PROPOSAL FOR G3 STAGE MINERAL EXPLORATION OF REE AND ASSOCIATED RARE EARTH METALS IN THE NB13 BLOCK OF THE NORTHRN PART OF THE SIWANA RING COMPLEX, BALOTRA DISTRICT, RAJASTHAN

(REE and Associated Rare Earth Metals)

By
Natural Resources Division-Tata Steel Limited

Place: Jamshedpur, Jharkhand, India

Features	Details
Block ID	NB13
Exploration Agency	Natural Resources Division- Tata Steel Limited
Commodity	REE and Associated Rare Earth Metals
Mineral Belt	Siwana Ring Complex (Malani Igneous Suite)
Completion Period with entire time schedule to complete the project	16 months
Objectives	To establish economic occurrences of REE and associate rare earth metals.
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	Field geological activities including mapping, collection of samples and preparation, chemical analysis, survey, interpretations, review, report writing etc., shall be conducted by inhouse team and facilities. Some of the other activities such as, exploratory drilling, borehole geophysical survey, mineral graphic study, shall be conducted thorough outsourced agencies.
Name/ Number of Geoscientists	Six (6) geoscientists shall be deployed in the project. 1. Sangeeth Gopi 2. Rituraj 3. Shramana Rudra Roy 4. Shreenivas Mishra 5. Shakti Sourav Das 6. Rajarshi Sarkar
Expected Field days (Geology) Geological Party Days	Geological Mapping and Channel Sampling = 100 days Pitting = 30 days Drilling = 180 days

1.	**Location**	
	Coordinates	<table><tr><th>Label</th><th>Latitude</th><th>Longitude</th></tr><tr><td>D</td><td>25.726980</td><td>72.386566</td></tr><tr><td>E</td><td>25.715305</td><td>72.391935</td></tr><tr><td>F</td><td>25.720823</td><td>72.405032</td></tr><tr><td>G</td><td>25.731769</td><td>72.400948</td></tr></table>
	Villages	Siwana (nearest town)
	State	Rajasthan
2.	**Area (hectares/ square kilometres)**	
	Block Area	2.0 Sq. Km
	Forest Area	To be updated
	Government Land Area	To be updated
	Private Land Area	To be updated
3.	**Accessibility**	
	Nearest Railway Head	Mokalsar (about 23 km southeast) and Balotra Junction (around 35 km west)
	Road	Block is located 12 km northwest of Siwana town, which is connected by metalled and unmetalled roads to Balotra and Barmer
	Airport	Jodhpur Airport, located roughly 150 km east of Siwana
4.	**Hydrography**	
	Local surface drainage pattern (Channels)	To be updated
	Rivers/ Streams	To be updated
5.	**Climate**	
	Mean Annual Rainfall	To be updated
	Temperatures (December) (Minimum) Temperature (June) (Maximum)	To be updated
6.	**Topography**	
	Toposheet Number	45 C/06
	Morphology of the Area	Rugged hill in the north will plain land in the central and southern parts.
	Availability of baseline geoscience data	
	Geological Map (1:50K/ 25K) Geochemical Map	Yes
	Geophysical Map (Aeromagnetic, ground geophysical, Regional as well as local scale GP maps)	Yes
	Justification for taking up Preliminary Exploration	G4 exploration by GSI established encouraging results.

