

GEOLOGICAL REPORT

ON

RECONNAISSANCE SURVEY (G-4)

FOR

REE AND ASSOCIATED MINERALS

IN

SUMARASAR AREA

DISTRICT KACHCHH,
GUJARAT

(Under NMEDT Programme)

TEXT, ANNEXURE AND PLATES

 Area
100.20 sq. km

 Toposheet
41E/11

 Location
23° 21' 0.675"N to
23° 16' 19.356"N
69° 38' 18.118"E to
69° 30' 31.828"E



A: Alternate layer of Shale and Sandstone in Katrol/Jhuran Formation; **B:** Alternate layers of grey, Fe Shale and gypseous bands with red bands in Katrol/Jhuran Formation; **C:** Ammonite fossil found within the Sandstone of Katrol/Jhuran Formation; **D:** Tabular & Trough cross bedding present in Feldspathic Sandstone of Bhuj Formation



MINERAL EXPLORATION & CONSULTANCY LIMITED
(formerly known as Mineral Exploration Corporation limited)
(A Government of India Enterprise)

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TEXT

सुमारासर क्षेत्र, जिला-कच्छ, गुजरात में दुर्लभ मृदा तत्वों एवं संबद्ध खनिजों हेतु पूर्वक्षण सर्वेक्षण (G-4) पर भूवैज्ञानिक प्रतिवेदन

अध्याय 1

1.0.0 कार्यकारी सारांश

सुमारासर ब्लॉक, जिसका क्षेत्रफल 100.20 वर्ग कि.मी. है, गुजरात राज्य के कच्छ जिले के भुज तालुका में स्थित है तथा यह सर्वे ऑफ इंडिया के टोपोशीट संख्या 41E/11 में आता है। इस क्षेत्र में राष्ट्रीय खनिज अन्वेषण न्यास (NMET) कार्यक्रम के अंतर्गत दुर्लभ मृदा तत्व (REE) एवं संबद्ध खनिजों की खोज हेतु पूर्वक्षण सर्वेक्षण (G-4) संचालित किया गया। इस अन्वेषण कार्यक्रम की अनुशंसा TCC-II की 6वीं बैठक में की गई तथा इसे बाद में NMET की 41वीं कार्यकारी समिति (EC) द्वारा अनुमोदित किया गया। क्षेत्रीय अन्वेषण कार्य मिनरल एक्सप्लोरेशन एंड कंसल्टेंसी लिमिटेड (MECL) द्वारा अप्रैल 2025 से दिसंबर 2025 की अवधि के दौरान संपादित किया गया, जिसके उपरांत प्रयोगशाला परीक्षण, आंकड़ों की व्याख्या तथा भूवैज्ञानिक प्रतिवेदन (Geological Report) तैयार किया गया।

यह ब्लॉक कच्छ रिफ्ट बेसिन का एक भाग है, जो पश्चिमी भारत के प्रमुख मेसोजोइक अवसादी बेसिनों में से एक है। अध्ययन क्षेत्र में मुख्यतः भुज संरचना (निम्न क्रिटेशियस) तथा झुरान संरचना/कट्रोल श्रृंखला (उच्च जुरासिक-निम्न क्रिटेशियस) की अवसादी शैलें पाई जाती हैं। वर्तमान अन्वेषण के दौरान प्रमुख रूप से फेल्डस्पैथिक बलुआ पत्थर, फेरुजिनस बलुआ पत्थर, कैल्केरियस बलुआ पत्थर, ग्रेटी बलुआ पत्थर, शेल-सिल्टस्टोन अंतर्विन्यास, जिप्सीयस शेल, जीवाश्मयुक्त चूना पत्थर तथा क्वार्ट्जाइट शैल इकाइयों की पहचान की गई। संरचनात्मक दृष्टि से क्षेत्र में NNW-SSE, NNE-SSW तथा ESE-WNW दिशा के प्रमुख संयुक्त तंत्र (Joint Sets) विकसित हैं, जबकि क्षेत्रीय विवर्तनिकी कट्रोल हिल भ्रंश (Katrol Hill Fault) एवं उससे संबंधित रेखीय संरचनाओं (Lineaments) से प्रभावित है।

अन्वेषण कार्यक्रम के अंतर्गत 1:12,500 मापक पर विस्तृत भूवैज्ञानिक मानचित्रण, भू-रासायनिक नमूनाकरण, पिटिंग, ऑगर ड्रिलिंग, पेट्रोग्राफिक अध्ययन तथा XRD

परीक्षण किए गए। अन्वेषण के दौरान विभिन्न शैल इकाइयों से कुल 169 नमूने, जिनमें 50 बेडरॉक नमूने, 25 पिट नमूने तथा 94 ऑगर नमूने सम्मिलित हैं, भू-रासायनिक मूल्यांकन हेतु एकत्रित किए गए। सभी नमूनों का ICP-MS द्वारा 34 तत्वों के लिए विश्लेषण किया गया। इसके अतिरिक्त, चयनित नमूनों पर खनिजवैज्ञानिक विशेषताओं के अध्ययन हेतु पेट्रोग्राफिक एवं XRD परीक्षण भी किए गए।

भू-रासायनिक अध्ययन से बलुआ पत्थर तथा शेल स्तरों में स्थानीयकृत REE संवर्धन का संकेत प्राप्त हुआ। बलुआ पत्थर नमूनों में $\Sigma\text{REE}+\text{Y}$ का मान 112.67 ppm से 514.60 ppm (औसत 346.56 ppm) तथा शेल नमूनों में 77.45 ppm से 1527.80 ppm (औसत 371.87 ppm) के मध्य पाया गया। विश्लेषित नमूनों में हल्के दुर्लभ मृदा तत्वों (LREE) का प्रभुत्व भारी दुर्लभ मृदा तत्वों (HREE) की तुलना में अधिक पाया गया। चोंड्राइट-नॉर्मलाइज़्ड REE प्रतिरूपों में स्पष्ट ऋणात्मक यूरोपियम विसंगति (Negative Eu Anomaly) पाई गई, जो फेल्सिक स्रोत शैलों से व्युत्पत्ति का संकेत देती है। Zr, Th, Hf तथा Y की उच्च सांद्रता REE-धारक प्रतिरोधी भारी खनिजों की उपस्थिति का द्योतक है।

पेट्रोग्राफिक तथा XRD अध्ययनों से मोनाजाइट, जेनोटाइम तथा जिरकॉन जैसे सहायक REE-वाहक खनिजों की उपस्थिति ज्ञात हुई। इसके अतिरिक्त, कुछ नमूनों में कोलोफेन, डाह्लाइट तथा एपेटाइट जैसे फॉस्फेट खनिजों की पहचान की गई, जो स्थानीय स्तर पर फॉस्फेटीय संवर्धन का संकेत देते हैं। REE-वाहक खनिजों का फॉस्फेटीय खनिजों के साथ सहसंबंध यह इंगित करता है कि क्षेत्र में REE संवर्धन संभवतः फेल्सिक स्रोतों से प्राप्त डिट्राइटल अवयवों तथा समुद्री परिवेश में निक्षेपित फॉस्फेटीय अवसादी स्तरों में द्वितीयक संकेन्द्रण, दोनों से प्रभावित रहा है। तथापि, वर्तमान अन्वेषण के दौरान किसी भी सतत एवं पार्श्वीय रूप से विस्तृत फॉस्फेटीय स्तर की पहचान नहीं की जा सकी। क्षेत्रीय परीक्षण के दौरान शापिरो विलयन (Shapiro Solution) के उपयोग से भी आर्थिक दृष्टि से महत्वपूर्ण फॉस्फोराइट स्तरों की उपस्थिति का संकेत नहीं मिला। अतः, स्वीकृत कार्य-परिधि से बाहर होने के कारण विस्तृत फॉस्फोराइट विश्लेषण नहीं किया गया।

यद्यपि कुछ पृथक नमूनों में $\Sigma\text{REE}+\text{Y}$ का मान 1000 ppm से अधिक प्राप्त हुआ, तथापि ऐसे विसंगत मान केवल सीमित एवं स्थानीय स्तरों तक ही प्रतिबंधित रहे तथा

REE खनिजीकरण की कोई महत्वपूर्ण पार्श्वीय निरंतरता स्थापित नहीं की जा सकी। इसके अतिरिक्त, सुमारासर ब्लॉक के ठीक पूर्व में स्थित समीपवर्ती नोकहानिया ब्लॉक में ब्लॉक सीमा के निकट 50 मीटर गहराई तक ड्रिल किए गए एक बोरहोल में कोई भी प्रोत्साहक REE-धारक स्तर प्राप्त नहीं हुआ। उपलब्ध भूवैज्ञानिक, भू-रासायनिक तथा खनिजवैज्ञानिक आंकड़ों के समेकित विश्लेषण से यह स्पष्ट होता है कि सुमारासर ब्लॉक में प्राप्त REE संवर्धन स्थानीय एवं असतत प्रकृति का है। अतः वर्तमान G-4 स्तर की अन्वेषण गतिविधियों के आधार पर इस ब्लॉक में आगे किसी व्यवस्थित अन्वेषण की आवश्यकता परिलक्षित नहीं होती तथा सुमारासर ब्लॉक को वर्तमान चरण में समापन (Closure) हेतु अनुशंसित किया जाता है। तथापि, भविष्य में यदि समीपवर्ती क्षेत्रों से नवीन क्षेत्रीय भूवैज्ञानिक, भू-रासायनिक, भूभौतिकीय अथवा खनिजवैज्ञानिक आंकड़े उपलब्ध होते हैं, तो अध्ययन क्षेत्र में अनुकूल शैल-स्तरों का पुनर्मूल्यांकन किया जा सकता है।

GEOLOGICAL REPORT ON RECONNAISSANCE SURVEY (G-4) FOR REE AND ASSOCIATED MINERALS IN SUMARASAR AREA, DISTRICT- KACHCHH, GUJARAT

CHAPTER - I

1.0.0 EXECUTIVE SUMMARY

The Sumarasar Block covering an area of 100.20 sq. km is situated in Bhuj Taluka, Kachchh District, Gujarat, and falls within Survey of India Toposheet No. 41E/11. The block was taken up for Reconnaissance Survey (G-4) for Rare Earth Elements (REE) and associated minerals under the National Mineral Exploration Trust (NMET) programme. The exploration programme was recommended in the 6th Meeting of TCC-II and subsequently approved in the 41st Meeting of the Executive Committee (EC), NMET. Field investigations were carried out by Mineral Exploration and Consultancy Limited (MECL) during the period from April 2025 to December 2025, followed by laboratory investigations, data interpretation and preparation of the Geological Report.

The block forms part of the Kachchh Rift Basin, one of the prominent Mesozoic sedimentary basins of western India. The area is mainly occupied by sedimentary rocks belonging to the Bhuj Formation (Lower Cretaceous) and Jhuran Formation/Katrol Series (Upper Jurassic–Lower Cretaceous). The principal lithological units encountered during the present investigation include feldspathic sandstone, ferruginous sandstone, calcareous sandstone, gritty sandstone, shale-siltstone alternations, gypseous shale, fossiliferous limestone and quartzite. Structurally, the area exhibits prominent NNW–SSE, NNE–SSW and ESE–WNW joint sets, while regional tectonics is influenced by the Katrol Hill Fault and associated lineaments.

The exploration programme comprised Large Scale Geological Mapping (1:12,500 scale), geochemical sampling, pitting, auger drilling, petrographic studies and XRD investigations. During the course of investigation, a total of 169 samples, comprising 50 bedrock samples, 25 pit samples and 94 auger samples, were collected from various lithological units for geochemical evaluation. All the samples were analysed for 34 elements by ICP-MS. In

addition, selected samples were subjected to petrographic and XRD studies for mineralogical characterization.

Geochemical investigations indicate the presence of localized enrichment of REE within sandstone and shale horizons. Sandstone samples yielded $\Sigma\text{REE}+\text{Y}$ values ranging from 112.67 ppm to 514.60 ppm with an average of 346.56 ppm, whereas shale samples recorded $\Sigma\text{REE}+\text{Y}$ values ranging from 77.45 ppm to 1527.80 ppm with an average value of 371.87 ppm. The analysed samples show enrichment of Light Rare Earth Elements (LREE) over Heavy Rare Earth Elements (HREE). Chondrite-normalized REE patterns exhibit a distinct negative Eu anomaly, suggesting derivation from felsic source rocks. High concentrations of Zr, Th, Hf and Y indicate the presence of resistant heavy minerals hosting REE.

Petrographic and XRD studies reveal the occurrence of monazite, xenotime and zircon as accessory REE-bearing minerals. In addition, phosphatic minerals such as collophane, dahllite and apatite have been identified in certain samples, indicating localized phosphatic enrichment. The association of REE-bearing minerals with phosphatic phases suggests that REE enrichment in the area may have been influenced by both detrital input from felsic provenance and secondary concentration within phosphatic sedimentary horizons deposited under marine conditions. However, no laterally persistent phosphatic horizon could be delineated during the present investigation. Field examination using Shapiro solution did not indicate the presence of economically significant phosphorite horizons and, therefore, detailed phosphorite analysis was not undertaken as it was beyond the approved scope of work.

Although a few isolated samples yielded $\Sigma\text{REE}+\text{Y}$ values exceeding 1000 ppm, the anomalous values are restricted to localized horizons and no significant lateral continuity of REE mineralization could be established. Furthermore, a borehole drilled up to 50 m depth in the adjoining Nokhaniya Block, located immediately east of the Sumarasar Block, did not intersect any encouraging REE-bearing horizon near the block boundary. The integrated geological, geochemical and mineralogical data therefore suggest that the REE

enrichment encountered in the Sumarasar Block is localized and discontinuous in nature. Accordingly, the present G-4 stage investigation does not warrant further systematic exploration within the block and the Sumarasar Block is recommended for closure at the present stage. However, any future investigations, if considered necessary on the basis of new regional geological, geochemical, geophysical or mineralogical inputs generated from adjacent areas, may focus on evaluating favourable lithological horizons within the study area.

CHAPTER - II

2.0.0. DETAILS OF THE QUALIFIED PERSON(S) / EXPLORATION AGENCY

(To be provided separately for all the qualified persons signing off the report)

Table No 2.1
Details of Qualified Person(S) / Exploration Agency

(a) Name:	MINERAL EXPLORATION AND CONSULTANCY LIMITED (Formerly Mineral Exploration Corporation Limited) (A Govt. of India Enterprise; A Miniratna-I PSE) (Ministry of Mines, Govt. of India)
(b) Address:	Dr. Babasaheb Ambedkar Bhawan, High Land Drive Road, Seminary Hills, Nagpur-440006.
(c) Contact Mobile No:	0712-2510289; 0712-2511829
(d) E-Mail id:	cmd@mecl.gov.in gm-exploration@mecl.gov.in
(e) Qualification:	Professionals with M.Sc. / M. Tech (Geology) Qualification
(f) Experience:	Professionals with experience > 30 Years
(g) Affiliation to any organization/company, if yes, specify the name of the organization or company.	A Govt. of India Enterprise; A Miniratna-I PSE Ministry of Mines, Govt. of India

2.1.0 Details of qualification and experience of persons associated with various aspects of exploration assessment of resources and reserves.

2.1.1 The Details of personnel associated with the Exploration in Sumarasar Block is given in following Table No 2.2

Table No 2.2

Details of Personnel Associated with The Exploration Sumarasar Block, Dist: Kachchh, Gujarat

1	Overall Planning, Co-ordination & Overall supervision	:	Shri P. Ravindran, GM (Exploration) (Retired)
		:	Shri Shrikant Sharma, DGM/HoD (Exploration)
		:	Shri Naveen Kumar Pala, Sr, Manager (Geology)
2	Project management & Field Operation	:	Shri Khushi Ram, Project Manager
		:	Smt. Aayushi Saraswat, Geologist
3	Chemical Laboratory, MECL	:	Shri Rohit Kumar Sharma, Manager (Chemistry)
		:	Dr. (Mrs.) Deepti R. Rahangdale, Manager (Chemistry)
4	Petrological Laboratory, MECL	:	Shri Sayantan Pal, Manager (Geology)
5	Data Processing & Documentation	:	Shri Sayandeep Chakraborty, Asst. Manager (Geology)
		:	Smt Moumita Ghosh, Asst. Manager (Geology)
		:	Smt. Aayushi Saraswat, Geologist
		:	Shri Shivananda, Sr. Operator (Computer)
6	Reprography & Printing	:	Shri P.S Negi, OIC, Survey

CHAPTER - III

3.0.0. TITLE AND OWNERSHIP

3.1.0 GEOLOGICAL REPORT ON RECONNAISSANCE SURVEY (G-4) FOR REE AND ASSOCIATED MINERALS IN SUMARASAR AREA (100.20 SQ. KM), DISTRICT- KACHCHH, GUJARAT

Ownership: Government of Gujarat

Name of Prospector: MINERAL EXPLORATION AND
CONSULTANCY LIMITED (Formerly Mineral
Exploration Corporation Limited)

(A Govt. of India Enterprise; A Miniratna-I PSE)

(Ministry of Mines, Govt. of India)

Address of Prospector: Dr. Babasaheb Ambedkar Bhavan, High Land
Drive Road, Seminary Hills, Nagpur, Pin- 440006

E-mail of Prospector: cmd@mecl.co.in; gm-exploration@mecl.co.in

Telephone numbers of Prospector: 0712-2510289; 0712-2511829

3.2.0 Details of period of Prospecting

3.2.1 Reconnaissance Survey (G-4) for REE and associated minerals in Sumarasar area, Kachchh District, Gujarat was recommended in the 6th Meeting of the Technical-cum-Cost Committee-II (TCC-II) of NMEDT and subsequently approved in the 41st Meeting of the Executive Committee (EC), NMEDT held on 11th March, 2025. The approval was communicated to MECL vide Ministry of Mines letter No. F.No. 23/601/2025-NMET/1044 dated 19th March, 2025.

3.2.2 Pursuant to the approval, MECL commenced field work on 6th April, 2025 and completed the first phase of exploration by the second week of August, 2025. The first phase comprised Large Scale Geological Mapping (1:12,500 scale) and collection of surface samples, including bedrock and petrographic samples. The results of the first phase were reviewed during the 12th Meeting of TCC-II held on 25th August, 2025, wherein the Committee advised continuation of the project work as per the approved scope.

- 3.2.3 Accordingly, pitting and auger drilling along with systematic sampling were carried out during September to December, 2025. The outcomes of the second phase were reviewed in the 20th Meeting of TCC-II held on 2nd and 5th January, 2026. After detailed deliberations, the Committee only recommended for approval of the PSC for timeline extension of 03 months and 12 days, up to 30th April 2026, for submission of the final Geological Report (GR).
- 3.2.4 Further, the project was discussed in the 22nd meeting of TCC-II held on 4th and 5th February, 2026 and the committee advised the MECL to keep core drilling on hold, and stated that further drilling will be decided after reviewing the core analysis from the adjacent ongoing exploration of Nokhania Block for REE mineralisation.
- 3.2.5 Upon completion of drilling in the adjacent Nokhania Block, MECL sought further guidance from TCC, NMEDT regarding continuation of exploration in the Sumarasar Block. Accordingly, the findings of the Nokhania Block were presented during the 28th Meeting of TCC-II, NMEDT held on 7th and 8th May, 2026. After detailed deliberations, the Committee opined that the exploration in the Sumarasar Block may be concluded, as a borehole drilled in the adjacent Nokhania Block, in close proximity to the Sumarasar Block, did not intersect any promising REE-bearing zones. The Committee further recommended the proposal for approval of PSC for extension of the project timeline by three months, i.e., up to 31st July, 2026, for preparation, peer review and submission of the Geological Report. Subsequently, MECL prepared the Geological Report for final submission within the stipulated time frame.

CHAPTER - IV

4.0.0 DETAILS OF THE AREA UNDER STUDY

4.1.0 Location of the Block

4.1.1 Sumarasar area having an area of 100.20 sq. km is bounded by latitude 23° 21' 0.68"N to 23° 16' 19.36"N and Longitude 69° 38' 18.12"E to 69° 30' 31.83"E. It lies in the South western part of Kachchh District, and towards South eastern side from the block is the Bhuj city (approximately 5 km). The location map of the block is furnished as Text Fig No-4.2 as well as Plate No-I.

4.1.2 The Block is located in the southern western part of Survey of India Toposheet No 41E/11. The coordinates of the cardinal points of the block boundary are given below in Table No. 4.1

Table No-4.1

**Coordinates of cardinal points of Sumarasar Block, District: Kachchh,
Gujarat**

Sl. No.	Point	GCS WGS 1984 (DMS)		UTM Zone: 42N (m)		Area (sq km)
		Latitude	Longitude	Easting	Northing	
1	A	23° 20' 58.68" N	69° 30' 33.93" E	552071.640	2582316.588	100.2
2	B	23° 21' 0.68" N	69° 37' 32.21" E	563948.076	2582424.658	
3	C	23° 18' 39.0" N	69° 37' 31.52" E	563947.376	2578067.624	
4	D	23° 18' 39.09" N	69° 38' 18.12" E	565270.901	2578076.168	
5	E	23° 16' 19.36" N	69° 38' 18.0" E	565286.5649	2573779.094	
6	F	23° 16' 19.44" N	69° 32' 57.07" E	556168.5693	2573744.312	
7	G	23° 18' 27.97" N	69° 30' 31.83" E	552028.3127	2577681.676	

4.2.0 Accessibility to the Block

4.2.1 All villages within and around the block are well connected to one another and to nearby highways through motorable roads and tracks. The interior villages of the area are connected by tar, semi-metalled roads. On the whole, the area is easily accessible by vehicle, except part of the area which occupied by high hills and dense forest.

4.2.2 The nearest railway station is located at Bhuj, the district headquarters of Kachchh in Gujarat. Bhuj Railway Station is a major railway station on the Western Railway network and serves as the terminal station of the western

railway line in the region. It provides connectivity to several major cities across India and serves as the nearest railhead for the block area.

- 4.2.3 Bhuj has a domestic airport located about 6 km South East of the Block area. It provides air connectivity to major cities, which helps in easy movement of staff and transport of important equipment

4.3.0 Land Use Pattern

- 4.3.1 The Land Use/Land Cover (LULC) map of the Sumarasar Block boundary area was prepared using satellite image interpretation and GIS analysis at a scale of 1:12,500. The analysis reveals that the area is predominantly occupied by rangeland, with limited occurrences of agricultural land, human settlements, water bodies, vegetation, and bare ground.

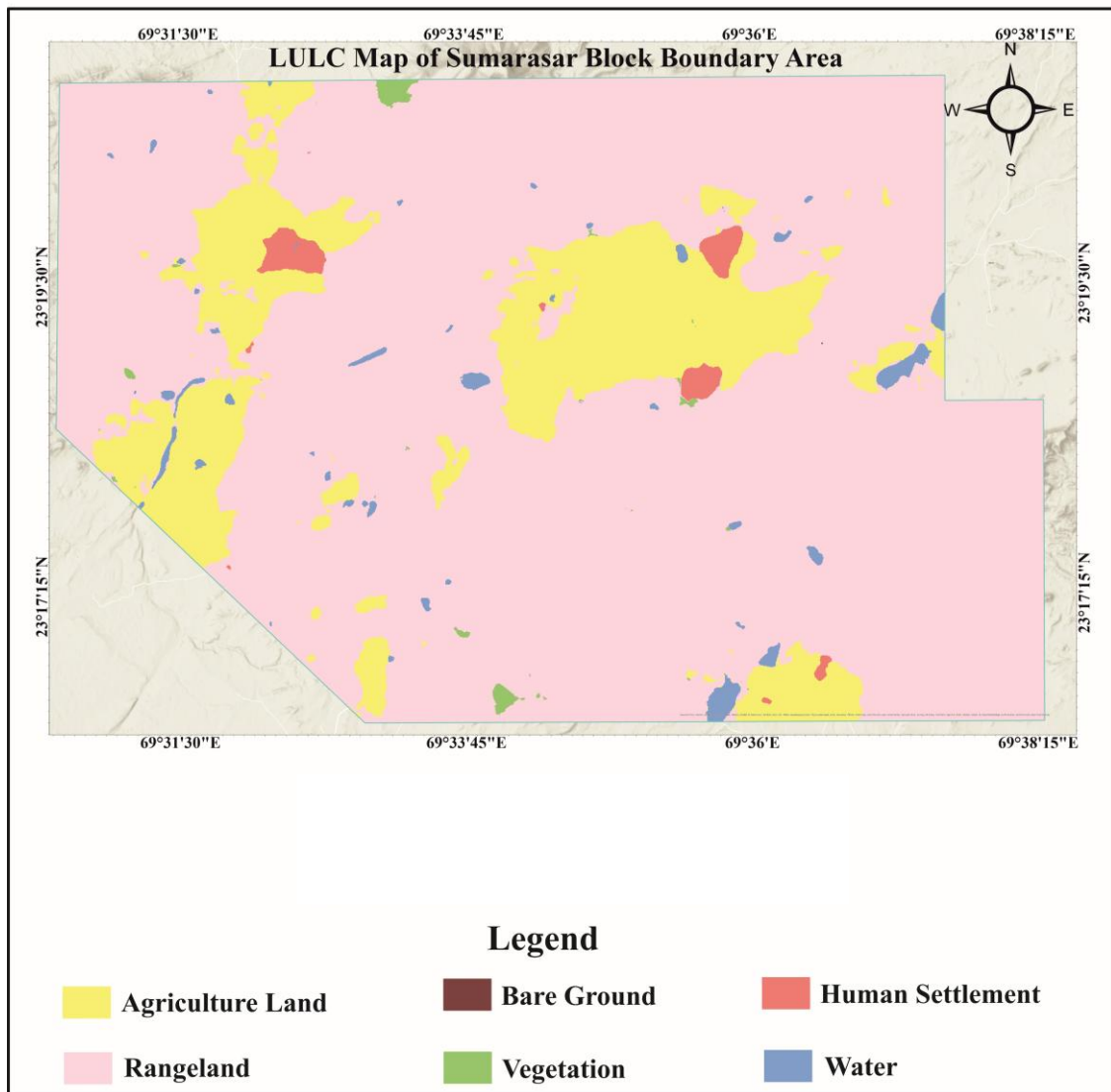
- 4.3.2 A total area of approximately 100.20 km² was mapped within the block boundary. Among the various land use classes, Rangeland constitutes the dominant category, covering 81.88 km² (81.65%) of the total area. The extensive rangeland reflects the semi-arid climatic conditions and sparse natural vegetation prevailing in the region.

- 4.3.3 Agricultural land occupies 16.23 km² (16.19%) of the mapped area and is mainly concentrated in relatively flat terrains where soil and moisture conditions are suitable for cultivation. Human settlements account for 0.90 km² (0.90%), indicating scattered village habitations and associated infrastructure.

- 4.3.4 Water bodies, including ponds, tanks, and small drainage channels, cover 0.96 km² (0.96%) of the area. Vegetation occupies only 0.30 km² (0.30%), occurring as isolated patches. Bare ground is negligible, covering merely 0.0003 km², representing exposed surfaces devoid of significant vegetation cover.

- 4.3.5 The LULC analysis indicates that the Sumarasar Block is characterized by a predominantly rangeland landscape with localized agricultural activities and sparse settlement distribution. The land use pattern reflects the dry

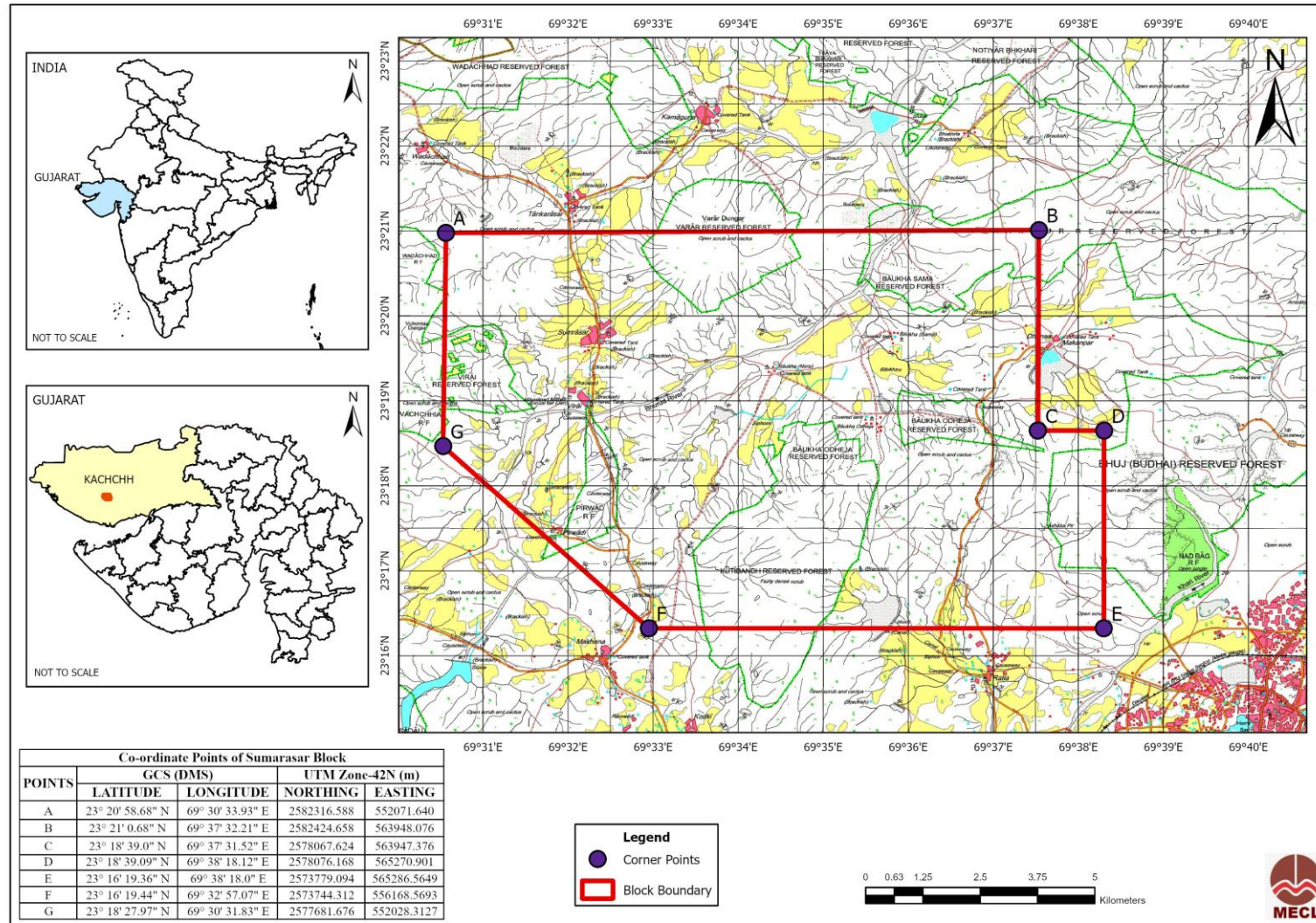
environmental conditions and supports the interpretation of the area as a predominantly grazing and open-land terrain.



