Proposal on prospecting for REE and associated rare metals in Redhakhol Area in parts of Sambalpur and Angul District, Odisha for Reconnaissance Survey (G4 Stage) under NMET.

(Strategic & Critical minerals)

By

My World Consultancy Services Pvt. Ltd.

Place:

Date:

Summary of the Block for Reconnaissance Survey (G4 Stage) GENERAL INFORMATION ABOUT THE BLOCK

	Features	**Details**
	Block ID	
	Exploration Agency	My World Consultancy Services Pvt. Ltd.
	Commodity	REE with associated Rare Metals
	Mineral Belt	Eastern Ghat Mobile Belt (EGMB)
	Completion Period with entire Time schedule to complete the project	12 months
	Objectives	1. To delineate potential zones of REE mineralization for further exploration under G3/ G2 stage. 2. To ascertain presence of rare metals associated with REE.
	Whether the work will be carried out by the proposed agency or through outsourcing and details thereof. Components to be outsourced and name of the outsource agency	The work components proposed will be carried out by WCS with its in-house facility except chemical analysis.
	Name/ Number of Geoscientists	2 Geologists 2 Geophysicist
	Expected Field days (Geology) Geological Party Days	120 Geologist party field days 45 Geophysicist Party field days
1.	**Location**	
	Latitude	21.034668 ^{0}N to 21.000071^{0} N
	Longitude	84.444029^{0} E to 84° 84.268371^{0} E
	Villages	**Sambalpur Dist:** Purunagarh, Kkhajurijharan, Kulhamali, Karada Pali Sashana, Laindamal, Jhankarpada, Baniabandha, Patakhamana, Barakura, Tala, Shishupanna, Tileimal, Angarpara, Ambpal, Sundhimundapahada, Kelakata, Badahal, Kendukata, Jhintikakhol, Maulabhanaja, Jaripani, Kuhi, Kulapathar, Podabalanda **Angul Dist:** Dadarpali, Nuagaragadabahal, Garagadabahal, Oskapali, Dalimura, Sahajabahal
	Tehsil/ Taluk	Redhakhol Tehsil of Sambalpur District and Kishorenagar Tehsil of Angul Dist.
	District	Sambalpur Districts and Angul District
	State	Odisha
2.	**Area (hectares/ square kilometres)**	
	Block Area	67.99 sq. km.
	Forest Area	13.25 sq. km.

	Government Land Area	0
	Private Land Area	54.74
3.	**Accessibility**	
	Nearest Rail Head	**Rairakhol or Redhakhol is the nearest Railway Station (RAIR)**, which falls under the Sambalpur Railway Division of the East Coast Railway zone and connects Eastern Odisha with Western Odisha.
	Road	NH-153B passes through the proposed block connecting Redhakhol (4km North) and Boudh (18km south). While **NH-55 (Formerly NH-42) passes through Redhakhol** connecting it directly to **Sambalpur** (approx. 67 km to the north) and **Bhubaneswar/Cuttack** (approx. 260 km to the southeast).
	Airport	Veer Surendra Sai Airport at Jharsuda is the nearest airport at a distance of 130km with regular flight service. Whereas, Biju Pattnaik International Airport at Bhubaneswar is at a distance of 190km from Redhakhol.
4.	**Hydrography**	
	Local Surface Drainage Pattern (Channels)	Drainage pattern is sub-dendritic to Sub-parallel. The drainage density is moderate.
	Rivers/ Streams	Karandi Jor a tributary of Mahanadi drains across the block area. It is the main drainage channel in the area flowing from north and meets Mahanadi river near Kiakata in south.
5.	**Climate**	
	Mean Annual Rainfall	1638 mm
	Temperatures (December) (Minimum) Temperatures (June) (Maximum)	5^0C 46^0C
6.	**Topography**	
	Toposheet Number	73C/08
	Morphology of the Area	The area represents an undulating topography covering northern boundary of EGMB. Topographic elevation ranges from 140m along the Karadi Nala to 600m on the south western corner.
7	**Availability of baseline geoscience data**	
	Geological Map (1:50K/ 25K)	**Available 50K and 25K**
	Geochemical Map	**Available (NGCM, FS 2001-02)**
	Geophysical Map (Aeromagnetic, ground geophysical, Regional as well as local scale GP maps)	**Available (Gravity, Magnetic)**

8.	**Justification for taking up Reconnaissance Survey / Regional Exploration**	Rare earth elements (REEs) are of critical importance to India's strategic, economic, and technological ambitions, particularly as the nation pursues its goals of energy transition, self-reliance (Atmanirbhar Bharat), and becoming a global economic powerhouse. Recognizing the strategic importance of REEs, several measures have been taken by Government of India including participation of Private Exploration Agencies to boost domestic exploration and production. Alkaline igneous rocks are a primary source for rare earth element (REE) mineralization. In Odisha, alkaline magmatism has been reported at the contact part of Cratons and the Mobile Belt. The alkaline rocks with their geological set up have been grouped into three domains i.e. (a) Northern alkaline province (NAP) in contact with Singhbhum Craton (b) Khariar alkaline province (KAP) in contact with Bastar Craton and (c) Koraput alkaline province (KRP) within EGMB. The alkaline bodies exposed for about 6 km length from west of Rairakhol up to Kusarimunda are grouped under Northern alkaline province (NAP). The proposed study area is part of the Rairakhol Alkaline complex and falls in parts of Toposheet No. 73C/08 and 73D/05 in Sambalpur and Angul Districts, Odisha. Basis of the proposal: 1. Geochemical mapping on 1:50,000 scale by S. N. Mohanty and P. Srinivas (FS:2001-02) in Toposheet no. 73C/8 reported, ΣREE concentration in the range of 94.98 ppm to 10112.89 ppm (≈1%). The higher concentration of REE observed over garnetiferous quartzo-feldspathic schist, granite gneiss, pegmatite and quartzite to the southern and western side of the Toposheet. 2. Moharana and Pachauri (2018) during Specialised Thematic Mapping (STM), identified REE mineral phases like allanite, xenotime in syenite pegmatite and nepheline syenite. 3. During 2017-18, reconnaissance survey for REE in alkaline rocks around Rairakhol (Redhakhol) area was taken up by GSI, SU: Odisha (Rana and Roychoudhury, 2019). The EPMA study revealed • presence of allanite, perrierite,

		monazite and Y+REE phosphate phases in the syenites of Beldih and Kusarimunda village. • The Total REE in BRS varied from 2.9 ppm to 2108 ppm. • Stream Sediments total REE varies from 85ppm to 7399ppm. • The highest value is obtained from a mafic granulite terrain SW of Beldihi village. 4. In southern part of the toposheet No. 73C/08, geochemical results of stream sediment samples show two anomaly peaks with ΣREE values of 2713 ppm and 10183 ppm. Accordingly, an area of 67.99 sq. km. on southern part of Toposheet No. 73C/08 near Redhakhol, Sambalpur district, Odisha has been proposed for reconnaissance survey (G4 stage) with following justifications: • The proposed block area includes 18 stream sediment composite samples of NGCM survey carried out during FS 2001-02. All the 18 samples show ΣREE values more than 500 ppm and 11 samples out of 18 samples show ΣREE values more than 1000 ppm. • The area is part of or proximate to the Northern Alkaline Province (NAP) consisting of Syenites and Nepheline Syenites and pegmatites, • Identification of REE phases like allanite, xenotime, perrierite, monazite and Y+REE phosphate in the EPMA studies during STM and reconnaissance study for REE mineralisation carried out on the north of the proposed area. • Presence of Pegmatoidal syenites, pyroxenites and mafic granulites. • Recently, REE mineralisation in EGMB associated with pyroxene bearing syenites and apatite veins in Nayagrah area has been reported for the first time by GSI. On the basis of this new finding, potentiality of pyroxenites and mafic granulites along with syenite and nepheline syenites associated with alkali magmatism in the present area also needs to be evaluated.

Detailed description on the following titles to be made in the proposal.

1. **Block Summary**

Physiography:

The Redhakhol area is mostly a hilly terrain interspersed with valleys of different shapes and sizes. The north eastern part and western part of the proposed area is occupied by hill ranging in height up to 600m RL with cliff faces. Whereas, the middle part of the block is occupied by valley area with an average height of 160m, as Karandi Jhor flowing in the middle from North to South and joins Mahanadi on the further south.

Background Geology (Regional Geology, Geology of the Block).

The Redhakhol area lies in the eastern Indian Shield near the northern margin of the Eastern Ghats Mobile Belt, and Bastar Craton. Its geology is dominated by high-grade metamorphic rocks, granitoids, and younger sedimentary outliers of the Gondwana Supergroup. The area also shows strong structural control, with quartz and pegmatite veining, foliation, and fault-bound contacts shaping the rock distribution.

The crystalline basement includes garnetiferous quartzofeldspathic schist, garnet-sillimanite schist, khondalite, quartzite, coarse granular quartzite, leptinite, and pyroxene granulite. Intrusive bodies such as biotite syenite and granitic gneiss are also present, with granite gneiss and biotite granite gneiss forming a major part of the exposed lithology.

The rocks generally trend WNW–ESE to ENE–WSW, and in places they are nearly vertical due to steep dipping and strong deformation. Granite gneiss commonly shows N–S to NNE–SSW foliation with steep easterly dips. Quartz veins and pegmatite veins are common throughout the area, indicating late-stage intrusive activity and structural reworking.

Gondwana rocks occur as fault-bounded outliers around the central granite gneiss body and rest unconformably on the older basement rocks. They include the Upper Kamthi Formation and Lower Talchir Formation, made up mainly of arkosic sandstone, siltstone, clay, and carbonaceous shale. These sedimentary units are best exposed along the northern and southern margins of the central crystalline tract.

The area is strategically located at the tri-junction of the EGMB to the south, the Singhbhum Craton to the north, and the Bastar Craton to the west. The interpreted tectono-stratigraphy proposed by Moharana & Pachauri (2018) is as follows:

Litho-Assemblage	**Main Rock Types**	**Geological Age**
Cap Rock	Laterite	Quaternary
Litho-assemblage II	Shale, siltstone, sandstone, and conglomerate (Gondwana)	Permo-Carboniferous
Later Intrusives	Syenite, Nepheline syenite, Gabbro/Dolerite, Pegmatite	Proterozoic
Litho-assemblage I	Khondalite, Quartzite, Charnockite gneiss, Mafic granulite (EGMB)	Proterozoic
Litho-assemblage III	Charnockite, K-granite (Singhbhum Craton)	Archaean (?)

The major components of the EGMB in Redhakhol region are high-grade metasediments consisting of :

- **Khondalite Group:** This suite includes light brown, coarse to medium-grained quartz-feldspar-garnet-sillimanite schists and gneisses. These rocks often contain large garnet porphyroblasts (up to 6 cm) and sillimanite needles that define the foliation. Variations include quartz-garnet-sillimanite-mica schists with or without graphite and pure sillimanite schists.
- **Quartzites:** These are the most abundant country rocks and are subdivided into three types based on their protoliths:
    - Coarse-grained Quartzite: White to dull white with a saccharoidal texture.
    - Fibrolite Quartzite: Medium-grained rocks characterized by abundant fibrous sillimanite.
    - Feldspathic Quartzite: Friable, foliated rocks containing kaolinised feldspar and garnet.
- **Mg-Al Metapelite:** A localized unit of orthopyroxene-cordierite gneiss occurs near Gunjighera, featuring alternating stromatic bands of leucosome and melanosome.

Meta-Igneous & Gneissic Rocks

- **Charnockite Gneiss:** Restricted to the southern part of the mapped area, these are melano to mesocratic rocks with a greasy appearance, composed of quartz, feldspar, hypersthene, and biotite.
- **Mafic Granulite:** Fine to medium-grained rocks consisting of plagioclase and pyroxene. Some variants are garnetiferous or contain tourmaline.
- **Granite Gneiss:** Well-foliated rocks featuring gneissic banding of mafic-rich (biotite, epidote) and felsic-rich layers. A megacrystic variety with alkali feldspar megacrysts up to 8 cm is also present.
- **Amphibolite & Schists:** Narrow linear bodies of amphibolite and chlorite schist occur, with the latter potentially representing retrograded metamorphic products of mafic rocks.

Alkaline Intrusive Suite

The EGMB assemblage is distinctively intruded by a Meso- to Neoproterozoic alkaline suite:

- **Nepheline Syenite:** Found near Gunjighera and Sahajbahal, this suite includes massive, gneissic, and pegmatoid varieties. They are mineralogically composed of nepheline, plagioclase, microcline, and biotite.
- **Syenite Pegmatite:** Dominant thick bands of pegmatite, some containing gem-quality minerals like corundum, beryl (emerald), and transparent quartz.

II. Gondwana Supergroup

These sedimentary rocks occur within a fault-bounded basin in the eastern and north eastern part of the TS No. 73C/8, extending towards east from Redhakhol and north east of Doincha area.

- **Sandstone:** Buff-colored, medium to coarse-grained, showing primary structures like trough cross-bedding and ripple marks.

- **Siltstone and Shale:** Laminated sequences; shales are often olive-green and splintery. Some unidentified plant fossils have been recorded in these units near Dalki and Luhapank.

III. Cratonic Assemblage (Singhbhum Craton)

Restricted to the northern part of the mapped area, representing the southern fringe of the craton.

- **Charnockite:** Greyish, greasy rocks with a well-developed gneissosity, often superimposed by mylonitic fabric due to shearing.
- **K-rich Granite:** Pink to grey, fine-grained granophyric rocks. They are often highly sheared, preserving protomylonitic to mylonitic fabrics and pseudotachylite veins.
- **Dolerite Dykes:** Mafic dykes and sills that intrude the K-rich granites and charnockites.

Mineral potentiality based on geology, geophysics, ground geochemistry etc.

The specialized thematic mapping (STM) of the **Rairakhol (Redhakhol)-Balikiari** area in Sambalpur District, Odisha, has revealed significant mineral potentiality ranging from semi-precious gemstones to industrial minerals and rare earth elements (REE).

The economic potentiality of the area is primarily linked to the alkaline suite of rocks and the high-grade metamorphic Khondalite Group within the Eastern Ghats Mobile Belt (EGMB).

1. Rare Earth Elements (REE) and Rare Metals (RM)

The alkaline rocks, specifically the **nepheline syenite** and **syenite pegmatite** suites, are the primary hosts for REE:

- **Geochemical Anomalies:** Previous regional surveys (Mohanty and Srinivasan, 2001-02) identified anomalous concentrations of **Lanthanum (La)**, **Samarium (Sm)**, **Neodymium (Nd)**, and **Cerium (Ce)**.
- **Additional Indicators:** Significant anomalies for **Thorium (Th)** (up to 737 ppm), **Uranium (U)** (up to 120 ppm), and **Zirconium (Zr)** (up to 5766 ppm) have been reported in the area.
- **Mineral Phases:** EPMA studies identified REE-bearing phases such as **xenotime** in cordierite gneiss and **allanite** in syenite pegmatite.
- **In view of recent discovery of REE mineralisation** in pyroxene bearing pegmatoidal syenites in EGMB in Nayagarh area, pyroxene granulites and mafic granulites occurrences of Redhakhol area may also be considered as potential host rocks for REE mineralisation.

2. Graphite

Graphite-enriched **khondalites** are a significant economic resource in this region:

- **Fixed Carbon Content:** Samples collected from the **Ghodadian** area have shown total carbon content up to **50%**.
- **Analysis:** Technical analysis indicates approximately **0.46% total organic carbon** and **0.04% inorganic carbon**, suggesting these khondalites are a primary source for potential graphite mining.

3. Semi-Precious Gemstones

The area is notable for occurrences of several gem-quality minerals, often found at the contact zones of intrusive bodies:

- **Corundum:** Gem-quality corundum is recorded in **mafic granulites** and at the contact between **nepheline syenite** and **syenite pegmatite**. Large crystals have also been reported in the scree of hillocks northeast of Rairakhol.
- **Beryl (Emerald):** Yellow beryl crystals have been identified in quartz syenite pegmatites near **Mangalpur** village. This location is locally known as "Hiraa Khani" due to its mineral wealth.
- **Quartz & Sodalite:** Transparent, hexagonal quartz crystals of gem variety are found in pegmatites, alongside occurrences of sodalite and tourmaline.

4. Industrial Minerals

- **Sillimanite:** A massive **sillimanite schist** body (75 m x 100 m) was reported near **Badmal** village. It contains "gigantic" sillimanite needles reaching up to **15 cm** in length, which are of significant industrial interest.
- **Syenite Pegmatite:** Industrial-grade syenite pegmatites are widely distributed, particularly as thick bands trending NE-SW and N-S near **Gunjighera**, **Sahajbahal**, and **Chhatarpur**.

5. Iron Ore

- **Ferruginous Sandstone:** Within the Gondwana Supergroup near **Dalki** village, chemical precipitation has created iron-rich facies (iron balls). While low-grade, these were historically used for local smelting, as evidenced by large ancient slag dumps found in the area.

Aeromagnetic Data

Aeromagnetic intensity varies significantly across the region, reflecting the underlying geological units and structural discontinuities (Moharana & Pachauri, 2018):

- **High Magnetic Intensity:** Primarily associated with **charnockite** and **granite gneisses**. In the northern part, a NW-SE trending zone of high magnetic values is observed.
- **Low Magnetic Intensity:** Typically found over sedimentary rock units of the **Gondwana Supergroup** and areas dominated by **quartzites**.
- **Structural Anomalies:** The juxtaposition of NW-SE high magnetic trends against adjacent low magnetic values suggests major structural anomalies, such as **faults or shear zones**.
- **Basement Influence:** High magnetic values recorded over certain sandstone and shale units in the central part of the area are attributed to the shallow depth of the underlying magnetic basement.

Implications for Mineralization Potentiality

The integration of aero-geophysical data with geological mapping highlights specific targets for exploration:

1. **Structural Control and Rare Earth Elements (REE)** The NW-SE trending magnetic anomalies align with major shear zones and tectonic contacts. These structures often served as conduits for the emplacement of **alkaline suites** (nepheline syenite and syenite pegmatites), which are the primary hosts for REE minerals like **allanite** and **xenotime**.
2. **Contact Mineralization (Gemstones)** Magnetic discontinuities often mark the contact between intrusive bodies (high magnetic signature) and country rocks like quartzite (low magnetic signature). These contact zones are the primary locations for semi-precious gemstones recorded in the area:
    - **Corundum:** Found at the contact of nepheline syenite and syenite pegmatites.
    - **Beryl (Emerald):** Located where quartz syenite pegmatites have intruded into coarse-grained quartzites.
3. **Graphite and Metasedimentary Targets** While quartzites and khondalites generally show low magnetic intensity, the geophysical maps help delineate the extent of the **Khondalite Group**. These areas are high-priority for graphite exploration, as seen in the **Ghodadian** area, where total carbon content reaches up to **50%**.
4. **Radioactive and Heavy Minerals** Strong geochemical anomalies for **Thorium (up to 737 ppm)** and **Zirconium (up to 5766 ppm)** often correlate with specific magnetic signatures of the granite gneisses and pegmatites, indicating potential for concentrated rare metal mineralization.

NGCM data (Mohanty & Srinivasan, (2016) for toposheet No. 73C/08 show significant variability, with some samples containing exceptionally high concentrations.

The total REE (tREE) values in this toposheet (73C/08)

Statistics	tREE (ppm)	La (ppm)	Ce (ppm)	Nd (ppm)	Y (ppm)
Mean	837.53	196.50	337.90	138.28	39.11
Median (50%)	525.72	110.96	202.76	79.79	37.00
Minimum	151.98	5.42	5.25	16.09	16.00
Maximum	10183.89	2706.88	4934.61	1467.03	79.00
Std. Deviation	1091.42	321.41	513.73	185.69	11.79

Key Observations

- Dominant Elements: Cerium (Ce) and Lanthanum (La) are the most abundant elements across the samples, contributing majority of the total REE content.
- Anomalous Peak: A Sample on the southern part of the TS No. 73C/08 stands out as a major outlier with a total REE value of 10,183.89 ppm, which is more than 12 times the average for the area.
- Heavy REE (HREE): Elements like Yttrium (Y) and Dysprosium (Dy) show much lower mean values (39.11 ppm and 8.19 ppm respectively), indicating that the mineralization in this toposheet is heavily skewed toward Light Rare Earth Elements (LREE).

The anomaly patterns for tREE aligns with regional geological setup indicating REE potentiality in the alkaline suites and pegmatites of the Redhakhol area.

Scope for proposed exploration.

The potential of proposed Redhakhol area is primarily driven by the unique geological setting where the Eastern Ghats Mobile Belt (EGMB) meets the Singhbhum Craton, creating favorable conditions for mineralization. The area shows high promise for REE, particularly Light Rare Earth Elements (LREE):

- **Target Lithologies:** The **nepheline syenite** and **syenite pegmatite** suites are identified as the primary hosts for REE mineralization.
- **Key Indicators:** Mineralogical analysis during Specialised Thematic Mapping as well as during G4 stage investigation for REE taken up by GSI has confirmed REE-bearing phases such as allanite, xenotime, perrierite, monazite and Y+REE phosphate phases in nepheline syenite, syenite pegmatites and cordierite gneiss.
- **Geochemical Potential:** Regional anomalies with total REE reaching up to 10,183.89 ppm (La: 2706.88ppm, Ce: 4934.61 ppm and Nd: 1467.03 ppm) suggest potentiality of the area for further investigation.
- **Remote Sensing and GIS analysis:** From the integrated remote sensing and GIS analysis, the Rairakhol block shows **favourable but heterogeneous REE potential**, with one clearly defined high-priority structural–alteration corridor and two lower-priority zones mainly limited by spectral confidence and structural intensity rather than by lithological suitability.

  Key controls identified

  - **Lithology:** The area is dominated by granite gneiss with granitoids, quartz veins and pegmatitic intrusions, all of which are recognised as favourable hosts and pathways for REE-bearing mineralization.
  - **Structure:** A strong NE–SW lineament fabric, with clusters and intersections in the eastern and western sectors, provides high-permeability zones for hydrothermal fluid flow and structurally controlled alteration, which is critical for REE concentration.
  - **Surface conditions:** ASTER FCC and DEM show ridge–valley topography with exposed, weakly vegetated ridges and structurally controlled highs, creating good windows for mapping alteration and targeting reconnaissance work.

  Remote sensing indicators of REE prospectivity

  - **ASTER FCC (3-2-1):** Highlights cyan/whitish, weakly vegetated rocky zones along NE–SW lineaments, interpreted as structurally controlled exposed surfaces where alteration and mineralization are more likely to be detectable (Fig-1).
  - **Sentinel-2 band ratios (8/6, 4/6, 2/1):** Enhance clay and Fe-oxide alteration and lithological contrast, allowing delineation of anomalous blue–cyan zones interpreted as potential alteration halos related to REE-bearing systems (Fig-2).
  - **Zonal potentiality (Z1–Z3)**
  - **Z1 – High REE potential:**
  - Coincidence of strong NE–SW lineament continuity and intersections with dominant blue–cyan spectral anomalies indicating clay/Fe-oxide alteration within granite gneiss close to quartz veins.

- Interpreted as a structurally controlled alteration corridor with intense fluid–rock interaction; this is the **primary REE target zone** for follow-up ground geological, geochemical and geophysical work.
- **Z2 – Moderate REE potential:**
- Shows patchy spectral anomalies with moderate alteration signatures and lower lineament density and intersection frequency compared to Z1, though still within favourable granitic terrain.
- Considered a **secondary target**, where REE enrichment may be localized and discontinuous, requiring more detailed field validation.
- **Z3 – Low to moderate REE potential (masked):**
- Structurally favourable with high lineament density, but strong vegetation cover suppresses spectral alteration signals, leading to sparse, low-confidence anomalies.
- Classified as **prospectively constrained by data quality**, warranting targeted ground checks and perhaps refined vegetation masking before any upgrading of its potential.

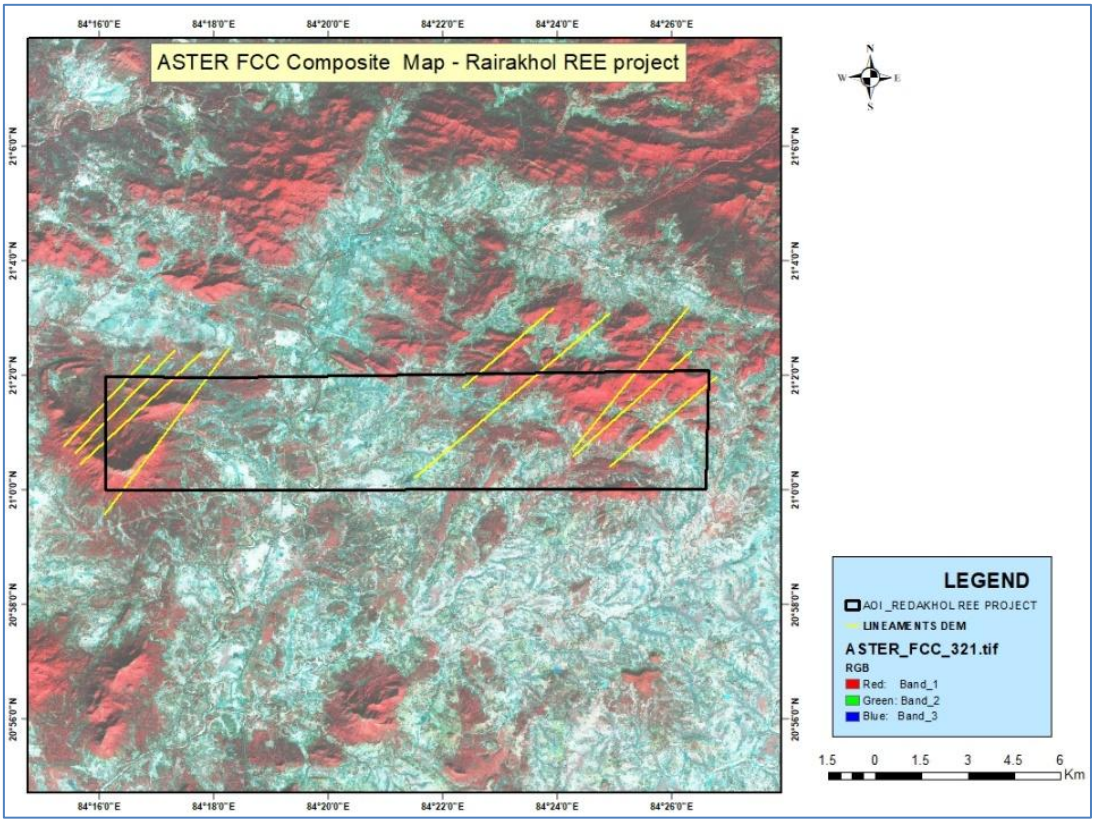

Figure-1: ASTER False Colour Composite (RGB 3-2-1) Map of the Project Area

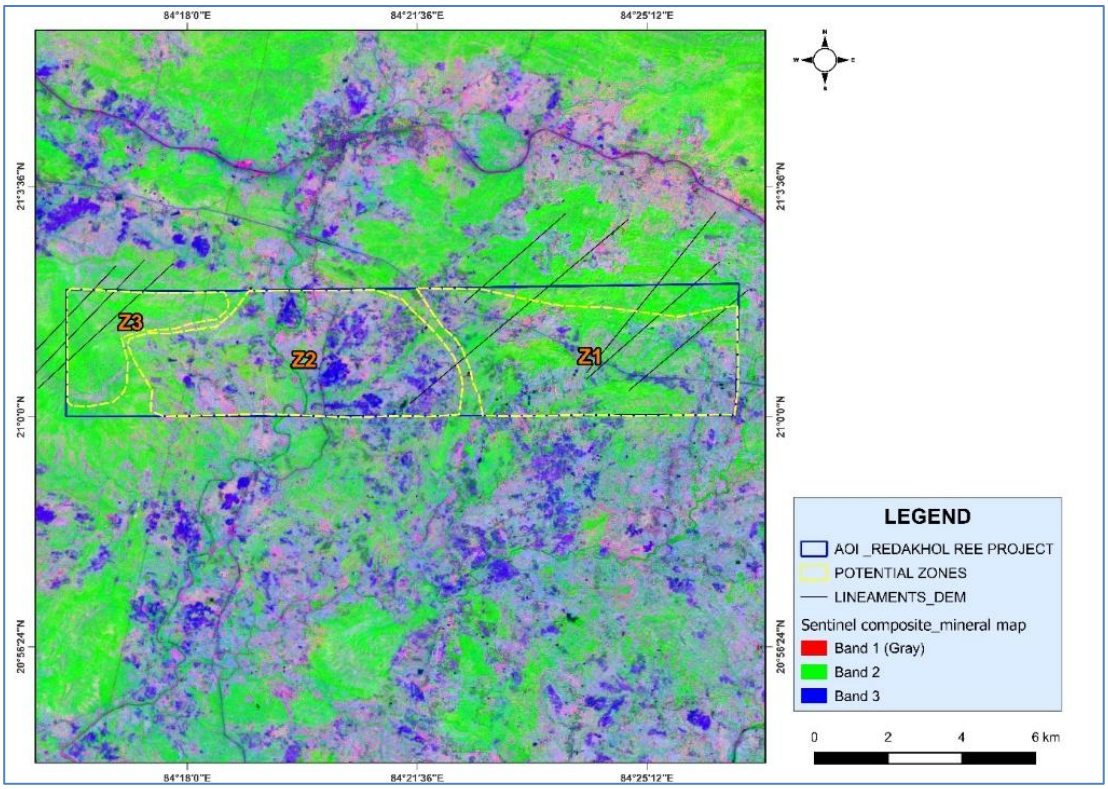

Figure-2: Sentinel-2 Band Ratio composite Map of the Project Area

Although, the proposed area has been covered by 1:25,000 scale mapping during the STM, to bring out details of lithological variations and spatial distribution of quartz and pegmatite veins, it needs to be mapped on 1: 12,500 scale. NGCM data is available for composite samples which represent an area of 4 sq.km. grid. For precise delineation of potential mineralised zones, systematic detailed geochemical sampling at a closer grid spacing (500m) is required. Geochemical information available for the area is restricted to surficial samples only. No subsurface information is available for the proposed area. Geophysical data also available for regional scale interpretation. Therefore, ground magnetic and radiometric survey can be undertaken to further narrow down the prospects and identify potential zones of REE mineralisation. Scout boreholes can contribute valuable subsurface information to understand the geology, structure and controls of mineralisation which can be helpful in further exploration planning.

Observation and Recommendations of previous work.

During the field season 2001-02, S. N. Mohanty and P. Srinivasan from GSI carried out Regional Geochemical Mapping (NGCM) around Rairakhol, Sambalpur District, Orissa (Toposheet No. 73C/08), to generate a geochemical database and assess the economic mineral potential of the area. The area being a circum-cratonic marginal zone of the Eastern Ghats Mobile Belt (EGMB) characterized by alkaline magmatism (nepheline syenite) and fault-bounded Gondwana outliers is significant from both geological and geochemical point of view. The survey identified significant anomalous concentrations for several elements based on stream sediment analysis:

- Rare Earth Elements (REE): Significant LREE enrichment in southern granites and HREE in northern granites. Notable values include Lanthanum (La): 2706.88 ppm, Cerium (Ce):

4,934.61 ppm and Neodymium (Nd): 1467.03 ppm.

- Base Metals and Rare Metals: Anomalies were detected for Copper (120 ppm), Tin (571.74 ppm), Zirconium (5766 ppm), and Barium (1700 ppm).
- Radioactive Elements: High values for Thorium (737 ppm) and Uranium (127 ppm) were recorded, showing a strong positive correlation with REEs.

Analysis of the available geochemical datasets of Toposheet 73C/08 indicate following positive correlations:

- Lanthanum (La) vs. Cerium (Ce): Shows a strong correlation coefficient of 0.87, confirming that LREEs typically concentrate together in this geological milieu.
- Lanthanum (La) vs. Total REE (tREE): Exhibits an even higher correlation of 0.93, indicating that Lanthanum is a dominant primary indicator for the total REE potential of the area.
- Thorium (Th) and Uranium (U) association: These elements show a very strong positive correlation with total REEs. This implies that ground radiometric "hotspots" of Thorium (recorded up to 700 ppm) can be used as reliable proxies to locate underlying REE-rich source rocks.

It was recommended to systematically evaluate the 2 km X 2 km area represented by the respective composite stream sediment samples showing anomalous values, by detailed geochemical sampling.

During the 2016-18 field season, Tapan Moharana and Priya Pachauri from GSI carried out Specialised Thematic Mapping in Rairakhol, Doincha, Balikiari area in Sambalpur District, Odisha (Parts of Toposheet 73 C/7 and 8) to establish contact relationship between Eastern Ghats Mobile Belt and Singhbhum Craton and to elucidate the different tectono-metamorphic episodes in the evolution of the granulites. They observed that, the study area is situated at the northern contact region of the **Eastern Ghats Mobile Belt (EGMB)** and the **Singhbhum Craton (SC)**. These two major crustal units are juxtaposed with a **thrusted and sheared contact** characterized by proto-mylonite, mylonite, and ultra-mylonites. In course of mapping, a significant new body of **nepheline syenite** was discovered at **Sahajbahal**. Based on their study and observations, they recommended:

- Continued investigation into the REE potential, specifically targeting the alkaline intrusive suites and syenite pegmatites that host these minerals
- Due to the high carbon content found in the khondalites, further systematic exploration is recommended to quantify the graphite resource potentiality of the area.
- Given the variety of semi-precious stones found (emerald, corundum, etc.), a dedicated study on the economic significance and distribution of these gemstones was suggested.

During the field season 2017-18, Geetanjali Rana and Kaberi Roychowdhury from GSI, carried out the "Reconnaissance survey for REE in the alkaline rocks and associated pegmatites in association with the Eastern Ghats rocks around Rairakhol area in parts of toposheet no. 73C/08, Sambalpur District, Odisha (Stage G-4). They observed that:

- The area is part of the **Northern Alkaline Province (NAP)** and features an intrusive suite of syenite and nepheline syenite within the Eastern Ghat Supergroup.
- EPMA and SEM-EDX studies identified several LREE (Light Rare Earth Element) mineral

phases, primarily in syenites:

  - **Allanite-(Ce)** is the dominant phase.
  - **Monazite-(La)**, **Perrierite-(Ce)**, and **Y+LREE phosphates** were also confirmed.

- These minerals are typically found at the margins of apatite or within amphibole and feldspar, indicating a **hydrothermal origin**.
- **Total** REE values in bed rock samples reached up to **2108.45 ppm** (recorded in a syenite south of Beldihi village).
- A peak total REE concentration of **7399.09 ppm** was identified in a stream sediment sample from a pyroxene granulite terrain northeast of Purunapani village.
- The area is characterized by enrichment of LREE (especially Cerium, Lanthanum, and Neodymium) but relatively flat HREE (Heavy Rare Earth Element) patterns. The average ΣLREE to ΣHREE ratio is approximately **21:1**.

Although, they observed the average concentrations of LREEs calculated across the mapped area does not seem to be economical at the current stage, they had recommended that:

- Future detailed exploration should focus specifically on the pyroxene granulites and syenites around the Beldihi and Kusarimunda areas, as these terrains provided the highest REE concentrations.
- Further study is recommended to better understand the REE mineralization patterns in the high-grade metamorphic rocks and their relationship to the alkaline intrusive events.
- Because ferrecrete-rich zones and saprolitic layers over bed rock showed better concentration than topsoil, these horizons should be prioritized in any future geochemical sampling programs.

2. Previous Work

During the 1975-76 field season, O.P Joshi and S. Chhattopadhyay from GSI carried out systematic geological mapping on a 1:63,360 scale in parts of the Sambalpur district, Orissa, covering approximately 392 sq. km around Kisinda and Rampur (Present Redhakhol). Based on the field findings, the following recommendations were made:

- **Detailed Structural Study:** Because the area is at the northern extremity of the Eastern Ghats and adjacent to the Mahanadi lineament, further detailed study of the variation in structure in relation to lithology and geodynamics is suggested.
- **Graphite Exploration:** While observed graphite occurrence near Chatuni village did not show encouraging FC content, considering hydrothermal origin of graphite occurrences in the region, further detailed study to fully evaluate controls of mineralization and their potentiality was suggested.

During the 1990-91 field season, P. K. Panda and P. C. Patra from GSI carried out Geotraverse in Rairakhol-Naktideola section along Bauda-Deogarh-Panposh transect across Eeastern Ghat, Iron Ore and Gondwana Supergroups. During mapping, a significant body of **nepheline syenite** was delineated around Rairakhol, occurring as two linear bodies totaling 10.5 km in strike length with an average width of 0.5 km.

During the field season 2001-02, S. N. Mohanty and P. Srinivasan from GSI carried out Regional Geochemical Mapping (NGCM) around Rairakhol, Sambalpur District, Orissa (Toposheet No. 73C/08), to generate a geochemical database and assess the economic mineral

potential of the area. The area being a circumcratonic marginal zone of the Eastern Ghats Mobile Belt (EGMB) characterized by alkaline magmatism (nepheline syenite) and fault-bounded Gondwana outliers is significant from both geological and geochemical point of view. The survey identified significant anomalous concentrations for several elements based on stream sediment analysis:

- Rare Earth Elements (REE): Significant LREE enrichment in southern granites and HREE in northern granites. Notable values include Lanthanum (La): 2706.88 ppm, Cerium (Ce): 4,934.61 ppm and Neodymium (Nd): 1467.03 ppm.
- Base Metals and Rare Metals: Anomalies were detected for Copper (120 ppm), Tin (571.74 ppm), Zirconium (5766 ppm), and Barium (1700 ppm).
- Radioactive Elements: High values for Thorium (737 ppm) and Uranium (127 ppm) were recorded, showing a strong positive correlation with REEs.

Analysis of the available geochemical datasets of Toposheet 73C/08 indicate following positive correlation:

- Lanthanum (La) vs. Cerium (Ce): Shows a strong correlation coefficient of 0.87, confirming that LREEs typically concentrate together in this geological milieu.
- Lanthanum (La) vs. Total REE (tREE): Exhibits an even higher correlation of 0.93, indicating that Lanthanum is a dominant primary indicator for the total REE potential of the area.
- Thorium (Th) and Uranium (U) association: These elements show a very strong positive correlation with total REEs. This implies that ground radiometric "hotspots" of Thorium (recorded up to 700 ppm) can be used as reliable proxies to locate underlying REE-rich source rocks.

It was recommended to systematically evaluate the 2 km X 2 km area represented by the respective composite stream sediment samples showing anomalous values, by detailed geochemical sampling.

During the 2016-18 field season, Tapan Moharana and Priya Pachauri from GSI carried out Specialised Thematic Mapping in Rairakhol, Doincha, Balikiari area in Sambalpur District, Odisha (Parts of Toposheet 73 C/7 and 8) to establish contact relationship between Eastern Ghats Mobile Belt and Singhbhum Craton and to elucidate the different tectono-metamorphic episodes in the evolution of the granulites. They observed that, the study area is situated at the northern contact region of the Eastern Ghats Mobile Belt (EGMB) and the Singhbhum Craton (SC). These two major crustal units are juxtaposed with a thrusted and sheared contact characterized by protomylonite, mylonite, and ultramylonites. During mapping a significant new body of nepheline syenite was discovered at Sahajbahal. Based on their study and observations, they recommended:

- Continued investigation into the REE potential, specifically targeting the alkaline intrusive suites and syenite pegmatites that host these minerals
- Due to the high carbon content found in the khondalites, further systematic exploration is recommended to quantify the graphite resource potentiality of the area.
- Given the variety of semi-precious stones found (emerald, corundum, etc.), a dedicated study on the economic significance and distribution of these gemstones was suggested.

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3. Block description

The Redhakhol Block covering about 67.99 sq. km in parts of Redhakhol sub-division of Sambalpur district and Kishornagar Sub-division of Angul district proposed for reconnaissance survey (G4) falling under Survey of India Toposheet No. 73 C/08. The corner coordinates of the rectangular area are given below (Fig-1) :

Block Corner points Cardinal Points	Latitude	Longitude
A.	21° 1' 59.252" N	84° 16' 6.408" E
B.	21° 2' 4.805" N	84° 26' 38.503" E
C.	21° 0' 1.454" N	84° 26' 35.076" E
D.	21° 0' 0.254" N	84° 16' 6.135" E

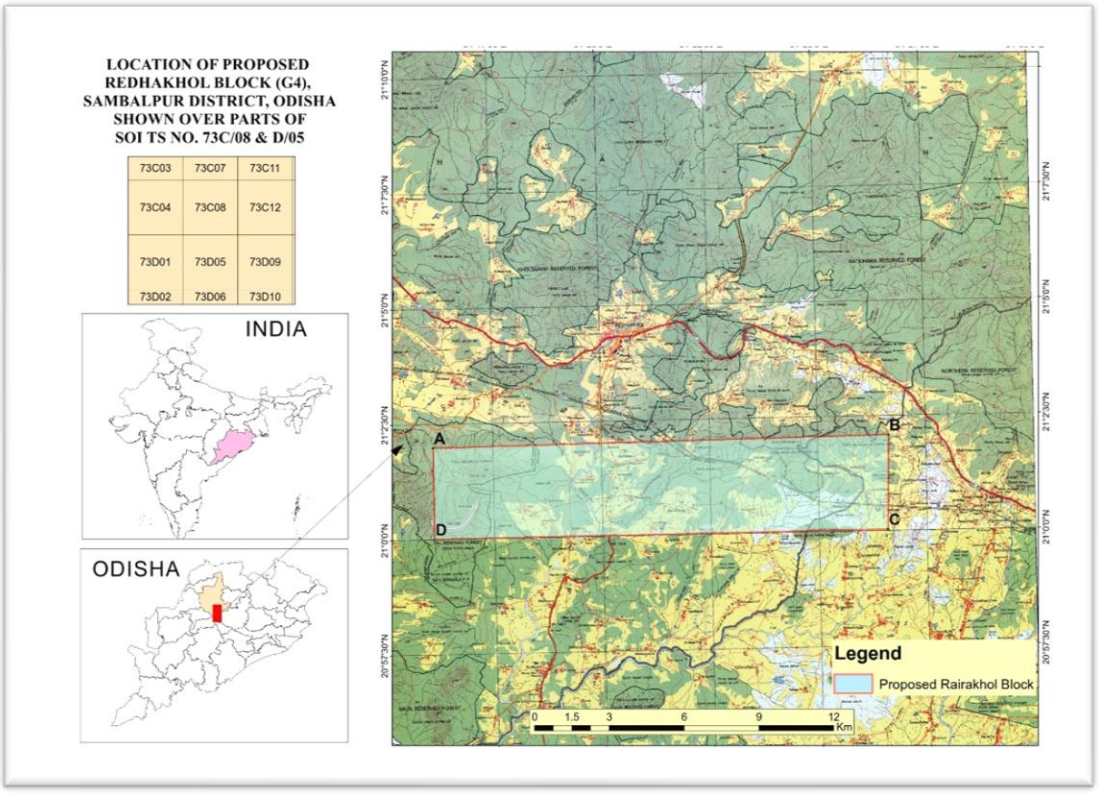

Figure-3: Index map showing Location of proposed Redhakhol Block (G4), Sambalpur and Angul Districts, Odisha falling in Toposheet No. 73 C/08

The Block was verified with the geo-spatial database available on NGDR portal and also from other sources like Parivesh Portal. As per the available data, it has been observed that,

1. No exploration work for REE investigation has so far been taken up within the proposed area. However, a G4 stage project for REE investigation had been taken up by GSI during 2017-18, on immediate north of the proposed block (Fig. 4).

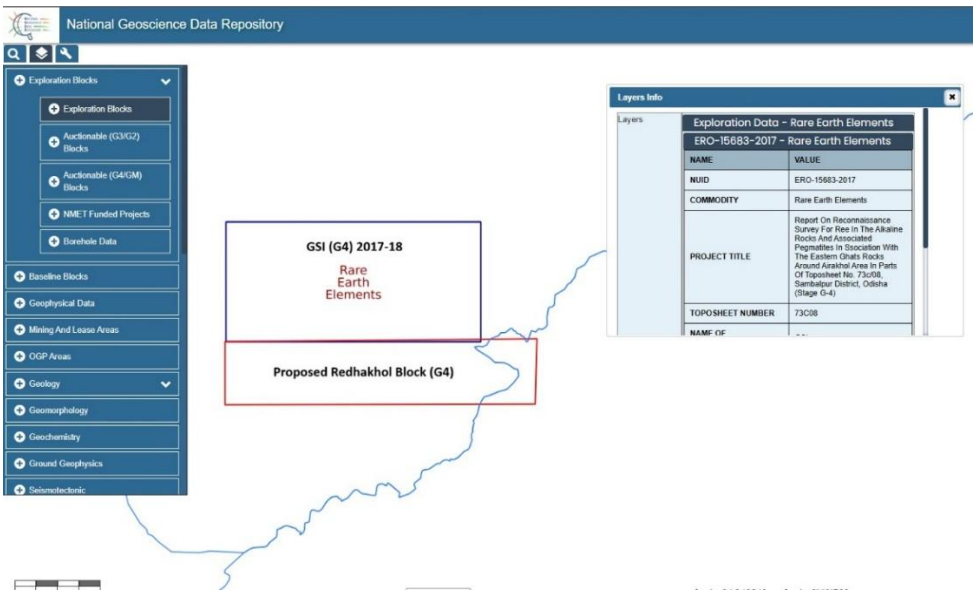

Figure-4

2. The proposed block does not overlap with any of the ongoing projects by GSI, State DGM, MECL and other exploration agencies (Fig. 5).

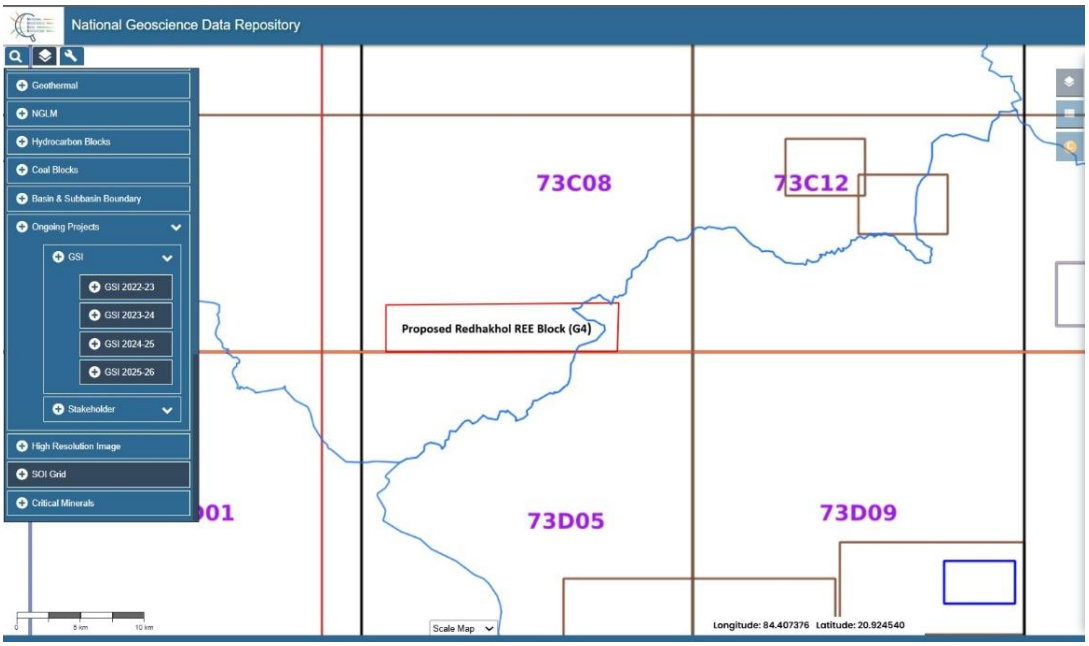

Figure-5

3. The proposed area does not overlap with any auctionable G2/G3 and G4/GM blocks. Although, there are two auctionable G4/ GM blocks are located in the surrounding, they are more than 10km further south of the proposed area (Fig. 6).

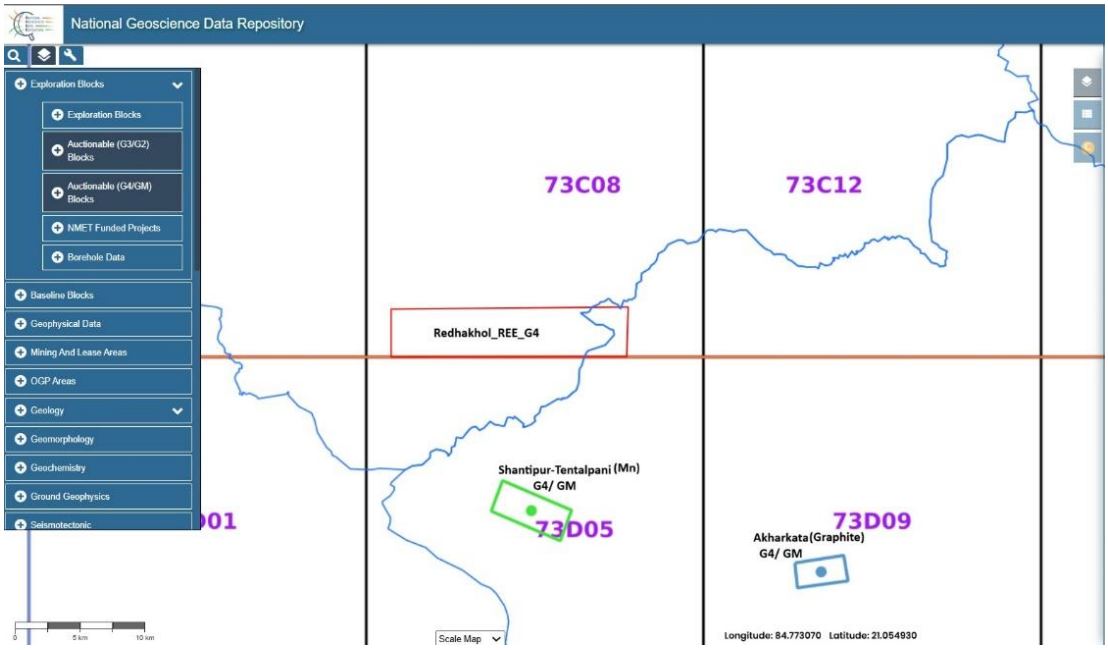

Figure-6

4. The block area is free from any existing CL and ML (Fig. 7).

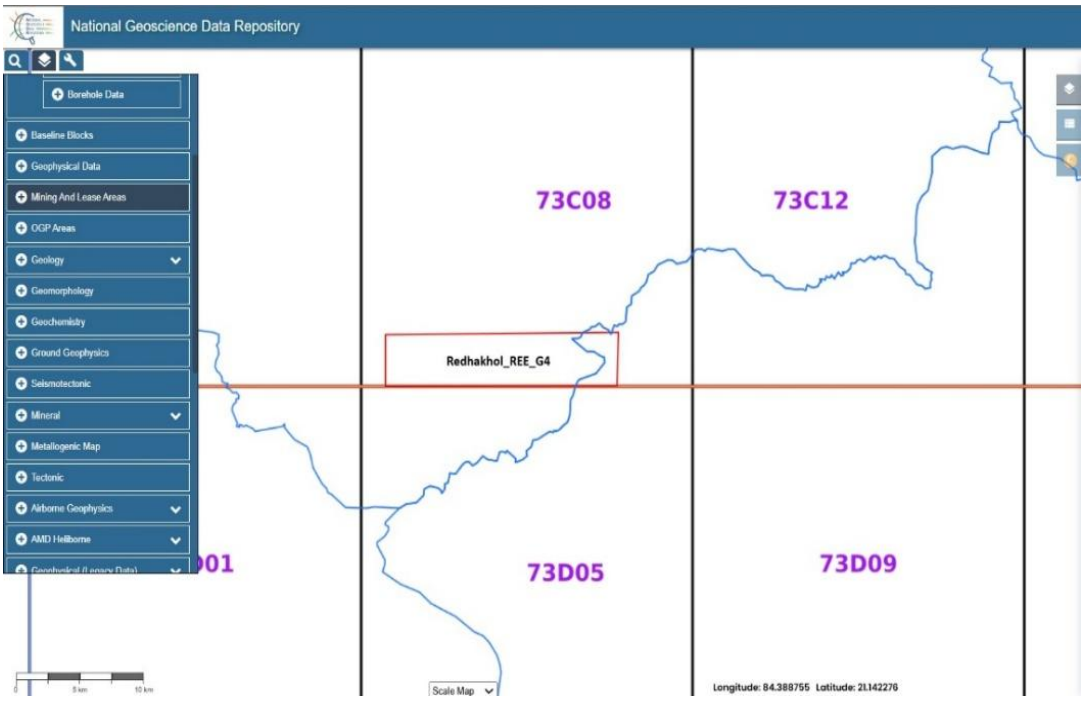

Figure-7

5. There is no NMEDT funded ongoing or completed project present in the area (Fig. 8).

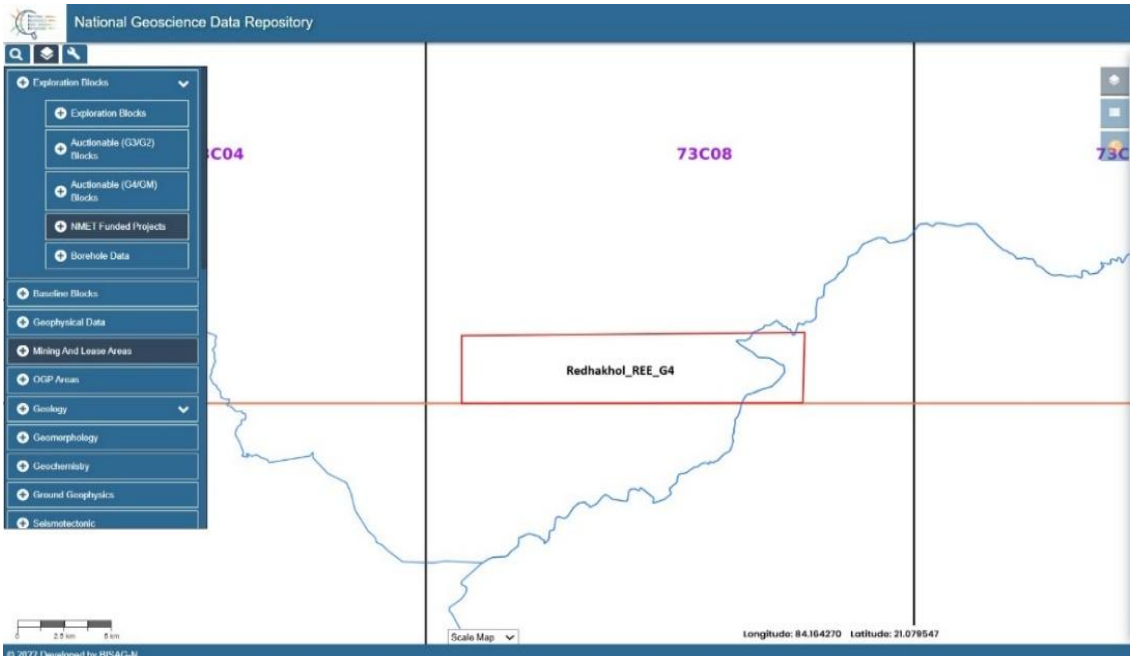

Figure-8

6. About 13.25 sq. km area is under Tala RF and Bindhabasini PF. It is also verified from the Parivesh Portal that the proposed block area does not overlap with any WLS or ESZ (Fig.9).

Figure-9

4. Planned Methodology

The exploration program is proposed to be carried out under G-4 stage of UNFC and in accordance with the Minerals (Evidence of Mineral Contents) Rule-2015. The proposed area for reconnaissance study (G4 stage) being located near the northern margin of EGMB with a tectonic contact with Singhbhum Craton marked by intrusion of nepheline syenite and pegmatoidal syenites along the margin, is significant from REE mineralisation point of view. The NGCM data with several anomalous values of tREE, U and Th corroborate the above assumption. Identification of REE mineral phases during STM as well as during G4 stage investigation in the area further strengthens the above view.

Geological

Although, geological maps on 1:50,000 scale and 1:25,000 scale are already available, large scale mapping (LSM) on 1:12,500 scale shall be carried out to bring out lithological variations as well as structural elements, in detail. Topographic survey with contouring shall be undertaken with the help of Drone and DGPS survey. High resolution photography of inaccessible and cliff sections would help in identification of lithologies and structural features. Mapping will be completed by field traverses and focus will be given to areas prioritised based on RS & GIS interpretation for detailed study.

Geophysical Study

In REE exploration, ground magnetic data constrains the structural and lithological framework (where could the REE-hosting bodies be?), while ground radiometric data pinpoints radio

element-enriched, altered segments of that framework (where is it most likely REE-bearing), helping to delineate focused zones for trenching and drilling.

Therefore, it is proposed to carry out Ground Magnetic survey of 200 line kilometres with 100 m line spacing in the priority zones identified from integration of remote sensing, geological and geochemical data to bring out structural discontinuities and change in lithology especially, the mafic intrusives as in the case of REE occurrences associated with pyroxene bearing syenites in Nayagarh district.

Ground spectral-gamma or scintillometer traverses of 200 line kilometre with line spacing of 100m is proposed to delineate radiometric contrasts between fertile intrusives (e.g., evolved granites, carbonatites, pegmatites) and barren country rocks. Highlight alteration zones (e.g., K-enrichment, Th/U redistribution) that correlate with the clay–Fe-oxide and integrated with magnetic data for identification of REE targets.

Geochemical Study

The available NGCM data of composite SSS represent an area of 4 sq. km. which is not sufficient to narrow down to identify the prospect. Therefore, a detailed soil geochemical sampling in anomalous zones, identified from NGCM data is proposed to be covered by 500m X 500m grid and rest of the area can be covered by 1km X 1km grid. A total of 200 nos. SGS are proposed to be collected. In addition to this, 50 nos. of regolith samples are proposed to be collected from the area to identify secondary enrichment of REE in regolith profile.

Pitting/ trenching and Scout Drilling

After integration of geological, geochemical and geophysical data, pitting/ trenching shall be undertaken to delineate the potential zones of mineralisation. Therefore, excavation of 100 cu. m. along with 100 nos. of PTS are proposed. After reviewing the results, with the approval of TCC, scout drilling of 400m in 4-5 boreholes can be undertaken in the potential mineralised zones.

Laboratory study

As REE mineralisation in the area is expected to be associated with pegmatites, syenites and nepheline syenite, pyroxenite and mafic granulite, petrographic study of these rocks is important to understand the nature and mode of occurrence of different REE phases and associated minerals. Therefore, it is proposed to carry out petrographic study of 30 bedrock/ drill core samples and 10 nos samples for EPMA study.

The soil geochemical samples (SGC), regolith samples (RS), pit & trench samples (PTS) and drill core samples (CS), if any to be analysed for REE and trace elements by ICP-MS. It is also proposed to carry out whole rock analysis of 10 samples for classification of rock types. In order to compare the analytical results and to check any analytical bias, 10% of the total samples will be analysed as check samples at an NABL accredited laboratory.

5. Nature and Quantum of work proposed

Sl. No.	Nature of Work	Unit	Target
1.	**Geological**		
	Large Scale Mapping (LSM) on 1:12,500 scale	Sq. km.	67.85
2.	**Geophysical**		
	Ground Magnetic survey	L. km.	200
	Ground Radiometric Survey	L. km.	200
3.	**Pitting & Trenching**	Cu. m.	100
4.	**Drilling**		
	Diamond core drilling	m	400
5.	**Sampling**		
	Petrographic Study (Thin Section)	Nos.	20
	Ore Microscopy (Thin/ Polished Section)	Nos.	10
	PTS	Nos.	100
	Soil/ SSS	Nos.	200
	RS	Nos.	50
	Core Sampling	Nos.	50
5.	**Laboratory Study**		
	Chemical analysis by ICP-MS (9 Trace & 14 REE) including check samples	Nos.	440
	EPMA	Nos.	10

6. Manpower deployment

Sl. No.	**Manpower**	**Nature of deployment**	**Field Days**
1.	Geologists – 2nos.	(F/T)	120 days each
2.	Geophysicist-2 nos.	(P/T)	75 days each
3.	Surveyor – 1 no.	(P/T)	30 days
4.	Supervisor – 1no.	(P/T)	25 days

7. Summary of Tentative estimated cost for Reconnaissance Survey for REE in Redhakhol area, Sambalpur and Angul Districts, Odisha

Sl. No.	Work/ Activity	Cost
A.	**Geological Mapping & Other Geological Work**	**56,97,915**
B.	**Ground Geophysical Survey**	**80,72,500**
C.	**Survey work**	**48,45,500**
D.	**Mineral Investigation**	**50,48,000**
E.	**Laboratory Studies**	**34,69,000**
F.	**Miscellaneous charges**	**19,16,000**
G.	**Total Estimated Cost without GST**	**2,90,48,915**
H.	**Provision for GST (18% of G)**	**52,28,805**
I.	**Total Estimated Cost with GST**	**3,42,77,720**

Expenditures with detailed breakup have been submitted separately in the cost sheet

8. References

Joshi, O. P. and Chhatopadhyay (1976); Systematic Geological Mapping around Kisinda and Rampur, Sambalpur District, Orissa (in Parts of TS. nos. 73 C/7 & C/8); Unpublished GSI Report FS 1975-76 (Acc. No. ERO_UE8951_1975).

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Mohanty, S. N. and Srinivasan, P. (2016); Final report on regional geochemical mapping round Rairakhol, Sambalpur district, Orissa for assessment of mineral potential (T.S.no.73C/08) Unpublished GSI Report FS 2001-02 (UE 15502).

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Rana, Gitanjali and Roychoudhury, Kaberi (2019); Report on reconnaissance survey for REE in the alkaline rocks and associated pegmatites in association with the Eastern Ghats rocks around Rairakhol area in parts of toposheet no. 73C/08, Sambalpur District, Odisha (stage G-4); Unpublished GSI Report FS 2017-18 (UE 15683).

List of Plates