

Indian Uranium Deposits

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By

R. Dhana Raju

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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,*

*for all their guidance, help and support during my education,
research and professional life.*

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CONTENTS

List of Figures.....	xiii
List of Tables.....	xviii
Permissions for Reproduction	xxi
Preface	xxii
Acknowledgements	xxv
Chapter One.....	1-30
Introduction	
Abstract.....	1
The Background	2
D.A.E. and Its Mandate.....	4
Stages of the Indian Nuclear Power Programme	5
AMD: Its Evolution and Role in DAE.....	9
<i>India's U-resource base</i>	9
<i>Resources of India's Nuclear Fuels</i>	10
<i>AMD's Methodology for U-exploration</i>	12
<i>Need for Comprehensive Mineral-Exploration/-Exploitation</i>	15
<i>Synopsis of the Geology of India and Its U-deposits</i>	17
Objective of the Book	27
Bibliography	28
Chapter Two	31-125
Hydrothermal Type U-deposits and QPC-type U-occurrences in the Singhbhum – North Odisha craton	
Abstract.....	31
Introduction.....	32
Historical Aspects and Conceptual Evolution.....	34
U-deposits/-occurrences in the Singhbhum- North Odisha Craton (SNOC)	36
Geological Setting of the Singhbhum craton	36

Salient attributes of U-mineralisation in SNOC – QPC and Hydrothermal Types.....	45
<i>QPC type U-occurrences</i>	45
<i>Hydrothermal type U-deposits in the Singhbhum Shear Zone (SSZ) ...</i>	52
<i>Geological Setting, Host Rocks for U-mineralisation and Metamorphism</i>	54
<i>Petrochemistry</i>	57
<i>Mineragraphy</i>	57
<i>Genesis of Hydrothermal type U-deposits</i>	59
<i>Jaduguda – Bhatin – Nimidih sector U-deposits</i>	68
<i>Jublatola U-deposit</i>	74
<i>Narwapahar – Garadiah – Turamdih – Nandup Sector U-deposits</i>	89
<i>Mohuldih – Dhatkidih Sector U-deposits</i>	98
<i>Bagjata – Kanyaluka Sector U-deposits</i>	101
<i>Gohala – Dalmakocha Sector U-deposits</i>	104
<i>Roam – Rakha – Surda Sector Cu-U-deposits</i>	104
Uranium Mines and Processing Plants in SSZ.....	104
Genetic Modelling of the U-mineralisation in SNOC.....	112
Bibliography	116
 Chapter Three	 126-183
Hydrothermal Type U-Deposit in the Gogi Area, Karnataka	
Abstract.....	126
Introduction.....	127
Historical Aspects and Conceptual Evolution.....	129
Geological Setting.....	131
<i>Host Rocks for U-mineralisation</i>	133
<i>Exploration Inputs</i>	137
<i>Structural Aspects</i>	139
Salient features of U-mineralisation in the Limestone and Granite ...	140
<i>U-mineralisation in the Limestone</i>	140
<i>U-mineralisation in the Basement Granite</i>	144
<i>Petrography</i>	147
<i>Petrochemistry</i>	149
<i>Mineragraphy</i>	156
<i>Mineral Chemistry</i>	158
<i>Radioactive Organic Matter and Clay</i>	164
<i>Sulphide phases</i>	165
<i>Paragenetic sequence of Ore and Gangue Minerals</i>	166
<i>Source and Nature of U-mineralisation</i>	168
<i>Physico-Chemical Conditions of U-mineralisation</i>	169