Text Fig. 4.1: LULC Map of Sumarasar Block, District Kachchh, Gujarat

4.4.0 Mineral(s) under investigation or granted under license or lease

4.4.1 The Sumarasar Block was explored for the occurrences of REE and Associated Minerals.



Text Fig. 4.2: Location map of Sumarasar Block, District Kachchh, Gujarat

CHAPTER - V

5.0.0 PHYSIOGRAPHY AND ENVIRONMENT

5.1.0 Topography

5.1.1 The study area forms a part of the gently undulating terrain of the Central Kachchh Mainland. The maximum elevation within the block occurs towards the northern part near Khatlo Dungar, reaching about 320 m above MSL, whereas the minimum elevation of approximately 101 m above MSL is recorded towards the south-eastern part of the block. An SSW–NNE trending ridge, attaining a maximum elevation of about 210 m above MSL, occurs along the southern margin of the block. In general, the area is characterized by low to moderate relief with isolated rocky uplands, ridges and intervening gently sloping plains.

5.2.0 Connectivity

5.2.1 The area is well connected by a network of motorable roads, village roads and cart tracks, facilitating easy movement within the area. The villages of Ratiya, Baukha and Sumarasar are connected by tarred and semi-metalled roads. Bhuj, the district headquarters, is the nearest major urban centre and serves as the principal logistical base for exploration activities. Bhuj Railway Station, located on the Western Railway network, is the nearest railhead and represents the terminal station of the Western Railway line in the Kachchh region. Vehicular access is available throughout most parts of the block. However, accessibility in certain western and north-western parts is relatively restricted due to rugged topography and hill slopes. Overall, the block area is easily accessible.

5.3.0 Population

5.3.1 As per the Census of India, 2011, the block area encompasses the villages of Ratiya, Sumarasar, Baukho (Odhejavalo), Baukho (Samavalo), Sumarasar (Jatvali), Dhonsa and Makhanapar. The total population of these villages is approximately 6,314 persons, comprising 2,988 males and 2,881 females. The average population density within the block area is about 114 persons per sq. km. Rural habitation predominates in the block area, with the majority of the

population residing in revenue villages, while Bhuj town constitutes the nearest urban settlement.

5.4.0 Socio Demographic profile

5.4.1 The socio-demographic characteristics of the block area are broadly similar to those of Bhuj Taluka and Kachchh District. As per Census 2011, the sex ratio in the region is approximately 964 females per 1,000 males, whereas the child sex ratio is about 933 girls per 1,000 boys. The overall literacy rate in the area is around 71–72%. The block area is predominantly rural in nature, with almost the entire population residing in villages under Bhuj Taluka of Kachchh District.

5.4.2 Kutchi is the principal language spoken in the area, followed by Gujarati and Hindi. Kutchi is extensively used for day-to-day communication, whereas Gujarati is predominantly used for administrative and educational purposes.

5.5.0 Historical / Archaeological Site

5.5.1 No notified historical or archaeological monument occurs within the Sumarasar Block area. However, Bhuj, the district headquarters located in the vicinity of the block, possesses considerable historical and cultural significance. Important heritage structures in and around Bhuj include Aina Mahal, Prag Mahal, Bhujiyo Fort, Chhatardi Cenotaphs, Sharad Baug Palace and the Kutch Museum. These monuments represent the rich architectural and cultural heritage of the erstwhile Kachchh State. In addition, the Smritivan Earthquake Memorial and Museum, established in memory of the victims of the 2001 Bhuj earthquake, constitutes an important modern heritage landmark of the region.

5.6.0 Forests, sanctuaries, national park and wild life sanctuaries

5.6.1 Approximately 30.94 sq. km of the block area falls within Reserved Forest land. Eight Reserved Forests occur within the block, namely Kuti Bandh, Bhuj-Bhudai, Baukha Odheja, Baukha Sama, Varar, Pirwadi, Vachchhia and Virai Reserved Forests. The Sumarasar Block does not fall within any notified National Park, Wildlife Sanctuary or Eco-Sensitive Zone. The forest cover is

sparse and mainly comprises open scrub vegetation and scattered thorny species, typical of the semi-arid climatic conditions of the region.

5.7.0 Flora and Fauna within and nearby

- 5.7.1 The block area falls within an arid to semi-arid climatic regime and is characterized by sparse vegetation cover. The floral assemblage is predominantly represented by xerophytic thorny scrub species such as *Capparis decidua*, *Calotropis procera* and *Prosopis juliflora*, along with scattered cactus growth. Seasonal grasses such as *Cenchrus setigerus* and *Dichanthium annulatum* occur during and immediately after the monsoon season.
- 5.7.2 Denser shrub growth is locally developed along seasonal drainage channels, tanks and small reservoirs where residual soil moisture is retained for a limited period after the monsoon. The trap uplands and rocky ridges are generally barren and devoid of significant vegetation. Agricultural activities are largely confined to gently sloping plains and low-lying areas having comparatively thicker soil cover.
- 5.7.3 The faunal assemblage reflects a typical arid to semi-arid scrubland ecosystem. Reptilian fauna includes *Uromastix hardwickii*, *Varanus bengalensis*, *Eryx johnii*, *Python molurus*, *Naja naja*, *Bungarus caeruleus* and *Crocodylus palustris* in the vicinity of perennial water bodies. Amphibians such as frogs and toads appear seasonally during the monsoon.
- 5.7.4 Mammalian fauna reported from the region includes *Boselaphus tragocamelus*, *Gazella bennettii*, *Sus scrofa*, *Canis lupus pallipes*, *Canis aureus*, *Manis crassicaudata* and *Panthera pardus fusca*. Avifauna is comparatively abundant during the post-monsoon and winter seasons and includes Indian Roller, Bee-eater, Lapwing, Egret, Partridge, Francolin and migratory waterfowl visiting seasonal ponds and water bodies. The ecological setting of the block thus represents a typical dry scrubland ecosystem adapted to arid climatic conditions.

5.8.0 Drainage Pattern

5.8.1 The drainage pattern of the area is primarily controlled by local topography, lithology and structural features. The drainage is predominantly sub-dendritic to dendritic in nature and has developed over trap rocks and associated sedimentary formations. Numerous seasonal streams (locally known as nullahs) originate from the elevated trap uplands and rocky ridges and flow towards adjoining low-lying plains. The overall slope of the area is gentle, facilitating surface runoff during the monsoon season.

No major perennial river traverses the block area. The drainage network mainly comprises seasonal nullahs, village ponds, tanks, small check dams and localized depressions that accumulate rainwater during the monsoon period (June to September). Most of the drainage channels remain dry during the remaining part of the year, although limited moisture persists near tanks and reservoirs.

5.9.0 Climatic Condition

5.9.1 The climate of the area is semi-arid to arid. The summer season extends from March to June, during which the maximum temperature generally ranges from 40°C to 45°C and occasionally exceeds these values during peak summer months. Hot and dry winds are common, resulting in high evaporation rates. Night temperatures during summer generally range between 18°C and 25°C.

5.9.2 The southwest monsoon prevails from June to September, bringing an average annual rainfall of about 350–400 mm, most of which is received during July and August. Rainfall is generally erratic and unevenly distributed. Winters, extending from November to February, are mild and pleasant, with minimum temperatures ranging from 8°C to 12°C and moderate daytime temperatures. Overall, the climate is characterized by low rainfall, high temperature variations and prolonged dry conditions typical of western Gujarat.

5.10.0 Any other factor having potential to affect the viability of the project and assessment of resources and reserves.

5.10.1 The feasibility or pre-feasibility studies were not undertaken during the G-4 stage of exploration, since the reconnaissance-level investigations did not

establish mineralization of sufficient continuity, grade, or extent to warrant further techno-economic evaluation or resource/reserve estimation.

CHAPTER - VI

6.0.0 INFRASTRUCTURE

6.1.0 Local infrastructure Connectivity and facilities

6.1.1 The Sumarasar Block and its adjoining areas are supported by basic rural infrastructure. A network of motorable roads, village roads and cart tracks connects the various settlements within and around the block, thereby facilitating easy movement of personnel, equipment and materials during exploration activities. Bhuj, the district headquarters, serves as the principal logistical centre for the block and provides access to rail, road and other essential services.

6.1.2 Essential civic amenities such as electricity supply, drinking water facilities, educational institutions, primary health centres, local markets and banking facilities are available in nearby villages as well as at Bhuj and other taluka-level centres. Communication facilities, including mobile and internet connectivity, are generally available across most parts of the block area. The existing infrastructure is considered adequate to support reconnaissance-level exploration activities, and no major infrastructural constraints are anticipated for carrying out geological operations within the block.

CHAPTER - VII

7.0.0. GEOLOGY

7.1.0. Regional Geology

7.1.1 The Sumarasar area under study forms part of the Kachchh Rift Basin, a pericratonic extensional basin developed along the north-western margin of the Indian Shield in western India. The basin represents one of the most prominent Mesozoic sedimentary basins of the Indian subcontinent and records nearly 200 million years of tectono-sedimentary evolution. The basin is bounded by the Kathiawar uplift (Saurashtra horst) to the south, the Nagar Parkar uplift to the north, and the Thar platform to the northeast, while the Radhanpur Arch separates it from the Cambay Basin to the east. The basin originated during Late Triassic–Early Jurassic rifting associated with the fragmentation of Gondwanaland and the northward drift of the Indian plate (Biswas, 1987; Biswas, 2005; Fürsich et al., 2020).

7.1.2 Structurally, the Kachchh Basin is characterised by a series of E–W trending uplifts and intervening depressions, controlled by major regional fault systems such as the Nagar Parkar Fault (NPF), Island Belt Fault (IBF), Kachchh Mainland Fault (KMF) and North Kathiawar Fault (NKF). Secondary faults including the Katrol Hill Fault (KHF), Gedi Fault and Banni Fault further segment the basin. These structural elements divide the basin into distinct morphotectonic units including the Kachchh Mainland Uplift, Banni Basin, Pachchham Island uplift and Wagad uplift (Biswas, 2016; Fürsich et al., 2020). The present study area falls within the Kachchh Mainland Uplift, a structurally elevated block bounded by the KMF to the north and the KHF to the south. The structural framework of this uplift exerts a strong control on sedimentation patterns, lithological distribution and structural deformation of the basin fill.

7.1.3 The stratigraphic succession exposed in the Kachchh Mainland comprises a thick sequence of Jurassic to Cretaceous sedimentary rocks exceeding 2000–3000 m in cumulative thickness, unconformably overlain by Tertiary and Quaternary deposits and locally capped by Deccan Trap volcanics. The Mesozoic succession records a complex depositional history involving fluvial,

deltaic, shallow marine and offshore depositional environments, reflecting repeated marine transgressions and regressions during the Jurassic period followed by progressive continental sedimentation during the Early Cretaceous (Biswas, 2005; Fürsich et al., 2020).

- 7.1.4 The earliest stratigraphic classification of the Kachchh Mesozoic succession was proposed by Waagen (1873–1875) based on ammonite faunal assemblages and was subsequently refined by Rajnath (1932). These workers divided the Jurassic–Cretaceous succession into four major lithostratigraphic units or Series, namely Pachchham, Chari, Katrol and Umia Series, primarily based on lithological characteristics and fossil content.
- 7.1.5 Subsequently, Biswas (1977) revised the stratigraphy of the Kachchh Basin in accordance with modern lithostratigraphic principles and reclassified the succession into formations, namely Jhurio, Jhumara, Jhuran and Bhuj Formations, broadly corresponding to the earlier Pachchham, Chari, Katrol and Umia Series, respectively (Biswas, 1977; Biswas, 2005; Merh, 1995). This lithostratigraphic scheme is widely adopted in modern geological studies of the basin. The generalized stratigraphic succession of the Kachchh Basin is furnished in Table 7.1 below.

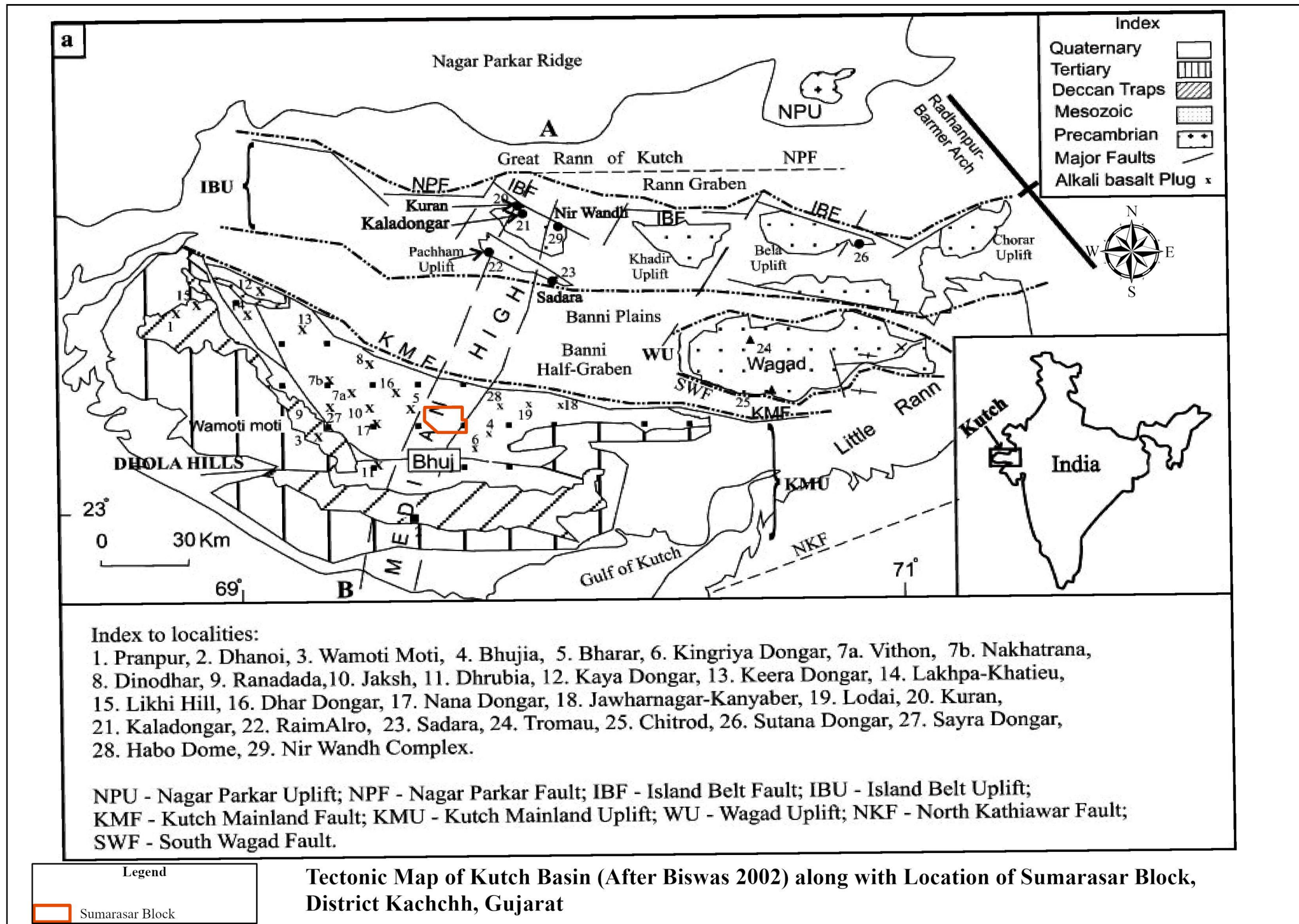
Table 7.1: Generalised Stratigraphic Succession of the Kachchh Basin

Age	Classical Nomenclature After Waagen (1875) & Rajnath (1932)	Modern Lithostratigraphy After Biswas (1977 & 1992) & Merh (1995)	General Lithology
Quaternary	—	Miliolite Formation / Alluvium / Aeolian Deposits	Calcareenite, marl, conglomerate, aeolian sand, alluvium and soil cover
Tertiary (Palaeocene–Miocene)	—	Matanomadh, Fulra, Khari Nadi, Gaj and Manchar Formations	Limestone, marl, shale, clay, bentonite, sandstone and conglomerate
Upper Cretaceous	—	Deccan Trap / Anjar Volcanics	Basaltic lava flows, mainly tholeiitic and alkali basalt with amygdaloidal textures
Lower Cretaceous	Umia Series	Bhuj Formation	Sandstone, shale, grit and conglomerate; feldspathic to ferruginous sandstone with cross-bedding, ripple marks and plant fossils
Upper Jurassic	Katrol Series	Jhuran Formation	Dark grey to black shale interbedded with calcareous and ferruginous sandstone, siltstone and claystone
Upper Jurassic	Chari Series	Jhumara Formation	Shale, limestone, marl, calcareous sandstone and fossiliferous beds
Middle Jurassic	Pachchham Series	Jhurio Formation	Limestone, shale, calcareous sandstone and fossiliferous conglomerate deposited in shallow marine environments

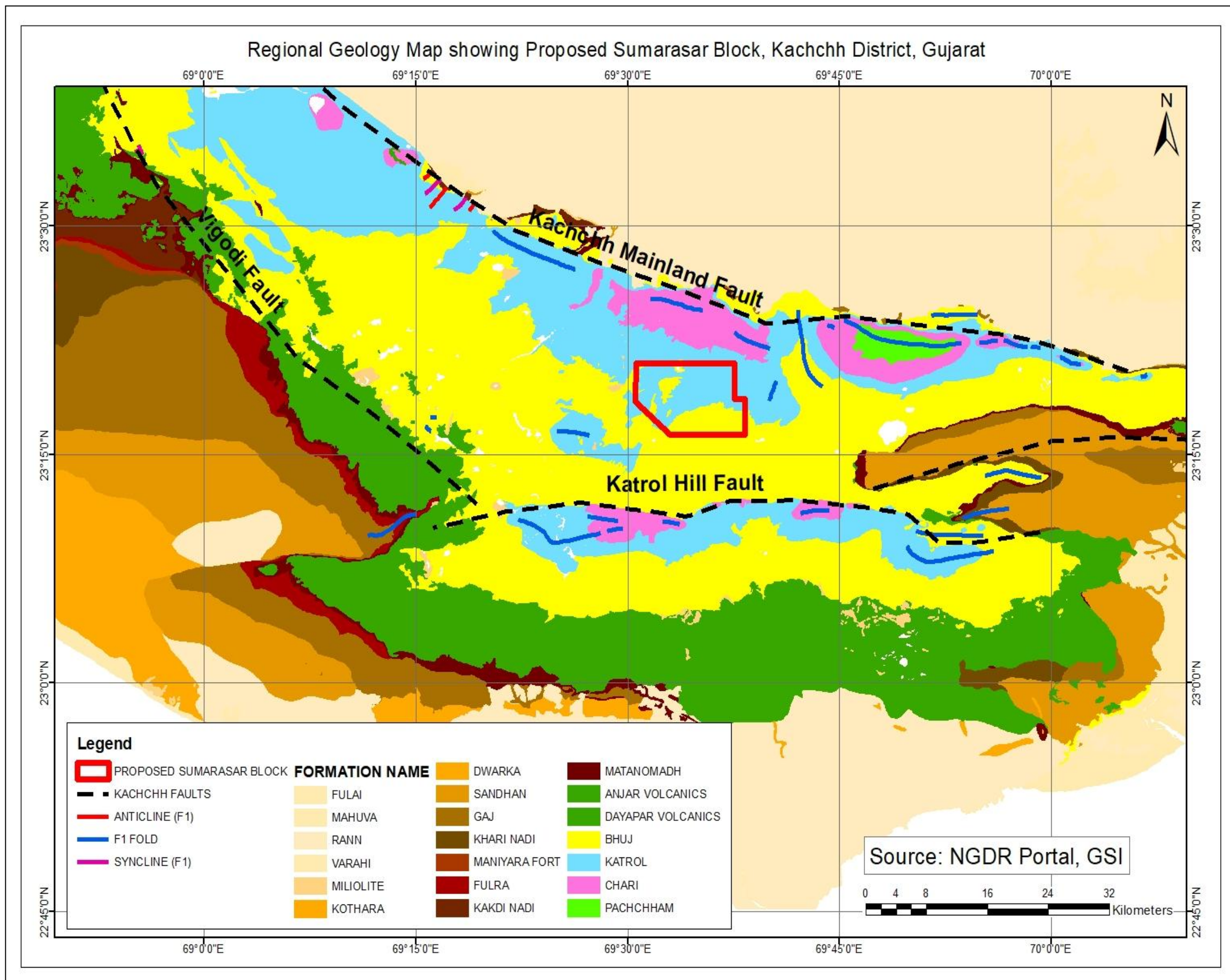
- 7.1.6 In the Bhuj–Nakhatrana region, the exposed lithostratigraphic units are mainly represented by the Jhumara, Jhuran and Bhuj Formations. The Pachchham Series (equivalent to Jhurio Formation) represents the oldest exposed Mesozoic unit in the basin and consists predominantly of interbedded shale, siltstone, calcareous sandstone and fossiliferous limestone, indicating deposition in shallow marine shelf environments.
- 7.1.7 The overlying Chari Series (Jhumara Formation) comprises polymictic conglomerate, fossiliferous gypseous shale, calcareous sandstone, oolitic limestone and marl, representing sedimentation in a shallow marine shelf to offshore environment. These sediments are widely exposed in the Katrol Hill Range, where they form prominent structural ridges.
- 7.1.8 The Katrol Series (Jhuran Formation) conformably overlies the Chari Series and consists mainly of dark grey to black shale interbedded with ferruginous and calcareous sandstone, siltstone and claystone. Fossil assemblages including ammonites, belemnites and gastropods are common within this formation. The lithological characteristics and sedimentary structures suggest deposition in deltaic to near-shore marine environments under fluctuating hydrodynamic conditions (Srivastava et al., 1994).
- 7.1.9 The Bhuj Formation, representing the youngest unit of the Mesozoic succession, conformably overlies the Jhuran Formation and consists of nearly 1000 m thick sequence of sandstone, shale, grit and conglomerate. The sandstones are typically feldspathic to ferruginous, medium to coarse grained and commonly exhibit cross-bedding, ripple lamination and channel-fill structures, indicating deposition in continental fluvial to alluvial-fan environments. Cyclic alternations of sandstone, shale and ironstone horizons are characteristic of this formation. The presence of glauconitic sandstone, carbonaceous shale and plant fossils suggests intermittent marine incursions during sedimentation.
- 7.1.10 Overlying the Mesozoic sedimentary sequence are the Deccan Trap basalts, which occur mainly in the southern parts of the Kachchh region. These volcanic rocks comprise multiple lava flows of olivine basalt, alkali basalt and tholeiitic basalt, commonly showing amygdaloidal textures with secondary silica and zeolite mineralisation. The emplacement of the Deccan volcanics

during the Late Cretaceous (~67–65 Ma) represents the terminal magmatic phase of basin evolution and is associated with regional crustal reactivation and uplift.

- 7.1.11 In addition to the Deccan Trap lava flows, several alkaline intrusive bodies (alkaline plugs) have been reported from the Bhuj–Nakhatrana region, where nearly 30–32 alkaline plugs intrude the Mesozoic sedimentary sequence. These plugs are composed mainly of nephelinite, phonolite and trachyte and represent late-stage intrusive activity associated with Deccan magmatism. The emplacement of these plugs is structurally controlled and commonly aligned along regional fault zones.
- 7.1.12 Subsequent to the volcanic phase, Tertiary sediments were deposited along the coastal parts of the Kachchh Mainland. These include formations such as Matanomadh, Fulra, Khari Nadi, Gaj and Manchar, representing marine transgressive and fluvial depositional environments during the Palaeocene to Miocene periods.
- 7.1.13 The youngest geological units in the region belong to the Quaternary period and include miliolite limestone, calcarenite, marl, alluvium and aeolian sand deposits, which form the surface cover across the low-lying plains and pediment surfaces surrounding the Bhuj–Nakhatrana region.
- 7.1.14 Structurally, the region exhibits a strong E–W structural grain, characterised by fault-controlled ridges and anticlines alternating with narrow synclinal depressions. The Katrol Hill Fault, a major south-dipping reverse fault, represents one of the most prominent tectonic features of the region and juxtaposes older Jurassic formations against the younger Bhuj strata (Biswas, 2016). Minor NNW–SSE and ENE–WSW fracture systems further dissect the basin and influence drainage alignment and post-depositional fluid migration.
- 7.1.15 Thus, the regional geological framework of the Kachchh Basin reflects a complex interplay of rift tectonics, marine transgressions, continental sedimentation, magmatism and subsequent tectonic inversion, resulting in the development of a thick and diverse sedimentary succession within which the study area is located.



Text Fig. 7.1: Tectonic Map of Kutch Basin (After Biswas 2002) along with Location of Sumarasar Block, District Kachchh, Gujarat



Text Fig. 7.2:
Regional
geological map of
Kutch Basin
(After GSI) along
with location of
Sumarasar Block

7.2.0 GEOLOGY OF THE BLOCK

7.2.1 The Sumarasar area is covered by Katrol Series/Jhuran Formation and Bhuj formation, predominantly composed of Feldspathic sandstone, ferruginous sandstone, shale –siltstone alternation, Gypseous Shale, calcareous sandstone, Feldspathic Sandstone with grit, Feldspathic sandstone with Ammonite Fossils.

The large-scale geological map of the block has been furnished in Text Fig No 3.

The generalized stratigraphy of the block area is given in Table No 7.2

Table- 7.2

The generalized stratigraphic succession in the block.

Age	Formation	Lithology
Lower Cretaceous	Bhuj Formation	Feldspathic sandstone, ferruginous sandstone, shale –siltstone in alternation
Upper Jurassic- Lower Cretaceous	Juran Formation / Katrol Series	Calcareous sandstone, gritty sandstone, siltstone, gypseous shale, fossiliferous limestone, ferruginous sandstone, quartzite

Katrol Series/Jhuran Formation:

The Katrol beds conformably overlie the Chari series/Jhumara formation. They are represented by shales and sandstones. To the north of the Katrol fault, the Katrol formations are met with from north of Tankanasar to the south up to Kodki where it is followed by the sandstones of Bhuj formation. The shales are grey to ash grey in colour and they have intercalations of jasper tabloids and pyrite nodules. Fossil wood is also not uncommon. The sandstones are of various hues, white grey, pinkish end brown. The brown sandstone is medium-grained with sub-angular grains of quartz and are calcareous. These sandstones have well-developed vertical joints; the major set of joints strike in NNW-SSE, NNE-SSW and ESE-WNW directions.

