എച്ച്5-52093/17

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ജില്ലാ കളക്ടർ,
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പ്രിൻസിപ്പൽ സെക്രട്ടറി,
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സർ,

വിഷയം : ദുരന്തനിവാരണം - കോളേജ് ഓഫ് എഞ്ചിനീയറിംഗ് ജിയോ ടെക്നിക്കൽ ഡിവിഷൻ മുഖാന്തിരം പഠനം - സംബന്ധിച്ച്.

സൂചന : (1) സർക്കാരിന്റെ 30/06/2022-ാം തീയതിയിലെ DMD 4/15/2022 DMD നമ്പർ കത്ത്

(2) തിരുവനന്തപുരം കോളേജ് ഓഫ് എഞ്ചിനീയറിംഗിലെ സെന്റർ ഫോർ ഇൻഡസ്ട്രിയൽ ട്രെയിനിംഗ് കൺസൾട്ടൻസി & സ്പോൺസേഡ് റിസർച്ച് വിഭാഗം 22/04/2025-ൽ സമർപ്പിച്ച CET/ITC & SR No 558/22-23 നമ്പർ പഠന റിപ്പോർട്ട്

****

മേൽ 1-ാം സൂചനയിലേയ്ക്ക് ശ്രദ്ധ ക്ഷണിക്കുന്നു. തിരുവനന്തപുരം താലൂക്കിലെ തിരുവല്ലം വില്ലേജിൽ പാച്ചല്ലൂർ റീസർവ്വെ 613-ൽ ഉൾപ്പെട്ട വസ്തുവിൽ നിന്നും പാറകളും മരങ്ങളും വീണ് അപകട ഭീഷണിയുണ്ടെന്ന വിഷയത്തിൽ സംരക്ഷണ ഭിത്തി നിർമ്മിക്കുന്നതിനുള്ള നടപടികൾ സ്വീകരിക്കുന്നതിന് തിരുവനന്തപുരം കോളേജ് ഓഫ് എഞ്ചിനീയറിംഗിലെ ജിയോ ടെക്നിക്കൽ ഡിവിഷൻ മുഖാന്തിരം സാങ്കേതിക പഠനം നടത്തി നടപടി സ്വീകരിക്കുന്നതിന് പരാമർശം (1) പ്രകാരം സർക്കാർ നിർദ്ദേശിച്ചിരുന്നതും ആയതിലേയ്ക്കായി ജി.എസ്.റ്റി ഉൾപ്പെടെ 1,97,060 രൂപ 25/06/2024-ൽ ITC & SR Industrial Consultancy, Collecge of Engineering, Thiruvananthapuram ന് അനുവദിച്ച് നല്കിയിരുന്നു. തിരുവനന്തപുരം CET യിലെ സെന്റർ ഫോർ ഇൻഡസ്ട്രിയൽ ട്രെയിനിംഗ് കൺസൾട്ടൻസി & സ്പോൺസേഡ് റിസർച്ച് വിഭാഗം ഫീൽഡ് സ്റ്റഡി നടത്തി ടെക്നിക്കൽ സ്റ്റഡി റിപ്പോർട്ടിന്മേൽ സൂചന (2) പ്രകാരം സമർപ്പിച്ചു. ടെക്നിക്കൽ സ്റ്റഡി റിപ്പോർട്ട് അനന്തര നടപടികൾക്കായി ഇതോടൊപ്പം സമർപ്പിക്കുന്നു.

വിശ്വസ്തതയോടെ

ഡെപ്യൂട്ടി കളക്ടർ (ദുരന്തനിവാരണം)
ജില്ലാ കളക്ടർക്കു വേണ്ടി

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COLLEGE OF ENGINEERING TRIVANDRUM

THIRUVANANTHAPURAM-695 016

DEPARTMENT OF CIVIL ENGINEERING

ROCK SLOPE STABILITY: TECHNICAL STUDY REPORT

Name of Client : District Collector, Disaster Management Authority, District Collectorate, Kudappanakunnu

Job No. : **CET/ITC&SR No. 558/22-23**

Report No. : **Technical Study Report**

Report Prepared by : **Dr. Jaya V, Professor, Department of Civil Engineering, CET**

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1. Introduction

A detailed study was conducted to assess the stability of the rock slope at Pachaloor Resurvey No. 613 Thiruvallam Village , Thiruvananthapuram district. This report presents the slope stability analysis for the site based on topographical survey profiling and Electro-Telluric Survey. The study aims to evaluate the present condition of the rock existing at the rock slope and recommend necessary measures to ensure stability of the rock slope behind the buildings.

2. Site Visit

The site is primarily composed of a top layer of lateritic soil, which is covered with vegetation. Beneath this, the subsurface comprises fractured rock, followed by a layer of hard, intact bedrock. Notably, the root systems of mature vegetation have penetrated the fractured rock layers, accelerating the disintegration and weathering of the rock mass, thereby potentially affecting slope stability.

Photo 1. Strectch of rock cutting

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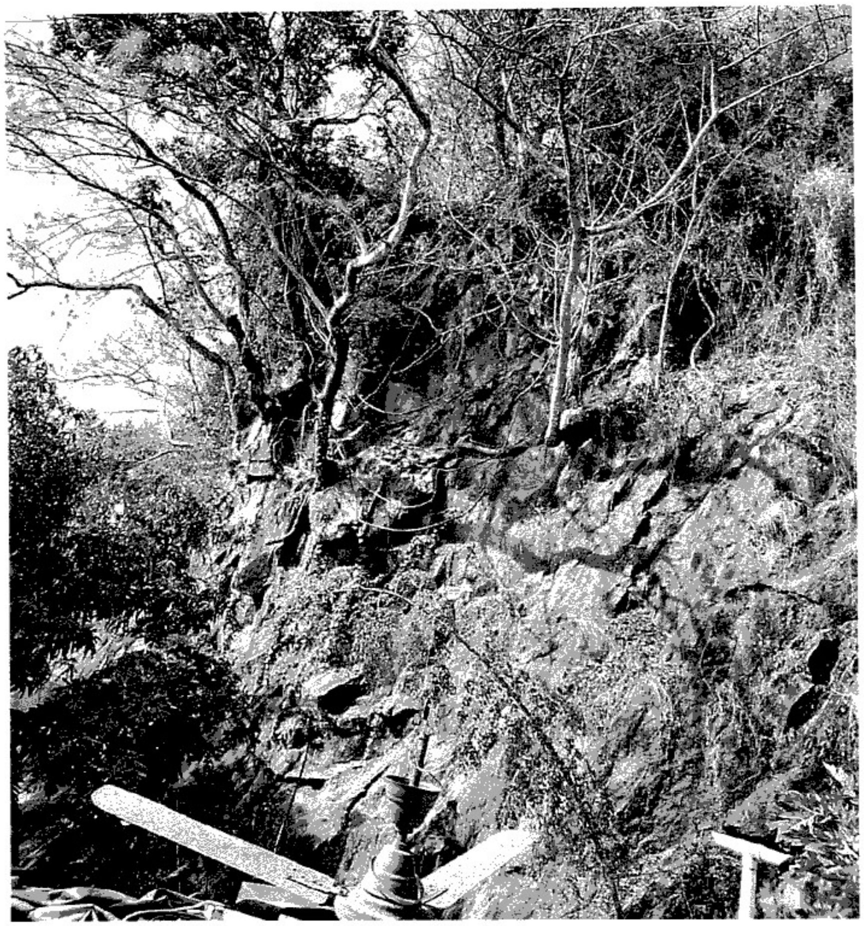

