for diamond and prospect areas in the cratons of Peninsular India. The author recommends for implementation of New Mineral Policy which favours participation of MNCs, make in India efforts and resolving the socio-political and environmental issues to boost diamond exploration in India.

Reshma et al. describe the first report of Rare Earth mineralization in regolith zones of the Neoarchean phoscorite plugs from the carbonatite-syenite complex in Dombarahalli area, Koppal district, Eastern Dharwar Craton, Karnataka.

Yugandhara Rao et al. present a case study on the implications of magnetic properties in the concentration and distribution of REEs in beach placer monazites from Chhatrapur Coast, Odisha. The study reports EPMA based variation in composition (REE, Th & U) of representative monazites separated, based on their variable paramagnetic properties. The paper concludes that the physical method of separation of monazite using magnetic properties may facilitate segregating the monazites of a particular chemical composition with respect to their constituent elements like U, Th and rare earths.

Srinivasa Rao et al. present a case study on application of microgravity survey in the exploration of rare-metal bearing pegmatites from Marlagalla area in Mandya district, Karnataka. The authors have established a technique for determining the subsurface geometry of the pegmatites intruding the amphibolites in Nagamangala schist belt by 2D-forward modelling of microgravity data, which helped in planning of subsurface exploration for pegmatite hosted lithium mineralisation in the area. The experiment carried out has proved as an effective exploration tool.

Rawat et al. have reported stratabound, organic matter associated uranium mineralisation in Kaimur Group of Vindhyan Supergroup at Maharampura, Gwalior district, Madhya Pradesh. Integrated field and petromineralogical studies have revealed a significant uranium mineralisation hosted by sub-feldspathic arenite with shale inter-calations containing organic matter. The finding reported in the paper has opened a large exploration target in the Vindhyan Basin, hitherto unexplored.

Pandey and Kumar present a review article on the challenges, understanding and strategies involved in six decades of uranium exploration in the Proterozoic and Phanerozoic Formations of Himalaya. The authors conclude that the understanding of tectonic evolution and regional correlation have helped in

identifying some common controls and potential locales for uranium metallogeny in the Himalaya and are considered as a guide for further exploration.

Experimental outcome on development and scale-up of chemical process for conversion of impure sodium di-uranate to uranium peroxide is presented in the article by *Anand Rao et al.* The paper discusses the process scheme developed for converting sodium di-uranate assaying 74% U_3O_8 into highly pure heat-treated uranium peroxide assaying ~91% demonstrated at large scale (about 100 kg/ batch).

The details of hydrometallurgical studies for recovery of REE from micro-granite hosted REE deposit at Bhatikhera in Siwana Ring Complex, Rajasthan is documented by *Ram Karan et al.* An integrated process scheme for the TREE recovery from the micro granites of Bhatikhera deposit has been described based on the study.

Mahanta et al. have reported mineralogical study based on SEM-EDS imaging, XRD, and Raman spectroscopy of lean grade iron ore fines during slow and rapid reduction roasting. The paper concludes that low intensity magnetic separation technique (LIMS) improves the grade of the roasted sample and suitable heat and mass transfer in the fluidized bed gives better reduction kinetics than in the fixed bed.

Krishnamurthy gives a historical overview of conceptual approaches in mineral exploration with special reference to uranium exploration in India. The paper emphasizes on understanding the basic geological features, earth processes and crustal evolution and its bearing on mineral exploration. The author advocates adopting advanced computing-based integration of multi-domain data on mineral deposit for developing identified greenfield exploration domains for uranium mineralisation.

The legislative reforms and challenges in the field of mineral exploration in India are documented in the article by *P.K. Jain*. The paper focusses on several legislative reforms introduced by the Government of India in the allocation of mineral concessions, through Mines and Minerals Development and Regulation (MMDR) Amendment Act, 2015 to promote sustainable growth of exploration for minerals in India in terms of quantity and value chain.

Kumar and Pandey propose certain policy reforms in the field of mineral exploration in India. The key aspects of National Mineral Policy, 2019 are enumerated in the article vis-à-vis few bottlenecks in mineral exploration sector. The authors emphasize on certain amendments which should be transparent, discretion free, investor friendly and favouring easier trading of mineral rights and transfer of mining lease for better utilization of the mineral resources of the country.

The 21 papers included in this special issue cover various aspects of mineral exploration, development of exploration techniques over time, policy reforms in the mineral sector, genetic aspects of mineralisation and their beneficiation techniques, especially for atomic minerals. The participation of other mineral industries in submission of full paper for peer reviewing was restrictive therefore the issue misses the flavour of all mineral commodities of India.

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