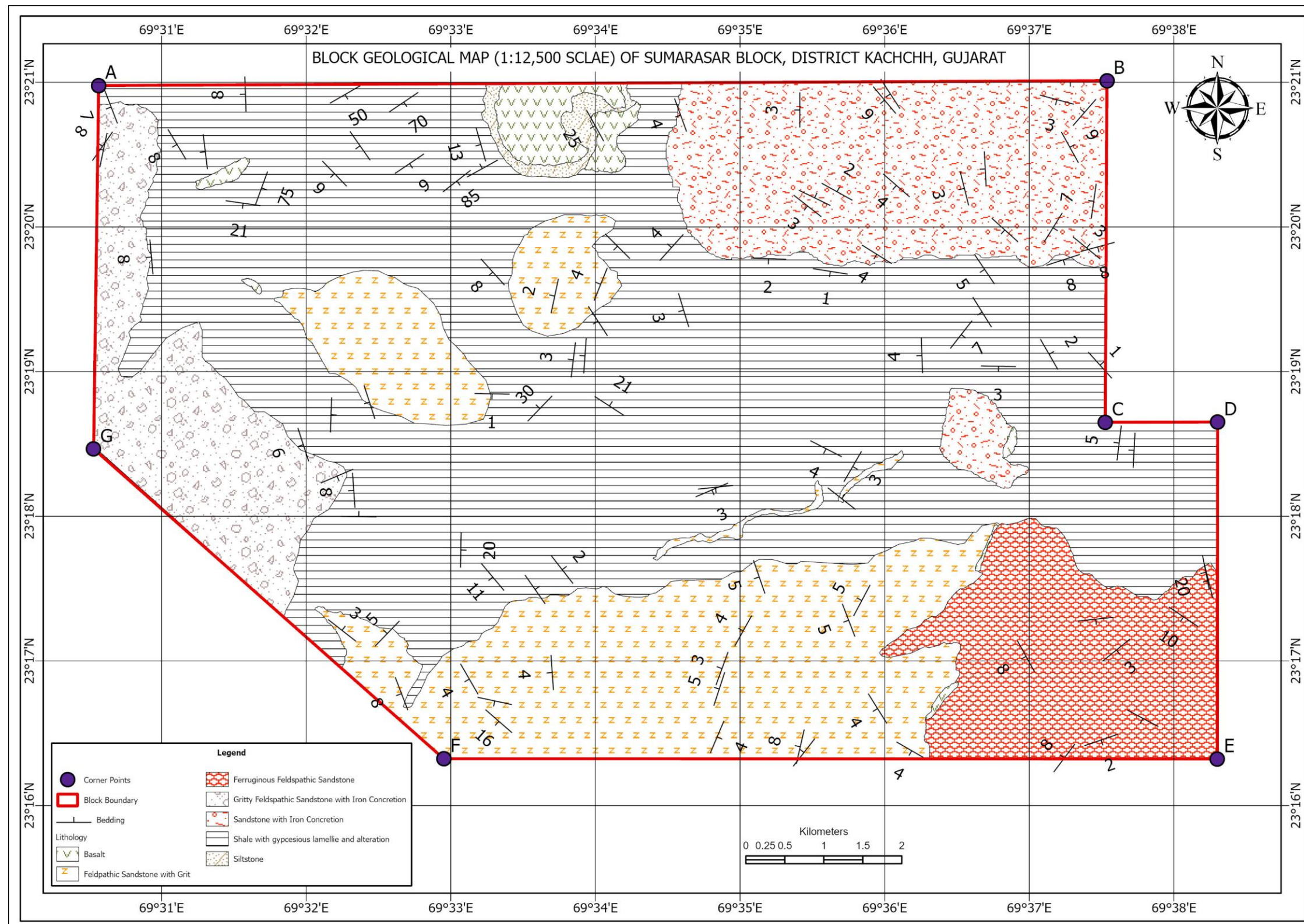
Bhuj Formation:

The rocks of this formation are exposed in areas overlying the Katrol series/Jhuran formation. The Bhuj sandstones are exposed from north of Godpar up to 1 km north of Chunadi where they are unconformably overlain by the Deccan trap lava flows.

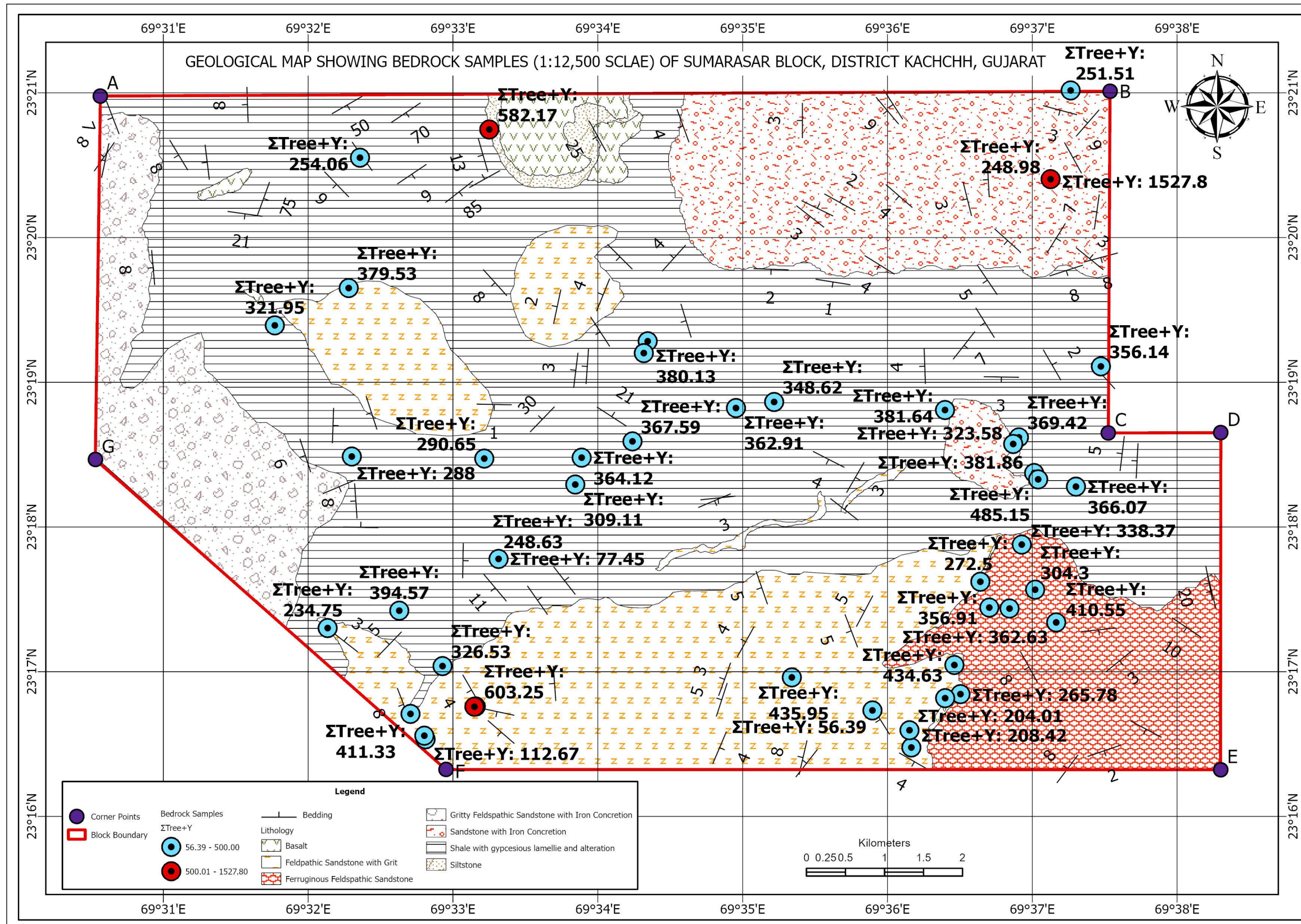
The rocks of this formation are essentially coarse-grained, current-bedded felspathic sandstones, with ferruginous, pink coloured sandstones towards the bottom. The sandstone occurring close to the contact with the overlying formations reveals a few intercalations of pebbly conglomerate, comprising rounded pebbles of shale, quartzite and porphyritic and amygdaloidal traps.

Connected with the Deccan trap igneous activity are the basic dykes which traverse the area. A majority of the dykes trend in a more or less NE-SW direction find a few in east-west direction, these dykes are generally emplaced along faults of the bubs trend and it is likely that the basic welled up along south-west trending fissure.

Supra-trappeans: These consist of laterites and aluminous laterites resting on either the Bhuj formations or the Deccan traps



Text Fig. 7.3A: Large Scale Geological map of Sumarasar Block, District-Kachchh, Gujarat



Text Fig. 7.3B: Large Scale Geological map with location of BRS samples and analysis of $\Sigma\text{REE}+\text{Y}$ in Sumarasar Block, District-Kachchh, Gujarat

7.2.2 Description of lithology

7.2.2.1 Sandstone:

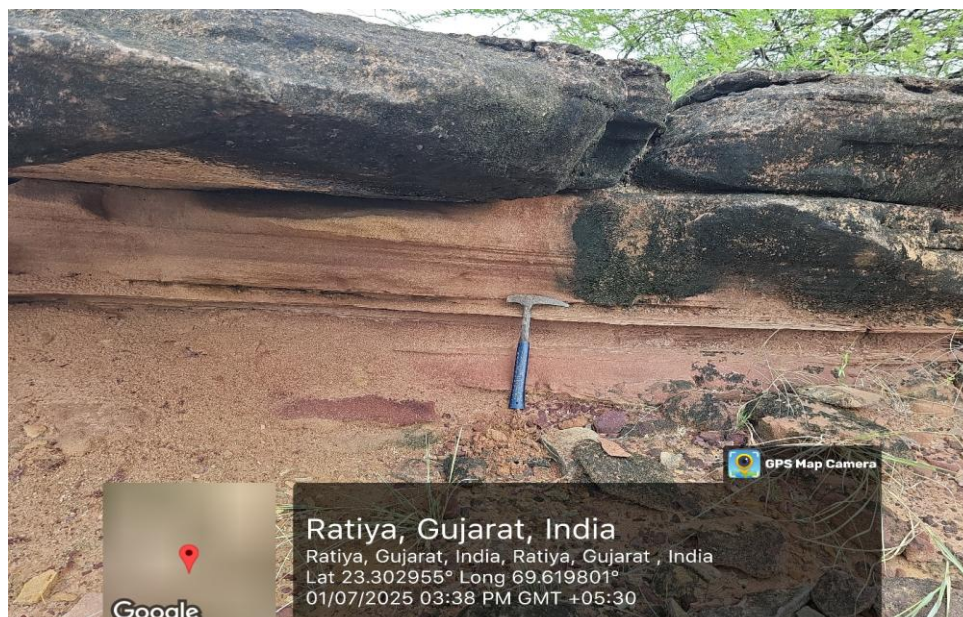
- i. **Feldspathic Sandstone:** Feldspathic sandstone is a major lithounit of the Kachchh Basin, prominently developed in the Bhuj Formation (Cretaceous) and locally in the upper Jhuran Formation (Jurassic) which is earlier known as Katrol series. Grains are sub-angular to sub-rounded and poorly to moderately sorted. The sandstone is generally friable to moderately compact in nature. Cement is predominantly ferruginous, with local siliceous cement. Clayey matrix is observed at places. Common sedimentary structures include planar and trough cross-bedding, ripple marks, and parallel lamination, suggesting deposition under high-energy fluvial to marginal-marine conditions. Outcrop of bedded sandstone displaying prominent horizontal laminations and differential weathering, with a resistant overlying rock unit forming a protective cap (**Photograph No-7.1**). The Feldspathic sandstone is present in the south, south west and middle of the block. i.e. in the west of Ratiya Village. Weathered surfaces show alteration of feldspar to clay minerals, resulting in a friable texture (**Photograph No-7.2**).

The feldspathic sandstone exposed in the area exhibits well-developed honeycomb weathering (tafoni), characterized by numerous closely spaced cavities and pits of varying sizes on the rock surface (**Photograph No-7.3**). This distinctive texture has developed as a result of differential weathering, wherein feldspar grains undergo chemical alteration to clay minerals and are subsequently removed by weathering agents. The selective disintegration of less resistant mineral constituents, coupled with the action of wind, moisture, and salt crystallization, has led to the formation of interconnected cavities, producing a honeycomb-like appearance. The presence of such weathering features indicates prolonged subaerial exposure and advanced stages of weathering of the feldspathic sandstone.

The sandstone exposed in the area contains prominent ferruginous concretions occurring as isolated to scattered nodular bodies within the host rock. These concretions are reddish-brown in colour and represent localized concentrations of iron oxides formed during diagenetic processes. The concretions are more resistant to weathering than the surrounding sandstone and are therefore prominently exposed on weathered rock surfaces (**Photograph No.-7.4**). Their

occurrence indicates post-depositional mobilization and precipitation of iron-rich fluids within the sandstone, resulting in the formation of discrete iron-rich nodules. Differential weathering between the concretions and the host sandstone has enhanced their visibility in the outcrop.

Petrographic study under microscope reveals that quartz and feldspar occur as very fine sand- to silt-sized, subangular to subrounded detrital grains embedded within a reddish ferruginous and calcitic matrix. Ooid/peloid-like structures are locally observed. Opaque minerals occur as anhedral patches and as patchy relics within ferruginous domains. Sericite is present as very fine flakes disseminated throughout the matrix. Glauconite occurs as very fine- to fine-grained subrounded pellets. Lithic fragments are present as accessory constituents in the form of fine-grained clasts (**Pmg-01, Pmg-02**). In another sample collected from the different location the rock is composed predominantly of Coarse sand size subrounded to subangular clasts floating over reddish ferruginous matter mixed/ stained silt sized quartz matrix. Opaque patches are seen associated with ferruginous patches. Lithic fragments occur as fine to medium subrounded clasts of quarzitic nature. Zeolite is noted as flaky or fibrous aggregates in pockets. Sericite occurs as very fine flakes in accessories (**Pmg-3**). In another sample of arkosic wacke the essential minerals found Quartz, Calcite, Ferruginous matter and Feldspar. Limonite is noted as fine pisolites and patches. Sericite occurs as very fine disseminated flakes. Fine to medium subrounded lithic fragments are seen present of quarzitic nature. Zeolite occurs as cavity fillings comprising flaky aggregates and also seen associated with limonite patches in areas. Tourmaline and monazite are found present as very fine prismatic grains in accessories (**Pmg-4**).



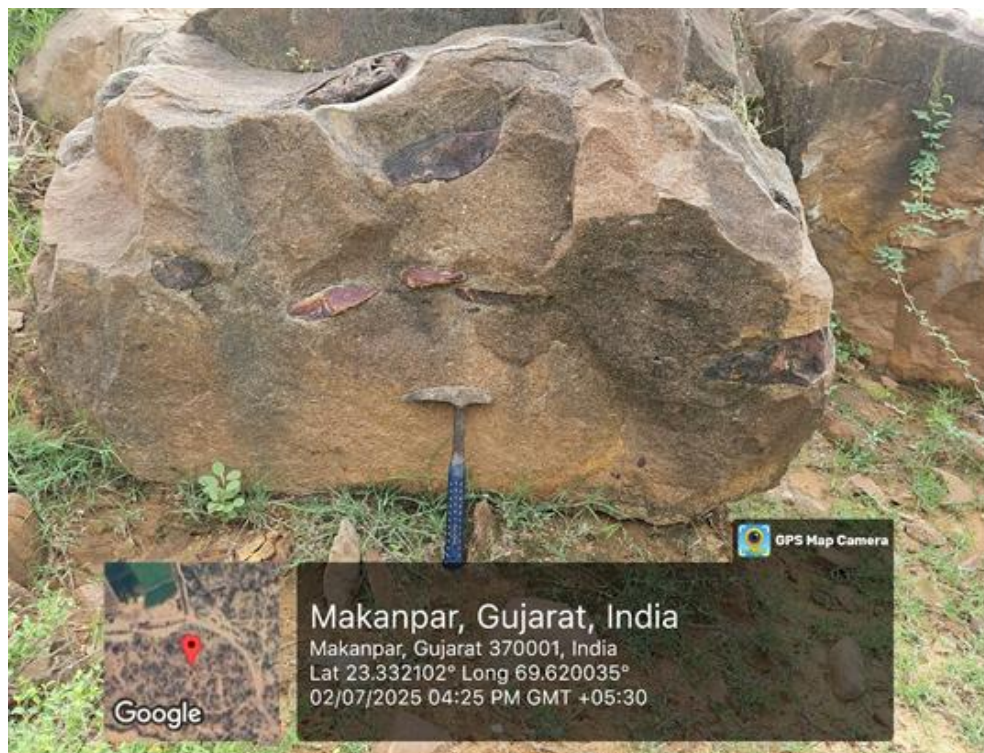
Photograph No-7.1: Outcrop of bedded feldspathic sandstone displaying prominent horizontal laminations and differential weathering, with a resistant overlying rock unit forming a protective cap.



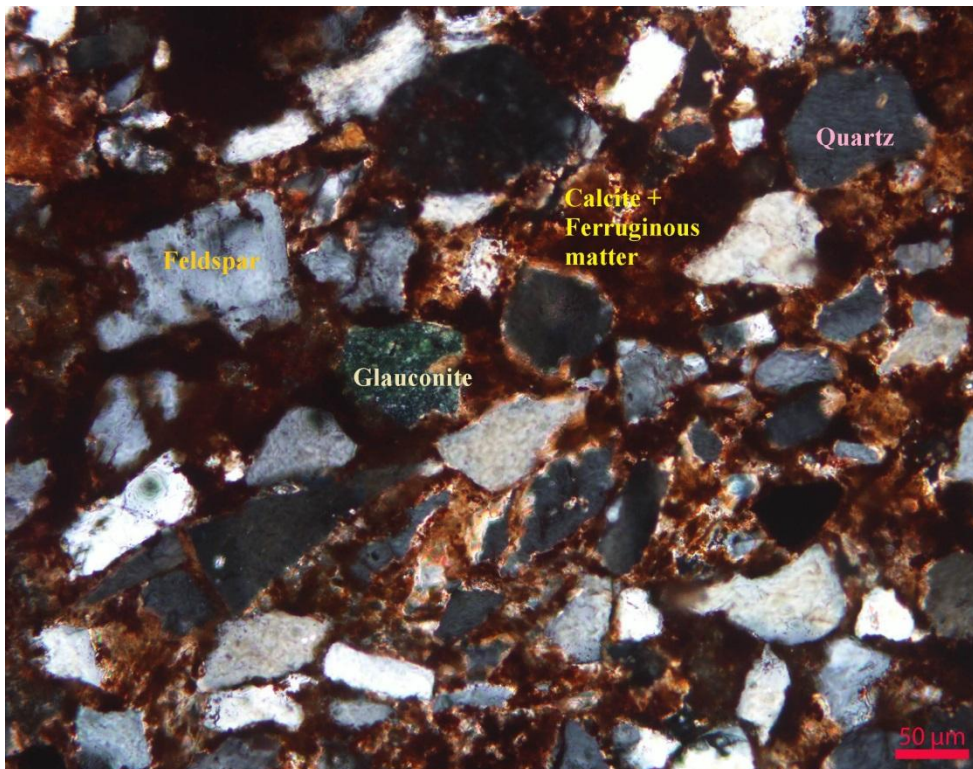
Photograph No-7.2: Weathered surfaces show alteration of feldspar to clay minerals, resulting in a friable texture.



Photograph No.-7.3: These structures appear as closely spaced, small to medium-sized cavities forming a honeycomb-like pattern exposed on feldspathic sandstone exposures.



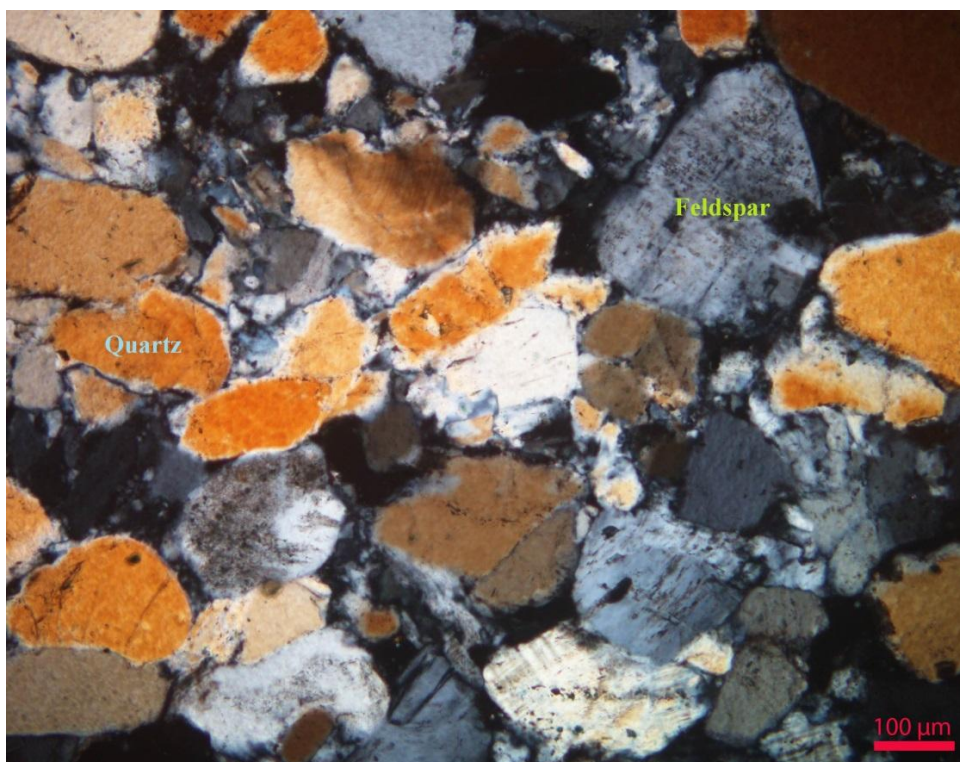
Photograph No.-7.4: Ferruginous concretions occurring as discrete nodular bodies within a sandstone matrix, formed by localized precipitation of iron oxides during diagenesis.



Pmg – 1:
Photomicrograph showing quartzo-feldspathic clasts floating over ferruginous matter mixed calcitic matrix and presence of glauconite in accessories as seen under crossed nicols.

Specimen No.:
SMRPT/01

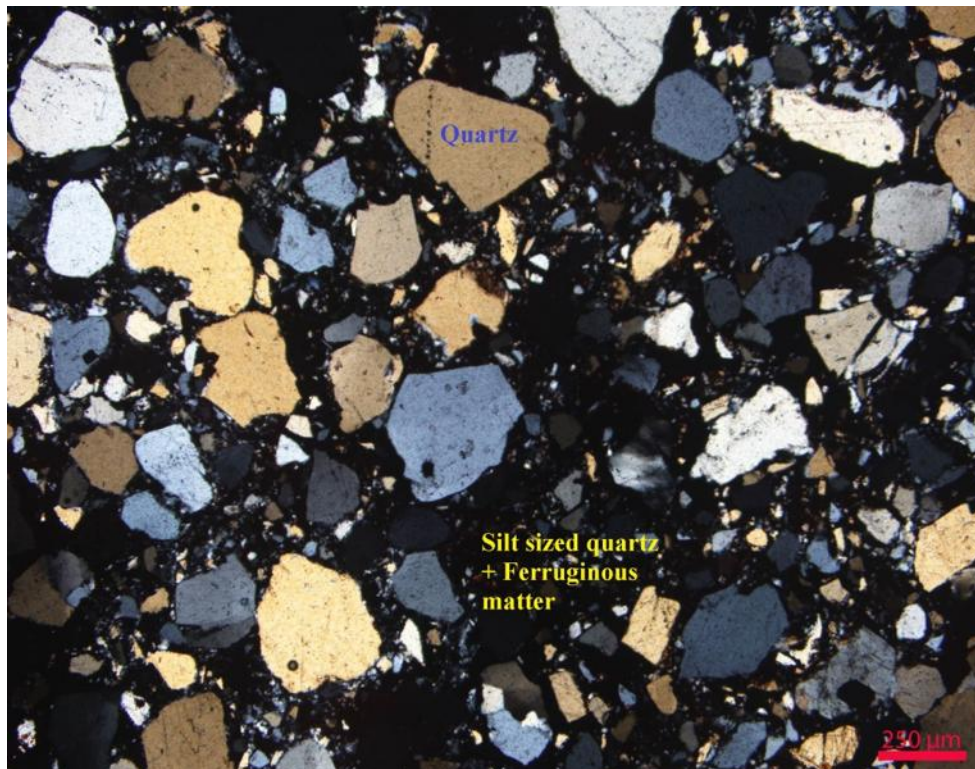
Magnification: 200X



Pmg – 2:
Photomicrograph depicts association of quartz and feldspar clasts showing moderate sorting and tight packing as seen under crossed nicols.

Specimen No.:
SMRPT/03

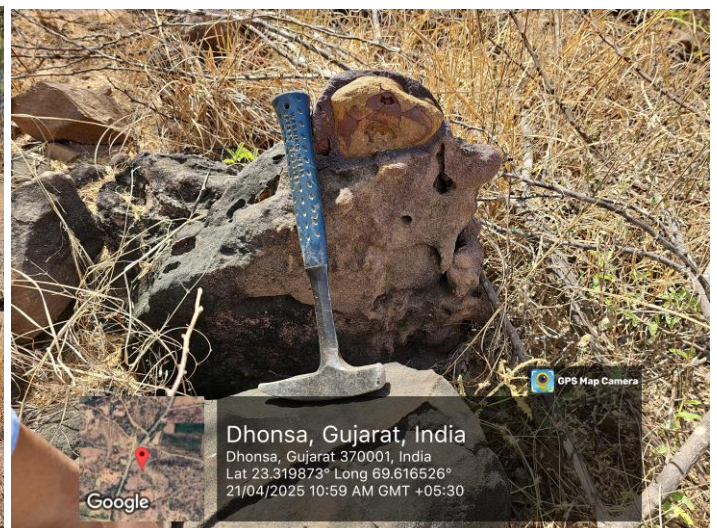
Magnification:
100X



Pmg – 3:
Photomicrograph showing fine to coarse sand sized clasts floating over ferruginous matter mixed silt sized quartz matrix as seen under crossed nicols.

Specimen No.:
SMRPT/05

Magnification:
40X



Photograph No.-7.5: Both Image from different locations showing the iron concretion embedded in the feldspathic sandstone.

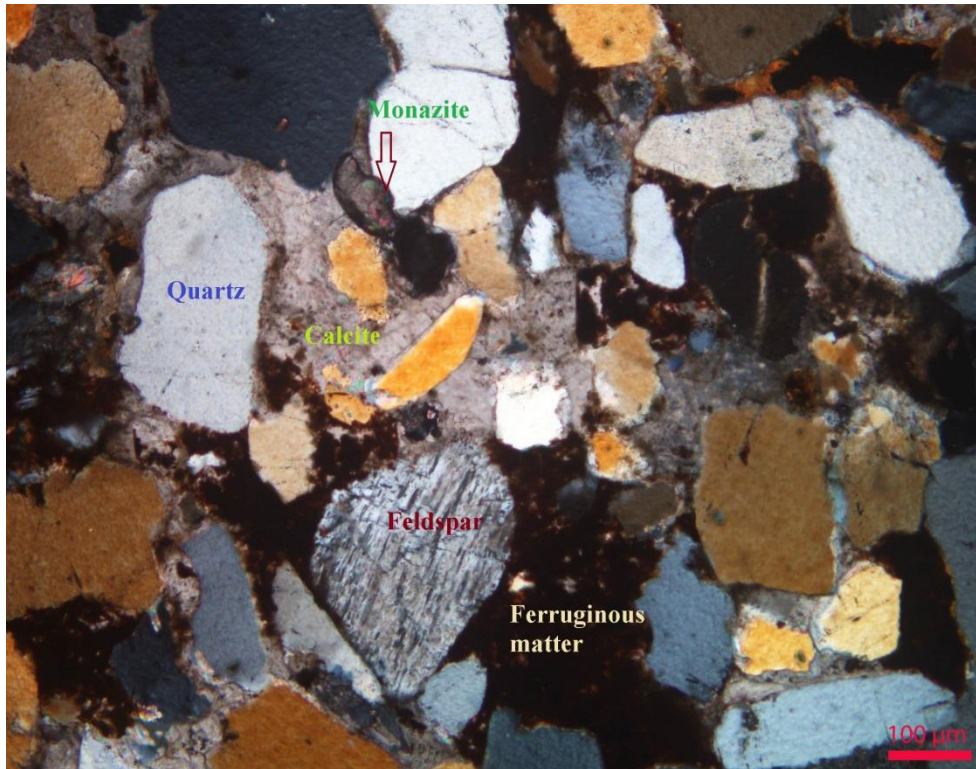


Photograph No.-7.6: Image showing the Distinct yellowish-brown limonitic staining and reddish ferruginous bands.



Photograph No.-7.7: Ferruginous feldspathic sandstone showing well-developed bedding, low-angle cross-lamination, and limonitic staining.

The outcrop of feldspathic sandstone (**Photograph No-7.6, 7.7**) displaying well-preserved planar lamination to low-angle cross-lamination. Distinct yellowish-brown limonitic staining and reddish ferruginous bands accentuate the sedimentary structures. The limonitic alteration reflects oxidation of iron-bearing constituents during weathering, while the laminated nature of the sandstone indicates deposition under moderate-energy current conditions. Petrographic examination reveals that the rock comprises fine- to coarse-grained, subangular to subrounded quartz and feldspar clasts exhibits a granular texture embedded within a reddish ferruginous matter mixed with and stained by a calcitic matrix. Opaque minerals occur as patches commonly associated with ferruginous concentrations. Limonite is present as fine pisolites and irregular patches. Sericite occurs as very fine disseminated flakes throughout the rock. Lithic fragments of quartzitic nature are present as fine- to medium-grained subrounded clasts. Zeolite occurs as cavity-filling flaky aggregates and is locally associated with limonitic patches. Tourmaline and monazite are present as very fine prismatic accessory grains (**Pmg-4**).



Pmg-4:
Photomicrograph showing quartzo-feldspathic clasts floating over ferruginous matter mixed calcitic matrix and presence of monazite in accessories as seen under crossed nicols.

Specimen No.:
SMRPT/08

Magnification: 100X

ii Feldspathic Sandstone with Grit: Gritty feldspathic sandstone belonging to the Bhuj Formation (Lower Cretaceous) is exposed mainly along the western margin of the block, extending from the northern part towards the southwestern side along the block boundary. The rock is pinkish-brown to reddish buff in colour and is coarse-grained to gritty, poorly sorted, and composed predominantly of K-feldspar and quartz. The sub-angular to angular nature of the grains indicates short transport from a nearby basement source. Iron concretions are also present within the gritty feldspathic sandstone.



Photograph No.-7.8, 7.9: The gritty fraction comprises sand- to granule- and pebble-sized clasts, which are sub-angular to angular Near Khilna village.

Geochemistry of Sandstone

A total of 32 samples were collected from different sandstone units in the Sumarasar Block, comprising 8 bedrock samples, and 24 samples from different auger boreholes. These samples were analysed for 34 elements using ICP-MS. The analytical results indicate the presence of Rare Earth Elements (REE), High Field Strength Elements (HFSE), and other incompatible trace elements within the sandstone. The summarized analytical values are presented in High Field Strength Elements (HFSE) and other incompatible

trace elements within the Sandstone. The summarized analytical values are given in Table no 7.3.

Table no 7.3.