<i>Grade – Extractability – Extent of Area – Tonnage</i>	171
<i>Controls for U-mineralisation</i>	172
Mineral Processing of the U-ore from Gogi	173
<i>Nature and Treatment of Mine Waste</i>	175
Genetic Model of the Gogi U-deposit.....	177
Evaluation of the Status of Areas.....	179
Bibliography	181
Chapter Four.....	184-245
Unconformity-Proximal, Hydrothermal type U-deposits in the Lambapur – Peddagattu – Chitrial – Koppunuru Area, Telangana and Andhra Pradesh	
Abstract.....	184
Introduction.....	185
Geological Setting.....	188
Heli-borne Magnetic Survey.....	191
U-deposits in the Srisailam Sub-basin	192
<i>Lambapur- Peddagattu – Chitrial U-deposits</i>	194
<i>Host-Rocks for U-mineralisation –</i>	195
(a) <i>Basement Granite</i>	195
(b) <i>Srisailam Sediments</i>	209
<i>Geometry of U-ore bodies in the Srisailam Sub-basin</i>	211
<i>Ore Mineralogy</i>	211
<i>Age of Mineralisation</i>	212
U-deposit in the Palnad Sub-basin	212
<i>Geological Set-up</i>	213
<i>Host-Rocks for U-mineralisation –</i>	214
(a) <i>Basement Granite</i>	215
(b) <i>Banganapalle sediments</i>	222
Controls of U-mineralisation	235
Genetic modelling of U-deposits	237
Bibliography	240
Chapter Five	246-325
Rare Stratabound, Carbonate-hosted U-deposit in the Tummalapalle – Gaddankipalle area, Andhra Pradesh	
Abstract.....	246
Introduction.....	247
Historical Aspects and Conceptual Evolution.....	249
Geological Set-up	251
<i>Sedimentary Structures</i>	265
Exploration for Uranium.....	268

<i>Aeromagnetic study over the Cuddapah Basin</i>	269
<i>Petrography</i>	270
<i>Petrochemistry</i>	278
<i>Mineragraphy</i>	282
<i>Mineral Chemistry</i>	285
<i>Isotope Chemistry</i>	289
<i>Pb-Pb age of Dolomite</i>	296
<i>Chronostratigraphy of the Cuddapah Suupergroup</i>	297
Depositional environment of UPSD	298
<i>Cyclic Sedimentation and Sequence Stratigraphy of the Papaghni Group</i>	302
Controls of U-mineralisation	305
Genetic aspects of U-mineralisation	309
<i>Evolutionary and Genetic model for the Vempalle Formation, hosting U-mineralisation</i>	310
Mineral Processing of UPSD for extraction of Uranium	312
<i>Value-Addition</i>	315
<i>Creation of Wealth from Waste</i>	316
<i>Meeting Societal Needs</i>	316
Bibliography	317
Chapter Six	326-393
Albitisation-related, Metasomatic Hydrothermal Type U-Deposits in the Rohil – Raghunathpura Area, NE Rajasthan and SW Haryana	
Abstract	326
Introduction	327
Historical Aspects and Conceptual Evolution	329
Geological Set-up	332
<i>Regional Geology of the Aravalli Craton</i>	332
<i>Local Geology</i>	337
<i>Structure</i>	342
Exploration for Albitisation-related U-deposits in the Khetri Sub-basin (KSB)	343
<i>Rohil U-deposit</i>	347
<i>Narsinghpuri – Gumansingh-ki-Dhani and Karoi</i>	349
<i>Jahaz – Maota area</i>	350
<i>Rambas-Gorir-Raghunathpura U-mineralisation</i>	350
<i>Petrography</i>	356
<i>Petrochemistry</i>	360
<i>Mineragraphy</i>	369
<i>X-ray Diffraction Study</i>	372

<i>EMP-based Mineral Chemistry of U-phases</i>	372
<i>Isotopic Study</i>	376
<i>Fluid Inclusion Study</i>	378
<i>Temperature of the formation of uraninites</i>	379
Controls of U-mineralisation	379
Factors that affect the Genetic Modelling of the U-mineralisation....	381
Mineral Processing of the U-ore	384
Bibliography	387
Chapter Seven.....	394-469
Sandstone Type U-Deposits at Domiasiat – Wahkyn and U-occurrences, Meghalaya	
Abstract.....	394
Introduction.....	395
Historical Aspects and Conceptual Evolution.....	397
Geological Setting.....	398
Regional Geological Set-up	398
Provenance Rocks and their Potentiality for Uranium	403
Local Geological Setting and Sandstone-type U-mineralisation.....	408
Pdengshakap – Tarangblang U-occurrence	409
Gomaghat U-occurrence	409
Mawkyrwat U-occurrence	411
Phlangdiloin U-occurrence	413
Domiasiat U-deposit	415
Waykyn U-deposit	421
Petrography	430
Lower Mahadek Sandstone (LMS).....	430
Diagenesis in LMS	433
Organic Matter in LMS.....	434
Palaeosols in LMS	436
Petrochemistry	438
Sulphur isotopic study.....	445
Natural Thermo-Luminescence (NTL) Study	445
Mineragraphy.....	447
XRD study	451
Depositional Environment of LMS.....	451
Controls of U-mineralisation	453
Genetic Model of U-mineralisation in LMS	456
Mineral Processing Study	458
Bibliography	462

