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URANIUM MINING IN JHARKHAND – STATE-OF-ART NEW VENTURES

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1. Introduction

Uranium is commonly understood as a naturally occurring radioactive material with a huge source of energy. Most of the world's mined uranium is used to generate electricity in nuclear power stations. Nuclear energy currently provides about 17 per cent of global electrical power, but there are some countries, which meet 75 per cent of their electricity need from nuclear power stations.

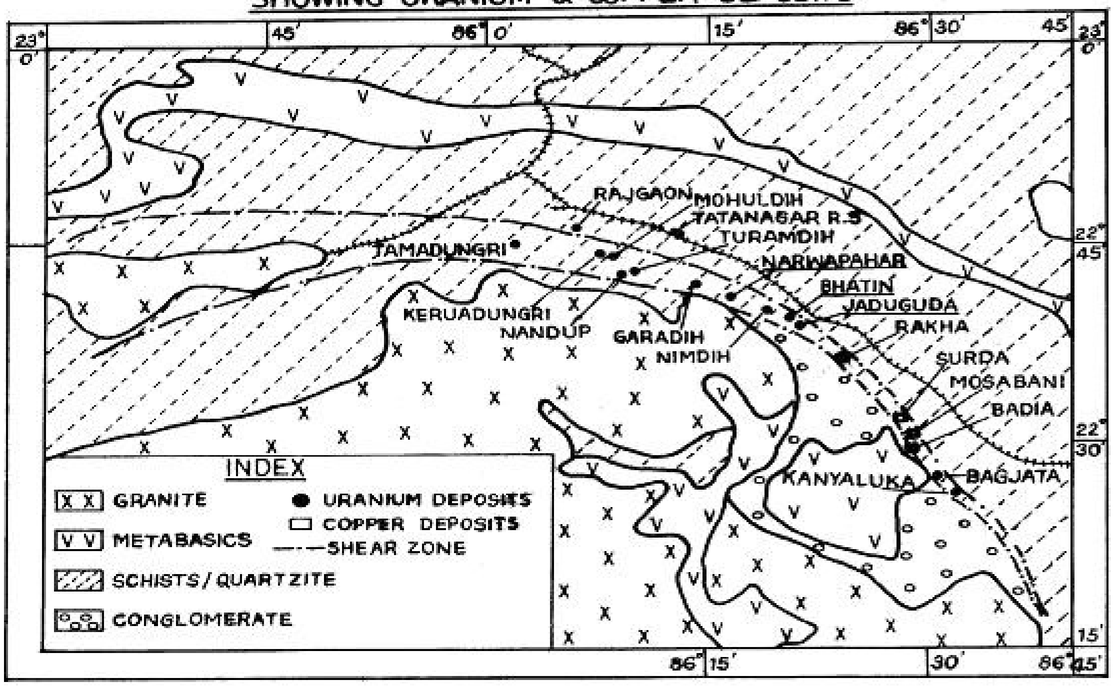
While traces of uranium occur almost everywhere on earth, the highest concentration is found in the earth's crust. Almost all types of rocks on earth contain some amount of uranium. It is also present in river water, ground water and even in seawater. But, the common source of uranium for mankind is the rocks. In spite of this ubiquitous nature of uranium, the rich uranium deposits are rarely occurring on earth. The method of mining of uranium ore is very much similar to other minerals. Conventional open pit or underground method of mining contributes about 75% of world uranium production. The growth of uranium mining normally follows the growth pattern of nuclear power generation capacity.

2. History of uranium mining in Jharkhand

In our country, a marked beginning for the ambitious atomic energy programme was made with the formation of Atomic Energy Commission in 1948. Consequent to this development, it was felt that the country must have indigenous resources of basic raw material i.e. uranium. A group called Raw Materials Division (later on renamed as Atomic Minerals directorate for Exploration and Research) was formed by Govt. of India to explore and locate good uranium deposits in the country. During that period (i.e. early fifties), not much of information on uranium occurrences was available. Hence, the first emphasis of search was laid on the existing mineral belts of the country and geologically favourable areas. Association of uranium with copper and gold was known in some parts of the world. On this analogy, the copper belt of Singhbhum (Singhbhum Thrust Belt in former Bihar, presently in Jharkhand) and Rajsthan and gold fields of Kolar (in Karnataka) were searched. The pioneering work of the first group of geologists, brought to light many uranium occurrences in Singhbhum Thrust belt and soon it became evident that this belt holds the potential for commercial uranium mining operation. Jaduguda in Singhbhum Thrust Belt is the first uranium deposit to be discovered in the country in 1951 and exploratory mining activities commenced in this deposit in 1957. Subsequently, intensive exploration work was taken up by AMD in this region and quite a few more deposits were brought to light. Some of these deposits like Bhatin, Narwapahar, Turamdih are well known uranium mines of the country now and other deposits like Bagjata, Banduhurang, Garadih, Mahuldih etc have the potential for commercial mining operations. Some of the other areas like Kanyaluka, Nimdih, Nandup in this belt are also known for occurrences of very limited poor grade reserve of uranium. Low values of uranium are also present in the copper ores of Singhbhum region with the potential for its extraction as by-product.