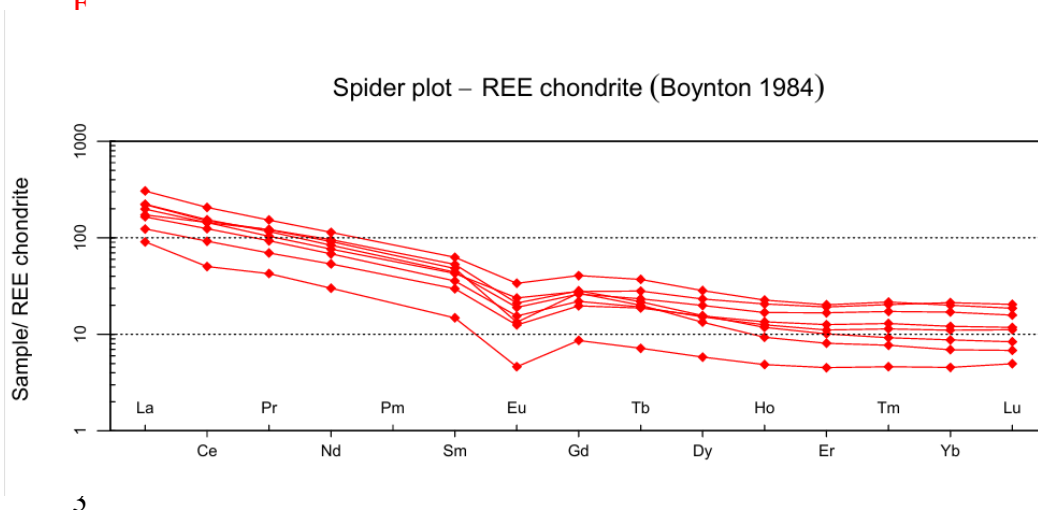
Summarized table of ICP-MS analysis of Sandstone (N-32) for 34 elements.

Elements	Min(ppm)	Max(ppm)	Mean(ppm)
Li	6.47	99.21	49.17
Sc	3.04	25.32	15.65
V	27.59	196.88	125.85
Cr	56.18	189.18	119.22
Co	1.85	63.57	17.95
Ni	12.81	70.98	41.08
Cu	11.60	49.71	32.68
Zn	20.64	210.61	89.49
Ga	5.49	35.54	23.67
Se	0.13	2.29	1.04
Rb	6.87	121.83	79.22
Sr	63.31	4400.00	596.23
Y	10.20	79.84	41.06
Zr	102.60	666.57	415.20
Nb	2.75	16.76	11.85
Mo	0.65	34.58	2.27
La	25.43	113.12	69.66
Ce	40.81	184.68	127.28
Pr	5.20	21.60	14.85
Nd	18.04	77.75	53.90
Sm	2.89	13.82	9.61
Eu	0.34	2.49	1.68
Gd	2.24	12.83	8.25
Tb	0.34	2.28	1.40
Dy	1.87	13.57	7.97
Ho	0.35	2.80	1.55
Er	0.95	7.70	4.10
Tm	0.15	1.23	0.67
Yb	0.95	7.21	3.98
Lu	0.16	1.07	0.60
Hf	2.88	17.75	11.69
Pb	14.23	35.15	22.12
Th	11.14	65.33	30.04
U	1.31	5.47	3.69
ΣREE+Y	112.67	514.60	346.56
ΣREE+Sc+Y	115.71	539.60	362.21

The Sandstone from both Bhuj and katrol formations shows total REE ($\Sigma\text{REE}+\text{Y}$) values ranging from 112.67 ppm to 514.60 ppm, with an average value of approximately 346.56 ppm. The analysed samples exhibit relative enrichment of Light Rare Earth Elements (LREE) such as La, Ce and Nd. Lanthanum values range from 25.43 ppm to 113.12 ppm, cerium from 40.81 ppm to 184.68 ppm and neodymium from 18.04 ppm to 77.75 ppm. The distribution pattern indicates predominance of LREE over HREE.

Among the Heavy Rare Earth Elements (HREE), yttrium ranges from 10.20 ppm to 79.84 ppm, dysprosium from 1.87 ppm to 13.57 ppm and ytterbium from 0.95 ppm to 7.70 ppm. The presence of both LREE and HREE suggests the occurrence of REE-bearing accessory minerals within the sandstone units.

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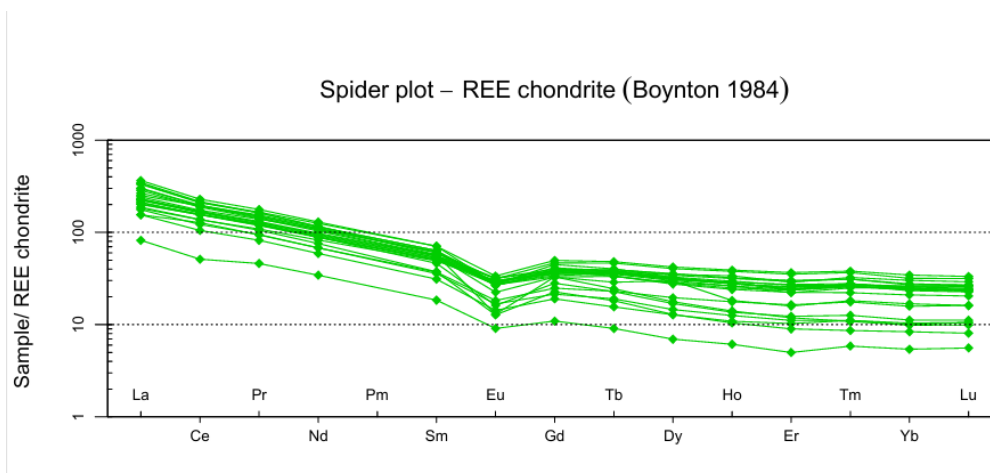


Text Fig. 7.4: The chondrite-normalised REE spider diagram of Bed Rock Samples drawn from Sandstone (N=8).

The chondrite-normalised REE spider diagram of sandstone (**Text Fig. 7.4**) from the Sumarasar Block bedrock samples (N=8) exhibit consistent enrichment of Light Rare Earth Elements (LREE) relative to Heavy Rare Earth Elements (HREE). The normalized patterns show a pronounced negative slope from La to Sm, indicating significant LREE enrichment and fractionation. The HREE segment (Gd–Lu) is relatively flat, suggesting limited HREE fractionation.

A distinct negative Eu anomaly is observed in most samples, which is indicative of plagioclase feldspar fractionation in the source rocks and reflects

derivation from felsic upper continental crustal material. The parallel nature of the REE patterns suggests a common provenance and uniform sediment supply during deposition.



Text Fig. 7.5: The chondrite-normalised REE spider diagram of Auger Samples drawn from Sandstone (N=24).

The chondrite-normalized REE patterns of the 24 auger borehole sandstone samples exhibit a consistent enrichment of Light Rare Earth Elements (LREE: La–Sm) relative to Heavy Rare Earth Elements (HREE: Gd–Lu). The patterns are characterized by steeply declining trends from La to Sm, followed by comparatively flatter HREE segments, indicating strong LREE enrichment and moderate HREE fractionation. Chondrite-normalized La values are significantly elevated, whereas the HREE concentrations remain relatively uniform, suggesting derivation from a felsic continental source.

A distinct negative europium (Eu) anomaly is observed in most samples, marked by a pronounced trough at Eu relative to adjacent Sm and Gd. This negative Eu anomaly indicates the fractionation or depletion of plagioclase feldspar in the source rocks and is typical of felsic igneous protoliths.

The sandstone samples contain appreciable concentrations of High Field Strength Elements (HFSE), including zirconium (102.60– 666.57 ppm), niobium (2.75–16.76 ppm), thorium (11.14–65.33 ppm), uranium (1.31–5.47 ppm) and hafnium (2.88-17.75). The relatively high zirconium and thorium contents indicate the presence of resistant accessory minerals such as zircon, monazite and sphene, which is consistent with petrographic observations.

These minerals are important hosts for REE and HFSE and contribute significantly to the geochemical characteristics of the sandstone.

Trace element concentrations show moderate enrichment of Rb (6.87–121.83 ppm) and variable Sr contents (63.31–4400 ppm). The observed geochemical signatures suggest derivation from felsic source rocks and indicate the influence of feldspar fractionation and sedimentary sorting processes during sandstone evolution.

Transition metal concentrations, including Cr (56.18–189.18 ppm), Ni (12.81–70.98 ppm), Cu (11.60–49.71 ppm) and Zn (20.64–210.61 ppm), occur in moderate amounts. These elements are likely associated with ferromagnesian minerals, heavy mineral assemblages and clay-rich components within the sandstone. Their distribution reflects contributions from both source rock composition and subsequent weathering and depositional processes.

7.2.2.2 Shale: Shale constitutes an important fine-grained sedimentary lithology within the Sumarasar Block and is predominantly represented by the Katrol Formation. The shale beds generally occur as thin to medium-bedded horizons, ranging from approximately 10 cm to 50 cm in thickness, and are commonly interbedded with sandstone units. These beds exhibit horizontal to sub-horizontal attitudes and represent deposition under relatively low-energy sedimentary conditions. The occurrence of shale in association with sandstone reflects alternating depositional regimes within a shallow marine to deltaic environment.

Based on field characteristics, four distinct varieties of shale have been identified within the block, namely Grey Shale, Yellow Shale, Ferruginous Shale, and Gypseous Shale. These shale types display variations in colour, mineralogical composition, and associated sedimentary features, indicating fluctuations in depositional conditions during sediment accumulation.

In and around Baukha and Khilna villages, shale horizons are predominantly yellow and grey in colour. These shales are fissile in nature, silty to clay-rich in composition, and occur as thin interbeds generally ranging from 10 cm to 30 cm in thickness. The shale layers are closely associated with sandstone

beds and represent sedimentation in a low-energy deltaic to shallow marine environment where fine-grained sediments accumulated during periods of reduced current activity.

The exposure shown in (Photograph No.-7.10) represents a prominent road-cut section of yellow shale near Khilna village within the Sumarasar Block. The shale is yellowish-brown to pale yellow in colour, fine-grained, and exhibits well-developed fissility, enabling it to split into thin laminae and plates. The exposed section is approximately 12–14 feet in height and displays thin to medium bedded shale horizons with sub-horizontal to gently dipping attitudes. The Sumarasar area exhibits extensive occurrences of dark grey shale, commonly interbedded with marl, ferruginous shale, and gypseous bands (Photograph No.-7.11). The intimate association of these lithologies suggests deposition under restricted, low-energy lagoonal to shallow marine conditions. The presence of ferruginous and gypseous layers indicates periodic variations in oxidation state, salinity, and chemical conditions within the depositional basin. Similar assemblages of dark grey shale interbedded with ferruginous and gypseous horizons (Photograph No.-7.12) are also observed north of Baukha village, indicating lateral continuity of these depositional facies across the study area. At certain locations in the Sumarasar village area, alternating bands of yellow and ferruginous shale are observed intercalated with sandstone beds (Photograph No.-7.13).

At the eastern margin of the block, particularly in the vicinity of Somnath Mahadev Temple, shale beds belonging to the Katrol Formation are well exposed (Photograph No.-7.14) These shales are predominantly grey, yellow, and ferruginous in nature and occasionally contain fossil fragments. The fossiliferous character of some horizons suggests marine influence during sediment deposition. The shale beds are interbedded with sandstone and represent periods of fine-grained sediment accumulation in a low-energy depositional setting. The beds generally exhibit horizontal to sub-horizontal attitudes and are laterally persistent over considerable distances.

Overall, the shale succession of the Sumarasar Block records sedimentation under varying low-energy depositional environments ranging from deltaic and shallow marine settings to restricted lagoonal conditions. The lithological

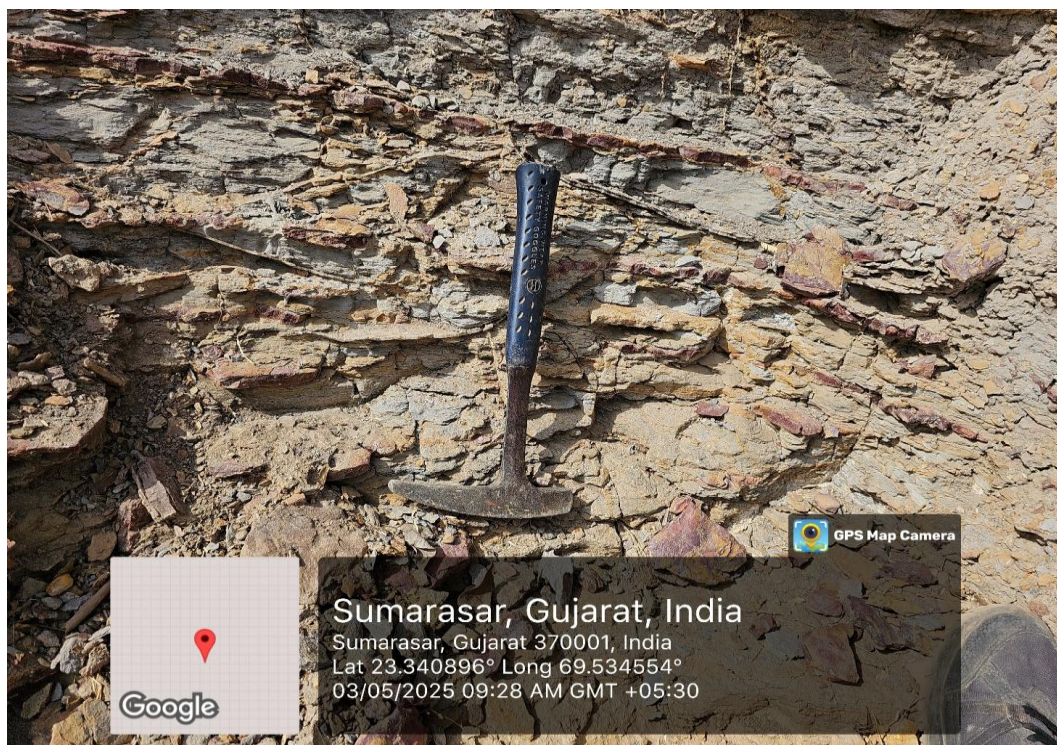
variations, association with sandstone, marl, ferruginous shale, and gypseous bands (Figure Below), together with occasional fossil occurrences, provide valuable evidence regarding the paleoenvironmental evolution of the Katrol Formation within the study area.



Photograph No.-7.10: Image showing road cut cross-section of yellow shale in the Khilna area 12 to 14 feet height.



Photograph No.-7.11: Image showing yellow shale intercalated with gypseous bands



Photograph No.-7.12: Image showing grey and yellow shale with Gypseous bands and ferruginous bands of 3 to 5 cm thickness.



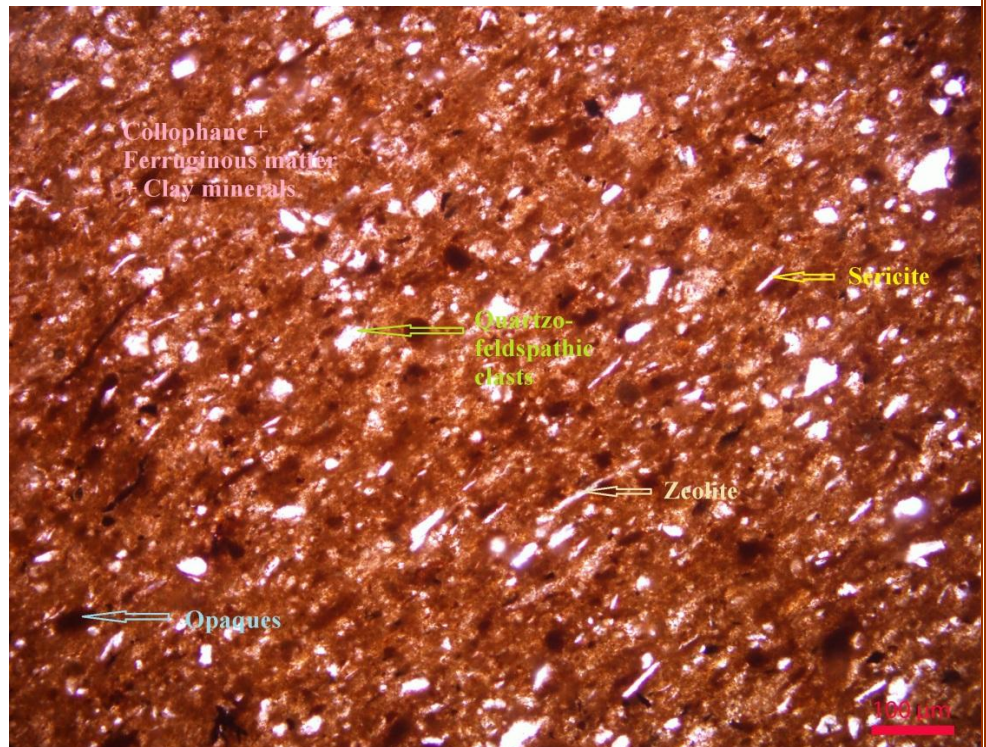
Photograph No. 7.13 Alternate bands of yellow and ferruginous shale intercalated with sandstone beds are observed near Sumarasar village.



Photograph No.-7.14: Image Showing Shale beds are interbedded with sandstone near Somnath Mahadev Temple, Dhonsa area.

Pmg – 5:
Photomicrograph showing very fine disseminated quartzo-feldspathic clasts, opaques, sericite and zeolite within amorphous collophane, ferruginous matter and clay mixed matrix as seen under plane polarized light.

Specimen No.:
SMRPT/10



Geochemistry of Shale

A total of 99 samples were collected from different shale units in the Sumarasar Block, comprising 37 bedrock samples, 19 pit sample, and 43 samples from different auger boreholes. These samples were analysed for 34 elements using ICP–MS. The analytical results indicate the presence of Rare Earth Elements (REE), High Field Strength Elements (HFSE), and other incompatible trace elements within the different units of shales. The summarized analytical values are presented in High Field Strength Elements (HFSE) and other incompatible trace elements within the Shales. The summarized analytical values are given in Table no 7.4.

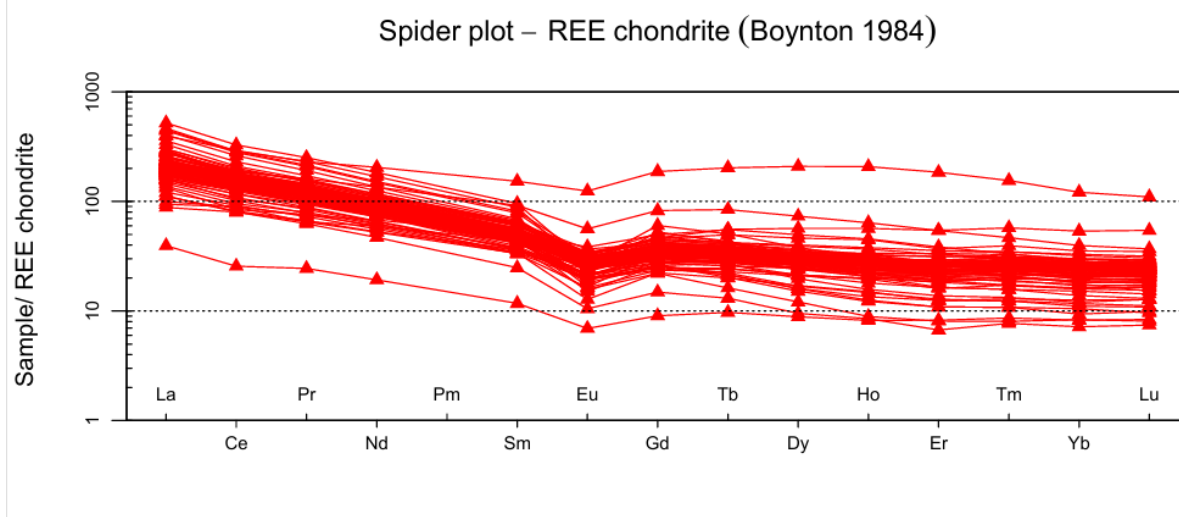
Table no 7.4.

Summarized table of ICP-MS analysis of Shale (N-99) for 34 elements.

Elements	Min(ppm)	Max(ppm)	Mean (ppm)
Li	10.47	115.49	58.12
Sc	4.38	53.45	19.50
V	34.12	328.16	148.82
Cr	53.03	209.26	113.56
Co	2.32	65.60	21.05
Ni	8.97	108.90	50.35
Cu	11.43	78.70	40.07
Zn	26.07	204.75	103.75
Ga	5.40	37.94	26.33
Se	0.12	3.45	1.04
Rb	8.24	143.97	85.56
Sr	56.22	1200.00	282.74
Y	16.52	767.07	58.85
Zr	80.22	849.70	397.43
Nb	2.13	17.66	11.20
Mo	0.47	3.92	1.13
La	12.24	161.40	68.20
Ce	20.74	264.58	127.78
Pr	2.98	30.69	14.83
Nd	11.55	122.63	54.62
Sm	2.29	29.77	10.16
Eu	0.51	9.13	2.02
Gd	2.34	48.45	9.49
Tb	0.46	9.61	1.69
Dy	2.85	67.34	10.06
Ho	0.59	14.89	2.04
Er	1.41	38.66	5.40
Tm	0.25	5.02	0.85
Yb	1.50	25.38	5.12
Lu	0.24	3.54	0.77
Hf	2.19	19.85	11.34
Pb	6.79	75.96	23.85
Th	4.75	82.08	26.62
U	0.87	8.08	3.95
ΣREE + Y	77.45	1527.80	371.87
ΣTREE+ Sc + Y	81.83	1581.25	391.37

The Shale from both Bhuj and Katrol formations shows total REE ($\Sigma\text{REE}+\text{Y}$) values ranging from 77.45 ppm to 1527.80 ppm, with an average value of approximately 371.87 ppm. The analysed samples exhibit relative enrichment of Light Rare Earth Elements (LREE) such as La, Ce and Nd. Lanthanum values range from 12.24 ppm to 161.40 ppm, cerium from 20.74 ppm to 264.58 ppm and neodymium from 11.55 ppm to 122.63 ppm. The distribution pattern indicates predominance of LREE over HREE.

Among the Heavy Rare Earth Elements (HREE), yttrium ranges from 16.52 ppm to 767.07 ppm, dysprosium from 2.85 ppm to 67.34 ppm and **ytterbium from 1.50 ppm to 25.38 ppm**. The presence of both LREE and HREE suggests the occurrence of REE-bearing accessory minerals within the different shale units.



Text Fig. 7.6: The chondrite-normalised REE spider diagram of samples drawn from different Shale units (N=99).

7.2.2.3 Kaolinitic sandstone/Altered Sandstone:

Kaolinitic sandstone (altered sandstone) is one of the characteristic lithological units encountered within the Bhuj Formation of the Kachchh Basin. The rock is white to creamy white, light grey or pale yellow in colour and is generally fine- to medium-grained, moderately sorted and friable to moderately hard. It is composed predominantly of quartz with varying amounts of kaolinite

formed by the alteration of feldspar minerals. Fresh feldspar grains are sparse to absent due to extensive kaolinization, while minor muscovite flakes and iron oxide stains are occasionally present.

The rock exhibits a massive to moderately bedded nature and locally displays planar and cross-bedding. Weathered surfaces are commonly yellowish-brown due to oxidation of iron-bearing minerals (Photograph No-7.15), whereas fresh exposures are white to cream coloured. The sandstone possesses a soft, chalky texture in highly altered zones owing to the abundance of kaolinite, while relatively fresh portions remain moderately compact.



Photograph No-7.15 Yellowish-brown weathered surfaces commonly due to oxidation of iron-bearing minerals in Ratiya area.

Geochemistry of Kaolinitic sandstone/Altered Sandstone:

A total of 08 samples were collected from kaolinitic units of different areas in the Sumarasar Block, comprising 04 bedrock samples, 04 pit sample. These samples were analysed for 34 elements using ICP–MS. The analytical results indicate the presence of Rare Earth Elements (REE), High Field Strength Elements (HFSE), and other incompatible trace elements. The summarized analytical values are presented in High Field Strength Elements (HFSE) and other incompatible trace elements within kaolinitic. The summarized analytical values are given in Table no 7.5.

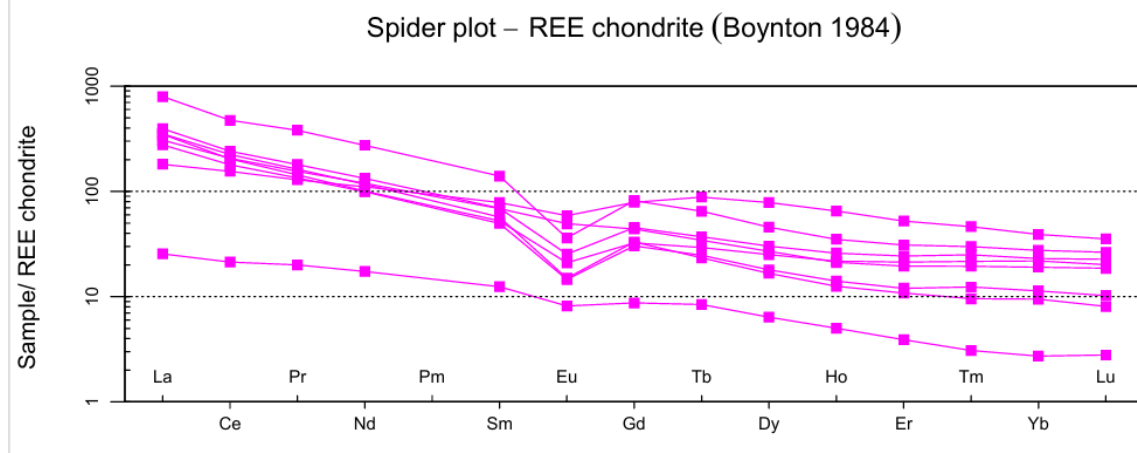
Table no 7.5

Summarized table of ICP-MS analysis of Kaolinitic sandstone/Altered Sandstone (N-8)
for 34 elements.

Elements	Min(ppm)	Max(ppm)	Mean (ppm)
Li	5.71	62.90	29.72
Sc	2.40	26.73	16.19
V	18.21	169.01	105.85
Cr	14.33	152.29	108.40
Co	3.20	48.31	19.27
Ni	6.09	71.56	28.44
Cu	8.26	55.31	29.91
Zn	24.79	116.71	57.31
Ga	2.00	40.98	26.07
Se	0.26	2.07	1.19
Rb	5.02	87.01	51.32
Sr	28.15	763.83	221.22
Y	8.69	125.42	48.65
Zr	52.95	912.29	527.34
Nb	1.25	18.87	12.62
Mo	0.36	2.09	0.96
La	7.92	246.33	103.89
Ce	17.23	382.25	172.03
Pr	2.44	46.42	19.91
Nd	10.42	164.40	72.89
Sm	2.43	27.23	12.87
Eu	0.60	4.32	2.10
Gd	2.26	21.20	11.48
Tb	0.40	4.19	1.84
Dy	2.06	25.26	9.96
Ho	0.36	4.68	1.80
Er	0.82	11.00	4.60
Tm	0.10	1.50	0.68
Yb	0.57	8.16	4.03
Lu	0.09	1.14	0.58
Hf	1.65	24.13	13.27
Pb	5.59	43.46	26.39
Th	3.39	122.54	49.09
U	0.68	10.06	4.92
ΣREE + Y	56.39	991.41	467.29
ΣTREE+ Sc + Y	58.78	1018.15	483.48

The Kaolinitic sandstone from both Bhuj and Katrol formations shows total REE ($\Sigma\text{REE}+\text{Y}$) values ranging from 56.39 ppm to 991.41 ppm, with an average value of approximately 467.29 ppm. The analysed samples exhibit relative enrichment of Light Rare Earth Elements (LREE) such as La, Ce and Nd. Lanthanum values range from 7.92 ppm to 246.33 ppm, cerium from 17.23 ppm to 382.25 ppm and neodymium from 10.42 ppm to 164.40 ppm. The distribution pattern indicates predominance of LREE over HREE.

Among the Heavy Rare Earth Elements (HREE), yttrium ranges from 8.69 ppm to 125.42 ppm, dysprosium from 2.06 ppm to 25.26 ppm and ytterbium from 0.57 ppm to 8.16 ppm. The presence of both LREE and HREE suggests the occurrence of REE-bearing accessory minerals within the different Kaolinitic units.



Text Fig. 7.7: The chondrite-normalised REE spider diagram of samples drawn from different Kaolinitic sandstone units (N=08).

The kaolinitic sandstone samples shows that the LREE are more enriched than the HREE. The REE patterns of most samples are similar, indicating that the sandstones were derived from a common source rock.

A negative europium (Eu) anomaly is present in almost all samples. This indicates that plagioclase feldspar was removed during weathering or altered to kaolinite, which is a common feature of kaolinitic sandstones. The negative Eu anomaly also suggests that the source rocks were mainly felsic (granitic) in composition.

The HREEs show a relatively flat pattern with less variation, indicating that they were not significantly affected during weathering and transport.

One or two samples have lower REE concentrations than the others, but their overall pattern is similar. This suggests that they were derived from the same source but contain fewer REE-bearing minerals.