Chapter Eight.....	470-518
Palaeo-Placer (P-P) Type Uranium Prospects in Karnataka	
Abstract.....	470
Introduction.....	471
Historical aspects and conceptual evolution	472
Geological Setting.....	474
<i>Regional Geology of the Western Dharwar Craton</i>	474
<i>Local Geology of the Areas of P-P type U-mineralisation</i>	481
<i>Walkunji QPC type U-occurrence</i>	481
<i>Arbail-Dabguli Meta-Arenite U-occurrence</i>	484
Petrography.....	489
Petrochemistry.....	490
Mineragraphy.....	494
EMP-based Mineral Chemistry of U-minerals	507
Age of the U-mineralised QPC and Meta-Arenite	509
Nature of Source Rocks	510
Genetic Model for the Palaeo-Placer type U-mineralisation.....	514
Bibliography	515
Chapter Nine.....	519-527
Concluding Remarks	
Abstract.....	519
Salient observations on the Indian U-deposits	519
Guides for U-exploration in the Indian scenario.....	524
Subject Index	528

LIST OF FIGURES

Chapter One

1-1. Generalised Geological map of India.....	18
1-1. Geological map of India, showing the distribution of metamorphic-igneous-sedimentary terrains.....	19
1-3 Major cratons and mobile belts of India.....	20
1-4 Potential U-belts, U-deposits/-occurrences and operating U-mines.....	21
1-5a. Atomic Minerals Map of India.....	22
1-5b. State-wise distribution of U-resources in India.....	22
1-6. U-(Th and Rare Metal and Rare Earth, RMRE) metallogeny in India.....	23

Chapter Two

2-1. Geological map of the Jharkhand–Odisha region.....	37
2-2. Sketch map showing the extent of the batholithic Singhbhum Granite.....	40
2-3a. Generalised geological map of the Singhbhum – North Odisha craton.....	47
2-3b. Geological map of the Dhanjori basin.....	48
2-4. Photomicrographs of the Oligomictic QPC.....	51
2-5. Geological map of the Singhbhum Uranium Province.....	53
2-6. Photomicrographs of hydrothermal type Uranium- and Sulphide-minerals in SSZ.....	61
2-7. Geological map of the Jaduguda area in SSZ.....	69
2-8. Geological map of Nimdih and Bhatin west in SSZ.....	69
2-9. Photomicrographs of U-minerals in the Jaduguda U-deposit.....	72-73
2-10. Geological map of part of the SUP, including Jublatola deposit.....	76
2-11. Photomicrographs of U- & Fe-Oxides and some Sulphide minerals in the Jublatola U-deposit.....	78-80
2-12. Photomicrographs of sulphide minerals in the Jublatola U-deposit.....	83-84
2-13. Location plan of the bore-holes in the Turamdih – Nandup area.....	92
2-14. Transverse sections through Turamdih West and Keruadungri.....	92
2-15. Transverse sections through Turamdih South and East.....	93
2-16. Transverse section through Nandup.....	93
2-17. Longitudinal correlation section through Central Keruadungri, Turamdih West and Keruadungri.....	94
2-18. Longitudinal correlation section through Turamdih East and South.....	95
2-19. Regional dip section through Nandup – Turamdih South and Central Keruadungri sectors.....	95
2-20. Geological map of Mohuldih – Dhadkidih – Turamdih – Nandup.....	99

2-21. Photomicrographs of ore minerals in the Mohuldih U-deposit	102
2-22. Geological map of Dalmakocha – Bagjatha West – Badia block.....	103
2-23. Geological sections showing disposition of the U-lodes in the Bagjata, Jaduguda, Turamdih and Banduhurang U-mines	109