Fig. 1

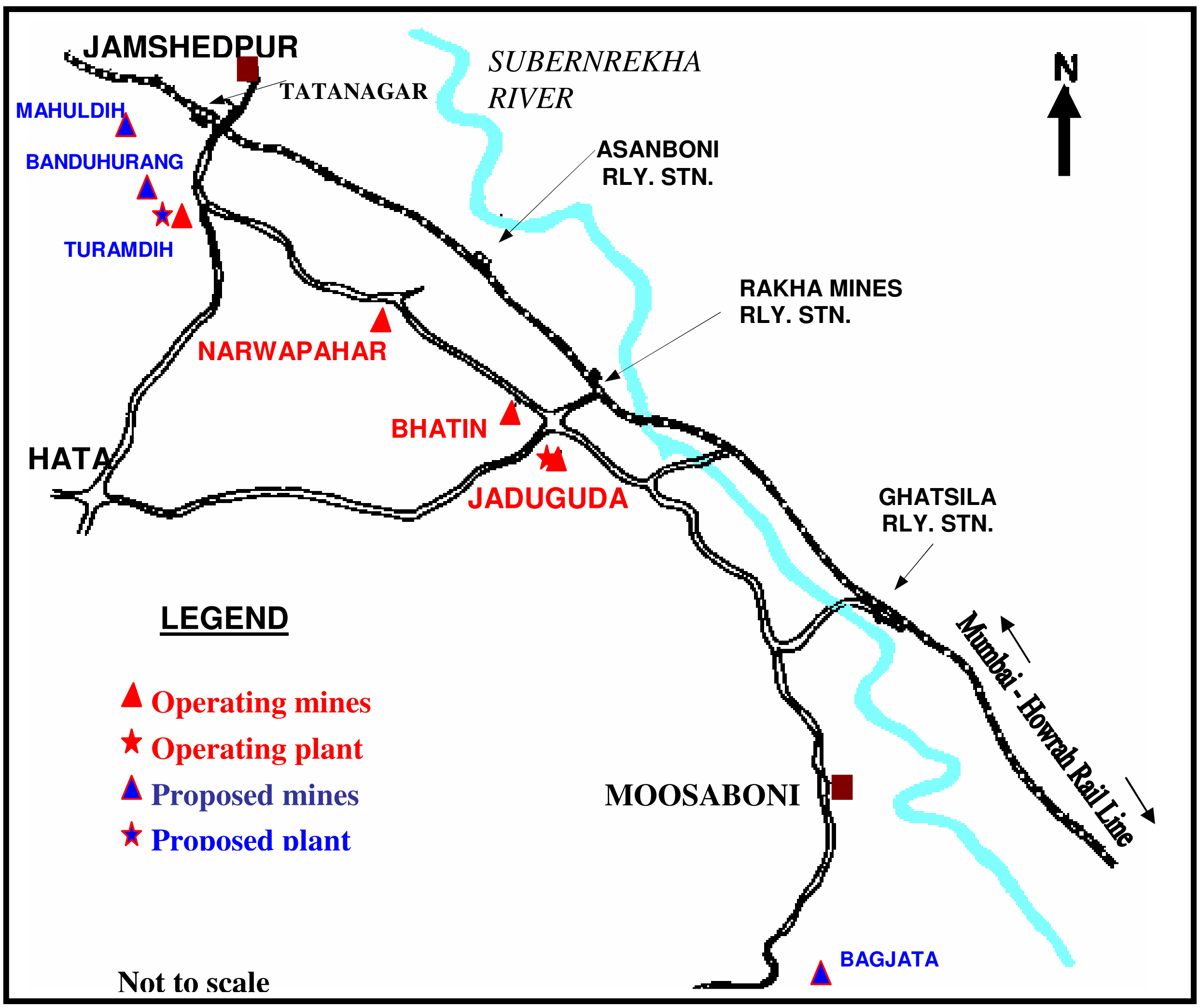
GEOLOGICAL MAP OF SINGHBHUM SHEAR ZONE
SHOWING URANIUM & COPPER DEPOSITS



3. Operations of UCIL

In Oct 1967, Uranium Corporation of India Ltd, a public sector enterprise under the administrative control of Department of Atomic Energy was formed with an objective to mine and process uranium ore in the country. The corporation made a humble beginning with only one underground mine at Jaduguda in the Singhbhum East district of Jharkhand and a process plant near the mine. As the requirement of uranium increased with the increasing capacity addition of nuclear power in the country, UCIL opened several new mines in this area. During the last four decades, the activities of the corporation has expanded manifold with the addition of some more operating units. Presently, all the operating units of UCIL are located in the Singhbhum East district of Jharkhand.

Fig.2



A brief description of all the operating units of UCIL is presented below.

3.1 Underground mining: UCIL, at present is operating four underground mines in the region.

3.1.1 Jaduguda mine: Jaduguda is the first mine in the country to produce uranium ore at a commercial scale. It was commissioned in 1967. The mineralisation at Jaduguda is structurally controlled and is confined to shears. The principal mineral of uranium is uraninite. The main entry to the mine is through a vertical shaft. The shaft is circular in shape having 5m finished diameter and is concrete lined throughout. The depth of the shaft is 640 metres, which was sunk in two stages. Levels are generally developed at vertical intervals of 65 meters. The principal stoping method adopted in Jaduguda Mine is horizontal cut-and-fill using deslimed mill tailing as the fill. The mine has now been deepened in third stage as the ore body continues downdip. An underground vertical shaft has been sunk from a depth of 555m to 905m. Deeper levels are being created now.