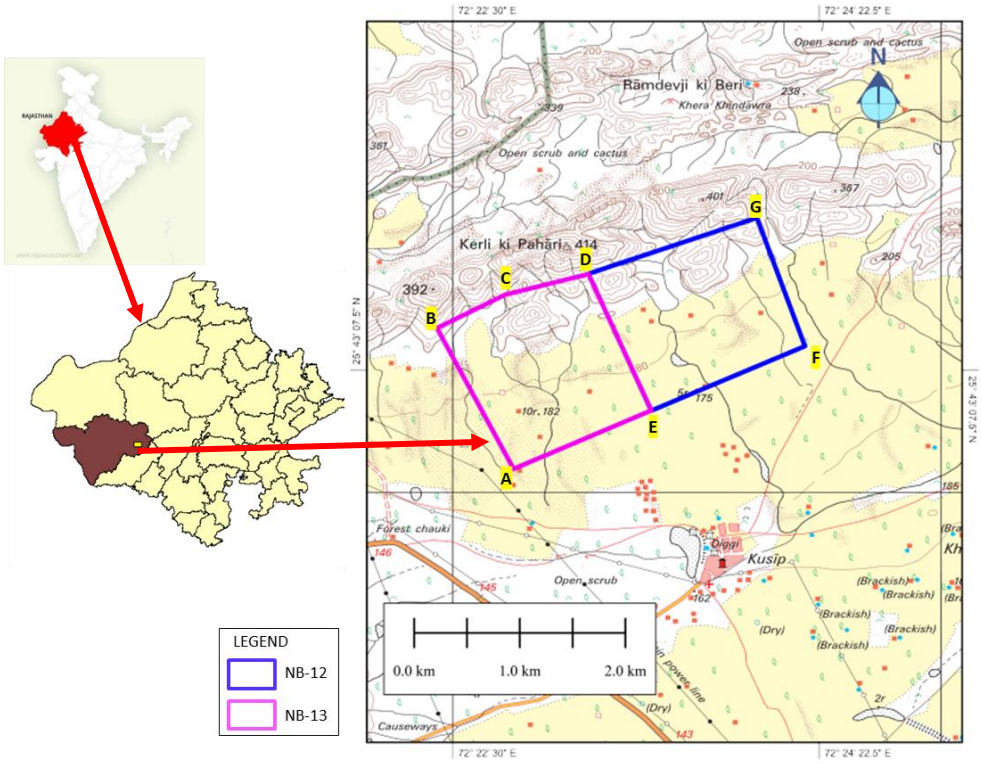
1. Block Summary

1.1 Location and accessibility:

The NB-13 block is in the northern part of the Siwana Ring Complex within Barmer District, Rajasthan. It falls under Survey of India Toposheet No. 45C/06 and lies approximately 12 km northwest of Siwana town, about 132 km east of Barmer and 35 km southeast of Balotra. The block occupies a segment of the ring-shaped volcanic terrain characterized by rhyolite flows and associated intrusive. Its geographic position places it within an arid region of western Rajasthan, marked by rocky outcrops and low-relief ridges interspersed with soil-covered plains.

block is easily accessible from nearby towns and major transport hubs. It lies approximately 12 km northwest of Siwana town, which is connected by metalled and unmetalled roads to Balotra and Barmer. The nearest railway stations are Mokalsar (about 23 km southeast) and Balotra Junction (around 35 km west), both providing connectivity to Jodhpur and other parts of Rajasthan. The closest airport is Jodhpur Airport, located roughly 150 km east of Siwana. Approach roads from Siwana and Balotra lead to the block, making it convenient for transportation of men and materials. The terrain comprises rocky outcrops and low-relief ridges typical of the Siwana Ring Complex, interspersed with soil-covered plains, which allows vehicular movement with minimal difficulty during dry seasons.

Label	Latitude	Longitude	Easting	Northing
D	25.726980	72.386566	237794.967	2848046.176
E	25.715305	72.391935	238308.295	2846741.785
F	25.720823	72.405032	239635.032	2847327.319
G	25.731769	72.400948	239248.989	2848548.326



Location map of NB12 and NB13 blocks

1.2 Physiography:

The NB-13 block forms part of the Siwana Ring Complex and exhibits a rugged physiography typical of volcanic terrains. The area is characterized by low-relief ring-shaped ridges composed mainly of rhyolite flows and associated intrusive, interspersed with shallow valleys and soil-covered plains. Rocky outcrops dominate the central and northern sectors, while the southern and peripheral zones show patches of aeolian sand. Elevation varies from about 180 m near Asotra village to approximately 414 m at Kerli ki Pahari. Drainage is controlled by ephemeral streams forming a dendritic to sub-radial pattern, ultimately joining the Luni River system. Overall, the terrain supports moderate accessibility for field operations during dry seasons.

