An overview of uranium exploration strategy in India

By
Anjan Chaki

Director
Atomic Minerals Directorate for Exploration and Research
Department of Atomic Energy
Government of India
Outline

- Uranium provinces of India
- India’s uranium exploration history
- Exploration strategy for Srisailam-Palnad-Kurnool sub-basins
- Exploration strategy for Southern Cuddapah basin
- Exploration strategy for North Delhi Fold Belt
- Exploration strategy for Cretaceous Mahadek basin
- Exploration strategy for Proterozoic Bhima basin
- Exploration strategy for Proterozoic Kaladgi basin
- Concluding remarks
Major Uranium Provinces of India

- North Delhi Fold Belt, Rajasthan and Haryana
- Mahadek basin, Meghalaya
- Kaladgi basin, Karnataka
- Singhbhum Shear Zone, Jharkhand
- Bhima basin, Karnataka
- Srisailam, Palnad and Kurnool sub-basins, Cuddapah basin
- Cuddapah basin, Andhra Pradesh
History of uranium exploration in India

Exploration started in early 1950’s

11 deposits ( > 500 t U₃O₈ of grade: 0.02-0.06% U₃O₈) proved between 1951-1975

New discoveries from widely different geological settings in Rajasthan and Himalayas

New Uranium provinces viz. SSZ, Southern Cuddapah and Mahadeks established


Proterozoic Cuddapah Basin emerge as a major uranium province. Tummalapalle (1984 to present) in Dolostone hosted strata-bound, Lambapur-Peddagattu-Chitrial (1992-Present) in unconformity-related


Proterozoic vein type U deposit in Rajasthan – Rohil – Ghateshwar (2000-Present)

Proterozoic Kaladgi basin – Emerging
Srisailam-Palnad-Kurnool sub-basins
Northern and north-western part of Cuddapah basin is the host for unconformity related uranium mineralisation

The formations are of Middle to Upper Proterozoic age

Unmetamorphosed sediments of orthoquartzite, limestone and shale

Three low grade – low tonnage deposits have been established in Lambapur - Peddagattu, Koppunuru and Chitrial in the northwestern periphery of Cuddapah basin

Nearly 60 sq.km area unexplored in Chitrial and Peddagattu deposits

3000 sq.km inside the basin under sanctuary holds high potential is yet to be explored

Prognostic reserves of Chitrial deposit is about 30,000 tonnes of $U_3O_8$
Uranium mineralisation in northwestern parts of Cuddapah basin

Lower Proterozoic granite unconformably overlain by Middle Proterozoic Srisaialam formation

Uranium mineralisation follows the unconformity contact between the Srisailam Formation and granite

Major part of the mineralisation is confined to basement granites

Pitchblende, Uraninite, Coffinite and Uranophane are uranium minerals
Exploration strategy for unconformity related deposits in Cuddapah basin

- Radiometric and Geological mapping
- Radiometric logging of groundwater tubewells
- Airborne and ground based geophysical surveys (TDEM, Magnetic and Radiometrics)
- Geochemical, petro-minerological and isotopic characterisation of ore body and host rocks
- Hyper-spectral Remote Sensing for alteration mapping
- Drill cores - mineral alteration studies
- Groundwater hydrology
- Genetic modeling of uranium mineralisation
Southern Cuddapah basin
Southern Cuddapah uranium province

Chitavati group

---------------------- disconformity ----------------------

Papagni group - Vempalle Formation
Limestone, dolostone
shale, chert

Gulcheru quartzite

---------------------- non-conformity ----------------------

Granites, gneissic rocks, Dharwar schists
## Characteristics of uranium mineralisation in Vempalle dolostone