3.1.2 Bhatin mine: Bhatin is a small uranium deposit situated 3km west of Jaduguda. Geological settings, mineral assemblages and other host rock characteristics in Bhatin are similar to Jadugdua deposit. This mine was commissioned in 1986. The entry to Bhatin mine is through an adit driven at ground elevation. Two principal winzes have been sunk upto 135m below surface. Levels are developed at every 28m vertical interval upto a depth of 84m. Horizontal cut-and-fill is the principal stoping method adopted in Bhatin Mine. The mine uses deslimed mill tailings of Jaduguda mill for back-filling. Mine deepening at Bhatin has now been taken up to create additional production levels.

3.1.3 Narwapahar mine: It is located 12km west of Jaduguda which was commissioned in 1995. A 7^0 decline has been developed as entry to the mine in the footwall side of the ore body through which large machinaries move underground. From the decline, ramps are developed as entry to the stopes at different elevations. This has helped in using large trackless mining machinaries like twin-boom drill jumbo, low-profile-dump-truck, service truck, passenger carrier, low profile grader, scissor-lift etc. The technology has brought early commissioning of the mine with high productivity and low mining cost. It has also provided the flexibility to adopt different stoping methods that becomes suitable due to the variations in width and inclination of the ore lenses. Cut-and-fill is the principal stoping method adopted in Narwapahar mine. The deslimed mill tailings of Jauguda mill and the waste generated from the mine are used as the filling material. Hoisting of ore from deeper levels is done through a vertical shaft sunk upto a depth of 355m.

3.1.4 Turamdih mine: Turamdih uranium deposit is located about 24km west of Jaduguda and 5km south of Tatanagar Railway Station. This mine started operation in 2003. The entry into the mine has been established through a 8 degree decline which provides facilities for using trackless mining equipment like passenger carrier, drill jumbo, low-profile dump truck etc. At a depth of 70m, the orebody has been accessed from the decline by a cross-cut. Drives are being developed following the contacts of orebody. A vertical shaft of 5m diameter will be sunk from surface upto a depth 250m with services for ore hoisting and movement of men & material.