1.3 Background Geology (Regional Geology, Geology of the Block):

The magmatic evolution of Siwana Ring Complex, part of Neoproterozoic Malani Igneous Suite (MIS); ca. 771±2 Ma (Torsvik *et al.* 2001), 745 Ma (Dhar *et al*., 1996; Rathore *et al*., 1999) can be divided into three phases (Kumar and Sharma, 2020). First phase is represented by bimodal volcanism of acid and basic flows (acid flows > basic flows). It is intruded by second, plutonic phase comprising arfvedsonite-reibeckite-aegirine bearing per-alkaline Siwana Granite. The third phase being later intrusive phase includes rhyolite, microgranite, andesite, and felsite dykes. All these three phases host anomalous ΣREE+Y concentration and the third phase is more enriched (Kumar and Sharma, 2020). Peralkaline igneous rocks, carbonatites, feldspathoid bearing rocks are the main source of REE minerals (± HFSE, U & Th etc) and therefore are suitable host for targeting REE/RM mineralisation. Peralkaline granites, volcanics and associated zoned pegmatoids are storehouse of REE and rare metals (Nb–Ta, Zr–Hf, Sn, W, Be) (Pollard, 1995) and in layered intrusions, the mineralisation mostly appears in the more evolved parts of the complexes (Dostal, 2017).

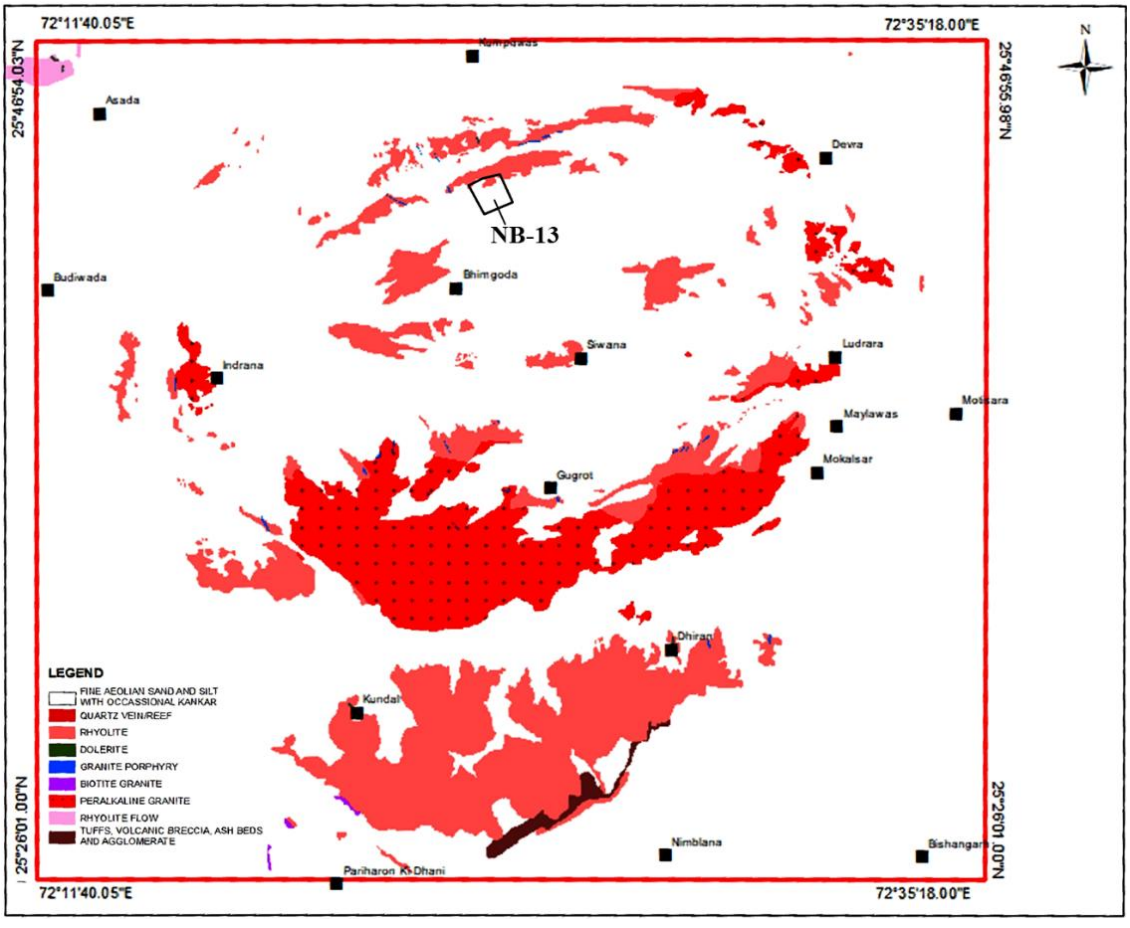
In the Western Indian Craton of Rajasthan, basement rocks and overlying supracrustal belts of Aravalli and Delhi Supergroups have witnessed magmatic events of volcanics and granitoids of Palaeo- to Neo-Proterozoic ages. Granitoids of different ages (~ 1.8 Ga, ~1.7 Ga, ~1.4 Ga, ~ 1.1Ga and 850-750 Ma) have intruded these belts. MIS magmatism occurred during Neoproterozoic age and comprised of peralkaline (Siwana), meta-aluminous to mildly peralkaline (Jalore) and peraluminous (Tusham and Jhunjhunu) granites with cogenetic carapace of acid volcanics (welded tuff, trachyte explosion braccia and perlite) and is characterised by volcano-plutonic ring structure and radial dykes (Singh and Vallinagayam, 2009). Three phases in Siwana magmatic activity are widely observed: i) the basal peralkaline (lower 24 flows), ii) middle meta-aluminous (top 21 flows), and iii) reappearance of peralkaline phase as intrusive (Siwana granite) at the end (Chittora and Bhushan, 1994).