Chapter Three

3-1. Geological map of the Neoproterozoic Bhima basin, with location of the Gogi Uranium deposit.....	134
3-2. Geological map of the Ukinal – Gogi – Kanchankayi – Madnal area, Gulbarga district, Karnataka	134
3-3. Drill-core of uranium-mineralised siliceous dolostone	141
3-4. 3-cm thick vein (black) with U-minerals traversing limestone	142
3-5. Transverse geological section of B.H. GGL-8, 4, 20, 11 & 15	145
3-6. Transverse geological section of B.H. GGL-53, 92, 37, 81 & 90	146
3-7. Fence diagram of the main U-mineralised zone in the Gogi area.....	147
3-8. Photomicrographs of uraniumiferous limestone from Gogi	148
3-9. Photomicrographs of uraniumiferous limestone and basement granitoid.....	150
3-10. Bi-linear plots of variation in the contents of U vs. Pb, Co and Ni	156
3-11. Sketch showing textural relationship of U-minerals in OM.....	158
3-12. Sketch showing the textural relationship of U-minerals and sulphides	159
3-13. Cartoon showing the elemental compositions in sulphides	166
3-14. Eh-pH fence diagram showing the conditions of formation of different minerals.....	170
3-15. Process flow-sheet for recovery of U from the U-ore at Gogi.....	176
3-16. Eight stage genetic model of the Gogi Uranium deposit.....	178

Chapter Four

4-1. Geological map of the Cuddapah Basin, showing disposition of its Sub-basins and U-occurrences	189
4-2. Schematic diagram showing the shapes of development and evolution of the Cuddapah basin and its sub-basins.....	191
4-3. Geological map of the N and NE parts of the Cuddapah basin	194
4-4a. Geological map of the Lambapur outlier.....	196
4-4b. Borehole correlation section, showing disposition of the U-ore body in the Lambapur deposit.....	196
4-5. Geological map and ore-body configuration in the Yellapur – Peddagattu area and a borehole correlation section.....	198
4-6. Geological map of the U-ore body configuration in the Chitrial area and a borehole correlation section	199
4-7. Field photos and photomicrographs of radioactive granite	200
4-8. Binary plot of ‘Oxidation Grade (UO _{2+x})’ vs. ‘a _o ’ of uraninites from the Srisaillam Sub-bsin	205
4-9. Plot of UO ₂ /ThO ₂ vs. CaO/ThO ₂ for the U-minerals of the Chitrial deposit..	209

4-9a. Chondrite-normalised REE patterns of the U-minerals from the unconformity-proximal U-deposit.....	209
4-10a. Geological map of the Koppunuru area, Guntur district, A.P.....	214
4-10b. Field disposition of the basement granite in the Palnad Sub-basin	215
4-11. Generalised lithology of the Palnad succession in the Koppunuru area, A.P.....	216
4-12. Chondrite-normalized REE patterns of granitoids from Palnad Sub-basin	221
4-13. Field, petrographic and mineragraphic features of the Banganapalle sediments of the Banganapalle Formation	224
4-14. Borehole lithology and gamma log the Koppunuru area.....	229
4-15. Geological map and U-ore body configuration in the Koppunuru area.....	230
4-16. Transverse section, showing correlation of litho-facies and U- mineralisation in the Koppunuru area.....	231
4-17. Borehole core showing occurrence of carbonaceous matter and sulphides in the Banganapalle Formation	232
4-18. Association of primary U-minerals with carbonaceous matter in the Banganapalle quartz arenite	232
4-19. Plot of a_0 vs. oxidation grade of uraninite from the Palnad basin.....	234