3.1.5 Uranium ore processing: The uranium ore processing plant at Jaduguda is the first and only one of its kind in the country to treat the uranium ore. It was commissioned in 1968 and is in continuous operation since then. With the opening of new mines, capacity of the mill has already been expanded in three different stages to treat the additional ore. Presently, the plant is fed with the ore produced from Jaduguda, Bhatin, Narwapahar and Turamdih mines. The ore of different sizes undergo crushing followed by two stages of wet grinding. The ground ore in the form of slurry is thickened and leached in leaching pachucas under controlled pH and temperature conditions. The leached liquor is then filtered and undergoes ion-exchange in which uranyl ions get absorbed in the resin. This is further eluted and treated with magnesia to get magnesium di-uranate or yellow cake which is thickened, washed, filtered, dried and packed in drums. The final product of UCIL plant is the Yellow-cake (magnesium di-uranate), which is sent to Nuclear Fuel Complex, Hyderabad for further processing to nuclear grade fuel.

The plant at Jaduguda is unique in design to maximize the re-use of water, high recovery of the product and minimum discharge of effluents. It has several automated process control mechanism and on-line monitoring system.

3.1.6 Uranium recovery from copper ore: The copper ore of Singhbhum Thrust Belt contain some low values of uranium. After detailed studies on mineral characteristics, UCIL had constructed three plants near the copper concentrators of Hindusthan Copper Ltd at Moosaboni, Surda and Rakha. After the extraction of copper, the tailings were being sent to UCIL plants. These copper tailings were being subjected to tabling process of separation generating uranium minerals concentrate. The uranium concentrates from all the three plants were being transported to Jaduguda mill by road for further processing. Unfortunately, with the closure of copper mines in this region, UCIL has also closed down these uranium recovery plants.

3.2 By-product recovery: The uranium ore of Singhbhum Thrust belt contain about 3% magnetic minerals. Magnetite is recovered in a magnetite recovery plant constructed near the mill. The magnetite produced in this plant is about 95% magnetic and finds its use in coal washeries.

4. Atomic energy programme of the country:

During last five decades, with the increasing need of energy for the accelerated agricultural and industrial growth, the Atomic Energy Programme of our country has gained considerable momentum. The Government is committed to appreciable increase in contribution of nuclear power to the total power generation capacity and it has been felt that a balance mix of hydel, coal and nuclear power is a must for meeting the long term power requirement. The Department of Atomic Energy accordingly, has very strategically designed the nuclear power programme of our country and an immediate goal has been set to produce 20,000 MWe of nuclear power by 2020 AD. The department has drawn a well thought-out plan to progressively achieve this target.

Consequently, the facilities are being built-up to augment the uranium production. The new areas with the potential of large good grade uranium reserve have been located in different parts of the country and production centers like mining and milling facilities are being constructed by UCIL in some of those areas.

5. New ventures of UCIL in Jharkhand

Though many uranium deposits have been discovered in different parts of the country, till today Singhbhum Thrust Belt in Jharkhand holds the largest inventory of uranium hosting a number of medium to small uranium ore deposits. This region has the potential to contribute lion's share of uranium for the country's need for many years to come. Accordingly, UCIL plans for optimal exploitation of uranium by developing three more mines and constructing a new processing plant in this region. All these new ventures are located in Singhbhum east district around Jaduguda. The new mines have been planned with several design inputs from reputed consultants, experts, educational & research institutes and in-house professionals. Various laboratory and site tests have been conducted and the inputs thus generated are used as the basis for mine design. Some state-of-art integrated software are used to establish the configuration of orebody. The proposed mines are also being designed with these software and modeled with various geo-technical and financial parameters. The new process plant has also been designed taking into account many modern concepts with due consideration to vast experience of plant operation at Jaduguda and inputs of various laboratory and pilot plant studies on ore samples conducted in-house and in selected laboratories of the country. Information and data available on several similar modern operations of overseas countries are also given due consideration.

All these mining and processing projects of UCIL are scheduled to be commissioned during X plan period. A brief description of these projects is given below.

5.1 Banduhurang opencast mine: Banduhurang uranium deposit is located 30km west of Jaduguda. It is the southern and western extension of orebody at Turamdih mine. The deposit has a large reserve with very low grade of uranium. The orebody lies very close to surface and is amenable to opencast mining.

The mine at Banduhurang will be the first opencast uranium mine of the country. Considering the strategic nature of mineral and low content of uranium, various design details and quality control techniques have been incorporated while designing the mine. MECON Ltd. was engaged as the consultant to prepare the detailed project report. The details in this regard are being dealt separately. Fund allocation for this project has already been made in X five year plan and pre-project activities have been taken up by UCIL. This mining project will be commissioned by 2006-07.