1.4 Regional Stratigraphy:

The Delhi Supergroup rocks form the foundational basement for the Malani Igneous Suite. Near Kankani, a volcaniclastic conglomerate marks a clear angular unconformity between the granites, phyllites, and quartzites of the Delhi Supergroup and the overlying pyroclastic deposits of the Malani Igneous Suite, located about 30 km south of Jodhpur. The rhyolite of the Malani Igneous Suite rests above the Mt. Abu granitoid (Choudhury et al., 1984). This volcano-plutonic assemblage is subsequently overlain either by the glacial Pokhran Boulder Bed or by sediments of the Marwar Supergroup. The magmatism of the Malani Igneous Suite occurred after the emplacement of Mt. Abu granitoids and before the Vendian glaciation.

Based on field relationships, magmatic style, texture, and composition, the Malani Igneous Suite is divided into three distinct phases of magmatic activity. The first phase began with the eruption of basic lava flows, followed by extensive outpouring of felsic lavas and deposition of ash flows. The second phase involved the intrusion of peraluminous, peralkaline, and meta-aluminous granites as plutons, ring dykes, bosses, and plugs within the earlier volcanic phase. The third phase is represented by swarms of mafic and felsic dykes and sills cutting across the earlier two phases. A detailed regional stratigraphic succession is presented in Table below:

Group/Supergroup	Age	Rock Type
Marwar Supergroup (Jodhpur Group)	Vendian to Lower Cambrian	Maroon and golden sandstone, siltstone, and shale
----------Unconformity----------		
Pokharan Boulder Beds	Vendian	Scattered boulders and pebbles of glacial origin
----------Unconformity----------		
Malani Igneous Suite	Neo-Proterozoic	Bimodal volcanics, granites and dyke swarms
----------Unconformity----------		
Delhi Supergroup (Basement)	Meso to Neo-Proterozoic	Abu and Erinpura Granite Metasediments of Sirohi and Pali area Unspecified gneisses of Balewa-Harsani area (Archean supracrustal?)