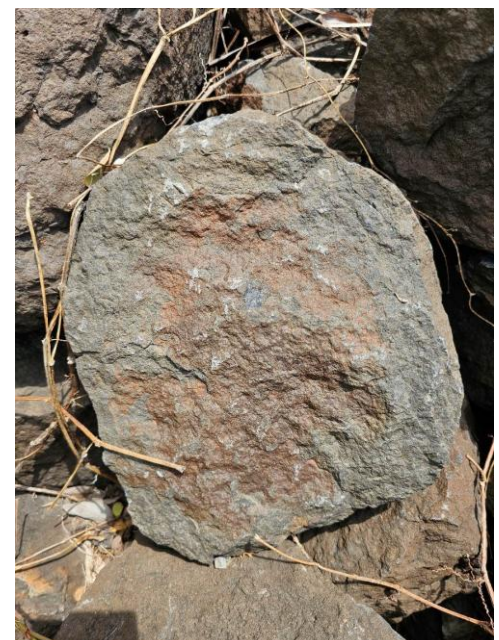
7.2.2.4 Basalt:

The Khatlo Dungar Basalt represents volcanic rocks of the Deccan Trap and forms prominent hillocks and ridges within the block area in the top north. The basalt is dark grey to black, fine- to medium-grained, massive, and compact in nature. Vesicular to amygdaloidal textures are locally observed, with vesicles filled by secondary minerals such as calcite and zeolites.

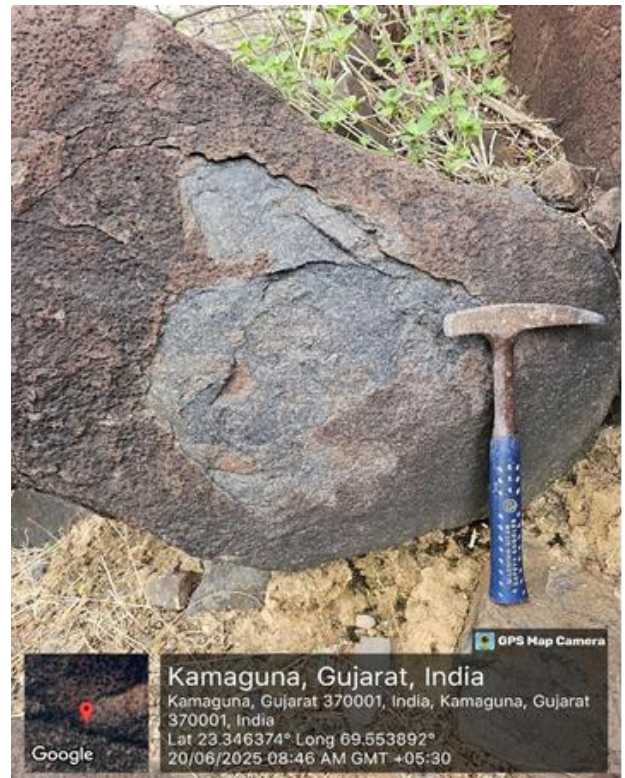
The basalt flows exhibit a horizontal to sub horizontal disposition and are locally jointed and fractured. Stratigraphically, the Khatlo Dungar Basalt overlies the sedimentary sequence of the Katrol formation at several places and forms a resistant capping unit over the underlying shale–sandstone succession. Owing to its massive and compact nature, the basalt exerts significant control on the local geomorphology of the area.



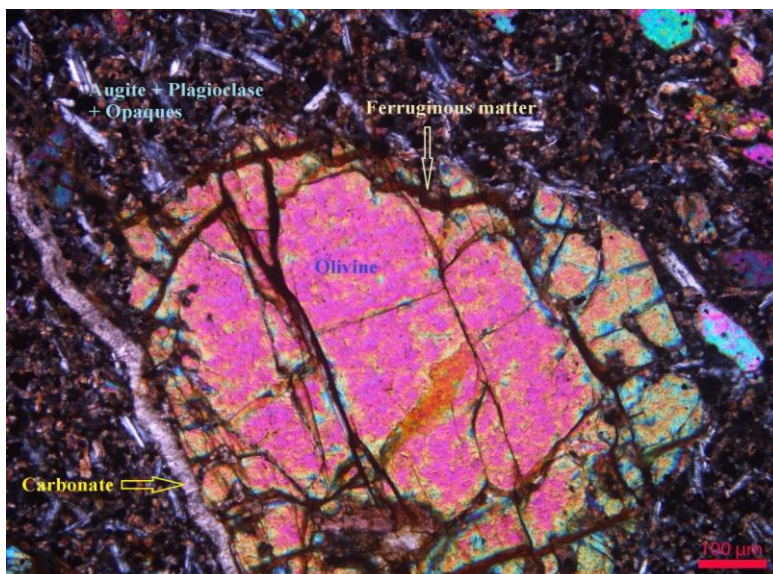
Photograph No-7.16: Image showing Khatlo Basalt which is jointed and fractured.



Photograph No-7.17: Image showing closer view of Khatlo Basalt which is dark grey to black, fine- to medium-grained, massive, and compact in nature.



Photograph No.- 7.18, 7.19: Image showing Khatlo Dungar Basalt of Deccan Trap affinity, exhibiting dark grey colour, massive and compact nature with reddish-brown iron-oxide staining due to surface weathering.



Pmg – 6: Photomicrograph showing moderately coarse to fine phenocrysts of olivine; very fine augite, plagioclase and opaques in matrix and intrusive fillings of carbonates and ferruginous matter in association with olivine as seen under crossed nicols.

Specimen No.: SMRPT/07

Magnification: 100X

Geochemistry of Basalt:

A total of 02 samples were collected from Basalt of different areas in the Sumarasar Block, comprising 01 bedrock samples, 01 pit sample. These samples were analysed for 34 elements using ICP–MS. The analytical results indicate the presence of Rare Earth Elements (REE), High Field Strength

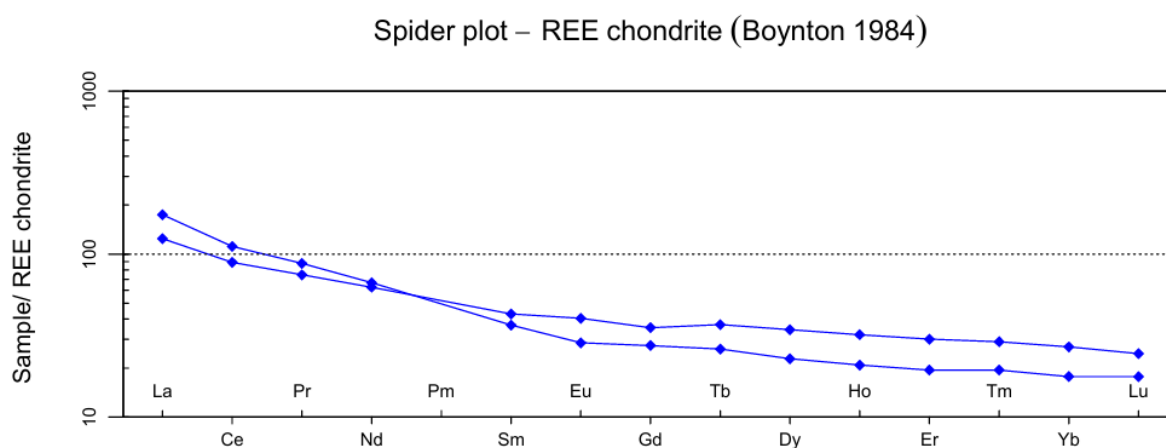
Elements (HFSE), and other incompatible trace elements. The summarized analytical values are presented in High Field Strength Elements (HFSE) and other incompatible trace elements within kaolinitic. The summarized analytical values are given in table no 7.6.

Table no 7.6. Summarized table of ICP-MS analysis of Basalt (N-2) for 34 elements.

Elements	Min(ppm)	Max(ppm)	Mean (ppm)
Li	5.60	16.17	10.88
Sc	24.05	33.10	28.58
V	165.21	235.71	200.46
Cr	28.88	153.89	91.38
Co	33.98	37.46	35.72
Ni	21.12	135.47	78.30
Cu	70.85	123.29	97.07
Zn	70.80	101.81	86.31
Ga	12.41	18.86	15.64
Se	0.69	1.22	0.96
Rb	44.95	169.24	107.10
Sr	191.83	615.84	403.83
Y	39.61	59.27	49.44
Zr	350.65	462.23	406.44
Nb	14.77	17.92	16.35
Mo	0.60	0.98	0.79
La	38.52	54.08	46.30
Ce	71.94	90.12	81.03
Pr	9.11	10.70	9.91
Nd	37.61	40.02	38.81
Sm	7.15	8.37	7.76
Eu	2.10	2.97	2.54
Gd	7.12	9.17	8.15
Tb	1.24	1.75	1.49
Dy	7.34	11.07	9.21
Ho	1.50	2.30	1.90
Er	4.09	6.32	5.20
Tm	0.63	0.94	0.79
Yb	3.71	5.64	4.67
Lu	0.57	0.79	0.68
Hf	8.97	13.02	11.00
Pb	6.99	7.77	7.38
Th	5.38	10.00	7.69
U	0.82	1.40	1.11
ΣREE + Y	265.78	269.98	267.88
ΣTREE+ Sc + Y	294.03	298.88	296.46

The Basaltic units show total REE ($\Sigma\text{REE}+\text{Y}$) values ranging from 265.78 ppm to 269.98 ppm, with an average value of approximately 267.88 ppm. The analysed samples exhibit relative enrichment of Light Rare Earth Elements (LREE) such as La, Ce and Nd. Lanthanum values range from 38.52 ppm to 54.08 ppm, cerium from 71.94 ppm to 90.12 ppm and neodymium from 37.61 ppm to 40.02 ppm. The distribution pattern indicates predominance of LREE over HREE.

Among the Heavy Rare Earth Elements (HREE), yttrium ranges from 39.61 ppm to 59.27 ppm, dysprosium from 7.34 ppm to 11.04 ppm and ytterbium from 3.71 ppm to 5.61 ppm. The presence of both LREE and HREE suggests the occurrence of REE-bearing accessory minerals.



Text Fig. 7.8: The chondrite-normalised REE spider diagram of samples drawn from Basaltic units (N=02).

The chondrite-normalized REE diagram in Text Fig. 7.8 shows that both basalt samples have higher concentrations of LREEs than HREEs. The REE pattern decreases smoothly from La to Lu, indicating that the magma was rich in LREEs and became gradually lower in HREEs. Both samples show almost the same REE pattern, which suggests that they were formed from the same magma source and underwent similar geological processes.

A small decrease in Europium (Eu) is seen, which indicates that a small amount of plagioclase feldspar was removed from the magma during cooling and crystallization.

The HREE values are relatively uniform, suggesting that the magma was produced by partial melting of the mantle without strong influence from deep mantle minerals like garnet.

7.2.2.5 Basic Dikes:

There are many basic dikes present in the block area of basaltic and dolerite composition. Out of the five basic dykes recorded in the block area, three dykes exhibit a well-defined and consistent trend, striking nearly northeast to southwest and extending consistently along the west side of Ratiya–Dausa Road. These dykes are comparatively more continuous and prominently exposed in the field, suggesting emplacement along a common fracture system controlled by regional tectonic stresses.



Photograph No.-7.20:
Image showing closer view of Dolerite dike fine to medium-grained, massive, and compact in nature in the Ratiya area.

7.2.2.6 Weathered Horizons:

The weathered horizons in the Sumarasar Block are developed over the sedimentary rocks of the Bhuj and Katrol Formation and associated shale units. The thickness of the weathered zone is variable, generally ranging from about 1 to 8 m, depending on the lithology, topography, and degree of weathering.

The uppermost layer consists of loose soil and alluvium composed of sand, silt, and clay. This is underlain by a zone of highly weathered sandstone, which is soft, friable, yellowish-brown to reddish-brown in colour, and locally kaolinitic due to the alteration of feldspar minerals. Iron oxide staining is common, giving the rock a brown to reddish appearance.

Below the highly weathered zone lies moderately weathered sandstone, which is comparatively compact but still shows discoloration along joints and fractures. Feldspar grains are partially altered to clay minerals, while quartz grains remain relatively unaltered. Thin intercalations of weathered grey shale and claystone may also be encountered in places. The shale is generally soft, fissile, and yellow, ferruginous, grey to dark grey in colour.

The weathered profile gradually passes into fresh sandstone and shale at depth.

The weathered zone is significant for exploration as it may contain secondary enrichment of iron oxides, clay minerals, and rare earth elements (REE) associated with kaolinization and weathering processes.

A total of 28 samples were collected from different units in the Sumarasar Block, comprising 1 pit sample, and 27 samples from different auger boreholes. These samples were analysed for 34 elements using ICP–MS. The analytical results indicate the presence of Rare Earth Elements (REE), High Field Strength Elements (HFSE), and other incompatible trace elements within the different units of shales. The summarized analytical values are presented in High Field Strength Elements (HFSE) and other incompatible trace elements within the Shales. The summarized analytical values are given in Table no 7.7.

Table no 7.7

Summarized table of ICP-MS analysis of Weathered Horizons (N-28) for 34 elements.

Elements	Min(ppm)	Max(ppm)	Mean (ppm)
Li	13.87	96.60	59.57
Sc	5.03	25.96	17.40
V	37.00	204.30	136.33
Cr	77.83	285.50	130.42
Co	2.02	39.24	21.72
Ni	23.47	104.41	54.75
Cu	12.01	54.05	36.08
Zn	34.34	805.38	129.86
Ga	7.25	38.08	25.50
Se	0.47	4.60	1.44
Rb	16.57	126.12	84.30
Sr	80.15	500.78	234.17
Y	17.91	81.41	46.13
Zr	238.89	704.22	425.81
Nb	6.42	33.84	13.36
Mo	0.46	3.72	1.10
La	24.90	109.36	65.39
Ce	49.25	206.56	131.30
Pr	5.16	22.03	14.48
Nd	18.66	82.34	52.73
Sm	3.58	15.64	9.72
Eu	0.57	2.55	1.79
Gd	3.20	13.70	8.62
Tb	0.57	2.59	1.51
Dy	3.27	14.79	8.63
Ho	0.65	3.02	1.75
Er	1.72	7.27	4.69
Tm	0.27	1.21	0.71
Yb	1.68	7.41	4.57
Lu	0.27	1.14	0.69
Hf	6.69	19.09	12.34
Pb	9.76	28.21	21.25
Th	10.96	49.87	27.46
U	1.67	5.19	3.71
ΣREE + Y	134.74	544.98	352.71
ΣTREE+ Sc + Y	142.22	565.32	370.46

The weathered horizons of both the Bhuj and Katrol Formations show total REE ($\Sigma\text{REE}+\text{Y}$) values ranging from 134.74 ppm to 544.98 ppm, with an average value of approximately 352.71 ppm. The analysed samples are relatively enriched in Light Rare Earth Elements (LREE), particularly La, Ce, and Nd. Lanthanum concentrations vary from 24.90 ppm to 109.36 ppm, cerium from 49.25 ppm to 206.56 ppm, and neodymium from 18.66 ppm to 82.34 ppm. The overall distribution pattern indicates predominance of LREE over HREE.

Among the Heavy Rare Earth Elements (HREE), yttrium concentrations range from 17.91 ppm to 81.41 ppm, dysprosium from 3.27 ppm to 14.79 ppm, and ytterbium from 1.68 ppm to 7.48 ppm. The occurrence of both LREE and HREE in the analysed samples suggests the presence of REE-bearing accessory minerals within the weathered horizons developed over the different shale units.

7.3.0 Structure of the block

7.3.1 Based on field observations, the structures identified in the study area are classified into:

- 1.Primary Sedimentary Structures
2. Secondary Sedimentary Structures

A. Primary Sedimentary Structures

i. Bedding and Lamination:

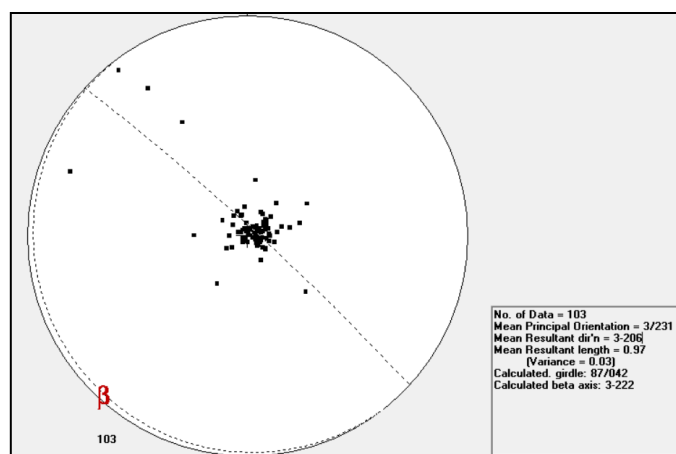
Bedding is one of the most prominent sedimentary features observed in the study area. The sedimentary rocks occur in the form of distinct layers differing in lithology, grain size, colour, and thickness. Planer bedding (**Photograph No.-7.21**) is Mainly present in the block area with the horizontal to sub horizontal dip. Laminations are represented by thin sedimentary layers generally less than 1 cm thick. Alternating sandstone, shale beds are mainly observed in Bhuj Sandstone. Thick-bedded sandstone units are dominant within high-energy depositional facies. But the Fine Laminated shale units are dominant in Katrol Formation.

The variation in bedding thickness and lithological association indicates fluctuations in depositional energy, sediment supply, and basin conditions. Laminated shale units suggest deposition under low-energy marine conditions, whereas thick sandstone beds indicate higher-energy fluvial or shoreface environments.



Photograph No.-7.21: Image showing Planer bedding in Katrol Formation

A total 103 nos of bedding plane orientation were measured in the field. The pole to plane plot on equal area sterionet shows mean principal orientation of the bedding plane having dip 3° toward 231° striking NW-SE which corroborate



Text Fig.7.9: Stereographic plot of pole to the bedding plane of Sumarasar Block

ii. Cross-Bedding:

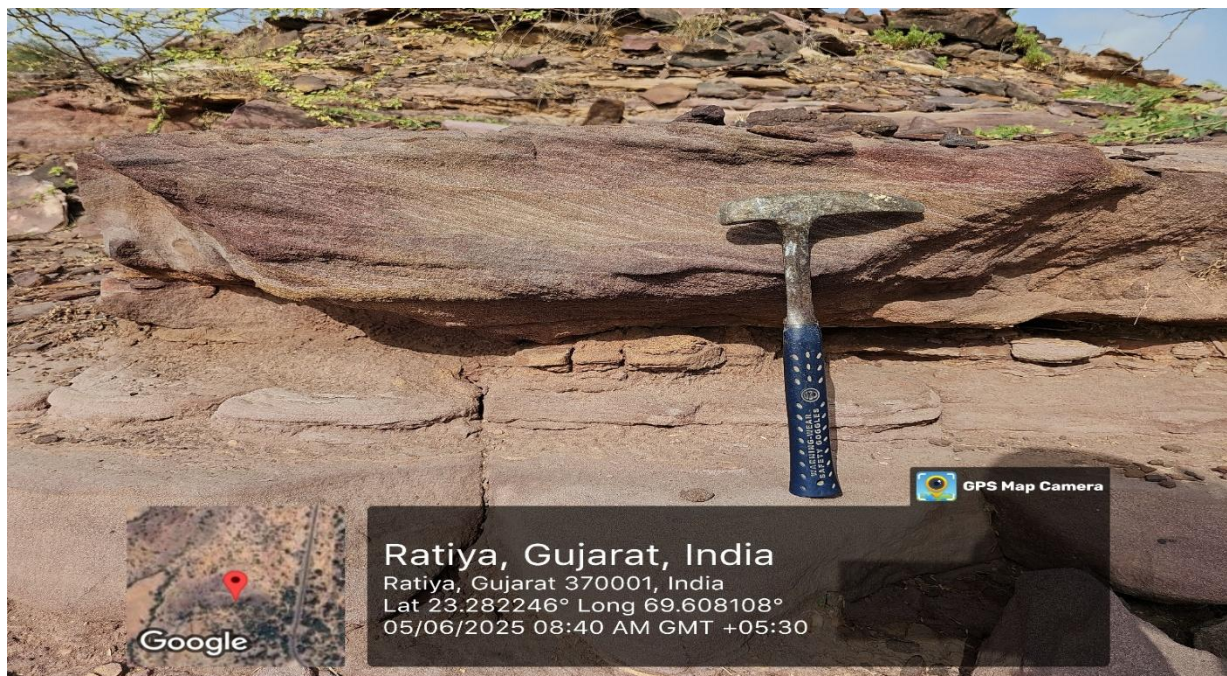
Well-developed planar to trough cross-bedding is observed in sandstone units of Bhuj formation in the block area. Large-scale foresets, concave-upward bounding surfaces and tangential contacts indicate fluvial channel deposition and paleocurrent-controlled sediment transport.



Photograph No.-7.22: Image showing Large Scale Tabular Cross bedding in sandstone of Bhuj Formation



Photograph No.-7.23 Small Scale Cross bedding in sandstone. The bounding surfaces of the cross-bedded units are planer and that the foreset laminar form mainly tangential contact with these planer surfaces.



Photograph No.-7.24: Small Scale Cross bedding in sandstone with the eroded bounding Surfaces.

Localized convolute lamination has been observed in the block area. These structures indicate that the sediments were deposited rapidly and were still soft when they got disturbed. Due to the heavy load of overlying sediments, the lower layers became unstable and partially liquefied, resulting in folding and bending of the layers. Such features suggest sudden sediment deposition and may also indicate minor tectonic movements during the time of deposition in Photograph No.-7.25.



Photograph No.-7.25
Image Showing
Convolute
Lamination.

ii. Ripple Marks:

Ripple marks are prominent primary sedimentary structures observed in the Mesozoic (Jurassic–Cretaceous) rocks of the Kachchh Basin, indicating deposition in shallow marine, tidal, and deltaic environments. The Bhuj Formation (Lower Cretaceous) of the block area is particularly known for the presence of well-developed wave ripple marks preserved in sandstones (Photograph No.-7.26).



Photograph No.-7.26: Image showing well preserved ripple marks exposed on feldspathic sandstone exposures in the Ratiya area.

B. Secondary Structure:

i. Fold Pattern: No mesoscopic or macroscopic folds were observed within the block area. No anticline/syncline geometry or axial plane cleavage was recorded. The absence of folding suggests deformation accommodated through brittle faulting rather than ductile folding.

ii. Faults and Fractures

No major fault planes were directly exposed within the block area; however, certain field indications and localized increases in dip suggest the presence of

faulting at a few locations. Such structural disturbances are observed north of the Kodki Fault, towards the southeastern part of the block boundary, and along the eastern side of Khatlo Dungar. Although no distinct fault plane was mapped at the surface, the area falls under the broader influence of regional fault systems. In some parts some fault impressions are seen (Photograph No.-7.27).



Photograph No.-7.27 Image showing Impressions of faulting localized in the area in Bhuj formation

Minor brittle cracks are observed within the outcrops; however, no measurable displacement is evident at the outcrop scale. These fractures are interpreted as rift-related extensional features formed under regional tectonic stress conditions. They may also have acted as potential magmatic pathways, facilitating the movement of magma or hydrothermal fluids during extensional phases of the Kachchh Basin's tectonic evolution.

iii. Joints and Fractures

Jointing is well developed in the ferruginous sandstone exposed within the western boundary of block area. The joints are predominantly sub-vertical in nature and, in several locations, exhibit an orthogonal pattern forming two prominent intersecting sets (Photograph No.-7.28). The spacing between individual joints varies from approximately 10 cm to 40 cm. No visible shear displacement or slickensides were

observed along the joint planes, indicating their tensional origin rather than shear-related movement. The development of these joint systems reflects brittle deformation under an extensional stress regime and plays a significant role in enhancing secondary permeability and weathering within the formation.

East–west trending linear brittle structural feature exposed at Khilna area, the feature is expressed as a narrow fracture/joint zone characterized by aligned, blocky rock fragments and joint-controlled weathering. No measurable displacement is observed at the outcrop scale, suggesting it represents a minor fracture zone. The E–W orientation corresponds with the dominant regional structural trend of the Kachchh rift system.



Photograph No.-
7.28: Well
Developed Joint
Sets in the
Massive
Sandstone of
Bhuj Formation.



Photograph No.-7.29
 Image showing One set of joint planes along with iron-rich concretion developed within the Sandstone of Bhuj Formation.



Photograph No.-7.30
 Image showing linear brittle structural feature exposed at Khilna area.

iii. Trace Fossils:

The Jurassic sedimentary sequence of the Kachchh Basin preserves abundant and well-preserved trace fossils occurring predominantly within sandstone, shale, siltstone, and limestone facies. The secondary sedimentary feature preserved on the feldspathic sandstone with horizontal burrow tube with partially preserved sprite (Photograph No.-7.31).



Photograph No.-7.31: Horizontal burrow tube with partially preserved sprite like in *Taenidium* exposed on feldspathic sandstone exposures.

7.4.0 Mineralisation

- 7.4.1 The Sumarasar Block is situated within the Kachchh Basin, a Mesozoic–Cenozoic pericratonic rift basin known for occurrences of phosphorite, bentonite, lignite, limestone, bauxite and heavy mineral concentrations. The block was selected for reconnaissance exploration for REE, primarily on the basis of anomalous Rare Earth Element (REE) concentrations recorded under the National Geochemical Mapping (NGCM) programme of the Geological Survey of India (GSI) in Survey of India Toposheet No. 41E/11. Evaluation of the NGCM database revealed that five stream sediment samples within the block recorded total REE values exceeding 1000 ppm, whereas seventeen samples yielded total REE values greater than 500 ppm. Individual REE concentrations attained values up to 424.38 ppm for La, 883.57 ppm for Ce and 416.32 ppm for Nd, indicating the presence of favourable REE source lithologies within the area.
- 7.4.2 Reconnaissance exploration carried out in the Sumarasar Block indicates localized enrichment of Rare Earth Elements (REE) within sedimentary horizons belonging mainly to the Bhuj and Katrol formations. Geochemical

analysis of 32 sandstone samples revealed $\Sigma\text{REE}+\text{Y}$ values ranging from 112.67 ppm to 514.60 ppm with an average value of 346.56 ppm, whereas 99 shale samples yielded $\Sigma\text{REE}+\text{Y}$ values ranging from 77.45 ppm to 1527.80 ppm with an average value of 371.87 ppm. The analysed sandstone and shale samples are characterized by enrichment of Light Rare Earth Elements (LREE), with La values ranging from 25.43–113.12 ppm in sandstone and 12.24–161.40 ppm in shale, Ce from 40.81–184.68 ppm in sandstone and 20.74–264.58 ppm in shale, and Nd from 18.04–77.75 ppm in sandstone and 11.55–122.63 ppm in shale. Among the Heavy Rare Earth Elements (HREE), Y values range from 10.20–79.84 ppm in sandstone and 16.52–767.07 ppm in shale. The chondrite-normalized REE patterns of both lithological units exhibit enrichment of LREE over HREE along with a distinct negative Eu anomaly, indicating derivation from felsic source rocks and concentration of REE within detrital heavy mineral phases.

- 7.4.3 Petrographic and mineralogical investigations provide evidence for the occurrence of REE-bearing and associated minerals within the sedimentary succession of the Sumarasar Block. Petrographic studies have identified monazite as fine accessory grains within ferruginous sandstone and arkosic wacke samples. Petrography further confirms the presence of monazite associated with ferruginous-calcitic matrix in sandstone samples. In addition, glauconite occurs as fine pellets in certain samples, whereas collophane has been identified in shale samples as an amorphous constituent associated with ferruginous matter, clay matrix, sericite and zeolite. XRD investigations corroborate the petrographic observations and indicate the presence of monazite, xenotime and apatite as subordinate mineral phases. The identification of monazite and xenotime suggests the presence of REE-bearing phosphate minerals within the sedimentary sequence, while the occurrence of collophane and apatite indicates localized phosphate enrichment. The association of REE-bearing minerals with collophane-, clay- and ferruginous-rich horizons suggests that these phases may have played an important role in the localized concentration and retention of REE within the block. Further, the association of monazite and zircon with collophane-, apatite- and glauconite-bearing horizons indicates that the REE enrichment may have been controlled

by both detrital input from felsic source rocks and localized fixation within phosphate-bearing marine sediments.

- 7.4.4 Investigations carried out in adjacent areas of the Kachchh Basin have also reported REE enrichment associated with ferruginous and phosphate-bearing sedimentary horizons and identified REE-bearing minerals such as monazite, xenotime and apatite. The similarity in lithological association suggests that ferruginous and phosphate-bearing horizons within the Sumarasar Block may constitute favourable sites for localized REE enrichment.
- 7.4.5 Although one shale samples have yielded anomalous $\Sigma\text{REE}+\text{Y}$ values exceeding 1000 ppm (maximum 1527.80 ppm), these enriched values are confined to isolated and localized horizons. Detailed geological mapping, pitting, auger drilling and geochemical investigations have not established any laterally persistent REE-bearing horizon within the block. Further, MECL is presently carrying out G-4 stage exploration in the adjoining Nokhaniya Block located immediately east of the Sumarasar Block. A borehole drilled up to a depth of 50 m in the boundary region between the Sumarasar and Nokhaniya blocks did not intersect any encouraging REE-bearing horizon. Therefore, the available geological, geochemical, petro-mineralogical and subsurface information suggest that the REE enrichment encountered in the Sumarasar Block is localized and discontinuous in nature.
- 7.4.6 All lithological units encountered during geological mapping, pitting and auger drilling were systematically examined in the field using Shapiro's rapid phosphate test. However, no persistent or economically significant phosphatic horizon was identified during the course of investigation.

7.5.0 EPMA STUDY

7.5.1 Bulk geochemical analysis of 169 primary samples from the Sumarasar Block established a rare earth signature characterised by strong enrichment of the light rare earth elements over the heavy rare earth elements, a distinct negative europium anomaly and elevated concentrations of zirconium, hafnium and thorium. This association was interpreted in Section 7.2.0 as indicating the residence of the rare earth elements in resistant detrital accessory minerals. Petrographic examination identified monazite as fine accessory grains within ferruginous sandstone and arkosic wacke, and X-ray diffraction indicated monazite, xenotime and apatite as subordinate to trace phases. Those identifications rested on optical and diffraction evidence alone and therefore required independent quantitative confirmation. Two polished sections were accordingly submitted to the Electron Probe Micro-Analysis Laboratory, National Centre of Excellence in Geoscience Research (NCEGR), Regional Sophisticated Analytical Services (RSAS), Geological Survey of India, Bengaluru, for identification and quantitative analysis of the rare earth bearing and associated phases.