Chapter Five

5-1. Geological map of the Cuddapah Basin, showing the locations of the Dolostone-hosted U-mineralisation.....	253
5-2a. Hypothetical crustal section across the Cuddapah basin	254
5-2b. Schematic section across the Cuddapah basin and its environs.....	254
5-3. Geological map of the SW part of the Cuddapah basin showing the occurrences of the U-mineralised carbonate rocks	255
5-4. Generalised cross-section across the Cuddapah basin showing the relative position of different Groups and Formations of the Cuddapah Supergroup.....	256
5-5. Generalised cross-section of the Papaghni Group.....	258
5-6. Litho-facies correlation section of the sediments of the Papaghni Group	261
5-7. Comparison of lithology of Tummalapalle with that of Korivipalle	262
5-8. Schematic sketch of different litho-facies in the Vempalle Formation	263
5-9. Block diagram showing the disposition of litho-units of the Papaghni Group.....	264
5-10. Sedimentary structures in different litho-units of the Vempalle Formation.....	267
5-11. Petrographic features of the U-mineralised Phosphatic Siliceous Dolostone.....	272
5-12. Stromatolitic dolostone with <i>Stratifera sp.</i> and <i>Oncolithic sp.</i>	277
5-13. Ore mineral textures in the U-mineralised Phosphatic Siliceous Dolostone	283
5-14. C- & O- isotopic compositions of U-rich and U-poor phases of the Phosphatic Siliceous dolostone	295
5-15. Eh – pH diagram showing the different facies of the Vempalle Formation	301
5-16. Three cycles of sedimentation in the Papaghni Group	303
5-17. Schematic diagram showing algae-controlled high-Mg calcite, phosphate (collophane) and pyrite precipitation	309
5-18. Geological section of the carbonate-hosted U-ore body at Tummalapalle	313
5-19. Process flow-sheet for recovery of U-values from UPSD of Tummalapalle.....	315

Chapter Six

6-1. Geological map of the Aravalli craton	329
6-2. Geological map showing the distribution of major stratigraphic units of the Aravalli craton	333
6-3. Crustal-scale lineaments in Rajasthan in relation to major stratigraphic units	335
6-4. Alwar and Bayana basins of North Delhi Fold Belt (NDFB).....	337
6-5. Simplified geological map showing the trace of ‘albitite- pyroxenite- microcline belt’ of Rajasthan	339
6-6. Geological map of NE Rajasthan and SW Haryana, showing the U-(-Th-Cu) mineralised area in NDFB.....	347
6-7. Geological map of the Rohil U-deposit in the Khetri Sub-basin, Rajasthan ..	348
6-8. Field photos of albitised calc-silicate rocks in the areas of SW Haryana	357
6-9. Photomicrographs of the Calc-Silicate Rock (CSR)	359
6-10. Textures of ore minerals in the U-mineralised CSRs, Raghunathpura.....	371

Chapter Seven

7-1. Generalised geological map of southern fringes of the Meghalaya Plateau ...	401
7-2. Generalised geological section along N-S line of the southern part of the Meghalaya Plateau, showing the ‘plateau’ and ‘ghat’ domains	402
7-2a. General view of the ‘plateau’ and ‘ghat’ domains.....	402
7-3. U-anomalies in the Pdengshakap – Tarangblang area, Meghalaya	410
7-4. Geological map of the Rilang - Alukwadi blocks, Meghalaya.....	411
7-5. Major U-occurrences in the Mawkyrwat area, Meghalaya.....	413
7-6. Drilling blocks and Bore Holes drilled in the Phlangdiloin area	414
7-7. Correlation section through the Sateek blocks in the Phlangdiloin area.....	415
7-8. Uranium occurrences around Domiasiat, Meghalaya.....	416
7-9. Sketch of the Domiasiat quartz-reef and conglomeratic sandstone with U-mineralised horizons	418
7-10. Generalised vertical section of lithological units within the Lower Mahadek sandstones in the Domiasiat area	419
7-11. Typical section through the U-ore zone in the Domiasiat area, Meghalaya ..	421
7-12. Major U-occurrences in the Wahkyn area, Meghalaya	422
7-13. Generalised lithological column in the Wahkyn area, Meghalaya	427
7-14. Borehole correlation section in the Wahkyn area, Meghalaya	428
7-15. Geological map of the Laitduh area, Meghalaya.....	428
7-16. Litholog of the Laitduh area, Meghalaya	429
7-17. Correlation section along borehole line A-B and C-D, Laitduh area.....	430
7-18. Textures of the OM in U-mineralised LMS from Domiasiat	436
7-19. Ore mineral textures in the U-mineralised LMS from Domiasiat	449
7-20. Geo-phantasmogram of the braided-channel sequence in Domiasiat.....	458
7-21. Flow-sheet for tentative beneficiation of the U-ore from Domiasiat.....	461
7-22. Flow-sheet for processing the U-ore from Domiasiat by wet-grinding – PCL process	462