5.2 **Bagjata underground mine:** This deposit is located about 24km east of Jaduguda. Detailed exploration of this deposit by AMD has proved the extension of two uranium lodes in the host rock of quartz-chlorite-biotite schist upto a depth of 600m. The exploratory mining activities have also been carried out by AMD soon after the surface exploration. UCIL has now undertaken the plan to construct an underground mine with an incline shaft and vertical shaft upto a depth of 300m. Levels will be developed at 50m interval. Cut-and-fill method of stoping has been proposed in his deposit with moderate level of mechanization employing macineries like drill jumbo, electric LHDs, pneumatic loaders, locomotives etc. The ore produced from this mine will be transported to Jaduguda mill for processing and the deslimed mill tailings from Jaduguda will be used as fill. Detailed project report has been prepared by UCIL and the fund allocation has already been made in X five year plan. UCIL has started pre-project activities like land surveying, EIA/EMP studies etc and various statutory clearances are being sought from Govt. agencies. This project will be commissioned in 2007-08.

5.3 **Mahuldih underground mine**: Mahuldih deposit is located 3km west of Turamdih mine, about 27km west of Jaduguda. The two prominent lodes in this deposit hosted by tourmaline bearing quartzite and quartz schist were explored in 1980s by AMD. UCIL has prepared the feasibility report to develop this deposit by underground mining operations. The mine is being proposed with a decline and a vertical shaft as entry. Cut-and fill method of stoping is being proposed with the use of trackless diesel equipment. The ore produced from this mine will be processed along with the ore of Turamdih mine and Banduhurang mine in the processing plant at Turamdih, which is under construction.

5.4 **Turamdih uranium ore processing plant**: A new ore processing plant at Turamdih is being set-up adjacent to Turamdih mine which will be fed by the ore produced from Turamdih and Banduhurang mines. As the mine development work of Mahuldih progresses, supplementary facility will be created in this plant to treat additional ore. The detailed flow sheet and design parameters for the Turamdih plant have been conceptualized by engineers and scientists of UCIL. The detailed project report of this plant has been prepared by Development Consultants (P) Ltd, Kolkata. This project has already got the approval of Govt. of India and the construction work is in progress. Many new technology and equipment have been proposed in this plant with large scale automation and state-of-art monitoring system. The operating procedure and environmental control measures proposed to be adopted in Turamidh plant are comparable with the best practiced in similar industries anywhere in the world. This plant will be made operational within next 30 months period.

6. State-of-art new mine – Banduhurang

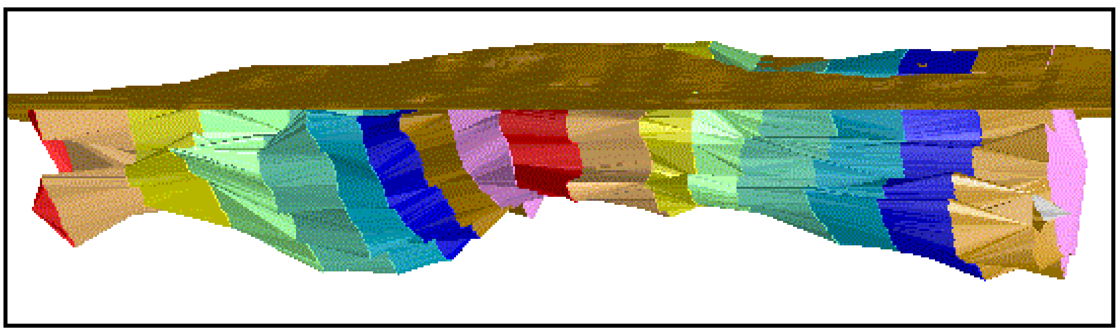
Banduhurang uranium deposit is located about 6 km south of Tatanagar railway station. Atomic Minerals Directorate for Exploration and Research (AMD) has carried out detailed exploration in this area during 1982-85 involving 24,600 m diamond core drilling at 138 locations. This deposit is now being developed as one of the most modern opencast mines of the country. The proposed mining lease covers approximately 466.5 acres.