<table>
<thead>
<tr>
<th>Nature of host rock</th>
<th>Impure, siliceous, phosphatic, dolomitic stromatolitic limestone</th>
</tr>
</thead>
<tbody>
<tr>
<td>Uranium Minerals</td>
<td>Pitchblende, Coffinite, U-Ti complex, Collophane</td>
</tr>
<tr>
<td>Associated minerals</td>
<td>Pyrite, Chalcopyrite, Molybdenite bornite, digenite, covellite</td>
</tr>
<tr>
<td>Gangue Minerals</td>
<td>Dolomite, Quartz, Microcline</td>
</tr>
<tr>
<td>Average Grade</td>
<td>0.040 to 0.046% $\text{eU}_3\text{O}_8$</td>
</tr>
<tr>
<td>Trace Elements</td>
<td>Molybdenum - 230 ppm</td>
</tr>
<tr>
<td></td>
<td>Nickel - 30 ppm</td>
</tr>
<tr>
<td></td>
<td>Copper - 90 ppm</td>
</tr>
<tr>
<td></td>
<td>Cobalt - 25 ppm</td>
</tr>
<tr>
<td></td>
<td>Barium - 215 ppm</td>
</tr>
<tr>
<td></td>
<td>$\text{P}_2\text{O}_5$ - 2.46%</td>
</tr>
<tr>
<td>Controls of mineralisation</td>
<td>Phosphate, silica and organic matter in the impure dolomitic</td>
</tr>
<tr>
<td></td>
<td>limestone are the main controlling factors for uranium</td>
</tr>
<tr>
<td></td>
<td>mineralisation</td>
</tr>
</tbody>
</table>
Thin alternating light and medium to dark gray color bands.

Light gray bands are fine grained and rich in carbonates (micritic and sparritic) mostly dolomites.

Medium to dark grey bands are ultrafine and rich in phosphates mostly collophane

These bands contain floating grains of detrital quartz, felspars and opaques (pyrites).

Uranium mineral - `pitchblende’ which occurs as ultrafine granular aggregate, in intimate association with both biogenic and diagenetic pyrite

Other primary uranium minerals in minor amounts are coffinite and U-Ti complex.

Coffinite is later to pitchblende, as it replaces the boundaries and fracture plane. U-Ti complex is present as stringers and inclusion in clastic quartz.
Shallow inter tidal flat / mud flat sediments -- Mud cracks, ripple marks, intraforamtional conglomerate layers

Organic activity /deposition of algal debris -- Secondary structures like secretion nodules, oolites and stromatolites

Source of uranium -- Fertile basement granite in the SW

3 stages of uranium concentration

*Syngenetic stage:* Adsorbed U in phosphate - Algal debris created reducing environment leading to the formation of pyrite and precipitation of uranium

*Diagenetic stage:* Dolomitisation/ formation of microstylolites and uranium mineralisation

*Epigenetic stage:* Pitchblende, coffinite in grain boundaries, micro fractures, bedding planes
Transverse Section along 1200 W Grid
Tummala Palle Area, Cuddapah Dist, A.P.

Scale 1:1000

INDEX
- One Band
- Cherty Limestone
- Purple Shale
- Dolomite
- Conglomerate
- Massive Limestone

URAM-2009
Tabular, stratabound, non-transgressive ore zones, homogenous

Mineralisation extends for 160 km along the strike

Limited variation in grade and thickness along strike as well as in dip directions

Two ore lodes – separated by 3m (average) lean zone

Basic dyke which lies in the centre of the deposit has not disturbed the continuity of the mineralization
Extensive Drilling -- 160 km long belt of near-isotropic(?) uranium mineralisation along the strike

Sedimentary facies mapping of massive / cherty limestones of Vempalle Formation to identify pockets of higher grade mineralisation

Geochemical characterisation and genetic modeling for U, Mo and other elements in the orebody and provenance rocks

Construction of mine and mill in progress
GEOLOGICAL MAP OF PART OF RAJASTHAN SHOWING URANIUM OCCURRENCES
Uranium mineralisation intermittently along 320 km long east west trending Kaliguman lineament

North Delhi fold belt lies in the northern part of the lineament

Comprise Khetri, Alwar and Lalsot-Bayana sub-basins

Middle Proterozoic Metasedimentary rocks with acidic intrusives

Extensive albitisation

Established a low grade – low tonnage uranium deposit in Rohil village

Scope for similar mineralisation along the 320 km long lineament in other sectors.
Disposition of orebody and surface projection - Rohil