Chapter Eight

8-1. Essential features of the Dharwar craton, southern India	476
8-2. Geological map of the Bababudan Schist Belt, Karnataka	478
8-3. Geological map of the Bababudan-Western Ghats-Shimoga Superbelt	480
8-4. Geological map of the western part of Karnataka, showing locations of Uraniferous QPC.....	481
8-5. Radioactive Quartz-Pebble Conglomerate (QPC) at Walkunji	482
8-6 Geological map of the Arbail-Dabguli area, showing the location of the U- mineralised meta-arenite	486
8-7. Three U-mineralised arenite bands in the Arbail – Dabguli area	487
8-8. Induced Polarization (IP) chargeability by contour map, showing the sub- surface position of arenite bands	488
8-9. Textures of Uraninites of the QPC from Walkunji, Karnataka	496
8-10. Photomicrographs of ore minerals in the meta-arenite from the Arbail- Dabguli area	502-506
8-11. UO ₂ -ThO ₂ bi-linear plot, with fields of detrital uraninites from the Witwatersrand, Blind River and Walkunji area.....	509

LIST OF TABLES

Chapter One

1-1. India's Nuclear Power Plants – operating and under construction.....	6
1-2. India's U-mines and U-mills – existing and planned	11
1-3. Generalised Uranium Exploration Spectrum.....	14
1-4. Salient attributes of the diverse types of U-deposits/-prospects in India.....	25

Chapter Two

2-1. Stratigraphic succession of the Singhbhum craton.....	42
2-2. Comparison of lithology, mineralogy, metamorphic grade and nature of U-mineralisation in the five parts of the SSZ.....	55
2-3. Paragenesis of ore minerals in SSZ.....	62
2-4. Comparative paragenetic sequence of ore minerals in Jublatola and Jaduguda U-deposits	86

Chapter Three

3-1. Stratigraphic succession of the Bhima basin.....	136
3-2. Chemical analyses of radioactive limestone from Gogi.....	152
3-3. Trace element analyses of uraniferous limestone (drill-core)	154
3-4. Chemical analyses of the basement granite from Gogi	155
3-5. EPMA data of the U-minerals in U-mineralised Limestone and Granite from Gogi	161
3-6. EPMA-data (in wt. %) of sulphides of U-mineralised Limestone & Granite.....	162
3-7. EPMA data (in wt. %) of carbonaceous matter, clays and apatite.....	163
3-8. Calculated chemical ages (in Ma) of the U-minerals	164
3-9. Paragenetic sequence of ore and gangue minerals in the Gogi U-deposit.....	167
3-10. Eh and pH conditions of formation of pyrite, OM and U-minerals.....	170

Chapter Four

4-1. Stratigraphic succession of the Cuddapah Supergroup and Kurnool Group.....	193
4-2. Modal analysis of the Granites from the Lambapur area	197
4-3. U- and Th-contents of the Granites in the Lambapur area	201
4-4. Chemical analyses of the granitoids from the Lambapur area.....	201

4-5. Selected trace and REE contents and ratios of the Granites of the Lambapur area.....	203
4-6. EPMA analysis of the U-minerals in the U-mineralised granitoids from the Srisailam Sub-basin	207
4-7. Lithostratigraphy of the Koppunuru and adjoining areas, A.P.	214
4-8. Chemical analysis of basement granitoids in the Palnad Sub-basin	220
4-9. REE and their ratios in basement granites of the Palnad Sub-basin	221
4-10. Chemical analysis of the low-U Banganapalle quartzite	226
4-11. Chemical analysis of the high-U Banganapalle quartzite	227

Chapter Five

5-1. Stratigraphic sequence of the Vempalle Formation	258
5-2. Chemical analyses of impure dolostone and cherty dolostone	279
5-3. Chemical analyses of the UPSD and PSD.....	280
5-4. Paragenetic sequence of Ore-/Gangue-Minerals and cement	286
5-5. EMP analysis (average, in wt. %) of U-phases	287
5-6. EMP analysis (average, in wt. %) of pyrite, collophane and dolomite.....	289
5-7. C-, O- and U-isotopic ratios of the dolostones from the U-deposits	292
5-8. Chronostratigraphy of the Cuddapah Supergroup	297
5-9. Comparative study of the U-mineralised and non-mineralised Dolostones....	306