6.1 General geology: The mineralisation in Banduhurang falls within Singhbhum Thrust Belt. Uranium mineralsation is confined within chlorites and felsparthitic-chlorite schist while the sericite quartz schist is devoid of any radio-activity and appear to act as footwall marker horizon of mineralisation. Topographically, the mineralisation is confined within moderately risen hillocks disposed as EW trending ridges having maximum elevation of 228 m from MSL. The surrounding topography has elevation varying from 140 to 178 mRL. The general strike of ore body is almost east-west with a variable dip. In the western part of the deposit, the dip of ore bodies varies between 60^o to 70^o due north, whereas the central and eastern part of deposit shows gentle dip of the order of 10^o to 20^o due north.

6.2 Ore body modeling and reserve estimation: After compositing the assay values at 2 m interval, ore zone limits have been interpreted on the 17 transverse sections (Fig.3). The details of these ore zones were used as the primary inputs for development of 3D ore body model of the deposit. The concept of triangulation and tribulation have been applied to convert the two dimensional ore boundaries into 3D solid model over the entire strike length of the deposit. A very marginal uranium value was considered as the minimum cut-off in order to demarcate the ore zone for the model. The transverse section of ore body stitched into a 3D ore body model with surface DTM has been shown in Fig 4.

Fig. 3 : Transverse sections of ore body

Fig. 4: 3-D Ore body model with surface topography



3D block model was used for subsequent pit optimisation and mine planning. The unit block size in block model was kept at 15m X 10m X 6m (bench height), considering the bore hole spacing across and along the strike. In order to select the optimum bench height, following criteria was kept in view:

- Minimum variability in ore quality between benches. The co-efficient of variation determined for various set of bench heights (block height) showed that 6m bench would have minimum variation. This criteria assumed significance because ore blocks within a bench are scattered and not limited within definitive boundaries.
- Limitation in blasted material size to –800 mm.

Thus, the bench height was selected as,

Ore	:		6m
OB/waste	:	a)	6m in immediate vicinity of ore benches
		b)	12 m composite bench beyond ore zone

Compositing overburden benches led to less number of benches at ultimate position, steeper pit slope and lower stripping ratio.

After carrying out statistical analysis, the geo-statistical studies showed that the deposit is not amenable to kriging. Therefore, inverse squared distance method was used for assigning assay data to each block.

6.3 Cut off : Geological cut off was kept at a value where it was observed that with marginal increase in cut off grade, the average grade increases minimally while the geological reserve reduces sharply. The cut off grade value was further confirmed during pit optimisation studies, where the economic pit shell remained almost the same with increase in cut off over a range.

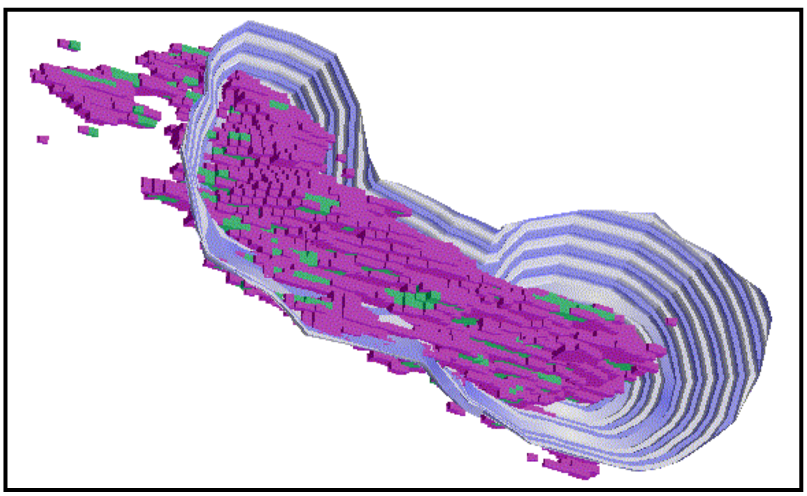
6.4 Dilution during mining: From the 3D block model it was observed that ore zone is enveloped by sub-grade zone (little less than the cut-off grade) which is further enveloped by a zone having still low uranium values. The average grade of sub-grade zone was estimated and it was envisaged as the contributory factor for diluting the run-off-mine ore during actual mining operation. This dilution factor was introduced in the block model before pit optimisation.

6.5 Geo-technical studies : CMRI, Dhanbad was assigned the task of geo-technical, blasting and hydro-geological studies. Boreholes were strategically drilled for the purpose and on-site as well as laboratory tests were conducted. Following details obtained from above studies were utilised during subsequent mine design.