Photo 2 Crumbling Rocks and Falling Trees

Photo 3a. Proximity of Buildings to the Slope Face

Photo 3b. Proximity of Buildings to the Slope Face

Photo 3c.Buildings Located in Close Proximity to the Slope Edge

Photo 3d. View Showing the Nearness of Structures to the Slope

Photo 3e. Illustration of Buildings Situated Adjacent to the Cut Slope

Reasons for Rock Fall

- **Construction & Blasting** – Road construction, mining, or explosions in the past may loosen rock.
- **Weathering & Erosion** – Rocks weaken over time due to wind, water, and chemical processes.
- **Gravity & Steep Slopes** – Rocks on steep inclines may naturally fall due to gravitational pull.
- **Root Growth** – Tree roots penetrate cracks, gradually forcing rocks apart.
- **Heavy Rainfall** – Water reduces friction and stability, triggering falls.

Danger or Disaster Due to Rock fall at site

- Large falling rocks can **destroy homes**, walls, and foundations.

- Smaller debris can **damage roofs, windows, and vehicles.**
- Rockfalls can **crush residents**, causing severe injury or fatalities.
- Flying debris may cause **head trauma, fractures, or internal injuries.**
- Residents may experience **stress and fear** of future rockfalls.

3. Studies Conducted

An **Electro-telluric survey** was carried out at the site to assess the stability of the rock slopes by detecting variations in the electrical conductivity of subsurface materials. This method is particularly effective in identifying zones of weakness and potential failure planes that are not apparent at the surface. The survey also aided in the detection of water-bearing fractures, estimation of the thickness of overburden or fractured rock above competent bedrock, and provided essential data for the design of appropriate slope angles and support measures. A detailed report of the Electro-telluric study is provided in the Annexure.

In addition, a **topographical survey** was conducted to evaluate the slope inclination and the overall extent of the rock face. The topographical layout of the site is also included in the Annexure for reference.

4. Results and Discussion

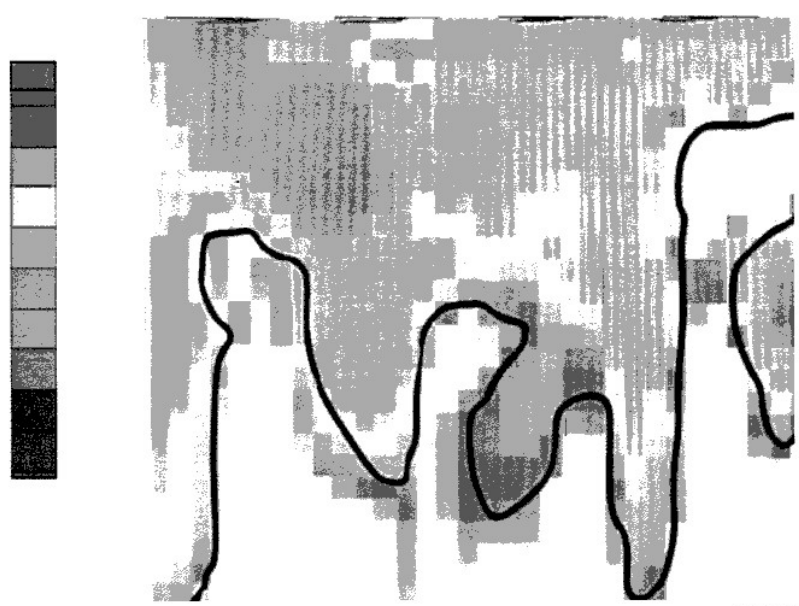

Fig. 1. Profile of the section averaged to the Transect taken

Figure 1 presents the section derived from the tellurograms obtained in this study. These visual representations of telluric currents aid in a comprehensive analysis of subsurface geological structures, including fracture planes and weathered horizons, and their correlation with the geological understanding of the terrain. The key features identified from the study are summarized in Table 1.

Table 1. The characteristics of the rock slope detected from the **Electro-telluric Survey**

Depth range (in metres)	**Characteristics (averaged)**
0-0.5	More soil, fewer rock blocks
0.5-1	Soil fills the gaps between underlying larger rock pieces
1-2	Disoriented rock pieces of 0.5m - 1m lying with soil and active plant roots filling the spaces.
2-5	Larger blocks of rocks, appearing to be more detached from the in-situ rock due to root growth inside. The presence of humidity and root zones are identified by lower resistivity in tellurograms. Removal of the vegetative cover would destabilize the present configuration of the rock /soil pack.
5 -15	The rock is slightly weathered, and influences of root zone weathering are observed. Surface water that sinks on the surface may drain here. At location (4-6 m south of the northern end of transect) the basement rock protrudes up to 5m and more towards the surface. A physical removal of rocks by heavy machineries at this location below 5m needs special attention.
15 and below	The country rock is highly intact, with less disturbance during quarrying, as tellurograms point to a high-resistant body. To the western end, the rock is more weathered to a depth of 15m and below.

Figure 2 shows the topographical section of the region across the road. The buildings are located in close proximity to the fractured face of the rock slope, which has an average height of approximately 20 meters.