Chapter Six

6-1. Stratigraphic schemes of the Aravalli Supergroup (Source: Ramakrishnan and Vaidyanadhan, 2008, p. 286)	334
6-2. Characteristic aspects of albitites, occurring along the Mewar-Maonda-Pachlangi-Rohil-Kerpura-Ladera-Tal tract	339
6-3. Generalised Geological succession of the Rohil area, Rajasthan	341
6-4. Geological succession of the Delhi Supergroup in Haryana	342
6-5. Results of Sub-surface exploration in the Rohil and other areas in NDFB	346
6-6. Comparison of the albitisation-related Rohil U-deposit, India with similar deposits in other countries	354
6-7. Chemical analyses of albitites and associated rocks of the Banjaron-ki-Dhani (BKD) area	362
6-8. Metasomatic changes in bulk composition of unaltered rocks of the Bhanjaron-ki-Dhani area.....	363
6-9. Chemical analyses of U-mineralised Calc-Silicate Rocks (CSR), Raghunathpura, SW Haryana.....	365
6-10. Salient variations in the chemistry of U-mineralised CSRs	366
6-11. Chemical analyses of non-mineralised CSRs, Raghunathpura.....	367
6-12. Paragenetic sequence of ore and gangue minerals in the U-mineralised CSR from Raghunathpura	373
6-13. EMP-based chemical analyses of U-minerals from Raghunathpura	374
6-14. EMP-based chemical analyses of Uranothorite from Raghunathpura	375

Chapter Seven

7-1. Stratigraphic succession of the Meghalaya Plateau.....	405
7-2. Characteristic features of the Mahadek sandstones in the Plateau and Ghat domains of the Mahadek Formation.....	406
7-3. Average abundances of U, Th and Th/U in some rock types of the provenance for sandstone-type U-mineralisation in Meghalaya.....	408
7-4. Surface attributes of major U-occurrences in the Phlangdiloin area	414
7-5. Surface attributes of major U-occurrences in the Domiasiat area	420
7-6. Salient attributes of U-anomalies in the Wahkyn area, Meghalaya.....	423
7-7. Comparative and contrasting features of the LMS in the Domiasiat (plateau), Gomaghat (ghat) and Pdengshakap areas, Meghalaya	432
7-8. Chemical analyses of LMS from the Pdengshakap, Gomaghat and Domiasiat (+ coal) areas.....	438
7-9. REE, Y, Sc, Cr, Co, Ta, Hf and Zr of the LMS from Domiasiat.....	439
7-10. REE, Y, Sc, Cr, Co, Ta, Hf and Zr contents of the LMS from Pdengshakap and Gomaghat	439
7-11. Chemical analyses of the LMS from the Wahkyn area	442
7-12. Chemical analyses of the Wahkyn Palaeosols from Wahkyn area	444
7-13. NTL glow-peak temperatures of LMS and its corresponding quartz-dominant bromo-light fraction, with respective U ₃ O ₈ contents.....	446
7-14. Paragenetic sequence of ore and gangue-minerals, and cement in the U-mineralised LMS from the Domiasiat area	450

Chapter Eight

8-1. Regional stratigraphy of the Western Dharwar Craton (WDC)	475
8-2. Chemical analyses of the Conglomerates from the Walkunji area, compared with that from Quirke Lake, Canada.....	491
8-3a. Chemical analyses of the Non-Radioactive Arenite (NRA) and Radioactive arenite from the Arbail-Dabguli area	492
8-3b. Trace element contents of radioactive and non-radioactive arenites from the Arbail-Dabguli area.....	494
8-4. EMP-based U-mineral analyses of the QPC of the Walkunji area and meta-arenite of the Arbail-Dabguli area.....	508
8-5. Some trace element contents in the QPC from the Bababudan and Chitradurga basins, Karnataka	512
8-6. Trace element abundances of the granitoids in Karnataka	513
8-7. Schematic model depicting the stages of development of QPC-type U-mineralisation in the Western Dharwar Craton	514

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Dr. A.V. Jeyagopal - Ph..D. thesis	<i>Figs.:</i> 5-4, 5-5, 5-6 and 5-9. <i>Table:</i> 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 ($\sim 0.17\%$ 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 1.3 billion (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: $< 20^{\circ}\text{C}$ to $> 27.5^{\circ}\text{C}$), 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 $\sim 30\%$ 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 $\sim 7\text{--}8\%$ 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 $< 1.5^{\circ}\text{C}$, *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.