GEOLICAL MAP SHOWING BOREHOLES LOCATION OF ROHIL AREA (CENTRAL BLOCK) DISTT. SIKAR, RAJASTHAN

TOPOSHEET NO. 45M/6

Scale

GEOLOGICAL MAP SHOWING BOREHOLES LOCATION OF ROHIL AREA (CENTRAL BLOCK) DISTT. SIKAR, RAJASTHAN

SCALE

INDEX

SOIL COVER QUARTZITE SHEAR ZONE/FAULT SURVEY STATION CONDUCTOR AXIS

Rohil Prospect

Dissection DVR Projection

Transverse Section through B.S. 8.5/21/45(1) RAH, 88.4/21.53
(Roohil Station Block) 8.5 B.S. 88.4/21.53 Rohil

3.4.11

D.D. 917.25m

1. Main Lodes
2. Right Lodes
3. Faults/Shear Zones
4. Contact Zones
5. Other Areas

Samadhi School

Projected U-Lodes

URAM-2009
Mineralisation along shear zones and fractures

Confined to albitised meta-pelitic rocks and neighborhood

Mineralisation is associated with massive sulphide minerals

Sulphide minerals are manifested as good conductors in the ground and airborne electromagnetic data/images

Areas of hydrothermal activity represented by a low magnetic zone as a result of alteration of minerals of high magnetic susceptibility

Axial planes are the zones of intense shearing
Exploration strategy for NDFB

Area is mostly covered by quaternary alluvium

Geological and radiometric study of scanty outcrops

Hydro-geochemical surveys

Radiometric logging of pre-existing groundwater tube wells

Areas along the Kaliguman lineament with
area of albitisation
linear low magnetic zones
association of high conductors
association of shear/fracture zone and axial planes of folds
are the signatures for possible uranium mineralisation in NDFB

Mathematical modeling of geological and geophysical datasets

Exploration programme stresses on extensive airborne geophysical surveys and a matching drilling campaign
Mahadek basin
Upper Cretaceous Lower Mahadek sediments are the host for Sandstone type uranium mineralisation in Meghalaya, India

Meghalaya plateau in northeast India is a horst block uplifted during Eocene along with Himalayan orogeny.

Southern part of Meghalaya plateau is exposed with 1800 sq.km of Cretaceous and Tertiary sediments.

Two medium grade low tonnage deposits and four satellite deposits have been established in this province.

Lower Mahadek sediments (thickness-30-40m) are of fluvial nature and characterised by Channel filled and flood plain sediments.

Lower Mahadek sediments are exposed over 500 sq.km area, while in the remaining 1300 sq.km, they are overlain by younger Tertiary sediments.

The channel filled sediments of the lower Mahadeiks are the target horizon for sandstone type of Uranium mineralisation.
Correlation sections of Domiasiat uranium deposit

CORRELATION SECTIONS
KILLUNG BLOCK
WEST KHASI HILLS, MEGHALAYA

DIP SECTION LINE NO. "E-0 5"

STRIKE SECTION LINE NO. "N-0 5"

LEGEND
- OXIDISED SANDSTONE
- GREY REDUCED SANDSTONE
- MINERALISED BAND AT 9.02% eU3O8 CUT OFF
- MINERALISED BAND AT 9.01% eU3O8 CUT OFF

URAM-2009
Deposited as tabular/peneconcordant body along palaeo channels of basement topographic lows in a proximal braided channel system

Average vertical impact is 30m

Pitchblende, uraninite, coffinite, U+Si+C complex & secondary uranyl complexes are the uranium minerals

73 - 92% laechability by pug Cure, hot agitation & conventional leaching

Associated elements are V, As, Co, Se, Mo, Organic matter : 0.5 to 1%
Uranium exploration strategy

Mahadek sediments -- 500 sq.km exposed: Radiometric surveys done; rest 1300 sq.km covered by up to 300m thick pile of Tertiary sediments.

Most of the area under thick forest cover and wildlife sanctuary.

Micro-geomorphological studies using aerial photos and high resolution satellite images for the delineation of Channel sediments and Flood plain sediments among the exposed parts of Lower Mahadeks.

Ground magnetic and resistivity surveys for the delineation of palaeo-channels and basement lows.

Other geophysical inputs

* TDEM for delineation of palaeo channels where the target is covered by a thick pile of Tertiary sediments
* Gamma-ray spectrometer survey
* Magnetics and Resistivity surveys for basement topography
* Drilling with geophysical logging
Characteristics of uranium mineralisation in Gogi area

Small – medium grade deposit

Uranium mineralisation associated with tectonised limestone and sheared basement granites

Mineralisation in the environs of thrust plane and unconformity

Coffinite and pitchblende are major uranium minerals

Mineralisation is intimately associated with carbonaceous matter

Alteration in basement are chloritisation and sericitisation
URAM-2009

1. Wadi fault zone
2. Karankot – Kallur
3. Wajhal – Tintini
4. Sedam – Ekmai
5. Santi – Achola:
6. Shahabad – Bankur
Exploration strategy

Radiometric and Geological mapping

Geochemical, petro-minerological characterisation of ore body and host rocks

Airborne and ground based geophysical surveys (TDEM, Magnetic and Radiometrics)

Radiometric logging of groundwater tubewells

Genetic modeling of uranium mineralisation
After Geological Society of India, 1999

- **Total aerial extent ~ 8500 sq km**

**Hungund Schist Belt**
- 2.7 Ga, Au-bearing

**Closepet Granite**
- 2.5 Ga, U & Th rich

**Peninsular Gneiss**
- 3.3-3.0 & 2.7-2.6 Ga

**Chitradurga Schist Belt**
- 2.6 Ga, U anomalies
Reduced nature of the radioactive core

Presence of rich sulphides in the mineralized portions in dispersed form as well as fracture fillings

Replacement of sulphide (pyrite) by the uranium phase.

Presence of secondary uranium mineral

Absence of oxidized basement schist below the unconformity

Higher concentration of uranium mineralization and the associated sulphides in structurally weak zones and in paleo-lows.
## Uranium mineralisation in Kaladgi sediments

<table>
<thead>
<tr>
<th>Nature of host rock</th>
<th>Quartz arenite</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Uranium Minerals</strong></td>
<td>Pitchblende, Uraninite, Brannerite and secondary uranium</td>
</tr>
<tr>
<td><strong>Associated minerals</strong></td>
<td>Pyrite, hematite and limonite</td>
</tr>
<tr>
<td><strong>Alteration</strong></td>
<td>Secondary silica overgrowth, replacement of pitchblende along borders and fractures of pyrites</td>
</tr>
<tr>
<td><strong>Controls of mineralisation</strong></td>
<td>Hydrothermal epigenetic along fractures and weak planes</td>
</tr>
</tbody>
</table>
The anomaly amplitudes decreases towards SW indicating the increase in the sediment thickness.
The high gradient in NE may be due to NW-SE trending structural dislocation.
Localized N-S trending gravity low in the vicinity of boreholes DNR-13 and DNR-17 is proved to be mineralized. Hence such lows may form favourable locales.
Magnetic Surveys in Deshnur area

Magnetic Image suggest the N – S feature associated with mineralisation

URAM-2009
Indian uranium deposits – a comparison
India’s Uranium Resources through the years

124,828 t U₃O₈
As on 2009
Concluding remarks

- India has vast low grade uranium resources in Cuddapah basin

- Very high potential to host high grade unconformity related mineralisation in the Proterozoic basins

- India has 14 Proterozoic basins, of which three known to host unconformity related uranium deposits hosted and vein type mineralisation – Potential for huge uranium resources

- Areas in Rajasthan along Kaliguman lineament is open for exploration

- Uranium mineralisation has been established in all the other Proterozoic basins
Uranium exploration in India is now geared up to face the challenges of the rapidly growing domestic nuclear power sector and has carefully laid down plans for the next five to ten years.

Airborne Time Domain Electromagnetic surveys have been introduced in a big way in the uranium exploration programme of the country. More than 4,00,000 line km of airborne geophysical surveys, including TDEM, Gamma-ray spectrometric and magnetic surveys are proposed to be carried out over potential Proterozoic Basins of India.

An ambitious drilling programme to drill about 7,00,000m in potential target areas of the country has already been formulated in order to augment the uranium resources.