NB-13 block shown on the Geological map of Siwana Ring Complex

1.5 Selection of the block for exploration:

NB-13 block lies within the northern part of the Siwana Ring Complex, which is part of the Malani Igneous Suite in Barmer District, Rajasthan. This area has been identified as highly prospective for Rare Earth Elements (REE) and associated rare metals based on previous reconnaissance surveys and thematic mapping by GSI and subsequent field validation.

The block covers approximately **2.0 sq. km** and includes peralkaline rhyolite flows, felsic dykes, and associated intrusive phases that have shown anomalous ΣREE+Y concentrations in earlier investigations. Geochemical analysis of bedrock and channel samples from adjacent areas indicates enrichment of Light Rare Earth Elements (LREE) and High Field Strength Elements (HFSE) within rhyolitic flows and felsic dykes.

Based on these findings, the exploration strategy focuses on delineating mineralized zones through detailed geological mapping, geochemical sampling, and exploratory drilling. The section selected for exploration represents the most promising part of the ring structure, where rhyolite flows exhibit continuity and structural features favourable for mineralization.

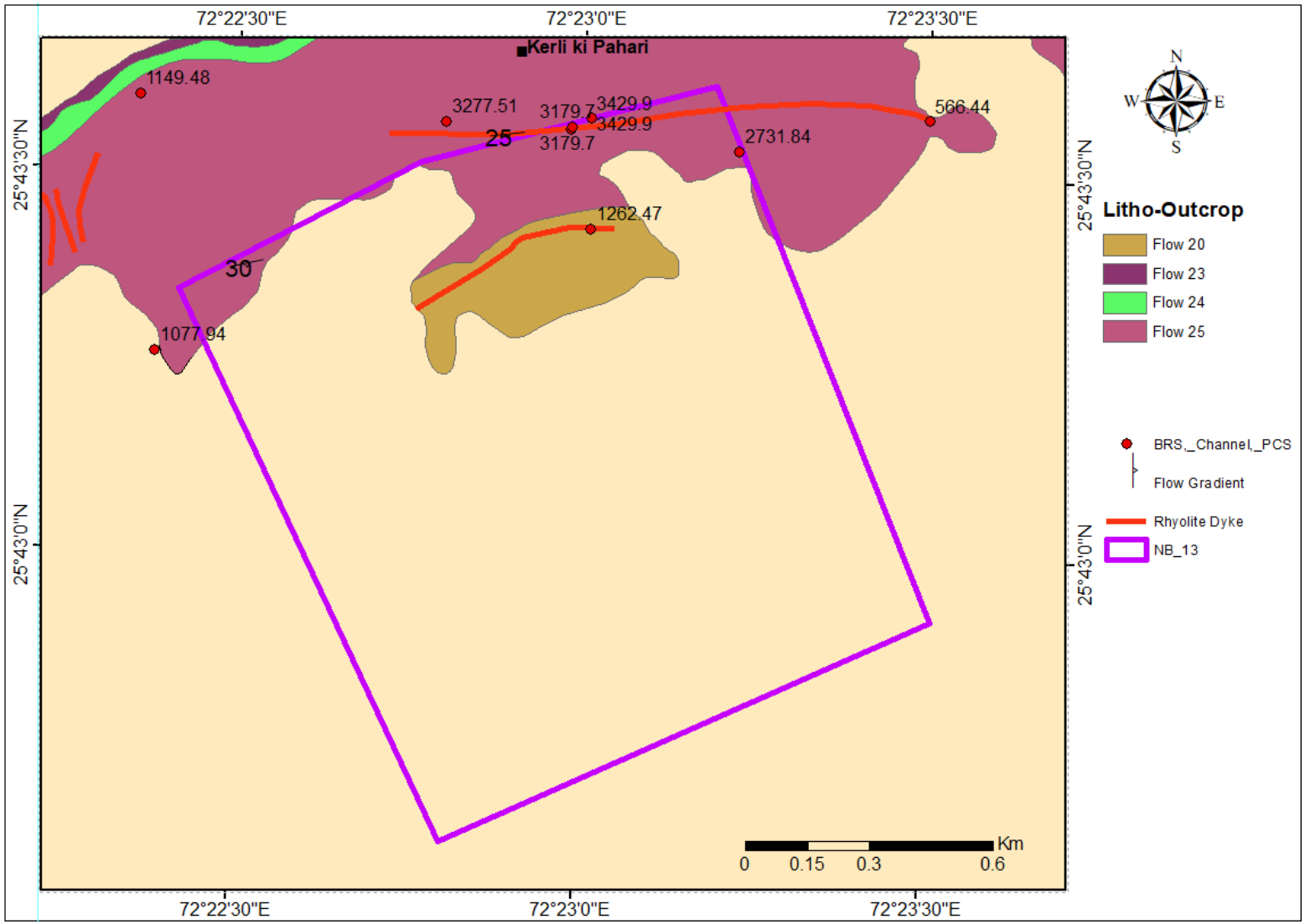
1.6 Geology of the Block

Most of the block is agricultural land which is covered in the alluvium soil. In the northern part of the block there is multiple flow of rhyolite description of the different flows are given below:

Flow 25 is rhyolite with varying colours from reddish brown and often contains ash material at the top part. Both tabular and lath-shaped phenocrysts of K-feldspar are present within fine-grained groundmass. Phenocryst size varies from 1mm to 5mm with phenocryst to groundmass ratio 02:98.

Flow 20 is porphyritic rhyolite rock where both tabular and lath-shaped phenocrysts of K-feldspar are observed within brown-coloured groundmass. Size of phenocrysts varies from 0.1cm to 1.0cm showing moderate to good contrast with groundmass. Phenocryst to groundmass ratio is approximately 05:95.

Rhyolite dykes are intruded within the rhyolite flows. Felsic/rhyolite dykes are comparatively wider than basic ones. Felsic dykes are showing coarse grained texture, primarily composed of K-feldspar, Na-feldspar and quartz. Often K-feldspars are rimmed by Na-feldspar.



LSM map of NB13 block (Lal and Ghosh, GSI 2023)