7.5.2 Mineral abbreviations used

Table No. 7.8: Mineral abbreviations used in the electron probe micro-analytical tables

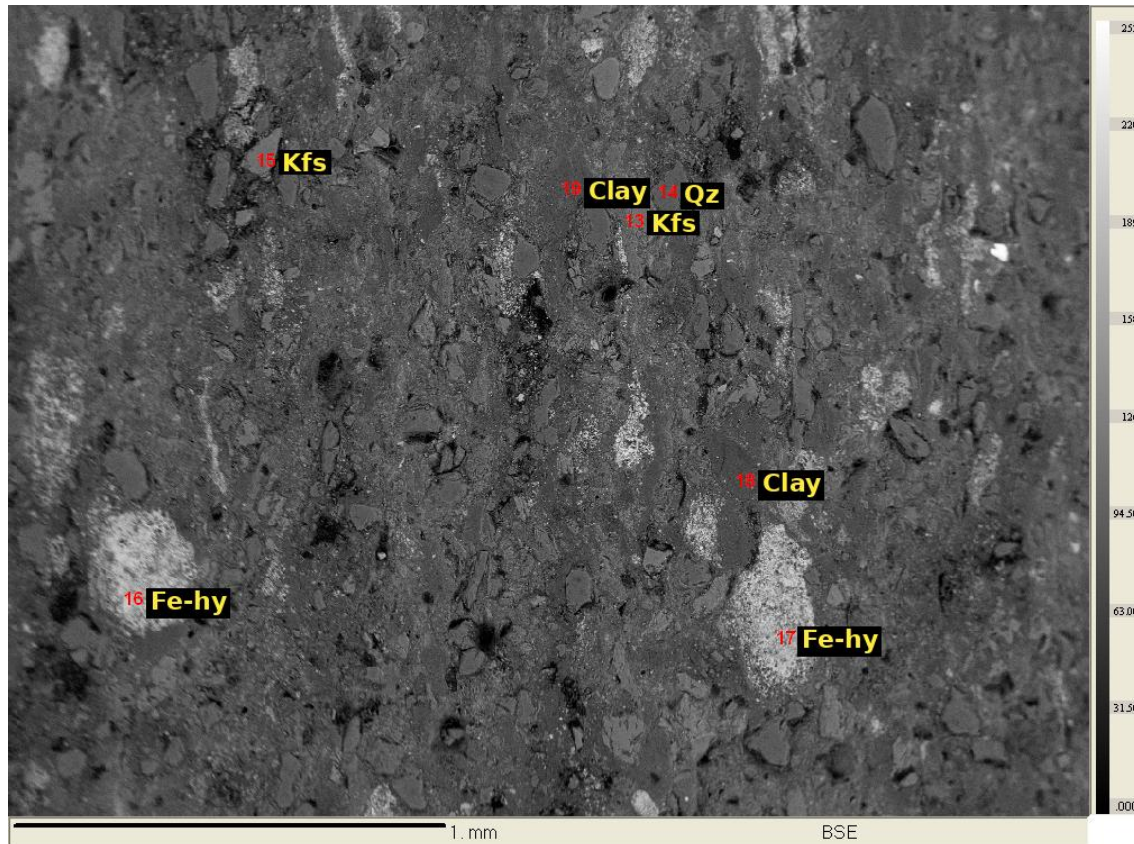
Abbrev.	Mineral	Abbrev.	Mineral
Clay	Clay mineral (kaolinite / illitic clay)	Mnz	Monazite
Fe-hy	Iron hydroxide (goethite–limonite)	Qz	Quartz
Kfs	K-feldspar	Zrn	Zircon

Abbreviations after Whitney and Evans (2010) where available.

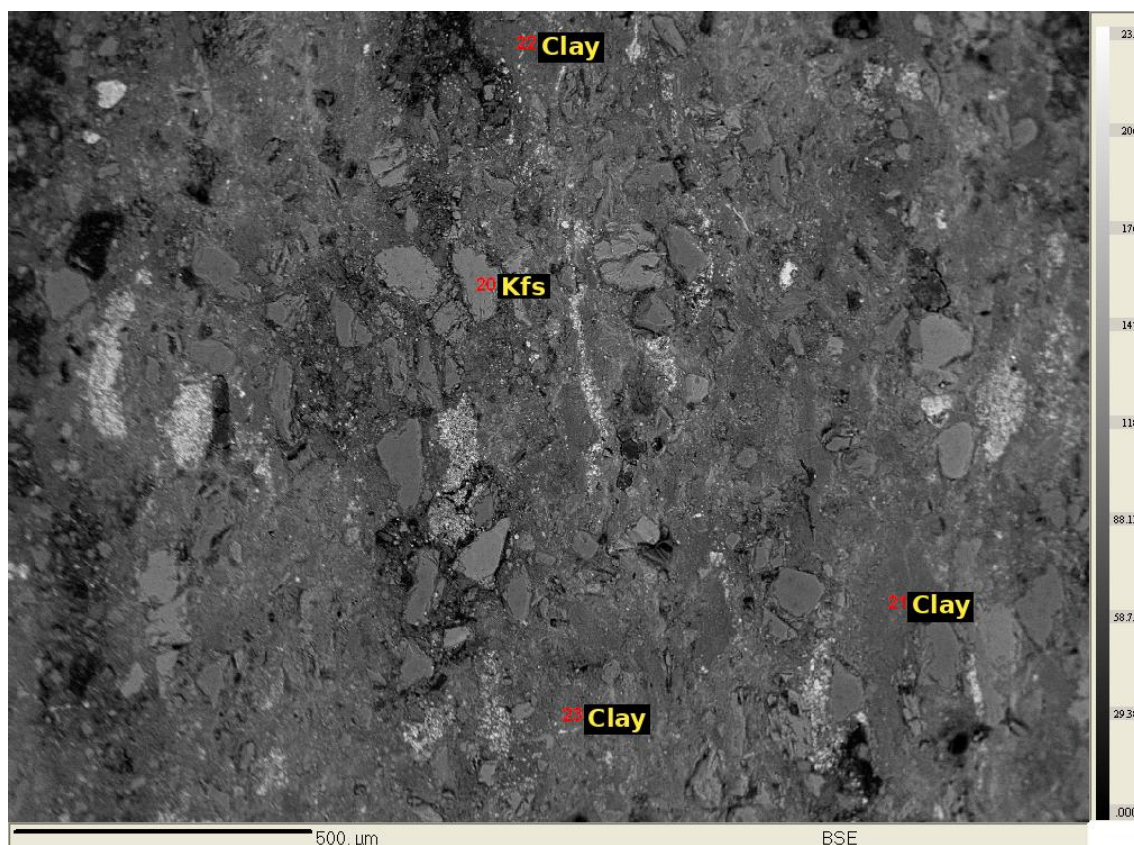
7.5.3 Section SMR/EPMA-01 — back-scattered electron imagery

Analytical point positions are marked on the plates for fields BSE-40 and BSE-41, together with the mineral identified at each point. In each case the marked positions are corroborated by the back-scattered electron contrast of the image: in BSE-40 the two points identified as iron hydroxide fall on the two conspicuously bright, high atomic-number segregations, at grey levels of 132 and 160 against 74 to 92 for the five points identified as quartz, K-feldspar and clay, the separation being that required by the difference in mean

atomic number between an iron hydroxide carrying 61 to 70 per cent FeO and the low-atomic-number silicates.



Photograph No. 7.32: BSE-40, section SMR/EPMA-01, with analytical points and identified minerals marked. Silicate-routine points 13 and 15 (K-feldspar), 14 (quartz), 16 and 17 (iron hydroxide) and 18 and 19 (clay). Points 16 and 17 fall on the two bright, high atomic-number iron-hydroxide segregations dispersed through the densely clast-bearing fine matrix. Scale bar 1 mm; 15 kV.



Photograph No. 7.33: BSE-41, section SMR/EPMA-01, with analytical points and identified minerals marked. Silicate-routine points 20 (K-feldspar) and 21, 22 and 23 (clay), all of low atomic number and of correspondingly uniform grey level, set in a clast-rich clay matrix traversed by bright irregular and vein-like iron-hydroxide segregations. Scale bar 500 μm ; 15 kV.

7.5.4 Section SMR/EPMA-01 — rare-earth-routine analyses

The five rare-earth-routine analyses of this section are reproduced in full in Table No. 7.11. Analytical totals of 97.80 to 101.44 per cent indicate that the analyses are of good quality and that the element suite of the routine accounts satisfactorily for the composition of the phases. Three of the five points are monazite and two are zircon.

Table No. 7.9: Electron probe micro-analyses, rare earth routine, section SMR/EPMA-01, Sumarasar Block (oxide wt %)

Oxide (wt %)	Pt 6	Pt 7	Pt 8	Pt 9	Pt 10
Mineral	Zrn	Mnz	Mnz	Mnz	Zrn
SiO ₂	26.76	1.00	1.07	1.37	30.42
P ₂ O ₅	2.96	31.08	30.08	28.62	0.50
Al ₂ O ₃	0.43	0.78	0.13	0.01	0.00
MgO	0.07	0.00	0.00	0.00	0.00
CaO	0.77	1.13	1.92	1.38	0.00
TiO ₂	0.09	0.06	0.03	0.00	0.00
FeO	0.72	0.19	0.00	0.00	0.12

MnO	0.03	0.00	0.00	0.00	0.00
ZrO₂	62.93	0.00	0.00	0.00	69.61
Y₂O₃	1.60	0.78	1.94	0.98	0.15
La₂O₃	0.12	12.30	12.07	13.64	0.01
Ce₂O₃	0.07	26.67	23.08	24.36	0.00
Pr₂O₃	0.00	3.75	3.35	3.05	0.00
Nd₂O₃	0.00	13.52	9.30	9.54	0.00
SmO	0.00	2.10	1.73	1.74	0.00
EuO	0.00	1.11	0.50	0.76	0.00
Gd₂O₃	0.27	1.50	1.23	1.20	0.06
Tb₂O₃	0.00	0.00	0.00	0.00	0.00
Dy₂O₃	0.04	0.28	0.29	0.43	0.02
Ho₂O₃	0.00	0.13	0.34	0.00	0.00
Er₂O₃	0.08	0.00	0.07	0.09	0.09
Tm₂O₃	0.11	0.23	0.23	0.28	0.00
Yb₂O₃	0.31	0.13	0.11	0.00	0.00
Lu₂O₃	0.00	0.00	0.00	0.00	0.03
ThO₂	0.06	2.42	12.02	9.88	0.03
UO₂	0.16	0.03	0.69	0.82	0.03
PbO	0.00	0.10	0.65	0.36	0.00
Ta₂O₅	0.22	0.00	0.00	0.00	0.24
Nb₂O₃	0.00	0.00	0.00	0.00	0.00
F	0.00	0.71	0.60	0.55	0.00
Total	97.80	99.97	101.44	99.06	101.31

Zrn = zircon; Mnz = monazite.

7.5.5 Composition of the monazite

7.5.5.1 Points 7, 8 and 9 record a phase carrying 28.62 to 31.08 per cent P₂O₅ with 54.24 to 62.50 per cent of combined rare earth and yttrium oxides, and are monazite. Cerium is the dominant rare earth in every analysis (23.08 to 26.67 per cent Ce₂O₃), followed by lanthanum (12.07 to 13.64 per cent La₂O₃) and neodymium (9.30 to 13.52 per cent Nd₂O₃), with praseodymium 3.05 to 3.75 per cent, samarium 1.73 to 2.10 per cent and europium 0.50 to 1.11 per cent. The phase is monazite-(Ce) throughout.

7.5.5.2 Recalculated as elements, the three grains carry 46.35 to 53.54 weight per cent ΣREE+Y, of which 92 to 95 per cent is light rare earth. The ratio of light rare earths to heavy rare earths plus yttrium ranges from 12.2 to 19.7, confirming the strongly light-rare-earth-selective character of the mineral and accounting directly for the LREE-dominated chondrite-normalised patterns of the bulk samples described in Section 7.2.2.

7.5.5.3 Thorium is a significant constituent and is markedly variable. Point 7 carries 2.42 per cent ThO₂ (2.13 per cent Th), whereas points 8 and 9 carry 12.02 and 9.88 per cent ThO₂ (10.56 and 8.68 per cent Th). Thorium to Σ LREE ratios are correspondingly 0.042, 0.247 and 0.191. Uranium is subordinate throughout at 0.03 to 0.82 per cent UO₂. Lead contents of 0.10 to 0.65 per cent PbO are radiogenic and, taken with the thorium contents, are consistent with a detrital grain population of appreciable age. The three-fold spread in thorium content within a single section indicates that the monazite population is not derived from a single source rock but represents a mixed detrital assemblage. The derived parameters are summarised in Table No. 7.10.

Table No. 7.10: Derived compositional parameters of the monazite, section SMR/EPMA-01, Sumarasar Block

Parameter	Pt 7	Pt 8	Pt 9	Range
P ₂ O ₅ (wt %)	31.08	30.08	28.62	28.62–31.08
Σ REE+Y as oxide (wt %)	62.50	54.24	56.07	54.24–62.50
Σ REE+Y as element (wt %)	53.54	46.35	47.99	46.35–53.54
Σ LREE as element (wt %)	50.96	42.85	45.47	42.85–50.96
Σ HREE+Y as element (wt %)	2.59	3.50	2.51	2.51–3.50
LREE / (HREE+Y)	19.68	12.23	18.11	12.2–19.7
Th (wt %)	2.13	10.56	8.68	2.13–10.56
U (wt %)	0.03	0.61	0.72	0.03–0.72
Pb (wt %)	0.09	0.60	0.33	0.09–0.60
Th / Σ LREE	0.042	0.247	0.191	0.042–0.247

7.5.4 Composition of the zircon

7.5.4.1 Points 6 and 10 of section SMR/EPMA-01 and point 5 of section SMR/EPMA-02 are zircon, carrying 62.93 to 69.61 per cent ZrO₂ and 26.76 to 30.87 per cent SiO₂ with analytical totals of 97.80 to 101.31 per cent. Points 10 and 5 are near end-member zircon: combined rare earth and yttrium oxides amount to only 0.36 and 0.44 per cent respectively, thorium and uranium are each below 0.06 per cent, and the grains are of no consequence as rare earth hosts, although they account for the elevated zirconium and hafnium recorded by bulk analysis.

7.5.4.2 Point 6 is compositionally distinct and is of particular interest. It carries 62.93 per cent ZrO₂ with 2.96 per cent P₂O₅, 1.60 per cent Y₂O₃ and detectable heavy rare earths (Gd₂O₃ 0.27, Yb₂O₃ 0.31, Tm₂O₃ 0.11 and Er₂O₃ 0.08 per

cent), the combined rare earth and yttrium oxides amounting to 2.60 per cent. The coupled enrichment of phosphorus, yttrium and the heavy rare earths, at the expense of zirconium and silicon, is the compositional expression of the xenotime substitution, $(Y,HREE)PO_4 \rightleftharpoons ZrSiO_4$, in which yttrium and the heavy rare earths enter the zircon structure together with phosphorus. The grain is therefore a phosphorus- and yttrium-bearing zircon, or a zircon carrying a submicroscopic xenotime component. This is the closest approach to xenotime encountered in either Sumarasar section, and it provides the mineralogical explanation for the modest heavy rare earth and yttrium contents of the bulk samples in the absence of a discrete xenotime phase.

7.5.5 Section SMR/EPMA-01 — silicate-routine analyses

7.5.5.1 The eleven silicate-routine analyses of this section are reproduced in full in Table No. 7.13. The section carries a detrital framework of quartz and fresh K-feldspar set in a matrix of kaolinitic to illitic clay with abundant iron hydroxide.

Table No. 7.11: Electron probe micro-analyses, silicate routine, section SMR/EPMA-01, Sumarasar Block (oxide wt %)

Oxide	Pt 13	Pt 14	Pt 15	Pt 16	Pt 17	Pt 18	Pt 19	Pt 20	Pt 21	Pt 22	Pt 23
Mineral	Kfs	Qz	Kfs	Fe-hy	Fe-hy	Clay	Clay	Kfs	Clay	Clay	Clay
Na ₂ O	1.75	0.00	0.52	0.11	0.08	0.10	0.06	0.78	0.07	0.12	0.35
SiO ₂	63.81	98.02	64.28	4.36	3.63	45.77	44.29	64.49	44.98	43.55	48.75
MgO	0.00	0.00	0.01	1.19	0.86	0.20	0.16	0.00	0.22	0.51	0.85
Al ₂ O ₃	18.50	0.00	18.58	1.20	2.67	39.53	37.80	18.69	39.15	34.41	34.84
K ₂ O	14.21	0.04	16.18	0.08	0.04	0.11	0.05	15.51	0.03	1.17	3.84
CaO	0.00	0.00	0.00	0.53	0.52	0.07	0.07	0.00	0.03	0.18	0.14
TiO ₂	0.00	0.00	0.00	0.19	0.49	0.03	0.00	0.01	0.00	0.23	0.11
V ₂ O ₃	0.00	0.04	0.00	0.08	0.07	0.06	0.06	0.00	0.05	0.00	0.00
FeO	0.15	0.10	0.30	70.00	61.34	0.60	0.56	0.10	0.62	2.83	1.12
MnO	0.14	0.01	0.02	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Cr ₂ O ₃	0.05	0.00	0.00	0.56	4.07	0.34	0.00	0.00	0.30	0.81	1.26
P ₂ O ₅	0.02	0.11	0.00	0.15	0.00	0.00	0.00	0.00	0.08	0.03	0.02
BaO	0.52	0.00	0.53	0.00	0.00	0.00	0.00	0.34	0.00	0.05	0.10
ZrO ₂	0.00	0.00	0.00	0.24	0.00	0.21	0.05	0.00	0.07	0.00	0.00
F	0.00	0.21	0.00	0.00	0.00	0.13	0.00	0.20	0.00	0.38	0.32
Total	99.16	98.52	100.42	78.69	73.79	87.16	83.10	100.12	85.60	84.27	91.70

Kfs = K-feldspar; Qz = quartz; Fe-hy = iron hydroxide; Clay = kaolinite / illitic clay. Strontium and the rare earth elements were not determined by this routine.

7.5.5.2 Points 13, 15 and 20 return 63.81 to 64.49 per cent SiO_2 , 18.50 to 18.69 per cent Al_2O_3 and 14.21 to 16.18 per cent K_2O with totals of 99.16 to 100.42 per cent, and are K-feldspar of orthoclase composition (Or 84 to 95). The preservation of fresh, unaltered detrital K-feldspar alongside a kaolinitic clay matrix is a diagnostic feature of the section and indicates an immature detrital assemblage in which weathering has affected the matrix more strongly than the framework grains. Point 14 is quartz at 98.02 per cent SiO_2 .

7.5.5.3 Points 16 and 17 return 70.00 and 61.34 per cent FeO with 4.36 and 3.63 per cent SiO_2 and totals of 78.69 and 73.79 per cent, and are iron hydroxide of goethite–limonite type, the deficit in the totals corresponding to structural water. Both carry appreciable chromium (0.56 and 4.07 per cent Cr_2O_3) and minor magnesium, calcium and titanium, indicating adsorption or co-precipitation of these elements during ferruginisation. The iron hydroxide forms the bright irregular patches and streaks visible in images.

7.5.5.4 Points 18, 19, 21, 22 and 23 return 43.55 to 48.75 per cent SiO_2 and 34.41 to 39.53 per cent Al_2O_3 with totals of 83.10 to 91.70 per cent and are clay minerals. Points 18, 19 and 21 have molar Si : Al ratios of 0.98, 0.99 and 0.98 against 1.00 for ideal kaolinite, with negligible potassium (0.03 to 0.11 per cent K_2O) and very low iron (0.56 to 0.62 per cent FeO), and are kaolinite essentially free of interlayer cations. Points 22 and 23 have ratios of 1.07 and 1.19 with 1.17 and 3.84 per cent K_2O and are kaolinite carrying an illitic component. The assemblage is consistent with the kaolinite, dickite and illite recorded by X-ray diffraction on samples from the same lithological units (Annexure V).

7.5.6 Section SMR/EPMA-02 — analyses

7.5.6.1 Two points only were analysed on this section, one under each routine. Point 12 of the silicate routine is quartz at 99.22 per cent SiO_2 with a total of 99.77 per cent. Point 5 of the rare earth routine is near end-member zircon at 68.40 per cent ZrO_2 and 30.87 per cent SiO_2 with a total of 100.46 per cent and negligible rare earth content. No rare earth phosphate and no calcium phosphate was encountered on this section. Both analyses are reproduced in Table No. 7.12.

Table No. 7.12: Electron probe micro-analyses, section SMR/EPMA-02, Sumarasar Block (oxide wt %)

Oxide (wt %)	Pt 12 — silicate routine	Pt 5 — rare earth routine
Mineral	Qz	Zrn
Na ₂ O	0.00	—
SiO ₂	99.22	30.87
MgO	0.00	0.01
Al ₂ O ₃	0.03	0.00
K ₂ O	0.00	—
CaO	0.00	0.02
TiO ₂	0.01	0.02
V ₂ O ₃	0.05	—
FeO	0.02	0.00
MnO	0.11	0.05
Cr ₂ O ₃	0.14	—
P ₂ O ₅	0.00	0.34
BaO	0.06	—
ZrO ₂	0.00	68.40
Y ₂ O ₃	—	0.03
La ₂ O ₃	—	0.00
Ce ₂ O ₃	—	0.00
Nd ₂ O ₃	—	0.00
ThO ₂	—	0.02
UO ₂	—	0.06
F	0.14	0.00
Total	99.77	100.46

Qz = quartz; Zrn = zircon. An em dash indicates that the element was not determined by that routine.

7.5.7 Phosphate phases

7.5.7.1 The behaviour of phosphorus in the two sections is of direct relevance to the phosphorite objective of the programme. In the twelve silicate-routine analyses of the two Sumarasar sections, P₂O₅ ranges from 0.00 to 0.15 per cent, that is, at or close to the detection limit in every phase analysed — quartz, K-feldspar, clay and iron hydroxide alike. No calcium phosphate phase was encountered at any of the eighteen points examined. Apatite, fluorapatite and collophane are absent from both sections, and the only phosphate phase identified in the Sumarasar Block is monazite, which is a rare earth phosphate and not a phosphorite mineral.

7.5.7.2 This is a significant negative result because the same analytical job, run under identical conditions on the same instrument, positively identified apatite and fluorapatite in sections from the adjoining Nokhaniya and Devpur blocks, with

representative compositions of 47.98 to 53.70 per cent CaO, 31.42 to 37.99 per cent P₂O₅ and 4.57 to 5.80 per cent F. The instrument, the routine and the analyst were therefore demonstrably capable of detecting and quantifying calcium phosphate phases had such phases been present in significant modal proportion in the Sumarasar sections.

7.5.7.3 The result is consistent with, and independently supports, the field and laboratory evidence set out in Section 7.4.0: the absence of any limestone, dolomite or chert horizon within the block; the absence of any indication of a persistent or nodular phosphatic horizon on field testing by Shapiro's rapid phosphate method; and the occurrence of collophane and apatite only as amorphous or trace accessory constituents disseminated within shale. It is recorded, however, that two polished sections cannot exclude the presence of apatite elsewhere within the block, and the observation is accordingly presented as corroborative of the field and diffraction evidence rather than as independent proof of absence.

7.5.8 Summary of phases identified

Table No. 7.13: Summary of mineral phases identified by electron probe micro-analysis, Sumarasar Block

Phase	SMR/EPMA-01 (n = 16)	SMR/EPMA-02 (n = 2)	Remarks
Monazite-(Ce)	3 points	Not detected	P ₂ O ₅ 28.62–31.08 %; ΣREE+Y 46.35–53.54 % as element; Th 2.13–10.56 %
Zircon	2 points	1 point	ZrO ₂ 62.93–69.61 %; Pt 6 carries 2.96 % P ₂ O ₅ and 1.60 % Y ₂ O ₃
K-feldspar	3 points	Not detected	Or 84–95; fresh, unaltered detrital grains
Quartz	1 point	1 point	SiO ₂ 98.02 and 99.22 %
Iron hydroxide	2 points	Not detected	FeO 61.34–70.00 %; Cr ₂ O ₃ 0.56–4.07 %
Clay (kaolinite / illitic)	5 points	Not detected	Si : Al 0.98–1.19; K ₂ O 0.03–3.84 %

7.5.9 Bearing of the results on the interpretation

7.5.9.1 Monazite-(Ce) is confirmed as the principal rare earth host of the Sumarasar Block and zircon as the subordinate host. The strongly light-rare-earth-selective composition of the monazite, with cerium dominant and LREE/(HREE+Y) of 12.2 to 19.7, accounts directly for the light-rare-earth-enriched chondrite-normalised patterns of the bulk samples; the thorium

contents of 2.13 to 10.56 per cent account for the elevated bulk thorium; and the zircon accounts for the elevated zirconium and hafnium. The negative europium anomaly of the bulk samples and the preservation of fresh detrital K-feldspar together indicate derivation from a felsic source terrain, and the mineralogy is that of a detrital heavy-mineral assemblage rather than of an authigenic or hydrothermal concentration.

- 7.5.9.2 The modal abundance of monazite required to account for the observed bulk tenor is very small. At a measured 46 to 54 weight per cent $\Sigma\text{REE}+\text{Y}$ in the monazite, a bulk composition of 400 ppm $\Sigma\text{REE}+\text{Y}$ — approximately the median of the block — requires only about 0.08 weight per cent monazite in the rock. The scarcity of monazite in the sections examined, three grains among eighteen analysed points, is therefore entirely consistent with the bulk geochemistry, and equally consistent with the finding that the rare earth enrichment of the block is localised and of sub-economic tenor.

CHAPTER - VIII

8.0.0. PREVIOUS EXPLORATION

8.1.0. General

- 8.1.1 The Kachchh Basin has been the subject of extensive geological investigations by the Geological Survey of India (GSI), Gujarat State agencies and other organizations for more than five decades. Systematic Geological Mapping carried out by GSI during the field season 1966–67 in parts of Kachchh district established the regional stratigraphic framework comprising the Jurassic sedimentary succession represented by the Chari and Katrol formations, overlain by the Cretaceous Bhuj Formation and Deccan volcanic rocks. The investigations revealed that the oldest exposed formations in the area belong to the Chari Group of Upper Jurassic age. The golden oolite horizons occurring within the lower part of the Chari Formation were found to be restricted mainly to the Jhura Dome area. The studies also identified at least twenty-six lava flows above the Bhuj Formation in southern Kachchh. Structural studies delineated the Banni and Katrol Fault systems as major tectonic elements controlling the regional disposition of lithological units. The Jhura Dome was interpreted as a doubly plunging asymmetrical anticline. Minor phosphorus-bearing horizons were reported from ferruginous sandstone of the Bhuj Formation and nodular horizons within the Chari Formation. The phosphatic concretions and nodules yielded P_2O_5 values ranging from 15 to 20%; however, no significant primary phosphorite deposit was established.
- 8.1.2 As part of the Field Season Programme (FSP) 2019–20, GSI carried out regional geophysical investigations comprising gravity and magnetic surveys in SOI Toposheet No. 41E/11 covering the present Sumarasar Block area. Interpretation of Bouguer gravity anomaly and total magnetic intensity data indicated a concentric gravity high anomaly towards the north of Sumarasar village beneath soil cover. This anomaly was designated as a Zone of Interest (Z1) and was corroborated by a circular magnetic high anomaly near Kadol village. The circular nature of the gravity and magnetic contours was interpreted to indicate the presence of an intrusive vertical to sub-vertical cylindrical body at shallow depth. Geophysical modelling suggested that the

source body has limited depth persistence, extending to approximately 1000 m below surface. The anomaly was interpreted to be related either to an intrusive body or to abrupt changes in lithological and depositional characteristics within the Sandhan and Khari Nadi formations.

8.1.3 The Kachchh Basin has long been investigated for phosphorite occurrences owing to the presence of phosphatic limestone, oolitic horizons and fossiliferous carbonate sequences. During the field season 1966–67, Desikan et al. (Report circulated in 1968) reported phosphorite occurrences at several localities in Bhuj and Mandvi talukas with P_2O_5 values reaching up to 20%. Subsequently, R.S. Kathiara re-investigated these occurrences during 1976–77 and observed that most of the reported occurrences were represented by scattered phosphatic nodules without any significant economic potential. Later, Kathiara (1984) carried out detailed traverse mapping over an area of about 220 sq. km in Toposheet Nos. 41E/4, 7, 8 and 12, and examined phosphatic cherty limestone horizons of the Chari Formation. More than 1500 field samples were tested for phosphate content, out of which 275 samples were analysed in laboratory. Based on these investigations, a phosphorite resource of approximately 9 million tonnes was tentatively estimated. Recent investigations by Kumar and Das (FSP 2019–20) in and around Bhasar, Samtra, Deshalpar and Vandhay identified phosphatic horizons represented by cherty limestone (Dhosa Oolite) and pisolitic/fossiliferous calcareous conglomerate. However, analytical results indicated comparatively low P_2O_5 values, ranging from 0.05% to 2.49%.