- Average rock strength characteristics are RQD = 80%, compressive strength = 80 MPa, tensile strength = 10 MPa.
- Ultimate pit slope for pit depth up to 120 m depth is 47^o while for depth more than 120 m it is 44^o.
- Bench orientation for optimum fragmentation is N80^o.

6.6 Pit optimisation: Whittle open pit optimisation package which uses Lersch-Grossman algorithm was used to carryout pit optimisation. As input data, cost of mining ore and waste per tonne was estimated for different depths of pit by dividing the pit vertically into five zones. Cost of processing ore, recovery at plant and sale price of processed ore was also taken as input beside the geo-technical parameters. After considering range of pit shells, the optimum shell was selected which would meet the ore reserves (life of mine), average grade and stripping ratio. 16 m wide haulage road was aligned at 1 in 16 gradient to reach the different benches of the optimum pit up to the pit bottom. The pit slope stipulation required berm width of 8 m for 12 m high bench at ultimate pit limit. There will be two pits within a large pit (Fig.3). The western pit will have pit bottom at 56 mRL while the eastern pit will bottom at 8 mRL. Thus maximum depth of pit from surface will be about 164m. At 2400 tpd or 0.72 Mt/yr of ROM ore and ore : waste ratio of 1:1.1 (t : m^3), the life of mine will be 25 years.

Fig. 5 : Ultimate Pit Outline with ore blocks



6.7 Mining method: The proposed mining at Banduhurang will be a conventional opencast mine using excavator-dumper combination. Careful selection of HEMM was required to maintain ore benches of 6m height, OB/waste benches of 6m/12m height while maintaining ROM quality as well as stripping requirements. A code of practice was formulated for control of ROM quality for this low grade deposit. All important areas will be connected by intranet system for proper planning and control.

6.8 Waste dumping and reclamation: To facilitate simultaneous backfilling of mined out void, it has been planned to first mine out the western pit which is shallower and back fill it with waste generated from the eastern pit. The waste generated from the western pit will be externally dumped in two layers of 20 m and 15 m thickness.

6.9 Ore Processing: ROM ore of Banduhurang mine will be transported to Turamdih mill (1.5 km) where it will be crushed along with ROM ore produced from Turamdih underground mine. The construction of Turamdih mill has already started.

6.10 Environmental Control Measures : Stringent control measures will be exercised to ensure that pollutants associated with mining activity are minimised. The mine water will be pumped to a series of de-silting and monitoring ponds before being stored in a pond which will serve as intake water source for mill operation. Thus mine water will not be allowed to escape into surrounding environment. Elaborate drainage network has been planned around the external waste dump to channelise the rain water which will be treated along with mine water.

Wet drilling, water sprinkling on haul roads, green belt, technical and biological reclamation of external dump and back fill are other environmental control measures which will be undertaken during the course of the operation.

As an independent monitoring unit, the Health Physics Unit of Bhabha Atomic Research Center, Mumbai located at Jaduguda and Narwapahar shall regularly carry out the radiological and other safety related aspects of this project.

The well-equipped Environmental Survey laboratory set-up by BARC at Jaduguda shall also regularly monitor the status of the environment around the mining unit.

7. Conclusion:

Today, Uranium Corporation of India Ltd. has emerged as a major mining giant of the country with various ongoing projects in Jharkhand. Some other mining and ore processing projects in different parts of the country are also in pre-project stage amongst which mention may be made of Lambapur uranium project in Andhra Pradesh and Domiasiat uranium project in Meghalaya. Tomorrow's UCIL is poised for a massive growth with technological and scientific excellence aspiring to progressively achieve the capability of meeting the entire fuel requirement for the targeted generation of nuclear power. The corporation during its 36 years of operation in Jharkhnad, has always shown utmost concern towards the safety of the people and the environment. Safety standards followed at all the operating units of UCIL are the best amongst the comparable industries. Environmental control measures adopted at all the units are very stringent following the guidelines of national and international regulatory bodies.

The corporation is always acclaimed amongst the local people for its multitudinous welfare activities undertaken specially towards the up-liftment of tribals. It has shown utmost concern for the employment, education, health care, infrastructure development, promotion of sports, cultural programme etc amongst the local people.

The corporation has successfully obtained ISO-9002 and ISO-14001 certification for its excellent work practices and environmental protection measures followed at different operating units. As the corporation marches ahead with its noble endeavor, all efforts are being made to accomplish a greater all-round socio-economic development around all its operating units.

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