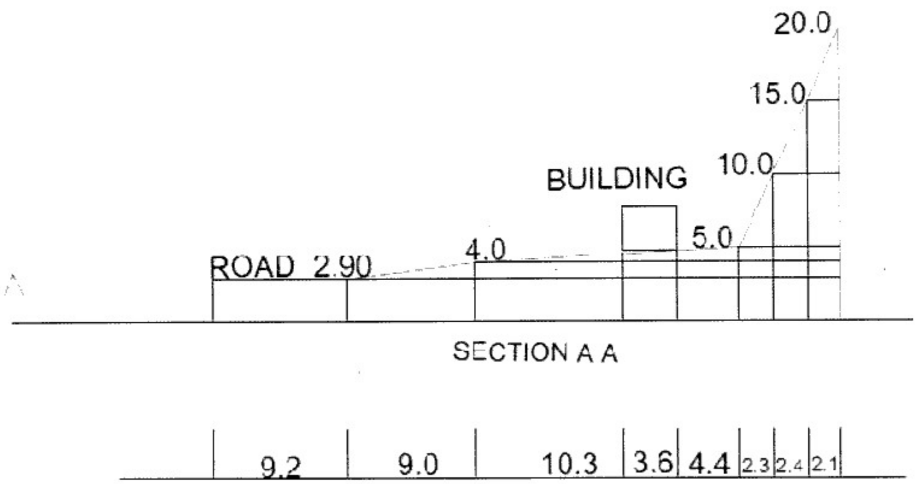

Fig. 2. Topographical Section

4. Recommendations

- Clear vegetation and debris to access the slope safely.
- **Remove loose and unstable rocks using hand tools or crowbars to a depth of 3 to 5 meters, extending 3 to 4 meters behind the rock slope face.**
- Avoid the use of mechanical or hydraulic excavators, as they may trigger large-scale failures that could lead to disastrous consequences.
- Install steel bolts to anchor stable rock masses
- Apply sprayed concrete to bind the rock face and prevent further weathering or erosion.
- A flat surface shall be created by applying grouts in to the fractured rock.
- **A structurally designed RCC retaining wall, 1.50 meters in height, should be constructed 3.00 meters behind the rock slope face to control debris and water flow down the slope.**
- These walls should incorporate adequate drainage provisions to manage water runoff.
- **Drainage systems should be implemented to collect and direct rainwater away from slopes.**
- During cutting operations, **temporary support measures** must be provided to ensure worker safety.
- A **stage-wise development approach** is recommended to minimize slope instability risks.

4. Conclusion

Based on the study, it is concluded that the rock slope requires appropriate protective measures to prevent severe damage and potential disasters. The removal of fractured rock and the construction of retaining structures are necessary to maintain stability at the specified locations, as indicated in the profile section. Additionally, proper drainage and erosion control measures must be implemented in accordance with relevant IS codes to ensure long-term slope stability. All site development activities must strictly adhere to the prescribed guidelines to effectively mitigate the risks associated with slope failure.

6. Attachments:

- Profile Section
- Electro-telluric Survey report

END OF REPORT

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Countersigned

PRINCIPAL
COLLEGE OF ENGINEERING TRIVANDRUM
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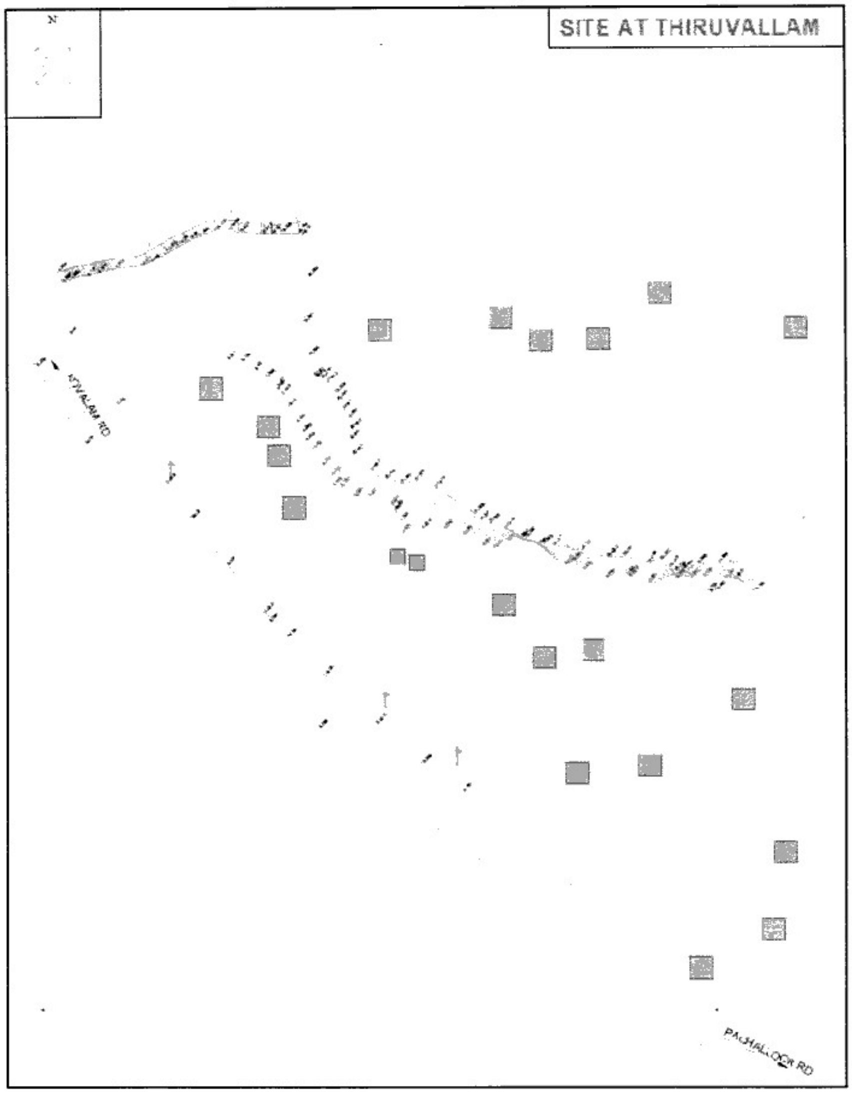

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APRIL 15, 2025

Ref No- Tgeo/2025/JVP/01

REPORT ON ELECTRO-TELLURIC SURVEY AT VELLAR, PACHALLOOR, TRIVANDRUM

Prepared for

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Copy of electro-Telluric survey

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GEO-TRANSECT

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REPORT ON ELECTRO-TELLURIC SURVEY AT VELLAR, PACHALLOOR, TRIVANDRUM

INTRODUCTION

Understanding subsurface geological structures is crucial for a wide range of applications, including resource exploration, groundwater management, civil engineering planning, slope management, restoration, and hazard assessment. Telluric surveys, which measure naturally occurring electromagnetic fields, provide a non-invasive method to investigate the Earth's subsurface conductivity. Variations in this conductivity are directly linked to key geological properties such as rock porosity, fracture density, degree of intactness, and fluid content. These factors significantly influence the mechanical behavior of rock under static forces. Therefore, conducting a telluric survey is essential for quantifying these subsurface variations, enabling geologists to accurately interpret strata and determine their extent. This detailed subsurface geological information is critical for engineers to develop reliable structural models and inform decision-making in construction and related fields

Physiography and Geology of the Region:

The study area features a quarry face on a lateritic plateau bordered by southwest-trending pericratonic faults, possibly reverse faults. The quarry face reaches a maximum height of approximately 40 meters above mean sea level and is east of the study area. Near-vertical fractures are present, supporting the growth of deep-rooted plants that survive summer dryness. While no groundwater seepages are observed, the vigorous growth of these trees indicates subsurface water sources and channels.

The geology of Thiruvananthapuram is known for a cliff basin structure where hard rock and laterites form the cliff along the east, and a sediment-laden basin lies to the west. This basin is drained by rivers into lakes and the sea further to the west. The hard rocks are admixtures of garnet biotite Gneiss, Quartzites, and Leptinite, belonging to a geological unit named the Trivandrum Block. They are metamorphic in origin and were exhumed to the surface through geological processes, which contributes to their inherent mechanical behaviour. In some areas, they are lateritized. Laterites are the product of prolonged and intense weathering processes, a common occurrence in tropical climates.

The geological characteristics of laterite significantly influence the hydrological regime of the region. The porosity and permeability of laterite affect water infiltration, storage, and runoff, influencing the chemical reactions at deeper levels of rock, which in turn affects the strength and the mechanical behaviour of the rock itself.

SCOPE OF THE WORK

This project focuses on identifying and assessing rolled blocks, boulders, and the extent of hard rock at the quarried cliff site using the telluric method. The scope includes:

* Site Investigation: A detailed telluric geophysical survey will be conducted to map subsurface geological structures and electrical conductivity.

* Rolled Block and Boulder Inventory: Spatial analysis of the size and distribution of rolled blocks and boulders.

* Hard Rock Stratigraphy: Delineation of the subsurface extent and depth of hard rock.

* Data Collection and Analysis: This involves acquiring field data, processing signals, and interpreting results to generate a subsurface profile.

This investigation will support informed decision-making for the construction of slope stability measures.

METHODOLOGY

Electro-Magnetotelluric (ET) method is used to identify the subsurface geology, formation and freshwater discharge, Li and Jie (2017), Vozoff and Keeva (1991), Abdelzaher et al. (2012), deGroot- Hedlin (1990), Jones and Alan (1988), Duque and Carlos (2008), Falgas (2009), Demirci and İsmail (2017), Albouy et al. (2001). This method has been used by GSEM W10 series, equipment with the help of M, N copper probe continuously shifted by equal distance and depth of coverage which was also changed to cover 300 m. The resistivity variation clearly democrats the different soil, rock types and coastal boundaries. The ground water interfaces were also distinguished with the help of pseudosections.

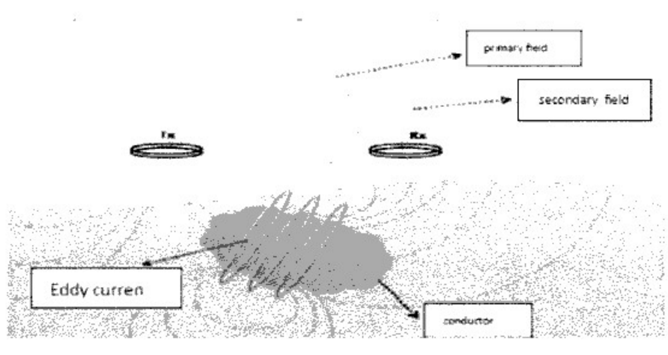

Figure 1- The working principal of Magneto Telluric method in identifying target body

The instrument used for the survey was GSEM W10. The data has been plotted processed and cross evaluated by open source ResPy 2v. And the field measurements were plotted using AutoCAD v.2021.

PROCEDURE

The survey was conducted on 6th of April 2025. Transects were taken viz. T1, T2 &T3 and a total of 127 points surveyed as in Fig. 2 and details are given in in Table. Field survey photos are given in Fig. 4.

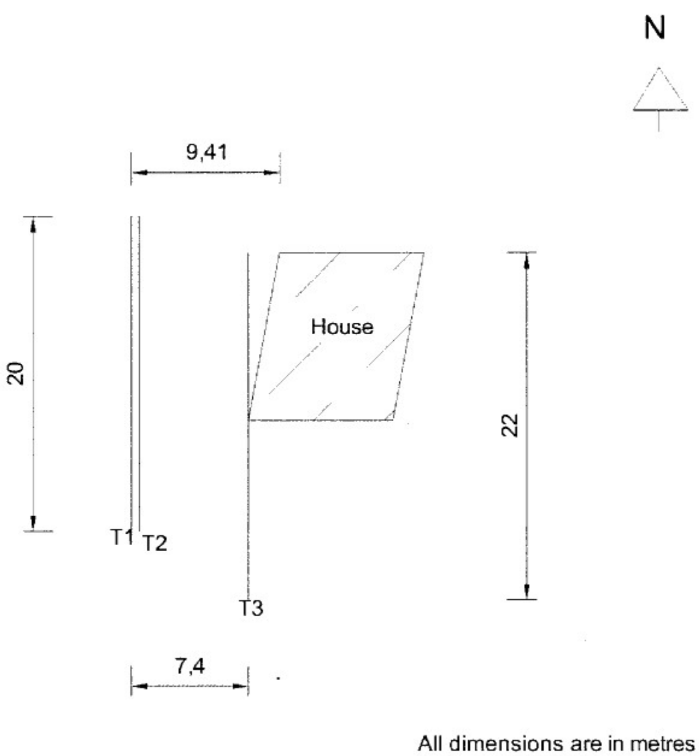

Figure 2- survey plan

Table 1-Transect length and data interval

Transect No.	Length (in m)	Data interval (in m)
T1	20	0.5
T2	20	0.5
T3	22	0.5

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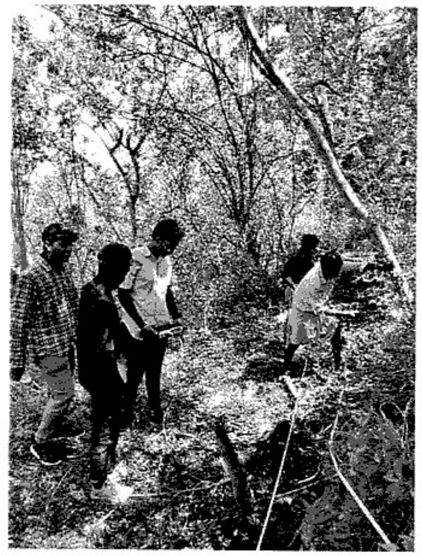

Fig 3- Field photos

RESULTS

The following section presents three tellurograms obtained from this study. These visual representations of telluric currents are included to facilitate a comprehensive analysis of the subsurface geological structures, the fracture planes and the weathered horizons and its correlation with the geological understanding derived from the terrain.

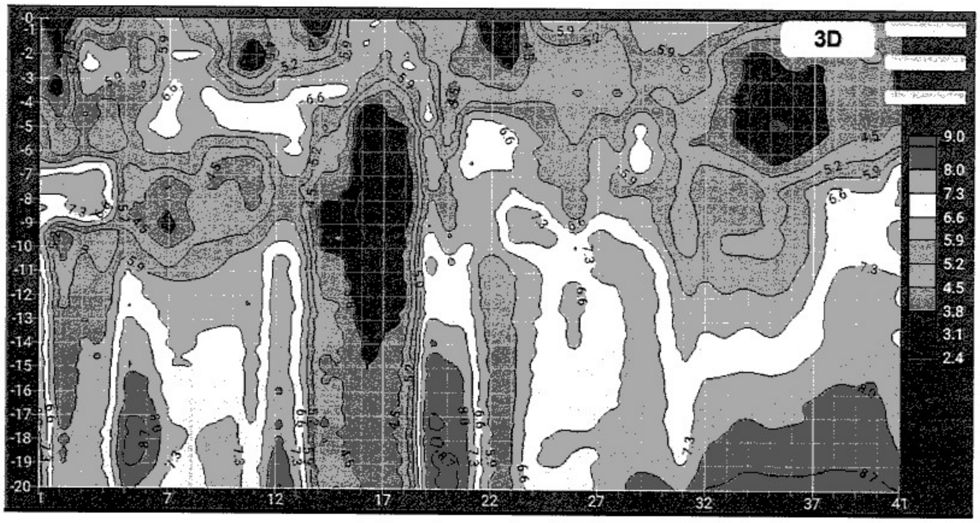

Figure 4- Transect 1

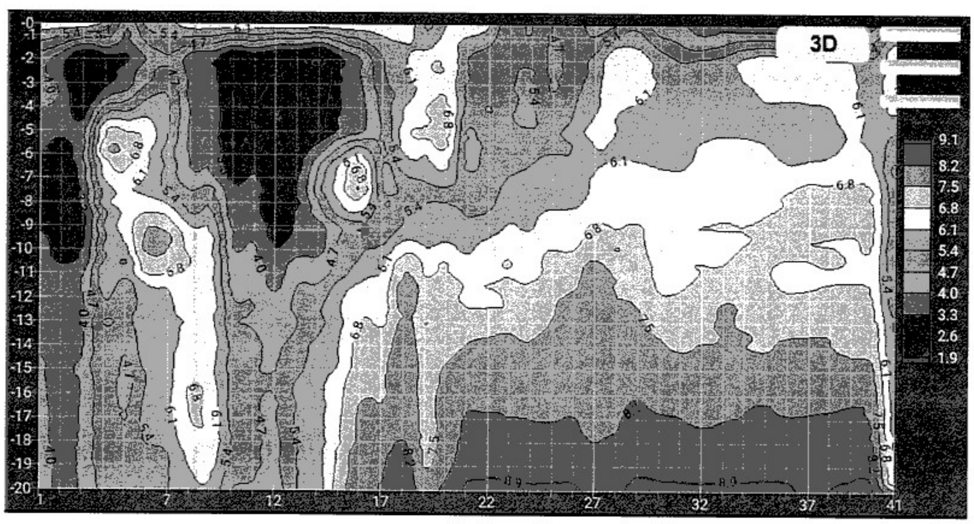

Figure 5-Transect 2

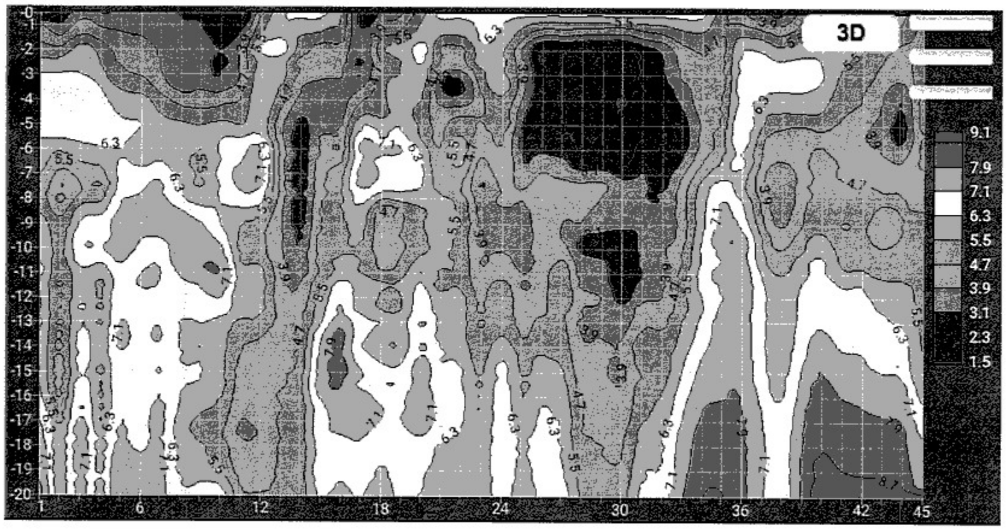

Figure 6-Transect

3D profiles

The following section presents three tellurograms obtained from this study. These visual representations of telluric currents are included to facilitate a comprehensive analysis of the subsurface geological structures, the fracture planes and the weathered horizons and its correlation with the geological understanding derived from the terrain

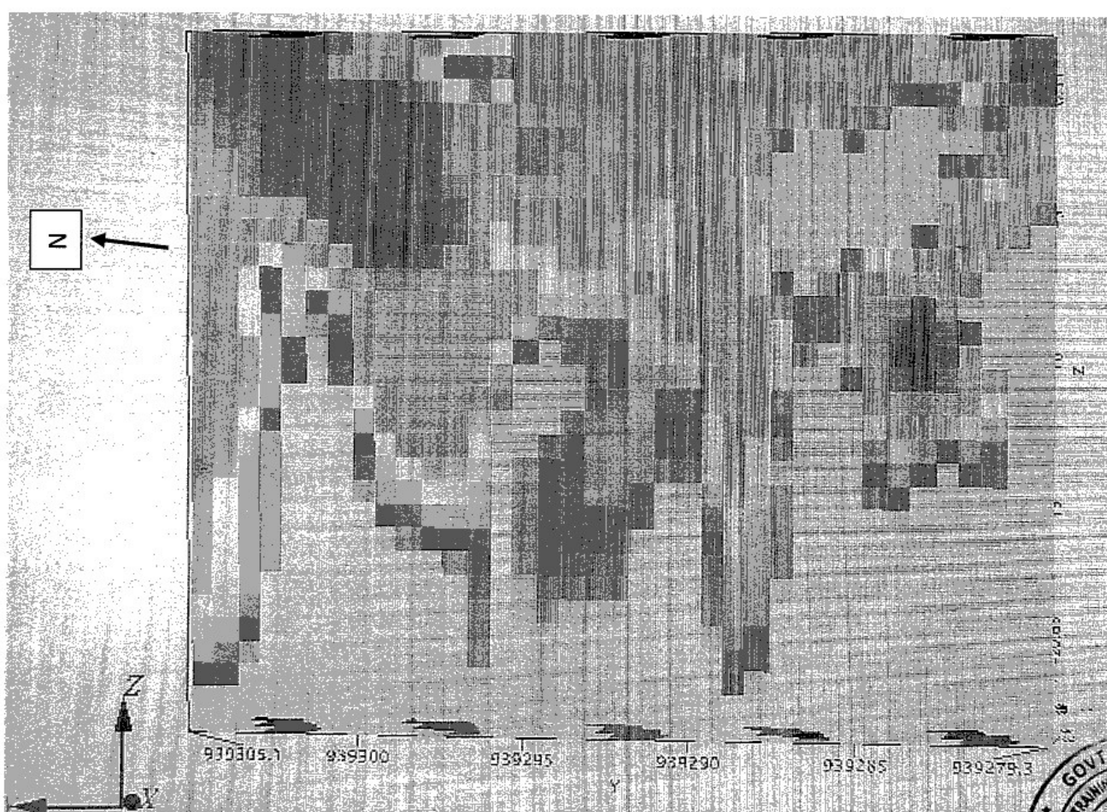

Figure 7-Profile of the section averaged to the Transect taken

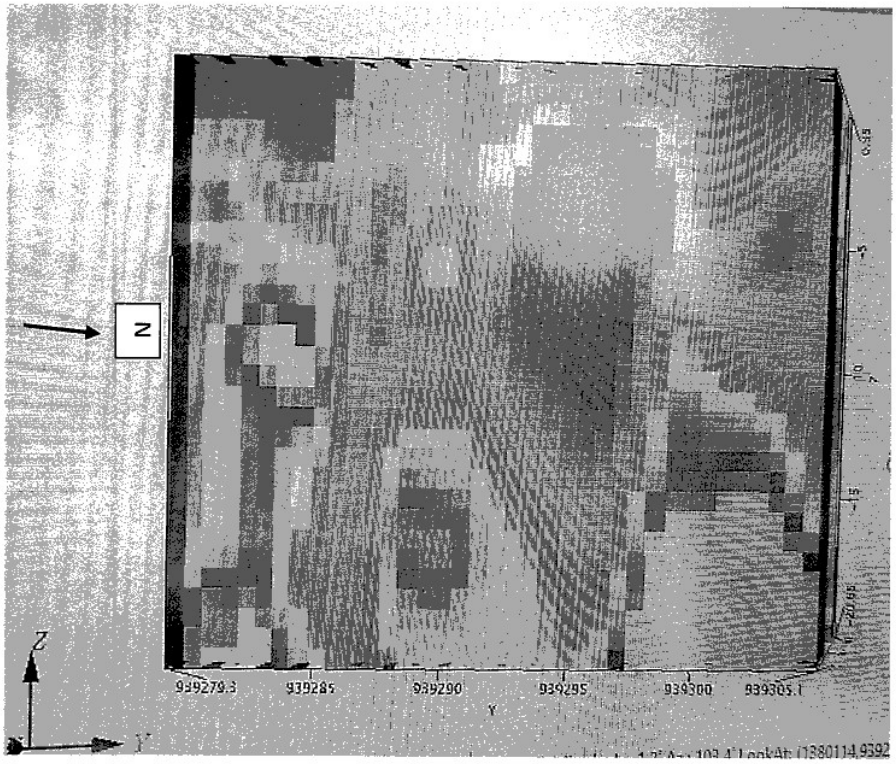

Figure 8-Profile of the section averaged to the Transect taken

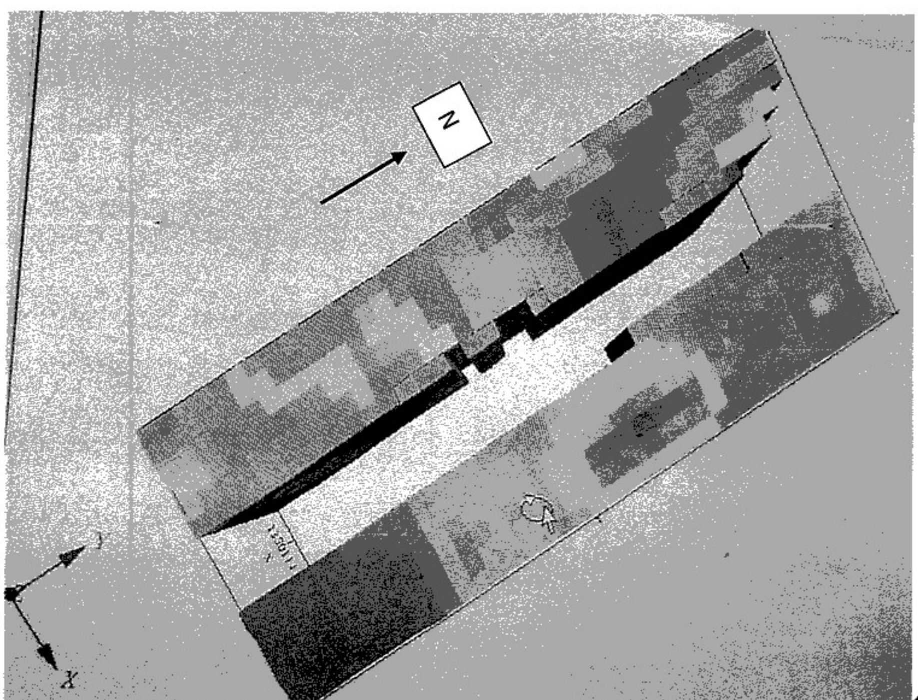

Figure9- Profile of the section averaged to the Transect taken(plan view)

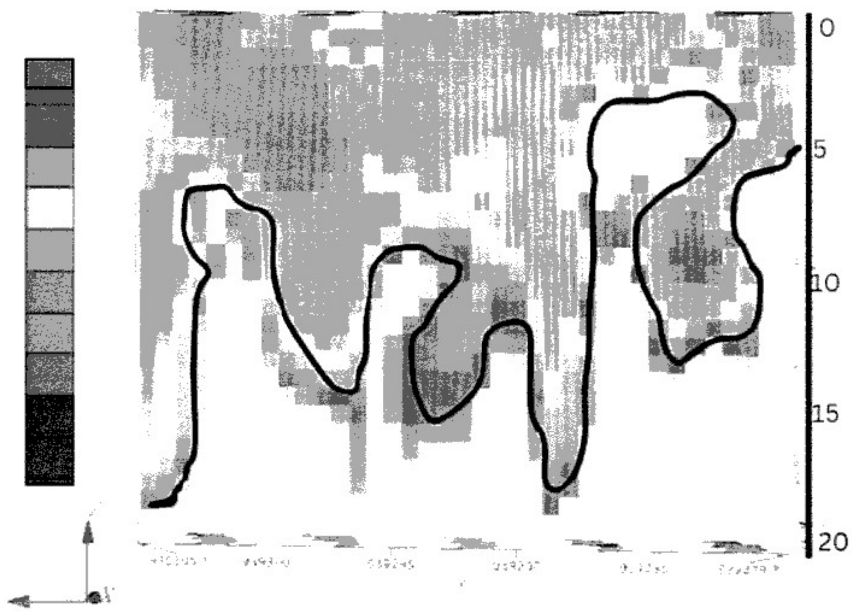

Figure 10-Profile of the section averaged to the Transect taken

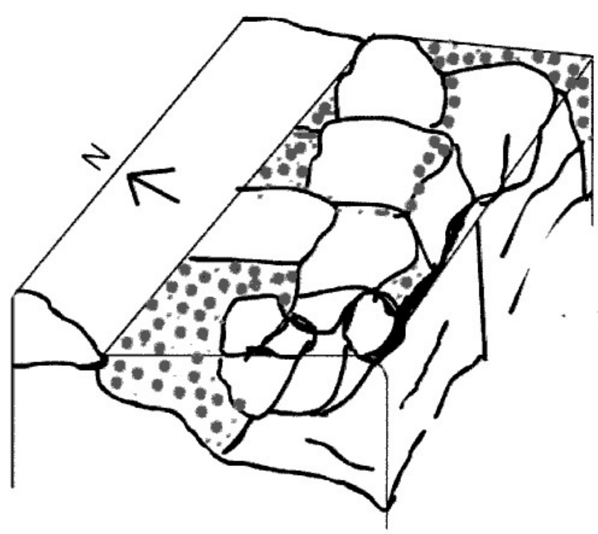

Figure 11-Pictograpgical representation of the tellurograms(not to scale)

Structural data

Rock structural data presented below were measured from nearby outcrops within the study area.

Table 2- foliation data

Strike(in degrees)	Dip Amount (in degrees)	Dip Direction(in degrees)
N88	55	N178
N88	56	N178
N89	54	N179
N89	55	N180
N88	56	N178
N91	55	N181
N88	55	N178
N92	55	N182
N88	55	N178

Table 3-Fracture and joint data

Strike(in degrees)	Dip Amount (in degrees)	Dip Direction(in degrees)
N300	85	N210
N301	85	N211
N300	85	N210
N302	80	N212
N300	85	N210
N300	85	N210
N300	85	N210

The topography of a quarried rock section, where the rock is gneiss and granulite, will be significantly influenced by the inherent characteristics of these metamorphic rocks and the methods employed during quarrying.

The high hardness and density of these rocks—gneiss, quartzo-feldspathic pegmatite, and granulite—indicate that they are high-grade metamorphic rocks, making them very hard and dense. This resistance to erosion means that natural outcrops tend to form relatively rugged terrain.

Foliation planes in gneiss (dipping 50° to N178°) with alternating bands of quartz, feldspar, and garnet, can create planes of weakness, influencing how the rock breaks during quarrying and weathers over time in the quarry walls. The orientation of foliation will significantly affect slope stability.

Granulite, exposed here, exhibits a granoblastic texture, which is a more equigranular, mosaic-like texture with less pronounced foliation or even a massive structure. This often results in more uniform strength in all directions compared to gneiss.

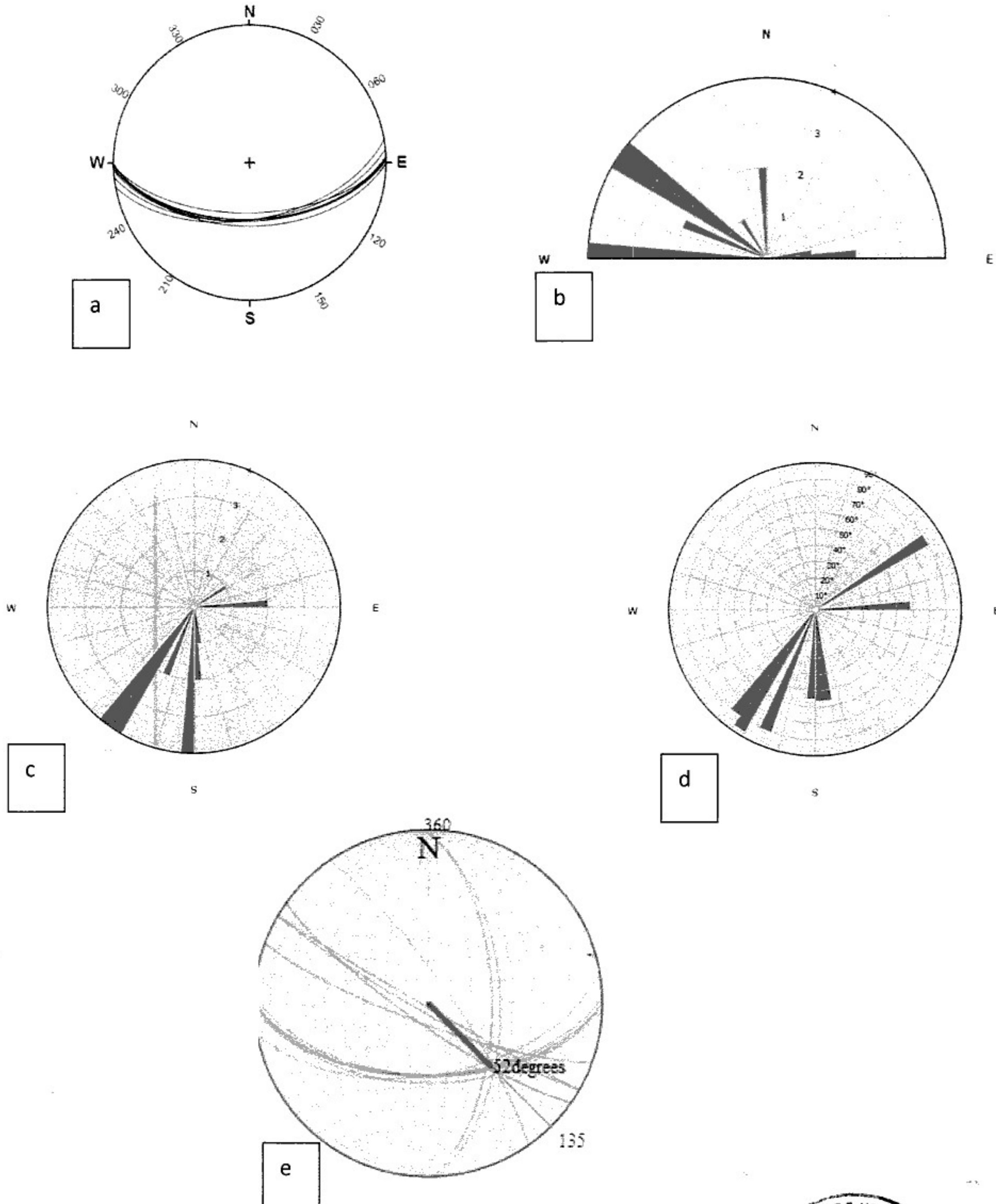

Figure 12-The stereo plot of structural planes of weakness observed in the rock Outcrosp

a. The Beta plot of bedding planes

b. Rose diagram of the trends of weakness like fracture and bedding plane

c. Rose diagram showing dip directions of fracture planes

d. Rose diagram on dip amount intensity with respect to directions.

e. The stereo plot showing the net strike and amount of dip of all the weaker planes taken in total.

The density of joints and fractures (dipping 80° towards N300°) in the bedrock (gneiss and granulite masses) represents discontinuities that can influence the mechanical properties of the rock mass. In an extremely fresh outcrop where a quartzite pegmatite intruded into the gneiss, 5 fractures were counted per 1 square foot. However, these fractures are not as clearly evident in the rest of the weathered rock. However, the persistence of these discontinuities are critical in determining how the rock mass behaves during excavation and the stability of the quarry slopes.

The studied quarried section has:

* Steep High Walls: Due to the hardness of the rock, quarries in gneiss and granulite can often have very steep to near-vertical faces. The height of these walls will depend on the depth of the quarry and the overall stability of the rock mass.

* Bench Formation: To ensure safety and efficient extraction, quarries are typically developed in a series of benches (horizontal steps). The height and width of these benches are designed based on the rock mass characteristics, the equipment used, and regulatory requirements. In hard rock like gneiss and granulite, bench heights can be significant. The tellurogram shows benches filled with rock blocks and soil , covered by vegetative matters.

* Blasted Faces: The quarry faces will often show the irregular and fractured surfaces resulting from blasting operations used to break the rock mass. These faces can be rough and uneven.

* Minor stockpiles with distinct mounds of leftover rock pieces and ballast are present. These potentially filled with topsoil and other soil, are drained by surface flows during rains. This further fills in the foliations and fractures of the basement rock, exerting a dominant control on rock breakage. Unfavourable orientations of foliation relative to the quarry face led to instability and slope failures. Lowering the slope is suggested to avoid mass downslope movements.

Soil deposits in the fracture planes and weathering within them have promoted plant growth. The tellurogram clearly shows that plants have developed roots into the rock through rock contacts, foliations, fractures, and weaker planes. This activates weathering and hence lowers intactness.

CONCLUSION

The study concludes with the following profile deduced from the tellurograms. The following also hints the rock mass property against an external mechanical force is briefed.

Depth range (in metres)	Characteristics(averaged)
0-0.5	More soil, fewer rock blocks
0.5-1	Soil fills the gaps between underlying larger rock pieces
1-2	Disoriented rock pieces of 0.5m - 1m lying with soil and active plant roots filling the spaces.
2-5	Larger blocks of rocks, appearing to be more detached from the in-situ rock due to root growth inside. The presence of humidity and root zones are identified by lower resistivity in tellurograms. Removal of the vegetative cover would destabilize the present configuration of the rock /soil pack.
5 -15	The rock is slightly weathered, and influences of root zone weathering are observed. Surface water that sinks on the surface may drain here. At location (4-6 m south of the northern end of transect) the basement rock protrudes up to 5m and more towards the surface. A physical removal of rocks by heavy machineries at this location below 5m needs special attention.
15 and below	The country rock is highly intact, with less disturbance during quarrying, as tellurograms point to a high-resistant body. To the western end, the rock is more weathered to a depth of 15m and below.

Geological studies categorize rocks with foliations and fractures as harder rocks. Structural analysis indicates a resultant weakness towards N135° at an angle of 52°

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