8.1.4 Recognising the affinity of phosphatic rocks for Rare Earth Element (REE) enrichment, several workers have highlighted the potential of the Kachchh Basin for REE mineralization. Previous studies have demonstrated that phosphatic sedimentary rocks commonly host appreciable concentrations of REEs owing to their association with apatite and related phosphate minerals. Frisch et al. (2013) and Patel et al. (2009) documented similar lithological and geological settings in the Jhura Dome area. Emsbo et al. (2015) and Pufahl and Groat (2016) emphasized the significance of phosphatic sedimentary environments as favourable repositories for REE accumulation. In view of these observations and the presence of prominent east-west trending

lineaments and fault systems, GSI initiated G-4 stage exploration for phosphorite and REE mineralization in adjoining areas under its subsequent Field Season Programmes.

8.1.5 National Geochemical Mapping (NGCM) data generated in SOI Toposheet No. 41E/11 indicated widespread REE anomalies within and around the Sumarasar Block. Evaluation of the NGCM database revealed that five stream sediment samples within the proposed block area recorded total REE values exceeding 1000 ppm, while seventeen samples yielded values greater than 500 ppm. Individual elemental concentrations reached up to 424.38 ppm for La, 883.57 ppm for Ce and 416.32 ppm for Nd. These anomalous values indicated the presence of favourable source lithologies and constituted one of the principal factors for taking up detailed reconnaissance exploration in the Sumarasar Block.

Table-8.1

Data showing NGCM (LREE & HREE) Stream Sediment results for proposed Sumarasar Block Toposheet No. 41E/11 (NGDR, GSI)

Item	Sl. No.	Element	RANGE (PPM)		Average crustal abundance values are from Lide (2004, p.17); REE, rare earth element
			MIN	MAX	
LREE	1	Lanthanum (La)	50.14	424.38	39
	2	Cerium (Ce)	104.84	883.57	66.5
	3	Praseodymium (Pr)	12.77	107.88	9.2
	4	Neodymium (Nd)	50.13	416.32	41.5
	5	Samarium (Sm)	9.38	68.90	7.05
	6	Europium (Eu)	0.86	3.60	2
	7	Gadolinium (Gd)	7.89	53.67	6.2
		LREE	237.22	1957.7	
HREE	8	Yttrium (Y)	24	57	33
	9	Terbium (Tb)	1.11	6.40	1.2
	10	Dysprosium (Dy)	5.77	33.21	5.2
	11	Holmium (Ho)	1.12	6.31	1.3
	12	Erbium (Er)	3.56	18.98	3.5
	13	Thulium (Tm)	0.51	2.77	0.52
	14	Ytterbium (Yb)	3.33	19.35	3.2
	15	Lutetium (Lu)	0.53	3.18	0.8
		HREE	40.94	144.19	

8.1.6 In the adjoining Bhuj Clay Prospect Block, Geovale Services Pvt. Ltd. carried out G-4 stage exploration for REE under the NMEDT programme during

2023–2025. The investigation comprised large-scale geological mapping, geochemical sampling, geophysical surveys, pitting and scout drilling. The study identified REE enrichment mainly within ferruginous and phosphatic horizons associated with shale-dominated heterolithic units of the Katrol Formation as well as ferruginized sandstone horizons of the Bhuj Formation. Petrographic, mineralogical and SEM-EPMA studies from the adjacent block established the presence of REE-bearing minerals such as monazite, xenotime and apatite within the sedimentary succession. The investigations also demonstrated the importance of structural controls, ferruginization and phosphatic horizons in localizing REE enrichment in the Kachchh Basin. These findings provided additional support for undertaking reconnaissance exploration for REE and associated minerals in the Sumarasar Block.

CHAPTER - IX

9.0.0. AERIAL OR GROUND GEOPHYSICAL OR GEOCHEMICAL SURVEY

9.1.0. Aerial Or Ground Geophysical Survey

9.1.1 Areal or ground geophysical survey was not been carried out during the present exploration.

9.2.0 Geochemical Survey

9.2.1 The ground geochemical survey in terms of Soil Sampling and Stream sediment sampling was not carried out in the G-4 stage exploration work in Sumarasar block.

CHAPTER - X

10.0.0 EXPLORATION UNDERTAKEN DURING CURRENT INVESTIGATION

10.1.0 Background

10.1.1 Sumarasar Block was proposed for G-4 level of exploration of REE and associated elements. The Exploration has been carried out as per Minerals (Evidence of Mineral Contents) Amendment Rules, 2021 to achieve the following objective

- i. To carry out Geological & Structural mapping on 1:12500 scale for identification of REE and rare metal bearing formation (host rock) with the structural features to identify the surface manifestation and lateral disposition of the mineralized zones.
- ii. To collect surface (Bedrock and soil) samples for analyses of REEs and Rare Metals to decide further course of exploration program
- iii. Pitting to know the concentration of RM/ REE in the regolith within the target area.

10.2.0 Exploration Methodology

The components of G-4 level of exploration for REE and associated elements in Sumarasar Block to full fill the above-mentioned objective in accordance with MEMC rule 2015(amended till 2021) as approved by NMET is furnished in the table no 10.1 and the field component wise description has been given in subsequent paragraphs.

Table No 10.1

Summarized Table showing Component wise Proposed quantum Vs. Quantum Achieved in
Sumarasar Block, District Kachchh, Gujarat

Sl. No.	Item of Work	Unit	Proposed Quantum of work	Revised Quantum of work	Quantum of work Executed
1	Geological Mapping (1:12500)	sq. km	100.20	100.20	100.20
2	Pitting x 10 Pits	Cu. m	20	20	20
3	Auger Drilling (100 Bh x 7m avg depth)	m.	700	271.85	271.85
4	Scout Drilling (10 Bh x 30 m depth)	m.	300	-	-
5	Sample Preparation & Chemical Analysis				
	i) Primary Samples for REE associated Trace Elements (34 Elements) by ICPMS. (50 bedrock, 30 Pit, 125 Auger drill core, 150 Scout Bh Samples)	Nos.	$50+30+125+150=355$	50 bedrock + 25 Pit Sample + 94 Auger Sample = 169 Total samples	50 bedrock + 25 Pit Sample + 94 Auger Sample = 169 Total samples
	ii) External Check sample (10 % of Primary samples) for REE associated Trace Elements (34 Elements) by ICPMS	Nos.	36	17	17
6	XRD analysis	Nos.	20	20	20
7	i) Petrographic Studies	Nos.	10	10	10
8	Digital Photographs		20	06	06
9	EPMA Study	Hr	15	2	2
10	Report Preparation (Digital format)	Nos.	1	1	1

10.2.1 Geological Mapping

10.2.1.1 Large scale Geological mapping (LSM) completed in the total area of 100.20 sq. km on 1:12500 scale in the part of Survey of India Toposheet No 41E/11. Survey of India toposheet was used to understand the topography, roads, and drainage of the mapped area and was also used as a base map for the LSM.

10.2.1.2 For recording precise sample location and to carry out a geological survey, handheld GPS of M/S BAAP has been used. The coordinates had been recorded in UTM coordinate system with WGS 1984 datum. Variation of lithologies along with the structural elements were systematically recorded and prepared the final geological map as presented in Plate No-III, Plate No IV as well as Text Fig No 7.3.

10.2.1.3 During the large-scale geological mapping (LSM) at a scale of 1:12,500, it was observed that the Sumarasar Block is predominantly composed of Feldspathic Sandstone, Gritty Sandstone, and various types of shale, including ferruginous shale, yellow shale, and gypseous shale, along with mafic intrusive dykes. Basic dykes intrude the sedimentary sequences at several locations, while minor mafic dykes cut across the pre-existing lithologies. The lithological descriptions are discussed in detail in Chapter VII.

10.2.2 Surface Sampling

10.2.2.1 In accordance with the approved NQT, the present G-4 stage exploration has been carried out with the surface sampling only which includes collection of 50 nos of surface BRS samples collected by grab sampling for analysis of 34 Trace elements through ICPMS.

10.2.2.2 The sampling technique has been described in detail in the Chapter-XII.

10.2.3 Pitting

10.2.3.1 Pitting during the present exploration programme was undertaken after detailed geological mapping with the objective of exposing concealed bedrock beneath soil and alluvial cover and to establish the subsurface litho-units of sandstone and shales lithology hosting REE mineralisation.

10.2.3.2 Pitting was carried out using a JCB machine having dimension of 1 m length, 1 m width and around 2 m depth. A total of 10 Pits, involving approximately 20 cu.m of excavation, were completed within different parts of the Sumarasar Block. Systematic channel sampling was carried out from different shale and sandstone exposures, resulting in collection of 26 pit channel samples. A total 25 Nos of samples have been analyzed from 10 Nos of Pit. SMR/PIT/10 shows higher value i.e. 527.42 ppm. The location of the pits has been mentioned below.

Table No 10.2

Summarized Table showing Details of Pits in Sumarasar Block, District Kachchh Gujarat

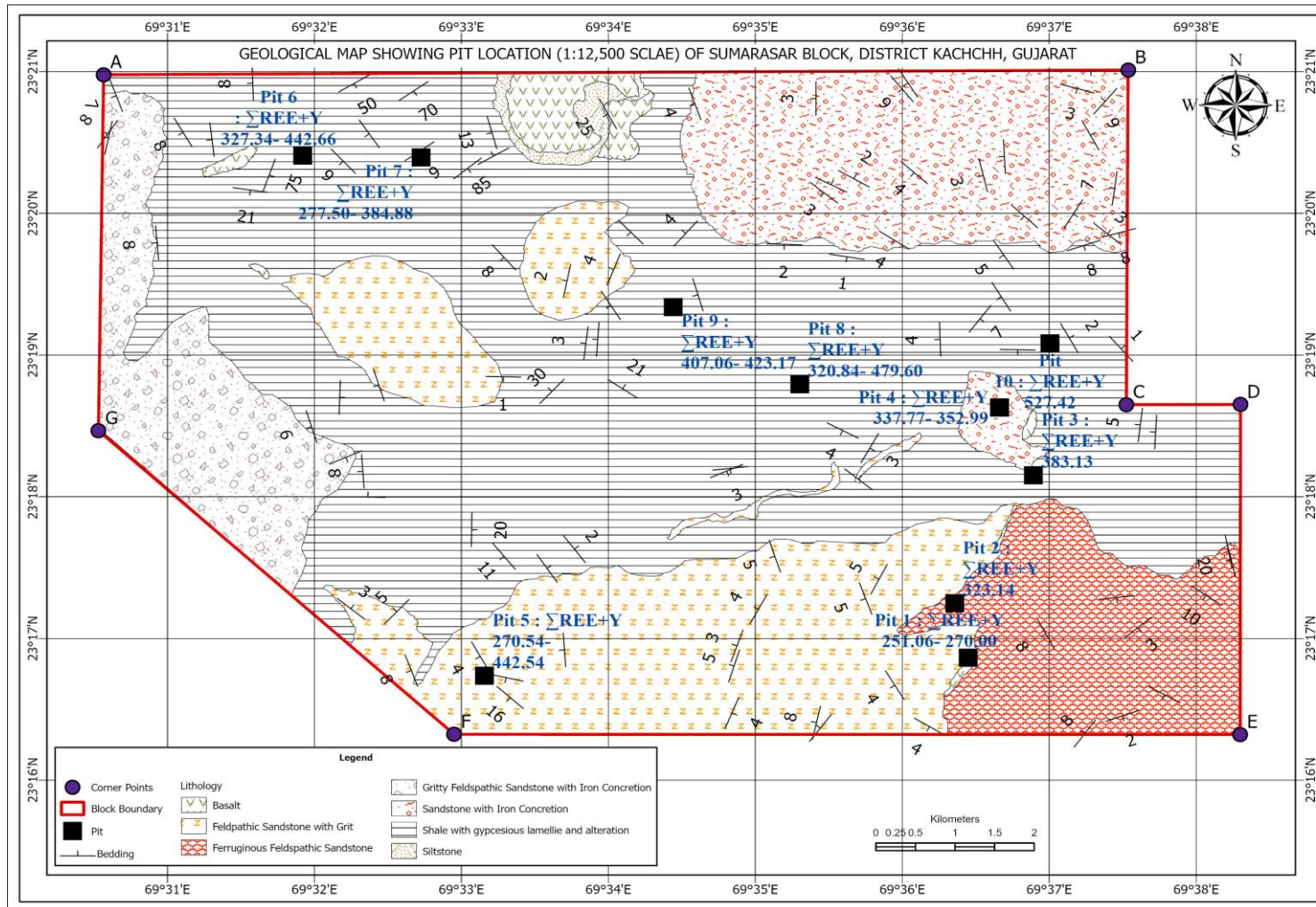
Pit No	Coordinate of Staring point of the trench in Degree Decimal		Samples Collected from Pits
	Latitude	Longitude	
SMR/PIT/1	23.28107138	69.60747376	2
SMR/PIT/2	23.28748147	69.60595787	1
SMR/PIT/3	23.30253150	69.61486660	1
SMR/PIT/4	23.31050434	69.61103038	2
SMR/PIT/5	23.27895274	69.55261115	5
SMR/PIT/6	23.34013106	69.53198873	3
SMR/PIT/7	23.33991317	69.54543842	4
SMR/PIT/8	23.31323758	69.58838215	4
SMR/PIT/9	23.32230552	69.57402460	3
SMR/PIT/10	23.31802424	69.61675702	1



Photograph No.-10.1: Image showing Pits in which vertical channel has been cut in different parts of study area.

Image (A) showing the presence of Different shale horizons in the Katrol formation

Image (C) showing the presence of gypseous bands with in the shale horizons in the Katrol formation.



Text Fig. 10.1 Geological map of Sumarasar Block Showing Pit Locations along with ranges of $\Sigma\text{REE}+\text{Y}$ in the Pit samples

10.2.3.3 Pit-wise Description

Pitting is a preliminary exploration method used to investigate the subsurface where bedrock is covered by soil, weathered material, or alluvium and cannot be directly observed at the surface. Total 10 pits are excavated throughout the block and total 25 Nos of samples were collected. The flower diagram of the Pits has been furnished in Plate No VII as well as Text Fig.10.2

Pit-01

Pit-01 was excavated up to a depth of 2.00 m in the western part of the block. The pit comprises 0.40 m of top soil from the surface, underlain by basalt. At many places in the block mafic intrusive were recorded. As No significant lithological variation was observed within the basaltic unit. Two representative samples collected from the 2 different horizons.

Pit-02

Pit 2 was excavated up to a depth of 2.00 m and predominantly comprises grey shale. 2 thin red ferruginous bands occur between the grey shale. Grey shale occurs above, between, and below these ferruginous bands.as same lithology persistent to entire depth. 1 representative sample collected from the pit.

Pit-03

Pit-03 was excavated to a depth of 2.00 m and encountered ferruginous shale throughout the entire depth. The ferruginous shale is reddish-brown in colour and shows a fairly uniform character.1 representative samples collected from the pit.

Pit-04

Pit-04 was excavated to a depth of 2.00 m and exposed a sequence of shale lithologies. The upper 1.00 m comprises yellow shale, which is fine-grained and moderately compact, indicating weathering and oxidation effects. A very thin ferruginized shale band was encountered at about 1.00 m depth, marked by iron oxide enrichment. Below this horizon, grey shale continues uniformly up to the final depth of 2.00 m. Two samples collected from the pit.

Pit-05

Pit-05 was excavated to a depth of 2.00 m and exposed a sequence of kaolinite, ferruginous bands, and altered sandstone. The upper 0.22 m consists

of kaolinitic material, followed by a thin red ferruginous band between 0.22 m and 0.25 m. Kaolinite continues up to 0.50 m depth, below which a prominent ferruginous band extends up to 0.93 m. The lower part of the pit comprises kaolinite associated with altered sandstone. The lithological succession indicates alternating phases of clay alteration and iron enrichment. 5 Samples Collected from the different horizons.

Pit-06

Pit-06 exposed a sequence comprising yellow soil, ferruginous bands, and ferruginous shale. The upper part of the pit consists of weathered yellow soil, which is underlain by ferruginous horizons marked by iron oxide enrichment. Ferruginous shale forms the dominant lithology throughout most of the pit and is intermittently interrupted by distinct ferruginous bands. The repeated occurrence of these iron-rich bands within the shale sequence indicates multiple phases of ferruginization and weathering. 3 representative samples were collected.

Pit-07

Pit-07 predominantly comprises grey shale interbedded with ferruginized shale and gypseous shale. Grey shale is the dominant lithology throughout the pit, while ferruginized shale occurs as iron-rich bands within the sequence. The presence of gypseous shale indicates gypsum enrichment at certain horizons. The alternating occurrence of these shale varieties reflects changes in depositional and weathering conditions. 4 samples Collected from the pit.

Pit-08:

Pit-08 was excavated to a depth of 2.00 m and encountered yellow shale throughout the entire excavated section. The shale is fine-grained, moderately compact, and exhibits a characteristic yellow colour due to weathering and oxidation. 4 samples collected from the different depths.

Pit-09

Pit-09 predominantly comprises grey shale with occasional ferruginized shale bands and grades into yellowish-grey shale towards the lower part of the pit. Grey shale forms the major lithology and is characterized by its fine-grained

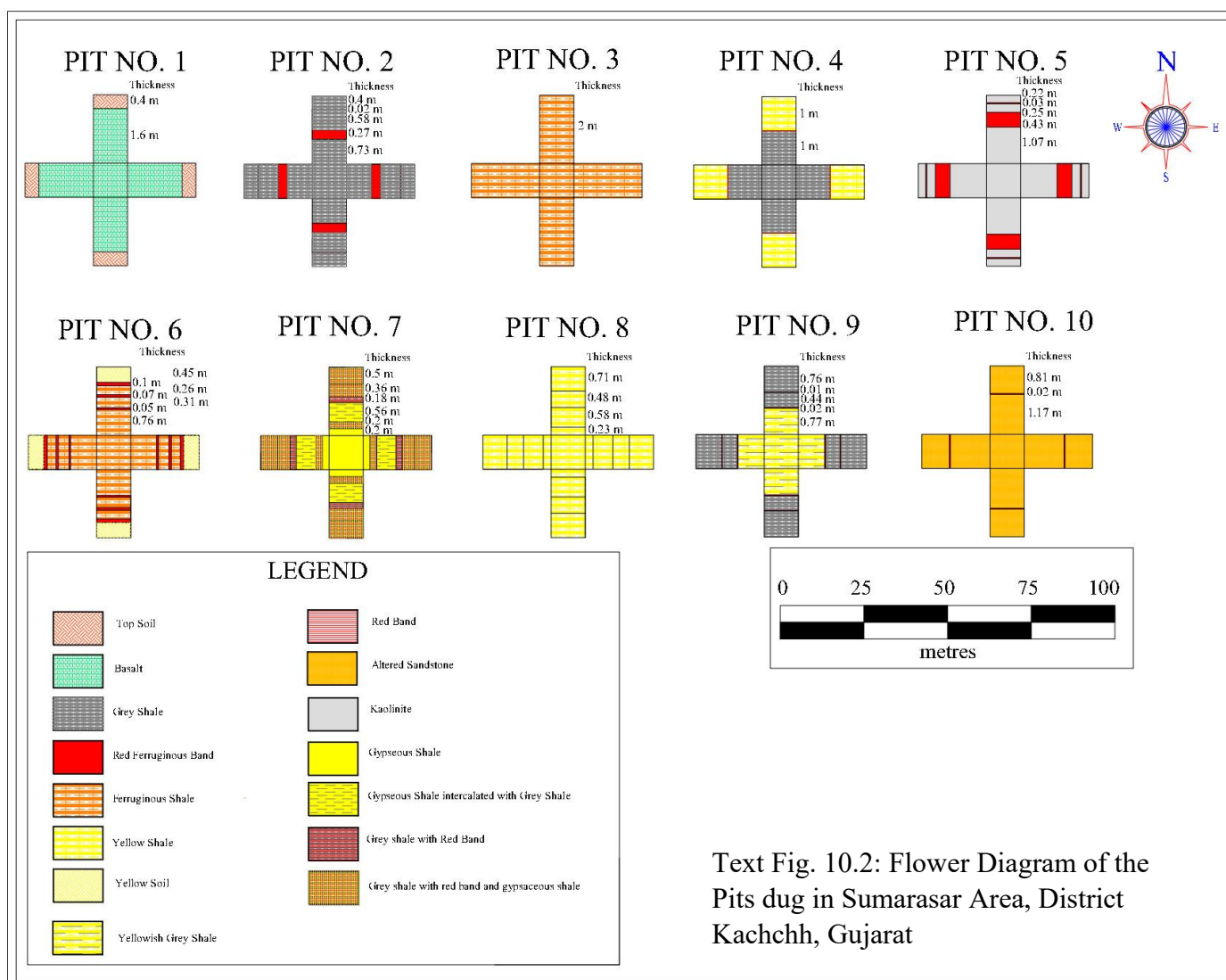
and compact nature. Thin ferruginized bands occur intermittently within the shale sequence, indicating localized iron oxide enrichment.

Pit-10

Pit-10 mainly comprises altered sandstone, which is the dominant rock type throughout the pit. The sandstone is weathered and shows signs of alteration due to natural geological processes. A thin ferruginized shale band is present within the sandstone sequence, indicating minor iron enrichment. Apart from this thin band, altered sandstone continues uniformly throughout the pit.

10.2.3.4 Outcome of Pitting

Pitting exposed subsurface bedrock beneath soil cover at several locations and confirmed the presence of multiple lithological units including Sandstone, Altered sandstone, different types of shales with mafic intrusions. A total of 25 pit channel samples were analysed for 34 elements analysis by ICP-MS, and the analytical results reflect the different values of REE and trace elements in different lithological horizons.



10.2.4 Chemical Analysis

10.2.4.1 The 169 Nos of primary samples (50 Nos of Bed rock, 25 Nos of Pit, 94 Auger Samples) were analysed for 34 elements, i.e., Sc, Y, Nb, Zr, Hf, Li, U, Th, Ga, Rb, Sr, Cu, Pb, Zn, V, Cr, Ni, Co, Mo, Se and REEs (La, Ce, Pr, Nd, Sm, Eu, Gd, Tb, Dy, Ho, Er, Tm, Yb, Lu) by ICP-MS instrument. The results have already been described under Chapter-VII along with the lithology wise geochemistry of different lithology. the analysis of trace elements has been furnished in Annexure No. II-A, II-B, II-C.

10.2.4.2 Moreover, the external check samples of 17 Nos have been analysed for same elements from JNARDDC Laboratory, Nagpur (Annexure-IX).

10.2.5 Physical Analysis

- 10.2.5.1 A total of 10 samples were examined under the microscope for detailed petrographic studies. The results of the petrographic investigation have been incorporated in the description of various lithologies under Chapter VII and are also presented as Annexure No. IV-A.
- 10.2.5.2 20 Nos of samples has been subjected to XRD study. The mineral phases have been discussed in under Chapter-VII and also annexed as Annexure No V for further reference.

10.2.6 Preparation of Geological Report:

- 10.2.6.1 Geological Report has been prepared in Corporate Office, MECL, Nagpur by integration of geological and geochemical data. ArcGIS and AutoCAD 2026 software have been used for preparation of various maps and GCD kit module of R programming language has been used for generating geochemical plots. The report has been written using Microsoft word and excel 2021 version.

10.3.0 Data spacing for reporting of exploration results

- 10.3.1 The objective of the G-4 stage exploration for REE in the Sumarasar Block was primarily to locate and establish the presence of REE mineralisation within the study area. The geological data generated through systematic reconnaissance and large-scale mapping were adequate for preparation of the Large-Scale Geological Map of the block at 1:12,500 scale. The occurrence of REE mineralization in the Sumarasar Block was found to be sparse and localized. As the mineralization lacks continuity and economic significance, drilling was not undertaken. The exploration data generated are considered sufficient for completion of the investigation and preparation of the Geological Report.

CHAPTER - XI

11.0.0 Location of Data Point

11.1.0 Accuracy and Quality of Survey

11.1.1 The current exploration for REE was conducted at the G-4 stage. To accurately record sample locations, Pit and perform geological surveys, a handheld GPS device from M/S BAAP was utilized. The coordinates were recorded using the UTM coordinate system with the WGS 1984 datum.

11.2.0 Quality and adequacy of topographic control

11.2.1 The topographic survey was not carried out as it is not in the scope of present G-4 stage exploration.

CHAPTER - XII

12.0.0 SAMPLING TECHNIQUE

12.1.0 Sampling

12.1.1 Sampling is a systematic process for collection of material from any media which can provide the best representation. In the present study in the Sumarasar Block, sampling includes bed rock samples, Pit samples, Auger Borehole Samples.

12.1.2 A total of 50 bedrock samples and 25 Nos of Pit samples were collected during the course of investigation. The bedrock samples were collected through systematic channel sampling across different lithologies exposed at the surface.

12.2.0 Nature, quality and measures taken to ensure sample representation

12.2.1 The detail description of sampling methods for Bed rock samples and Pit Samples has been discussed in subsequent paragraphs.

12.2.2 Sampling techniques:

Bedrock Sampling: A total of 50 Nos. of bed rock samples were collected systematically through chipping and channelling from different litho units exposed in the study area, mainly from the Felspathic Sandstone, Ferruginous sandstone, altered sandstone, yellow shale, grey shale, ferruginous shale, gypseous shale, Basalt. Each sample were collected by cutting channels on exposed rock units in 1 – 2 m length by sledge hammer (5kg) and chisel. The sample locations are plotted on geological map (Text figure No 7.3B as well as Plate No-IV). First, each Bed rock sample of 2-3 kgs collected from the field was crushed. After crushing, the crushed samples were mixed thoroughly and reduced the sample size to 500 gm by coning and quartering. This representative samples were powdered and completely passed through (-) 200 mesh size sieves from which 100 g sample packed in polythene sample pouch and send for chemical analysis for 34 elements by ICP-MS. The remaining 400 g sample has been preserved for future reference.

Pit Sampling:

A total of 25 channel samples were collected systematically from different sandstone and different shale units lithology exposed within the excavated

Pits. Sampling was carried out along freshly exposed pit faces to obtain representative material from subsurface exposures beneath the soil cover. Channel samples were collected by cutting continuous channels of approximately 0.4 m to 1.0 m length, depending upon the thickness and exposure of the lithological units, using a 5 kg sledge hammer and chisel, ensuring uniform sampling across the mineralised zone wherever encountered. The pit locations were recorded and plotted on the detail geological map (Plate No-V).

Each pit sample weighing about 2–3 kg collected from the field was initially crushed, after which the crushed material was thoroughly mixed and reduced to approximately 500 g by the method of coning and quartering to obtain a representative sample. The reduced sample was then pulverised and passed completely through (–) 200 mesh sieve size. From this, about 100 g of powdered sample was packed in polythene sample pouches and submitted for 34 elements by ICP-MS at MECL Laboratory, Nagpur, the remaining portion of the sample was preserved for future reference and verification.

12.3.0 Quality control procedures adopted during sampling

The samples have been prepared under the supervision of geologist and qualified sampling technician. All the samples collected from the field were packed properly in the polythene sample bag with proper tag. Then the entire samples were transported to central sample processing unit located in Nagpur. It has been thoroughly checked that none of the sample bags were damaged during the transportation.

Further measures have been taken during sieving and pounding/grinding of samples. The sieve and containers have been cleaned after processing of each sample to avoid contamination and measures have also been taken to avoid loss of powder in air.

12.4.0 Measures taken to ensure sample representation

It is very important to submit the representative sample of collected material for geochemical analyses. As discussed in the previously, bed rock samples were collected systematically through chipping and channelling from different lithounits as a representative sample. Further these samples after crushing and

pulverisation passed through (-) 200 mesh sieve. Further, quantity of the samples has been reduced to 500 gm by coning and quartering method after thoroughly mixing to maintain the homogeneity of the samples. Hence it can be assumed that the samples remain representative in nature of in situ material collected.

12.5.0 Appropriateness of grain size

In accordance with the standard sampling procedures, it has also been observed that smaller the particle size, higher the homogeneity of the sample as well as higher the dissolvability during the chemical analysis. As per the standard practice, samples are generally pounded to (-)200 mesh size for analysis through ICP-MS.

CHAPTER - XIII

13.0.0 DRILLING TECHNIQUES AND DRILL SAMPLING EMPLOYED

13.1.0 DRILL TYPE (EG. CORE, REVERSE CIRCULATION, OPEN-HOLE HAMMER, ROTARY AIRBLAST, AUGER, BANGKA, SONIC, ETC.) AND DETAILS (EG. CORE DIAMETER, TRIPLE OR STANDARD TUBE):

- 13.1.1 The exploration work was carried out using an Auger Drill for soil investigation and sample collection. Drilling was conducted using a Mobile Drilling Co., Inc. Auger Drill (Model: B-47), Unit No. MEC-331, which is operated using High-Speed Diesel (HSD) fuel. The auger drill uses a rotating screw-shaped tool (auger) to cut through the ground and bring soil to the surface. It is suitable for drilling in soil, clay, sand, and weathered formations. This method is mainly used for shallow drilling and for collecting representative soil samples for geological logging and laboratory analysis.

As auger drilling does not recover continuous rock cores, core recovery, core diameter, and single, double, or triple core tube details are not applicable.

The auger drilling was carried out to study the soil profile and to investigate the occurrence and distribution of REE-bearing horizons within the soil profile. However, a well-developed soil profile was not encountered at most of the drilling locations. Instead, the boreholes penetrated the upper weathered zone of the bedrock, indicating that the soil cover was generally thin.

- 13.1.2 A total of 271.85 m in 47 auger boreholes were drilled at strategically selected locations across the block based on geological mapping, geomorphological observations, and geochemical indications. The depth of the boreholes varied from 1.0 m to 7.0 m, depending upon the thickness of overburden, depth of weathering, and the nature of the underlying bedrock encountered at each location.
- 13.1.3 During drilling, lithological details such as soil, weathered zone, shale, sandstone, and other rock units were carefully recorded. Representative samples were collected at regular intervals and at every change in lithology for

laboratory analysis. The borehole logs provided valuable information on the subsurface stratigraphy and aided in correlating surface geological observations with subsurface conditions. Details of the drilled auger locations within Sumarasar Block is as below: -

Table No 13.1
Details of Auger holes within Sumarasar Block (100.20 sq.km.)

