Indian Uranium Deposits

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By

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Dedicated, with reverence, to my

School – under-graduate teacher,
the late Shri Pilla Rama Rao,

Post-graduate teacher and research supervisor,
the late Prof. J.S.R. Krishna Rao and

Mentors during my service in the AMD, the late Shri Abhilash C. Saraswat, Shri T.M. Mahadevan and late Dr. S. Viswanathan, former Directors of AMD, DAE, Govt. of India,

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Dr. A.V. Jeyagopal - Ph..D. thesis	*Figs.*: 5-4, 5-5, 5-6 and 5-9. *Table*: 5-1.

PREFACE

India is one of the major developing countries in the world, and has the following unique attributes: it is the 7th largest country in the world, a subcontinent with a population of 1.3 billion (2nd most populated country in the world, with ~ 25% below the poverty line, but with ~ 30% young people); has a coastline of > 7500 km; consistent high GDP growth of 7-8% during the last few years; and the largest functional democracy in the world for the last seven decades. Since its independence from the British Empire on August 15, 1947, its planned growth led it from an earlier under-developed country with a predominant agro-based economy to its present state of notable industrial-base in diverse fields of conventional and high-tech industries, all of which require large-scale, cost-effective, dependable energy, both to sustain industry and for further development. For its present energy sector, coal accounts for 53% of its fuel sources, hydro – 25%, gas – 11%, renewable sources – 8%, nuclear – 2% and oil – 1%. It has a large transport sector and major industries, like steel, aluminium, cement, fertilizers, automobiles, etc., which are predominantly dependent on fossil fuels, nearly 80% of which are imported, thereby draining much foreign exchange. Furthermore, fossil fuels emit a huge amount of greenhouse gases which are causing global warming with the attendant numerous disastrous consequences for people, land, health, monsoon, floods, landslides, tsunamis, rise in sea-level and the environment. To save our mother Earth and its inhabitants from these disastrous events, the international community came together in the year 2015 and declared the 'Paris agreement on Climate Change' so as to take effective measures to control the rise in global temperature to 'well below' 2°C in the next one to two decades. In order to meet the requirements of the Paris agreement as well as to save substantial foreign exchange for large scale import of the fossil fuels, the Government of India (GoI) has been giving importance to greenhouse gases-free clean nuclear- and renewable-energy. Under GoI, the Dept. of Atomic Energy (DAE) was started in August, 1948, with the mandate to work for the Country's nuclear industry, mainly for the generation of nuclear power and for its wide applications in other industries, agriculture, health and defence, preferably using indigenous nuclear resources. To meet these requirements of the nuclear industry, the Atomic Minerals Directorate (AMD) for

Exploration and Research, the oldest unit of DAE has been exploring since 1949, using both the field- and laboratory-based multi-disciplinary, -dimensional and -faceted work spectrum, for the radioactive minerals (of U and Th, besides Rare Metals and Rare Earths) in different parts of India. Sustained efforts of numerous geo-scientists of AMD during the last seven decades led to the establishment of a resource base of 3,06,042 te *in situ* U_3O_8 (as on December 31, 2018), under different categories from diverse types of mostly low-grade (< 0.2% U_3O_8) U-deposits. These U-deposits are: (i) metamorphic hydrothermal type in the Singhbhum shear zone in the state of Jharkhand, which have been exploited since the late 1960s; (ii) medium grade (~ 0.17% U_3O_8) hydrothermal type in the Gogi area of Karnataka in the basement granite and its overlying limestone; (iii) unconformity-proximal, hydrothermal type, both below and above unconformity, respectively, in the basement granite and its overlying sediments in the Lambapur–Peddagattu–Chitrial–Koppunuru area in the states of Telangana and Andhra Pradesh; (iv) rare, giant-size (> 0.15 million tonnes U_3O_8), carbonate (impure dolostone)-hosted deposit in the Tummalapalle – Gadankipalle area in Andhra Pradesh, which has been exploited for the last few years; (v) albitisation-related, metasomatic type deposit in parts of NE Rajasthan and SW Haryana; and (vi) sandstone-type deposits in Meghalaya, besides (vii) potential prospects of palaeo-placer type – hosted by older quartz pebble conglomerate (QPC) and relatively younger meta-arenite – in western Karnataka. Though there are numerous publications that highlight a few aspects of each deposit, there is no consolidated and comprehensive account on these in one place. The present book aims to address this major lacuna by giving a consolidated, fairly comprehensive account of each of the above Indian U-deposits and potential prospects in seven chapters (nos. 2 to 8), with each starting from the introduction through development to resource-establishment and mineral processing of the U-ores, established by the AMD's multi-disciplinary, -dimensional and -faceted field- and laboratory-based exploration for U. In these seven chapters, the available geological information in the public domain and data on each type are presented in the following general format, comprising in a more or less sequential order: the abstract, introduction, historical aspects and conceptual evolution, regional and local geological setting, structure, geological - geophysical (surface and remote-sensing based) - geochemical exploration, core- and non-core (down-the-hole, DTH) drilling, petrography, petrochemistry, mineragraphy, XRD study, paragenetic sequence of ore and gangue minerals, mineral chemistry of radioactive minerals (mostly EMP-based), radio- and stable-isotope geochemistry, source/provenance rocks for U, depositional environment, controls and genetic-aspects/-modelling of U-mineralisation and mineral processing for extraction of U from ore, besides possible by-products, value-addition and treatment of waste, both for its reduction and creation of wealth. Besides the seven chapters, two more chapters are included in the book, namely the first chapter on the 'introduction', covering India's present scenario of available energy, need for nuclear (and renewable) energy, DAE and AMD and their respective mandates, nuclear power plants (running and under construction), unit cost of generated nuclear power in the country, need for comprehensive mineral-exploration/-exploitation with some new cost-effective techniques in mineral exploration - drilling - mining, an overview of the major attributes of the Indian U-deposits/-prospects and the objective of the present book. The last chapter (no. 9) presents 'concluding remarks', based on an overview of the information and data on the U-deposits and potential U-prospects, presented in chapters 2 to 8, and a few suggestions for U-exploration in India and elsewhere. The *main objectives* of the present book are two-fold: (i) the account given in chapters, 2 to 8 to serve as a *case-study* on different types of Indian U-deposits, which may help brown-field and green-field exploration for uranium, both in India and elsewhere, with a similar geological set-up, and (ii) presenting a consolidated account of AMD's exploration on each type of Indian U-deposits at one place, which, it is hoped, will be of interest for the international community of geo-scientists. Lastly, the author will be grateful if any omissions and commissions in the book are brought to his notice, so that the same will be attended to in its subsequent editions.

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R. Dhana Raju

CHAPTER ONE

INTRODUCTION

Abstract

India is one of the major developing countries in the world, and has the following unique attributes: a subcontinent with a population of 1.3billion (2nd most populated country in the world, with ~ 25% below the poverty line, but with ~ 30% young people); 7th largest country in the world; has a coastline of > 7500 km long; consistent high GDP growth of 7-8% during the last few years; and the largest functional democracy in the world. Since its independence on August 15, 1947 from the then British Empire, its planned growth led it from an earlier under-developed country with a predominant agro-based economy to the present major developing country with a notable industrial-base in diverse fields of conventional and high-tech industries, all of which require large-scale, dependable energy, both to sustain industry and for further development. For its present energy sector, coal accounts for 53% of its fuel sources, hydro – 25%, gas – 11%, renewable sources – 8%, nuclear – 2% and oil –1%. It has a large transport sector and major industries, like steel, aluminium, cement, fertilizers, automobiles, etc., which are predominantly dependent on fossil fuels, nearly 80% of which are imported, thereby draining much foreign exchange. Furthermore, fossil fuels emit a huge amount of greenhouse gases, which are causing global warming with the attendant numerous disastrous consequences for people, land, health, monsoon, floods, landslides, tsunamis, rise in sea-level and the environment. To save our mother Earth and its inhabitants from these disastrous events, the international community came together in the year 2015 and declared the 'Paris agreement on Climate Change' so as to take effective measures to control the rise in global temperature to 'well below' 2°C in the next one to two decades. In order to meet the requirements of the Paris agreement as well as to save substantial foreign exchange, presently spent on large-scale import of fossil fuels, the Government of India (GoI) has been giving importance for the last few years to greenhouse gases-free clean nuclear- and renewable-energy. The Dept. of Atomic Energy (DAE) under GoI is

mandated to work for the country's nuclear industry, mainly for the generation of nuclear power and for its wide applications in industry, agriculture, health and defence, preferably using indigenous nuclear resources. To meet these requirements of the nuclear industry, the Atomic Minerals Directorate (AMD) for Exploration and Research unit of the DAE has been exploring since 1949, using both the field- and laboratory-based multi-disciplinary, -dimensional and -faceted work spectrum, for the radioactive minerals (of U and Th, besides Rare Metals and Rare Earths) in different parts of India. Sustained efforts of numerous geo-scientists of AMD during the last seven decades led to the establishment of a resource base of 3,06,042 te in situ U_3O_8 *(as on December 31, 2018), under different categories from diverse types of U-deposits. Brief accounts on the (i) DAE and its mandate; (ii) proposed 3-stage development of the Indian nuclear power programme, including nuclear power plants; (iii) AMD – its evolution and role in DAE; (iv) India's nuclear resources; (v) need for comprehensive mineral-exploration and -exploitation; and (vi) objective of the present book are given. To familiarise the reader with the geology of India and its U-deposits, maps of its geology, cratons/rifts, U-belts, U-metallogeny and the Atomic Minerals Map, along with a tabulated comparison of the major attributes of the U-deposits/potential prospects, are presented. Though information and data on the major/minor deposits as well as a few potential U-prospects of India have been published since the mid-1950s, they were much scattered with no comprehensive account on each, in one place. In order to address this lacuna, the proposed book aims to integrate all the information and data on the diverse types of Indian U-deposits and potential prospects, viz., hydrothermal, unconformity-proximal, rare carbonate-hosted, albitite and sandstone-type deposits, and prospects of Palaeo-placer type in both the Quartz Pebble Conglomerate (QPC) and meta-arenite. Each chapter moves from the discovery to the establishment of a deposit/prospect, through multi-disciplined, -faceted and -dimensional field- and laboratory-based exploration, including drilling, thereby serving as a case-study for each of these types, which, it is hoped, will help the brown-field and green-field exploration for Uranium, both in India and in other countries, with a similar geological set-up.*

The Background

India, one of the major developing countries in the world, has some unique attributes. These are: (a) it is a subcontinent, comprising regions of diverse climates (tropical, sub-tropical, humid sub-tropical, arid, semi-arid, warm summer, mountain climate, dry and desert; see maps on www.mapsofindia.com), annual temperature (average: < 20ºC to > 27.5ºC), rainfall (the least in the desert region to the highest in the world at Cherrapunjee in Meghalaya), water-/natural-resources, cultures and religions; (b) its population of 1.3 billion is the second highest in the world, with nearly 25% below the poverty line, and ~ 30% young people; (c) area-wise, it is the 7th largest country in the world, with a long coast line of over 7,500 km; (d) its economy is mainly agriculture-based, involving > 50% population in the rural areas, with lesser in the urban/semi-urban areas, and less of industrial-base; (e) it has consistent high GDP growth of ~ 7-8% during the last few years; and (f) it is credited with the largest functional democracy during the last 72 years. Since its independence on August 15, 1947 from the then British Empire due to the unique, peaceful revolution under the leadership of the late Mohandas K. Gandhi, known worldwide as *Bapuji* and *Mahatma*, its planned growth led it from an earlier under-developed country with a predominant agro-based economy to the present major developing country, with a notable industrial-base in the diverse fields of manufacturing, mining, metals, alloys/super-alloys, chemicals and high-tech industries, like the nuclear, space, telecommunications, information technology and the technology-based agriculture, all of which require large-scale, dependable energy, both to sustain and for further development. Its energy scenario is characterised by (i) a rapid economic growth and increasing population with a high demand for energy, (ii) sustained GDP growth, requiring an annual increase of commercial energy-supply from 3.7% to 6.1%, (iii) short supply of coal and its poor quality, and (iv) limited domestic reserves and uncertain foreign supply of hydrocarbons (https:www.google.co.in/search?= indian + energy + scenarios). For its present energy sector, coal accounts for 53% of its fuel sources, hydro – 25%, gas –11%, renewable sources – 8%, nuclear – 2% and oil –1%, with a large transport sector and major industries depending mostly on fossil fuels, nearly 80% of which is imported, draining much foreign exchange. Furthermore, fossil fuels emit a huge amount of the greenhouse gases that are causing global warming with the attendant numerous disastrous consequences for people, land, health, monsoon, floods, landslides, tsunamis, rise in sea-level and the environment. To save our mother Earth and its inhabitants from these disastrous events, the international community came together in the year 2015 and declared the 'Paris agreement on Climate Change' so as to take effective measures to control the rise in global temperature to 'well below' 2°C, preferably < 1.5°C, *in the next one to two decades.* Furthermore, the ambitious action on climate change for a low-carbon economy could contribute an extra $ 26 trillion to the world economy by 2030, generate over 65 million new low-C jobs and avoid over 7,00,000 premature deaths due to pollution. In order to meet the requirements of the Paris agreement and to save substantial foreign exchange, presently spent on the import of fossil fuels, the Government of India (GoI), for the last few years, has been giving importance to greenhouse gases-free, clean nuclear- and renewable-energy, taking advantages of (i) the long coast, with three sides of the country surrounded by sea, and abundant large water bodies, which are ideal for the location of nuclear power plants, and (ii) the location of the country near the equator, with plenty of sunshine, and a notable windy desert area and coast, which are favourable, respectively, for the generation of solar- and wind-power (Dhana Raju and Venkat Reddy, 2018).

DAE and its Mandate

Realising the importance of nuclear energy in meeting a part of the growing power requirements in many developed countries of the world (e.g., ~ 75% in France and 20-60% in Belgium, Sweden, Japan, UK and USA), GoI, within one year of the country's independence, passed the Atomic Energy Act on April 15, 1948 and set up the Atomic Energy Commission (AEC) on August 10, 1948. For this, Dr. Homi J. Bhabha was appointed as the Chairman, AEC and the Secretary to the Department of Atomic Energy (DAE), with a mandate to plan, develop and execute the required multi-disciplinary and multi-stage nuclear operations, including nuclear power reactors. Dr. Bhabha, regarded as the father of the Indian Nuclear Programme, with his visionary zeal and active support from the late Pt. Jawaharlal Nehru, the first Prime Minister of India, together with his dedicated team of multi-disciplinary, specialist-scientists in different branches of nuclear science, commendably executed the given mandate till his untimely death in an air-crash on Jan. 24, 1966, at the relatively young age of 56 years. Since then, his many illustrious successors have continued the work with exemplary zeal to make India one of the few countries in the world operating, mostly with indigenous technology, the complex 'Nuclear Fuel Cycle'. This encompasses from the 'first end' of exploration – mining – milling – conversion – fabrication of the fuel [Uranium (U) and Thorium (Th)] to the 'back end' of treatment of the spent fuel and radioactive waste by the 'storage – recovery – recycling – disposal' in a high-integrity geologic repository, through the most important and intermediate stage of production of (a) electricity in the nuclear power reactors and (b) the radiation sources and radio-isotopes in a few nuclear research centres.