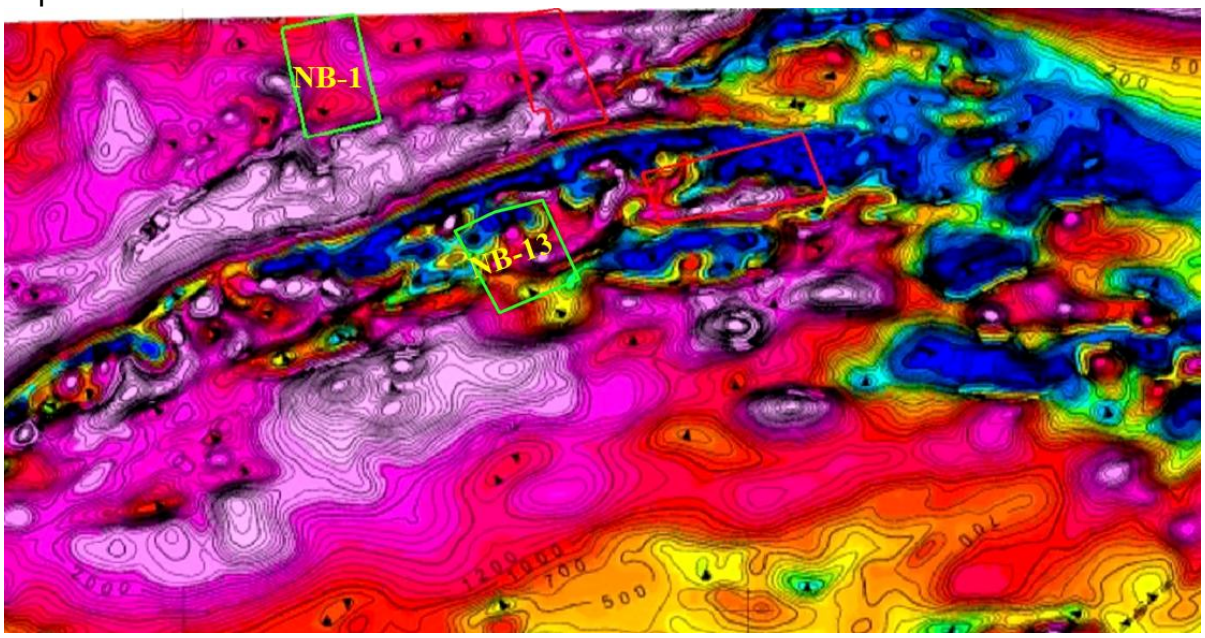
2. Previous Work

Preliminary sampling of the rhyolites and associated tuffs of Siwana Ring Complex, Balotra district, carried out by GSI during 2013-14, indicated anomalous REE values with ΣREE ranging from 1334 to 3319ppm ΣREE (Rastogi & Mukherjee, 2015). Bidwai et al., 2014, reported the presence of high LREE, Zr, Nb, Th and U along with Ag in surface samples in the Siwana Ring Complex. Das et al., 2015, carried G4 investigation in Siwana eastern and central block. Kumar and Sharma, 2020, carried out G-4 investigation and reported ∑ REE+Y ranges in various litho-units are i) Plagioclase rich granite (n=79) ∑ REE+Y = 0.029%-0.70%. ii) K-feldspar rich granite (n=116) ∑ REE+Y= 0.047%-0.66%. iii) Younger Intrusive (n=146) ∑ REE+Y= 0.019%-2.66%. iv) Felsic volcanic (n=43) ∑REE+Y = 0.015%-0.96% and v) Enclave/Restite (n=19) ∑REE+Y = 0.022%-1.27%. LREE/HREE ratio indicates that LREE>>HREE in the area and LREE values ranges between 86.45ppm to 1.93%, however, HREE values ranges between 23.94ppm to 0.26%. LREE:HREE ratio in Siwana area is 4:1 approximately. Apart from REE, rare metals and some trace elements also indicate very encouraging results, Zr (0.1% to 1.1%), Nb (2.5ppm to 1039ppm), Ba (25ppm to 3948ppm), Zn (120ppm to 1258ppm), U (0.61ppm to 124ppm), Th (2ppm to 481ppm) and Hf (4.52ppm to 828.18ppm).

Barman and Neog, 2018 mapped the peralkaline – peraluminous granite (A type) and in the Siwana area extending from Mokalsar in the east to Siner in the west through Mawri, Gugrot, Piplun, Goliyan Bhairan and Kalur Ka Danta area. REE bearing carbonates (perisite) and phosphates (monazite) were identified in both plutonic and volcanic rock types. In addition to REE bearing mineral phases, haematite, ilmenite and zircon are also identified from both plutonic and volcanic phases. The granite recorded values ranging from 182.77 ppm to 8611.11 ppm and the average being 2006.95 ppm (count=84). The volcanic recorded values ranging from 142.3 ppm to 8502.50 ppm, average value being 2008.03 ppm (count=116). Sukleswar Ka Mandir (G3) block yields tREE up to 2901ppm in microgranite dyke, 2121 ppm in alkali feldspar granite and 2996ppm in andesite.

Lal and Ghosh, 2021 carried out large scale geological mapping (1:12500 scale) at the northern periphery of the Siwana Ring Complex, stretching from Sainji ki Beri to Meli area. They marked 32 nos. of rhyolitic flows along with several felsic dykes in the area. Several flows are found to be highly enriched in tREE concentration. Chemical analysis data from rhyolite samples of study area yielded ΣREE+Y values ranging from 91.76ppm to 9764.68ppm, with average value of 1844.84ppm. ΣHREE/ΣLREE ratio of the same is 0.15. 22 BRS samples from felsic/rhyolite dykes yielded ΣREE+Y values ranging from 144.77ppm to 7678.75ppm, with average value of 1400.14ppm. ΣREE+Y value in channel samples ranging from 261.73 to 6224.81ppm, with ΣHREE/ΣLREE ratio of 0.19. Flow no. 14 and 15 are highly enriched REE flow of rhyolite in the area. In the block ΣREE+Y in flow no. 15 ranges between 2213.43ppm to 8027.71ppm with maximum value of LREE 5079.52ppm and maximum value of HREE 992.05ppm. In flow no. 14, ΣREE+Y ranges between 6944.16ppm to 7528.11ppm with maximum LREE 4848.19ppm and maximum HREE 941.11ppm. Remote Sensing and Aerial Survey for toposheet no. 45C/06 and 45C/10 were carried out by RSAS Division, GSI, Bangalore, during FS. 2017-18. Aeromagnetic maps help in delineating the regional continuity of magnetically susceptible litho-units of Siwana Ring Complex even under

soil-covered terrain. Spectrometric maps of potassium and thorium further suggest that the area possesses good potential for rare earth element (REE) mineralization in exposed area.



NB-13 Block shown on Aeromag map.

3. Planned Methodology

Detailed mapping of 2.0 sq. km area (on 1:2,000) is to be carried out for the item along with collection of surface samples to delineate REE & RM mineralised zones. The depth continuity, grade and thickness of these zones will be checked by drilling about 24 vertical boreholes of 125m depth on a grid of 400m x 200m.

As most of the REE minerals are not identified by study of thin sections, 05 samples for EPMA and 05 samples for XRD studies are also proposed to identify the REE mineral phases.

Initially few boreholes will be drilled, and respective core samples will be tested for REE and associated RM concentrations. If encouraging results are received the remaining drilling and core sampling will be done simultaneously.

4. Nature, Quantum, and Target

4.1 Detailed mapping

Detailed mapping of 2.0 sq. km area (on 1:2,000) is to be carried out for the block along with collection of surface samples and channel samples to delineate REE & RM mineralised zones.

4.2 Pitting at Selected locations

Based on the initial understanding there is soil cover up to substantial depth. Pitting shall be done using long arm excavators up to a depth of 3 meter and samples shall be collected from the bottom of the pit. Pitting is proposed for 50 locations with 150 Cum. of excavation for sample collection. At the concept stage pits are dug at 200m regular grid interval.

4.3 Drilling and borehole geophysical survey.

The depth continuity, grade and thickness of these zones will be checked by drilling vertical boreholes on a grid of 400m x 200m. A total of 24 boreholes of 125m depth are proposed to be drilled across the block area summing up to 3000m of core drilling.

In addition, 1000 of borehole geophysics shall be undertaken in approximately 10 nos. of boreholes.

4.4 Petrochemical samples (PCS)

Petrochemical samples (PCS) will be used for geochemical characterisation of important lithological unit of the study area. 15 Petro-chemical samples and 15 Petro mineragraphic samples study.

4.5 X-Ray Diffraction and EPMA

X- Ray Diffraction (XRD) and EPMA studies are proposed to identify the REE mineral phases. 05 samples for EPMA and 05 samples for XRD studies proposed to identify the REE mineral phases.

Summary of proposed exploration quantum is as below:

Sl. No.	Item of Work	UoM	Proposed Quantum
1	Detailed Geological Mapping (1:2000 scale)	Sq. Km.	2.0
2	Topographic survey using drone and DGPS	Sq. Km.	2.0
3	Pitting	Cum	150
4	Channel Sampling	Nos.	100
5	Pit Samples	Nos.	50
6	Core Drilling (24 nos of Boreholes)	m	3000
7	Geophysical BH logging	m	1000
8	Chemical Analyses (number)- *REEs, Y, Hf, Zr, Nb, Ta (ICP-MS for 34 elements)	Nos.	950
9	PCS (Major, Minor, Trace, REEs)	Nos.	15
10	Complete mineragraphic studies	Nos.	15
11	XRD	Nos.	5
12	EPMA (Avg. 6 hours/sample)	Nos.	5
13	Geological Report	Qty.	1

References

Reconnaissance survey for Rare Earth Elements and associated mineralisation around Sainji ki Beri-Meli area, northern part of Siwana ring complex (SRC), Siwana, Barmer district, Rajasthan (Stage: G4)

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