Sr.No	Borehole No	Meterage Drilled(m)	Latitude	Longitude	RL
1	SMA_1	6.00	23.27420066	69.5470458	142.80
2	SMA_2	6.00	23.28073828	69.5462018	135.88
3	SMA_3	6.35	23.29012126	69.5424558	121.22
4	SMA_4	7.00	23.29691816	69.539865	110.74
5	SMA_5	7.00	23.30133881	69.5432418	105.40
6	SMA_6	5.50	23.30484946	69.5378611	108.54
7	SMA_7	6.00	23.30534434	69.5515629	105.66
8	SMA_8	6.00	23.30039246	69.5325156	120.68
9	SMA_9	7.00	23.31032663	69.5586165	94.83
10	SMA_10	6.00	23.31451786	69.5365199	95.74
11	SMA_11	7.00	23.3056722	69.5607458	102.50
12	SMA_12	6.00	23.32422069	69.5375383	109.78
13	SMA_13	6.00	23.32767398	69.5382412	113.37
14	SMA_14	6.00	23.33351858	69.5374071	108.78
15	SMA_15	7.00	23.30599449	69.5656451	102.77
16	SMA_16	7.00	23.31081848	69.5752845	95.05
17	SMA_17	3.00	23.30155532	69.5736114	116.80
18	SMA_18	7.00	23.31419033	69.5856468	98.39
19	SMA_19	7.00	23.30482338	69.5819393	108.62
20	SMA_20	6.00	23.31588899	69.5696631	92.17
21	SMA_21	7.00	23.31979654	69.5774167	82.19
22	SMA_22	7.00	23.31794747	69.5959186	81.31
23	SMA_23	7.00	23.30804029	69.5961279	94.17
24	SMA_24	7.00	23.31334784	69.6073098	94.02
25	SMA_25	6.00	23.31690376	69.6134132	91.15
26	SMA_26	7.00	23.31033097	69.6150266	107.90
27	SMA_27	7.00	23.32692585	69.6251282	104.04
28	SMA_28	7.00	23.30303968	69.6161863	128.01

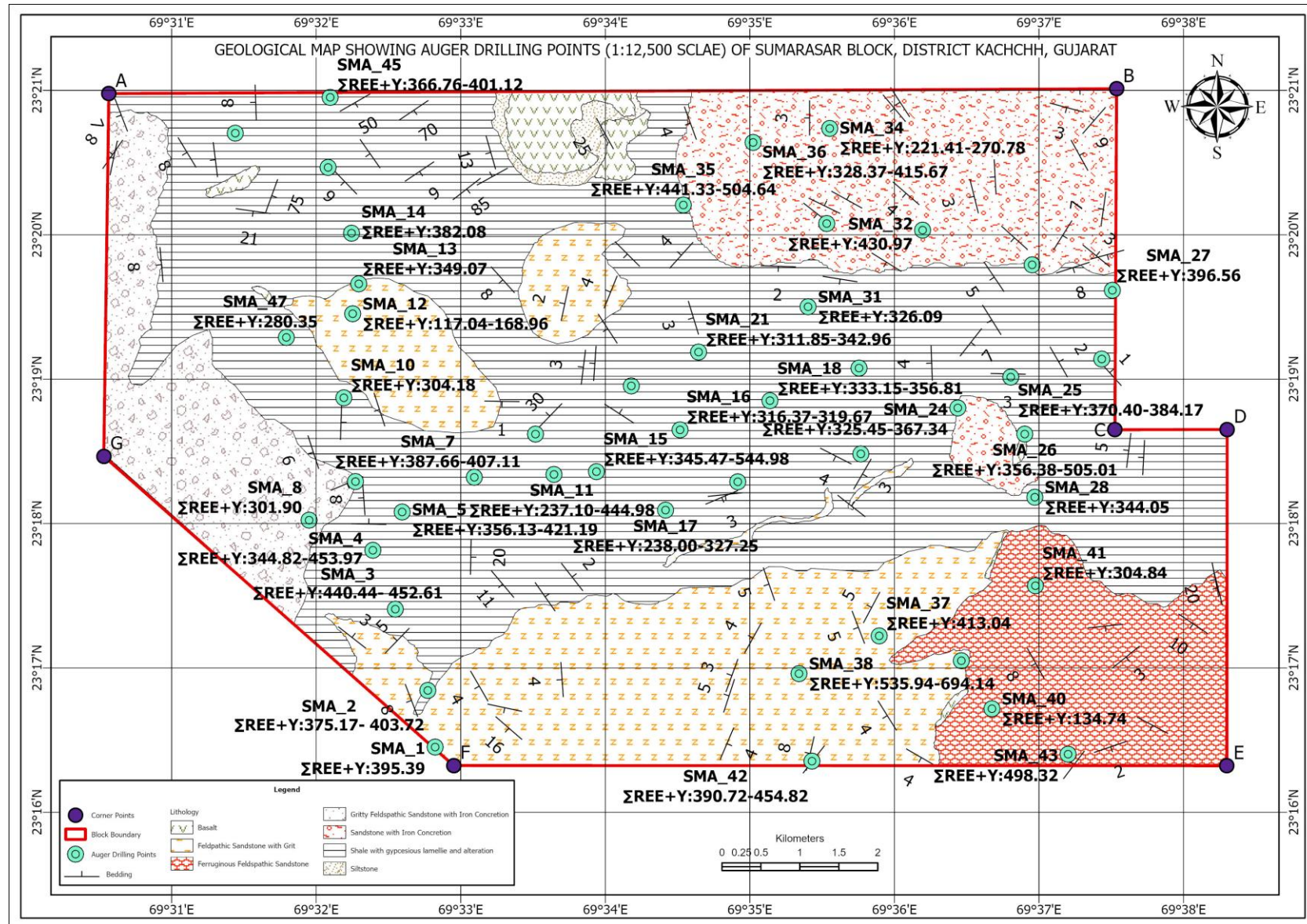
29	SMA_29	6.00	23.31899322	69.6239069	103.60
30	SMA_30	7.00	23.32986706	69.615879	91.88
31	SMA_31	7.00	23.32503055	69.5900405	78.15
32	SMA_32	3.00	23.33387169	69.6032491	81.89
33	SMA_33	5.50	23.33463478	69.5921936	74.10
34	SMA_34	7.00	23.34561366	69.5925418	75.33
35	SMA_35	1.50	23.33677279	69.5756646	91.00
36	SMA_36	6.00	23.3439946	69.5837062	102.81
37	SMA_37	4.30	23.28703318	69.5982436	133.32
38	SMA_38	5.50	23.28267835	69.5889969	130.50
39	SMA_39	3.00	23.28416781	69.6077151	125.23
40	SMA_40	7.00	23.27862451	69.6112423	115.55
41	SMA_41	3.40	23.29282683	69.6162533	136.35
42	SMA_42	2.80	23.27257496	69.5904933	122.43
43	SMA_43	1.00	23.27337502	69.6200207	111.00
44	SMA_44	3.00	23.345066	69.524004	120.00
45	SMA_45	7.00	23.34919806	69.5349433	105.89
46	SMA_46	7.00	23.34111047	69.5347031	109.00
47	SMA_47	5.00	23.32148635	69.5298925	106.05



Photograph No:13.1: Image showing auger drilling rig in operation for systematic soil sample collection during exploration in the Ratiya area.



Photograph No:13.2: Image showing a rotating screw-shaped tool (auger) to cut through the ground and bring soil to the surface.



Text Fig. 13.1: Location of Auger Boreholes with ranges of ΣREE+Y of auger samples on Large Scale Geological map of Sumarasar Block.

13.2.0 WHETHER CORE AND CHIP SAMPLE RECOVERIES HAVE BEEN PROPERLY RECORDED AND RESULTS ASSESSED.

13.2.1 The auger samples were logged in detail for, lithology, recovery grain size, colour wherever present. Logging was carried out run-wise, and the observations were recorded systematically for each borehole. Based on these records, summarized lithologs of all boreholes were prepared and are presented in Annexure-II-D.

13.3.0 MEASURES TAKEN TO MAXIMIZE SAMPLE RECOVERY AND ENSURE REPRESENTATIVE NATURE OF THE SAMPLES.

13.3.1 During auger drilling, care was taken to recover the maximum possible sample from each borehole. Drilling was carried out carefully to avoid unnecessary mixing or loss of material. Only meter wise run was carried out. Samples were collected from each depth interval and wherever a change in lithology was observed. The recovered material was examined in the field, and representative samples were selected based on their colour, grain size, and lithology. All samples were properly labelled with borehole number and depth before being sent for laboratory analysis. These measures helped to ensure that the collected samples accurately represented the subsurface geology of the Sumarasar Block.

13.4.0 WHETHER A RELATIONSHIP EXISTS BETWEEN SAMPLE RECOVERY AND GRADE AND WHETHER SAMPLE BIAS COULD HAVE OCCURRED DUE TO PREFERENTIAL LOSS OR GAIN OF FINE OR COARSE MATERIAL.

13.4.1 No significant relationship was observed between sample recovery and assay grade, and no evidence of sample bias due to preferential loss or gain of fine or coarse material was identified. Therefore, the analytical results are considered representative of the sampled intervals.

13.5.0 LOGGING: -WHETHER CORE AND CHIP SAMPLES HAVE BEEN LOGGED TO A LEVEL OF DETAIL TO SUPPORT APPROPRIATE MINERAL RESOURCE ESTIMATION, MINING STUDIES AND METALLURGICAL STUDIES.

13.5.1 All auger drill samples were systematically logged in sufficient detail to record lithology, colour, grain size, weathering, ferruginization, clay content, and other relevant geological features. The logging data were adequate for geological interpretation, delineation of lithological units, and planning of

further exploration. However, as auger drilling primarily provides weathered overburden and shallow subsurface samples without significant enrichment of $\Sigma\text{REE}+\text{Y}$, mineral resource estimation, mining studies, or metallurgical studies has not been carried out with the generated data.

13.6.0 DISCUSSION ON HANDHELD X-RAY FLUORESCENCE (XRF), IF USED IN THE INVESTIGATION.

13.6.1 MECL is having a Olympus made Hand held GPS and continuously used during the field operation for identifying relatively elevated REE concentration. However, among the REE suite, only Y, La, Ce, Nd and Pr generally detected in hand held XRF. Hence, the selected samples on basis of the observation from Handheld XRF have been sent for analysis by ICP-MS.

13.6.2 It has also been observed the there is no correlation between the analysed value of Hand held XRF and ICP-MS analysis. Hence, the values obtained in Hand Held XRF has been used as relative marker for prioritising the samples for analysis only.

CHAPTER - XIV

14.0.0 SUB SAMPLING TECHNIQUES AND SAMPLE PREPARATION

14.1.0 IF CORE WHETHER CUT OR DRAWN AND WHETHER QUARTER, HALF OR ALL CORE TAKEN

14.1.1 All the boreholes drilled in the Sumarasar block is auger in nature which is non coring method of drilling.

14.2.0 IF NON-CORE, WHETHER RIFFLED, TUBE SAMPLED, ROTARY SPLIT, ETC., AND WHETHER SAMPLED WET OR DRY

14.2.1 271.85 m auger drilling has been carried out in 47 Nos of auger boreholes. The spiral head auger drill was used, as a results after drilling of each meter, the priral head was pulled up and the samples were collected from the spiral head manually for further processing.

14.2.2 The in-situ moisture was associated with the samples. The samples were first sun dried for few days before pulverisation.

14.3.0 NATURE, QUALITY AND APPROPRIATENESS OF THE SAMPLE PREPARATION TECHNIQUE

14.3.1 A total of 94 samples was collected from 47 auger boreholes after systematic logging of 271.85 m of auger drilling. The logging revealed the occurrence of different lithological units, including volcanics, intrusive rocks, sandstone, and shale. During logging, variations in lithology, colour, grain size, ferruginous zones, clay-rich horizons, weathered zones, and other significant geological features were identified and used for selecting representative sampling intervals. Samples were collected from these designated intervals and properly labelled.

14.3.2 The collected samples were sun-dried, and pulverized to approximately –200 mesh using an iron mortar and pestle. The powdered samples were thoroughly mixed and reduced to representative quantities by the coning and quartering method. One part of each sample was sent to the Chemical Laboratory for

analysis of 34 elements, namely Sc, Y, Nb, Zr, Hf, Li, U, Th, Ga, Rb, Sr, Cu, Pb, Zn, V, Cr, Ni, Co, Mo, Se, and the rare earth elements (REEs) La, Ce, Pr, Nd, Sm, Eu, Gd, Tb, Dy, Ho, Er, Tm, Yb, and Lu, using the ICP-MS technique. The remaining portion of each sample was preserved as a duplicate sample for future reference and verification.

14.4.0 QUALITY CONTROL PROCEDURES ADOPTED MEASURES TAKEN TO ENSURE THAT THE SAMPLING IS REPRESENTATIVE OF THE IN-SITU MATERIAL COLLECTED

14.4.1 The samples have been prepared under the supervision of geologist and qualified sampling technician. All the auger samples collected from the field were packed properly in the polythene sample bag with proper tag. Then the entire samples were transported to central sample processing unit located in Nagpur. It has been thoroughly checked that none of the sample bags were damaged during the transportation.

14.4.2 Further measures have been taken during sieving and pounding/grinding of samples. The sieve and containers have been cleaned after processing of each sample to avoid contamination and measures have also been taken to avoid loss of powder in air.

14.5.0 MEASURES TAKEN TO ENSURE THAT THE SAMPLING IS REPRESENTATIVE OF THE IN-SITU MATERIAL COLLECTED

14.5.1 As mentioned previously, meter wise run has been conducted during the auger drilling. The logging process identified different lithological units encountered in the Sumarasar Block, including sandstone, shale, clay, ferruginous horizons, and weathered rock. Variations in lithology, colour, grain size, weathering, ferruginization, and other significant geological features were carefully recorded during logging.

14.5.2 Representative sampling intervals were selected based on changes in lithology and the occurrence of ferruginous or other geologically significant horizons. Samples were collected from the designated intervals, properly labelled, and transported to the laboratory. The collected samples were air-dried, wherever

necessary, and pulverized to –200 mesh using an iron mortar and pestle. The pulverized samples were thoroughly homogenized and reduced to representative quantities by the coning and quartering method.

14.5.3 One part of each sample was submitted to the Chemical Laboratory for analysis of 34 elements, namely Sc, Y, Nb, Zr, Hf, Li, U, Th, Ga, Rb, Sr, Cu, Pb, Zn, V, Cr, Ni, Co, Mo, Se, and the rare earth elements (La, Ce, Pr, Nd, Sm, Eu, Gd, Tb, Dy, Ho, Er, Tm, Yb, and Lu), using the ICP-MS technique. The remaining portion of each sample was preserved as a duplicate sample for future reference and verification.

14.5.4 Hence it can be assumed that the methodology adopted for auger samples is representative of the in-situ material collected

14.6.0 WHETHER SAMPLE SIZES ARE APPROPRIATE TO THE GRAIN SIZE OF THE MATERIAL BEING SAMPLED

14.6.1 In accordance with the standard sampling procedures, it has also been observed that smaller the particle size, higher the homogeneity of the sample as well as higher the dissolvability during the chemical analysis. As per the standard practice, samples are generally pounded to (-)200 mesh size for analysis through ICP-MS.

CHAPTER - XV

15.0.0 QUALITY OF ASSAY DATA AND LABORATORY TEST

15.1.0 The nature, quality and appropriateness of Chemical analysis

15.1.1 All the 169 Nos of primary samples (50 Nos of bedrock samples, 25 Nos of Pit Samples and 94 Nos of auger samples) were analysed for 34 elements, namely Sc, Y, Nb, Zr, Hf, Li, U, Th, Ga, Rb, Sr, Cu, Pb, Zn, V, Cr, Ni, Co, Mo, Se, and the rare earth elements (La, Ce, Pr, Nd, Sm, Eu, Gd, Tb, Dy, Ho, Er, Tm, Yb, and Lu) using the Inductively Coupled Plasma–Mass Spectrometry (ICP-MS) technique.

15.1.2 Methodology of Chemical Analyses by ICP-MS

Chemical Laboratory, MECL, Nagpur is having Agilent make ICPMS 7800 model for elemental analyses. ICP-MS (inductively coupled plasma-mass-spectrometry) is a technique to determine low-concentrations (ppb = parts per billion = $\mu\text{g/l}$) and ultra-low-concentrations of elements (ppt = parts per trillion = ng/l). ICP-MS can also measure elements at concentrations up to 100s or even 1000s of parts per million (ppm). Accuracy and precision (standard deviation) for 34 of these elements is either excellent ($<5\%$) or good (5–10%).

Methodology for analysing 34 elements: A simple HCL-HF-HNO₃ dissolution in screw top Teflon bombs is used in microwave Digester for sample preparation. ICP-MS instrumental sensitivity is measured by external solutions (Tuning solution provided by Agilent), with surrogate calibration for 4 elements (Li, Co, Y). Matrix correction is made by use of standard CRM (Certified reference material).

The following Precautions are followed in the laboratory while doing chemical analysis.

- Safety goggles (department approved) and apron dress must be worn in the lab at all times.
- Use of fume hoods for dangerous or irritating chemicals.
- Label all containers to identify their contents.
- Never put anything back into a reagent bottle. Once a reagent has passed the mouth of its container, it has passed the point of no return. Always take

as little of a chemical as possible. Use only clean, dry spatulas for removing chemicals from bottles. Properly dispose of excess chemicals.

- Avoid touching hot objects. Burns are a common accident in the chemistry lab. Be careful when using hot plates and objects which have been heated on them. Use beaker tongs to remove hot containers from the hot plate.
- Rinse off any chemicals spilled on the skin immediately with large amounts of water.
- Clean up broken glassware immediately. Place it in the labelled crock at the front of the lab.
- Properly dispose of waste chemicals. Certain liquids can be poured into the sink and flushed with water while others are poured into designated waste containers. Most solid wastes are placed in designated crocks.

15.2.0 Quality control procedure

15.2.1 The standard procedure of quality control has been adopted during the chemical analysis in Chemical laboratory, MECL, Nagpur which includes

- (i) Analysis of Certified reference materials/measurement standards
- (ii) Analysis of blind samples
- (iii) Use of QC samples and control charts
- (iv) Analysis of blank samples
- (v) Analysis of spiked samples
- (vi) Analysis in duplicate samples.

15.3.0 External Check Analyses

15.3.1 In accordance to the standard practice of quality assurance and quality control, 17 numbers of primary samples were analysed at JNARDDC, Nagpur as external check samples (10% of primary samples).

15.3.2 The analytical results of external check samples has been represented as Annexure No III.

15.3.3 A statistical comparison has been carried out between the primary analytical results of the MECL Chemical Laboratory, Nagpur and the corresponding external check results of JNARDDC, Nagpur, for the 17 paired samples. The evaluation follows the methods normally adopted for geochemical quality assurance and quality control and comprises element-wise correlation,

coefficient of determination (R^2), reduced major axis regression, examination of the primary-to-external ratio, and assessment of the reproducibility of the derived geochemical parameters on which the interpretation of the block depends.

- 15.3.4 The results for the complete rare earth suite, together with yttrium and scandium, are summarised in Table No 15.1. The correlation between the two laboratories is high. For the summed rare earth content the coefficient of determination is $R^2 = 0.904$ and the Spearman rank correlation is 0.826, rising to $R^2 = 0.966$ and 0.953 respectively on exclusion of a single reversed pair, indicating that the relative ranking of the samples is reproduced closely by the external laboratory. The summed heavy rare earth content returns $R^2 = 0.976$ and the summed light rare earth content $R^2 = 0.809$. Individually, R^2 exceeds 0.90 for Y (0.989) and Tm (0.939), and exceeds 0.80 for Lu (0.872), La (0.866), Eu (0.845), Er (0.841), Sc (0.830) and Ce (0.818).
- 15.3.5 The comparatively lower coefficients returned by gadolinium, terbium and holmium reflect the low absolute abundance of these elements within the block, their mean primary concentrations being 11.14, 1.99 and 2.44 ppm respectively, at which levels a proportionally greater analytical scatter is to be expected between laboratories. Their combined contribution is nevertheless faithfully reproduced, the summed heavy rare earth content of the block returning $R^2 = 0.976$ with a Spearman coefficient of 0.809.
- 15.3.6 For the purposes of the present investigation the significant point is that the geochemical parameters upon which the interpretation rests are reproduced by both laboratories. The LREE/(HREE+Y) ratio returns $R^2 = 0.862$ with median values of 3.22 for the primary and 3.23 for the external check data; the chondrite-normalised pattern slope, expressed as (La/Lu)_N, returns median values of 9.79 and 10.77 respectively; and the rank order of $\Sigma\text{REE}+\text{Y}$ is reproduced with a Spearman coefficient of 0.953. The lithological discrimination, the relative enrichment of the individual lithological units and the light-to-heavy rare earth fractionation described in Chapter-VII are therefore independently supported by the external check analyses.

15.3.7 The external check analyses demonstrate a high degree of analytical reproducibility between the primary and external laboratories across the rare earth suite, yttrium and scandium. The relative distribution of the rare earths between samples and between lithological units, the shape of the chondrite-normalised patterns and the light-to-heavy rare earth fractionation are all reproduced, the summed light rare earth, heavy rare earth and total rare earth contents returning coefficients of determination of 0.809, 0.976 and 0.904 respectively. The analytical data generated during the present investigation are accordingly considered reliable and suitable for the geological interpretation presented in this report.

Table No 15.1:

Statistical comparison of primary and external check analyses for the rare earth suite, yttrium and scandium, Sumarasar Block (17 paired samples)

Element	N	r	R ²	RMA slope	External/Primary (median)
La	17	0.931	0.866	0.309	0.52
Ce	17	0.904	0.818	0.351	0.45
Pr	17	0.883	0.780	0.355	0.48
Nd	17	0.853	0.728	0.363	0.44
Sm	17	0.865	0.749	0.411	0.47
Eu	17	0.919	0.845	0.459	0.49
Gd	17	0.671	0.451	0.209	0.50
Tb	17	0.692	0.479	0.166	0.52
Dy	17	0.819	0.671	0.130	0.37
Ho	17	0.729	0.531	0.123	0.46
Er	17	0.917	0.841	0.169	0.50
Tm	17	0.969	0.939	0.318	0.53
Yb	17	0.836	0.698	0.174	0.46
Lu	17	0.934	0.872	0.256	0.49
Y	17	0.995	0.989	0.297	0.54
Sc	17	0.911	0.830	0.605	0.77
ΣLREE	17	0.899	0.809	0.342	0.47
ΣHREE+Y	17	0.988	0.976	0.263	0.49
ΣREE+Y	17	0.951	0.904	0.319	0.45

15.4.0 Security and chain of control of samples

- 15.4.1 The samples have been prepared at centralized mechanized sampling unit with proper labeling and tag and sent to chemical laboratory in supervision of qualified sampling technician.
- 15.4.2 The samples has been transported from field to sample processing unit with proper sealing of sampling bags and the same has been verified in the sampling unit before opening the bags.
- 15.4.3 At the sampling unit, standard procedure has been followed and all the precautionary measures have been taken to avoid the contamination. Further the remaining samples are propoerly preserved with sample tags for any future reference under the custody of the company.

CHAPTER - XVI

16.0.0 MOISTURE

16.1.0 Method of determination of the moisture content.

16.1.1 All the analysis has been carried out with natural moisture. Moisture content has not been determined.

CHAPTER - XVII

17.0.0 BULK DENSITY

17.1.0 Method of determination and result

- 17.1.1 Drilling of scout boreholes was not recommended due to non-encouraging results for REE in the area. So, resource estimation was not carried out. As a result, bulk density or specific gravity has not been determined.

CHAPTER - XVIII

18.0.0 BENEFICIATION STUDIES AS MAY BE REQUIRED

18.1.0 Details of beneficiation studies

- 18.1.1 Beneficiation studies have not been carried out in the present exploration as it was out of the scope of the approved quantum of work.

CHAPTER - XIX

19.0.0. RESOURCE ESTIMATION TECHNIQUES

The REE mineral is mainly confined in few sporadic places. Hence drilling has not been taken up in the present stage of exploration in Sumarasar Block, as a result resource has not been estimated in the block.

CHAPTER - XX

20.0.0. REPORTING OF RESOURCE

As mentioned in the Chapter – XIX, resource has not been estimated in the present stage of exploration.

CHAPTER - XXI

21.0.0 SUMMARY & RECOMMENDATION

21.1.0 SUMMARY

- 21.1.1 Reconnaissance Survey (G-4) for REE and Associated Minerals in Sumarasar Area, District Kachchh, Gujarat, covering an area of 100.20 sq. km in SOI Toposheet No. 41E/11, was taken up by MECL under the NMEDT programme following approval accorded in the 41st Meeting of the Executive Committee (EC), NMEDT held on 11th March, 2025. The project was executed in phases involving large scale geological mapping, pitting, auger drilling, systematic sampling and laboratory investigations.
- 21.1.2 The study area forms part of the Kachchh Mainland Uplift within the Kachchh Rift Basin. The block is chiefly occupied by sedimentary rocks belonging to the Katrol Series/Jhuran Formation and Bhuj Formation. The major lithological units encountered during exploration include feldspathic sandstone, ferruginous sandstone, calcareous sandstone, shale-siltstone alternations, gypseous shale, gritty sandstone and fossiliferous sandstone. Structurally, the area exhibits prominent E–W to ENE–WSW trends with well-developed joint systems and gentle to moderate dips.
- 21.1.3 A total area of 100.20 sq. km was covered by large scale geological mapping on 1:12,500 scale. Systematic geological investigations comprised geological mapping, collection of bedrock samples, petrographic samples, pit samples and auger borehole samples for geochemical evaluation. Detailed petrographic and XRD studies were also carried out to understand the mineralogical characteristics and mode of occurrence of REE-bearing phases.
- 21.1.4 Geochemical investigations indicate localized enrichment of REE within sandstone and shale horizons. The sandstone samples yielded $\Sigma\text{REE}+\text{Y}$ values ranging from 112.67 ppm to 514.60 ppm with an average value of 346.56 ppm, whereas shale samples yielded $\Sigma\text{REE}+\text{Y}$ values ranging from 77.45 ppm to 1527.80 ppm with an average value of 371.87 ppm. Both lithological units exhibit enrichment of Light Rare Earth Elements (LREE) over Heavy Rare

Earth Elements (HREE) along with distinct negative Eu anomalies, indicating derivation from felsic source rocks.

21.1.5 Petrographic and mineralogical studies identified monazite as the principal REE-bearing mineral phase occurring as fine accessory grains. XRD studies confirmed the presence of monazite, xenotime and apatite as subordinate mineral phases. Collophane and glauconite were also identified in certain shale and sandstone horizons, suggesting localized phosphate enrichment and possible fixation of REE within phosphatic marine sediments. The mineralogical association indicates that REE enrichment was controlled by both detrital input from felsic source rocks and localized concentration within phosphate-bearing sedimentary environments.

21.1.6 Although one shale BRS samples yielded anomalous values exceeding 1000 ppm $\Sigma\text{REE}+\text{Y}$, the anomalous zones are restricted to isolated horizons and no laterally persistent mineralized zone could be established during the present investigation. Further, a borehole drilled in the adjoining Nokhaniya Block near the eastern boundary of the Sumarasar Block did not intersect any encouraging REE-bearing horizon. Therefore, the available geological, geochemical, petro-mineralogical and subsurface data suggest that the REE enrichment encountered within the Sumarasar Block is localized and discontinuous in nature.

21.1.7 All lithological units encountered during geological mapping, pitting and auger drilling were examined in the field using Shapiro's rapid phosphate test. However, no persistent or economically significant phosphatic horizon was identified during the course of investigation.

21.2.0 RECOMMENDATION

21.2.1 The present G-4 stage exploration has established the presence of localized REE enrichment within sandstone and shale horizons of the Bhuj and Katrol formations. However, the anomalous REE values are sporadic and restricted to isolated horizons without demonstrable lateral continuity. No economically significant phosphorite horizon was encountered during the investigation.

Therefore, the present study does not warrant further systematic exploration within the Sumarasar Block under the existing exploration framework.

- 21.2.2 In view of the localized nature of REE enrichment, absence of persistent mineralized horizons and lack of encouraging subsurface evidence from the adjoining areas, it is recommended that exploration in the Sumarasar Block may be concluded at the present stage.
- 21.2.3 However, previous investigations carried out in adjacent areas of the Kachchh Basin have reported REE enrichment associated with ferruginous, phosphatic and clay-rich horizons within the Bhuj and Katrol formations. Any future exploration in the region, if considered necessary on the basis of new regional geological, geochemical, geophysical or mineralogical inputs, may focus on evaluating the subsurface continuity of such favourable lithological horizons through appropriate geophysical investigations and exploratory drilling.

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22.0.0. PLATES AND MAPS

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23.0.0. ANNEXURES OR ENCLOSURES TO THE REPORT

23.1.0. List of Annexure

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24.0.0. ANY OTHER INFORMATION

24.1.0. Any other information as may be available or required by any authority as prescribed.

24.1.1 References

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CHAPTER - XXV

25.0.0 CERTIFICATION

This is to certify that geological report has been prepared in respect of Reconnaissance Survey in Sumarasar Area, District: Kachchh, State: Gujarat by Mineral Exploration and Consultancy Limited (MECL) on behalf of National Mineral Exploration and Development Trust (NMEDT). The report has been prepared in accordance with the Minerals (Evidence of Mineral Contents) Rule 2015 specified under Mineral Auction Rule, 2015 and amended up to 2021.

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DATE: